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"THE AUTOMATIC TRAIN CONTROL SYSTEM OF THE GREAT WESTERN RAILWAY"

BY

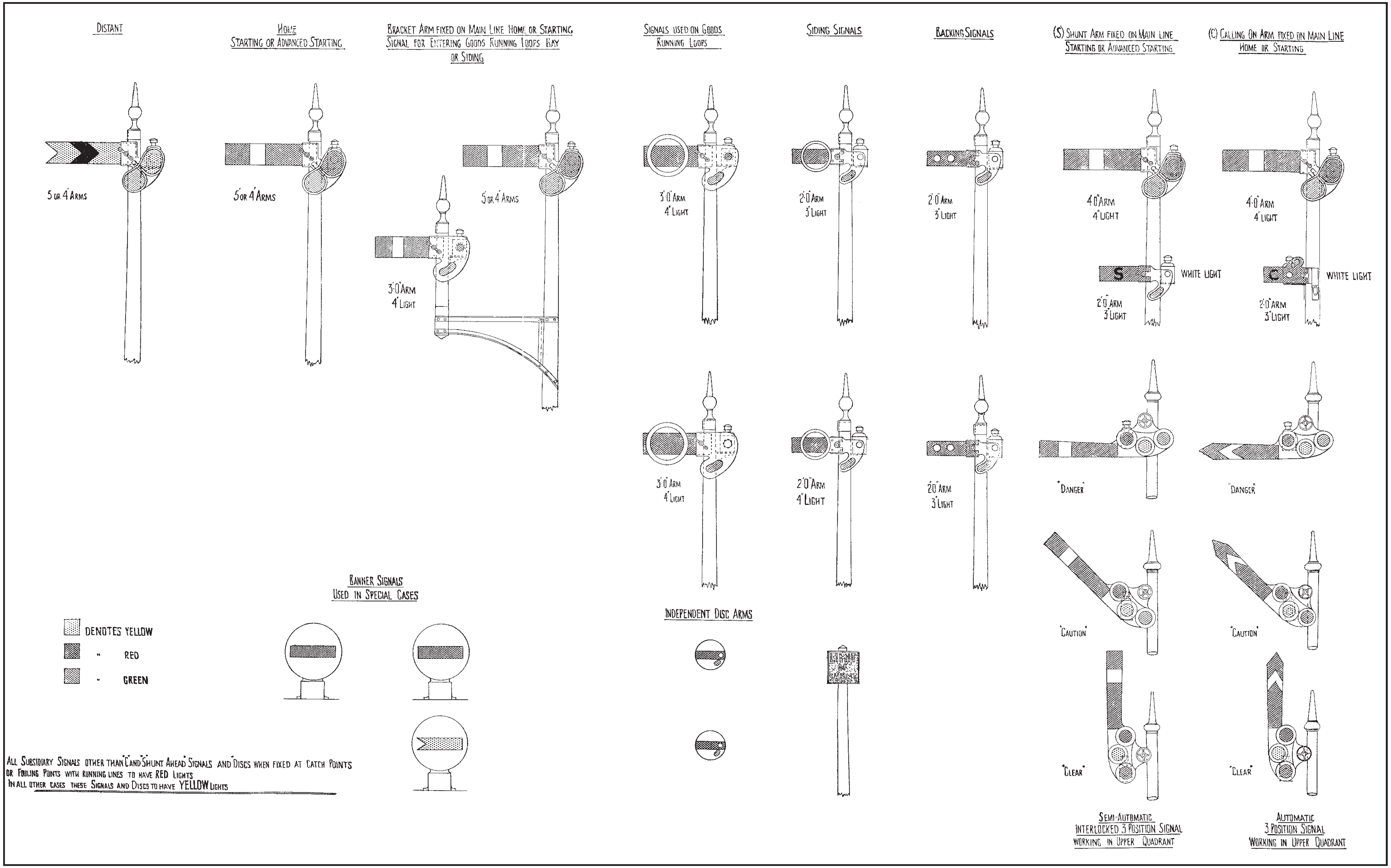
A. W. J. DYMOND, B.Sc., A.M.Inst.C.E., A.M.I.Mech.E.
(Member).

Automatic Train Control properly so-called may be defined as the operation of trains on railways by means which exclude the agency of the driver on the power vehicles. The extent to which this is completely carried out varies with the different installations, but, in passing, it may be of interest to state that in this country the Post Office Tube Railway in London is run with driverless trains, and is the only complete system of Automatic Train Control in existence.

In America the idea has been carried out in many forms. While, of course, not dispensing with the drivers on the engines, in certain installations the behaviour of the train on the track is nevertheless controlled very completely; for example, in the case of an obstruction on the line ahead, and also where permanent speed restrictions are in force. It follows from these considerations that the basis of Automatic Train Control is some form of correlation of the functions of the driver on the engine with those of the signalman in his cabin, and properly to understand the principles of Automatic Train Control, some idea should be obtained of the nature of the normal control exercised by the track signals.

In this country signalling for passenger train services is of the absolute block type, each signalman in his signalbox having charge of a certain length of line, the whole line being divided into "block sections." The principle of block working is that no two trains proceeding on the same road shall be allowed in one section at the same time.

Covering movements of trains through the sections are, of course, the familiar semaphore signals (Fig. 1). These are of two



Distant
5 or 4' Arms
Home
Starting or Advanced Starting
5 or 4' Arms
Bracket Arm fixed on Main Line Home or Starting Signal for Entering Goods Running Loops Bay or Siding
5 or 4' Arms
3'0" Arm
4" Light
Signals used on Goods Running Loops
3'0" Arm
4" Light
3'0" Arm
4" Light
Siding Signals
2'0" Arm
3" Light
2'0" Arm
4" Light
Backing Signals
2'0" Arm
3" Light
2'0" Arm
3" Light
(S) Shunt Arm fixed on Main Line Starting or Advanced Starting
4'0" Arm
4" Light
S
White Light
2'0" Arm
3" Light
(C) Calling On Arm fixed on Main Line Home or Starting
4'0" Arm
4" Light
C
White Light
2'0" Arm
3" Light
"Danger"
"Danger"
"Caution"
"Caution"
"Clear"
"Clear"
Semi-Automatic Interlocked 3 Position Signal working in Upper Quadrant
Automatic 3 Position Signal Working in Upper Quadrant
Banner Signals Used in Special Cases
Independent Disc Arms
Denotes Yellow
" Red
" Green
All Subsidiary Signals other than "C" and "Shunt Ahead" Signals and Discs when fixed at Catch Points or Fouling Points with running lines to have RED Lights
In all other cases these Signals and Discs to have YELLOW Lights

Fig. 1.

main types. The one which is painted red and white on that side facing the oncoming train, the end of the arms being rectangular, is known as a stop signal, and beyond this, when it is horizontal, in no circumstances whatever, is the driver allowed to take the train. Stop signals themselves can be divided into classes. The stop signal first met by a train passing through the section is the Outer Home and following this the Home signal proper, which is usually situated fairly close to the cabin. Beyond the signal cabin may be other stop signals called the Starters, of which there may be two, the Starter and Advanced Starter. All stop signals exhibit a red light to correspond with the "stop" position and a green light to correspond with the "proceed" position.

The other type of semaphore signal is known as the Distant, which is painted orange and black on the side facing the driver, and the end of the arm is shaped like a fish tail. Distant signals exhibit an orange light to correspond with the "caution" position and a green light to correspond with the "proceed" position. The function of the Distant signal is to indicate to the driver the state of the Stop signals ahead of it in the section. Should the whole of the Stop signals be in the "proceed" position, the Distant signal arm may and probably will be dropped, and the driver will thus be sure that he will receive no check in that section. Should, however, any one of the Stop signals be at danger, the Distant signal arm will be horizontal, and this is interpreted by the driver as a caution that he may be called upon to stop in the section at one of the Stop signals therein. The driver may thus pass the Distant signal in the horizontal position.

It is necessary, of course, to ensure that there shall be no conflict of indication between the Distant signal and its related Stop signals, i.e., the Distant signal must never be at "proceed" (or dropped) when either of the Stop signals in the section is at "stop," and this is achieved by an extremely ingenious system of locking in the frame in the signal box.

From the foregoing, it follows that for fast running, on entering the section, the driver directs his attention first to the position of the Distant signal. If he finds this in the "proceed" position, he is thereby assured that all Stop signals are certain to be at "proceed," and he may thereupon run through the section at full speed. On the other hand, if the Distant signal is at "caution," viz., horizontal, he must be prepared to stop at any of the Stop signals in the section. This places the Distant signal in a paramount position as a means for the operation of traffic at high speed.

Whatever system of Automatic Train Control may be in use, it is clear that its functioning is dependent on the production of a suitable and clearly distinguishable signal of some type or other on the locomotive, depending on the state of the semaphore signals on the track, and this raises the question as to which of the signals on the track are to be repeated in the cab of the locomotive. It is on this general question of the nature of the signals to be repeated in the cab of the engine that the various diverse designs of Automatic Train Control have been evolved. Completely automatic control of the train, which means the repetition in the cab of the engine of the state of every signal passed and the production of suitable braking effects on the engine where necessary, is effected, of course, on the Post Office Tube Railway previously referred to, and is also achieved, in some degree, in America by the extremely ingenious systems in partial use in that country. There is, however, serious objection to completely Automatic Train Control apart from the necessarily expensive and complicated apparatus necessary to produce it, and that is the undesirability of taking complete control of the train out of the driver's hands, thereby relieving him of his personal responsibility for the safety of his train.

In this country the general opinion is towards a system of train control which aims not at relieving the driver of this responsibility but rather towards assisting him in his duty by affording him every assistance, especially in adverse circumstances such as bad visibility, during falling snow or fog, to receive and interpret the indications of the semaphore signals. Together with other important considerations affecting technical points of design and questions of expenditure, this has resulted in completely Automatic Train Control not being favoured in this country. The extent then to which partial control may be effectively undertaken will depend on the degree of assistance which it is intended to afford the driver, and this, in turn, will depend on which of the two signals, viz., Stop or Distant, is to be selected for repetition in the cab of the engine.

From the earlier remarks on the differing functions of the Stop and Distant signals, it will be appreciated that the repetition of the indication of the Distant in the cab of the locomotive will afford the driver considerable assistance in all circumstances, particularly those of adverse visibility, because should the driver be reassured by a repetition of, say, the "proceed" position of the Distant signal in his cab, he will then run through the section with confidence knowing that the Stop signals in the section will necessarily also be at "proceed." Should circumstances arise, however, when the Distant Signal is not at "proceed," the responsibility of correct observation and interpretation of the dependent Stop signals is thrown entirely on the driver.

This type of partial Automatic Train Control depending on the repetition of the state of the Distant signal in the cab has been accepted as the standard for this country by the findings of the Automatic Train Control Committee of 1927, and no type of control is likely to be favoured by the Board of Trade which does not conform with this essential condition.

The Great Western type of train control, therefore, aims at the production in the engine cab of two distinct signals corresponding with the two possible states of the Distant signal arm. The indications produced are as follows:—

DISTANT SIGNAL at "CAUTION" (i.e., arm horizontal)
A syren is sounded and the brakes are automatically applied with increasing force.

DISTANT SIGNAL at "PROCEED" (i.e., arm dropped)

A bell rings.

In order to produce these differing effects in the cab of the engine, some kind of contact must obviously be made between apparatus on the engine and on the track.

The track element (Fig. 2) is fixed in the centre of the four-foot way and consists of an immovable ramp composed of a baulk of timber on the top of which is mounted a T iron with its stem vertically upward. The ramp is 44 feet 3 inches long and at its highest point is $3\frac{1}{2}''$ inches above the level of the rails, the ends being sloped to just above rail level. By means of this ramp two different, distinct indications, have to be produced on the engine. This is achieved by electrical means.

When the signal arm is at "caution," the ramp is electrically dead, but when the arm drops to the "proceed" position, the positive end of an electric battery is automatically connected to the ramp, its other end being earthed. By suitable means, to which reference will be made subsequently, it is made impossible for the electrical state of the ramp to be at variance with the position of the signal arm.

The engine,element (Fig. 3) consists of a skid or shoe carried in the centre of the engine, the bottom of which is in the normal position, $2\frac{1}{2}''$ inches above the rail, and is, therefore, lifted 1 inch every time the engine passes over the ramp. The mechanical lift of the shoe passing over a dead ramp is utilised to produce the "caution" indication in the engine cab, viz., syren and brake applied, and the contact of the shoe with the ramp when this

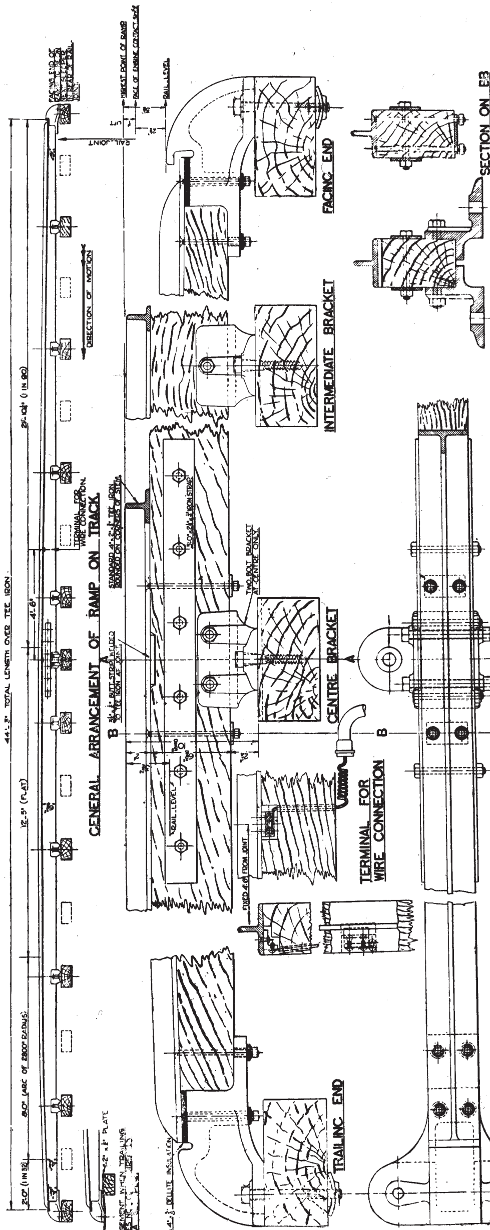

GENERAL ARRANGEMENT OF RAMP ON TRACK
44'-3" TOTAL LENGTH OVER TEE IRON
DIRECTION OF MOTION
RAIL JOINT
RAIL LEVEL
FACINC END
INTERMEDIATE BRACKET
CENTRE BRACKET
TRAILINC END
TERMINAL FOR WIRE CONNECTION
SECTION ON AA
SECTION ON BB

Fig. 2.

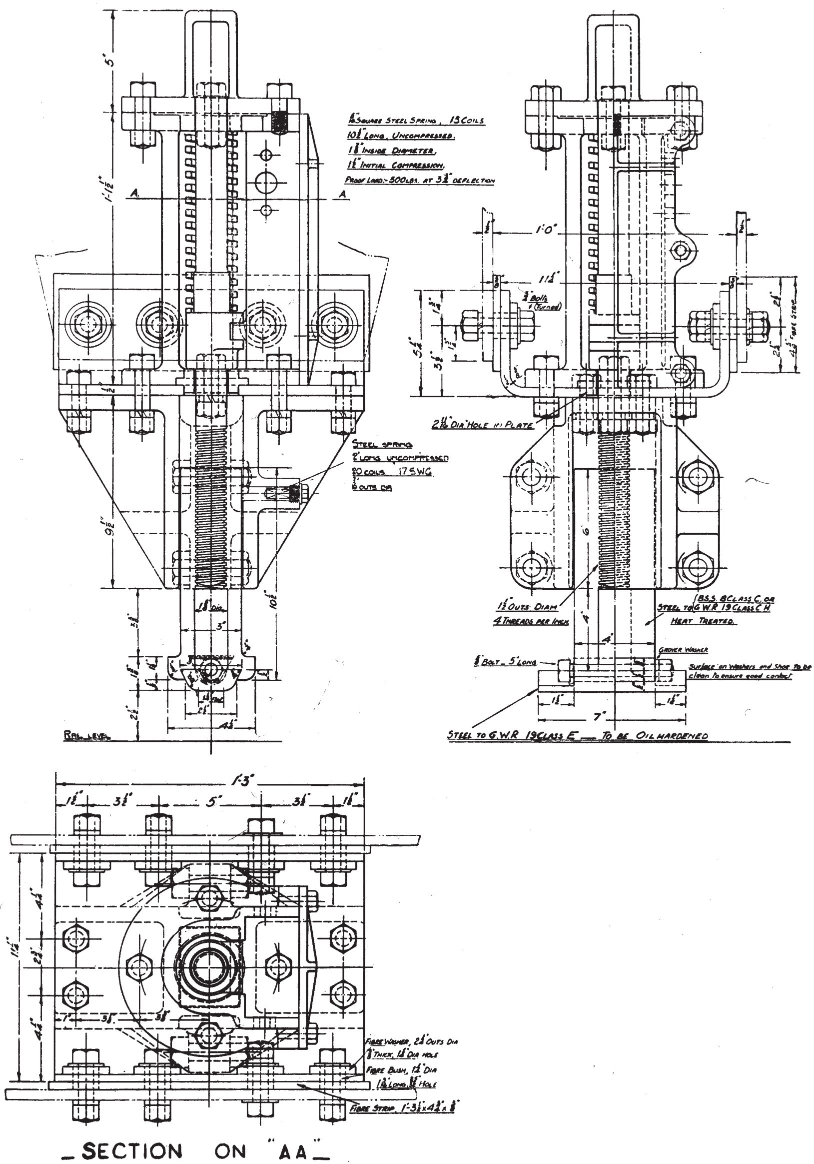

Square Steel Spring, 13 Coils
10½" Long, Uncompressed.
1⅜" Inside Diameter.
1½" Initial Compression.
Proof Load:- 500 lbs. at 3½" deflection
Steel spring
2" Long uncompressed
20 coils 17 SWG
2'Dia Hole in Plate
1½" Outs. Diam
4 Threads per Inch
B.S.S. 8 Class C. or
Steel to G.W.R 19 Class C.H.
Heat Treated.
Grover Washer
Surface on Washers and Shoe to be clean to ensure good contact
Steel to G.W.R 19 Class E — To be Oil hardened
Rail level
Fibre Washer, 2¼" Outs Dia
Fibre Bush, 1½" Dia
Fibre Strip, 1'-3½" x 4¾" x ⅛"
— SECTION ON "AA" —

Fig. 3.

latter is electrically energised, results in the current therein being picked up and fed through suitable leads for the production of the bell signal.

Proceeding now to a detailed description of the track apparatus. In (Fig. 4) a telegraph wire connects the ramp with a switch in the signal box through a contact on the Distant signal arm in the following manner. The switch in the signal box, which is attached to the lever controlling the Distant signal, is in the circuit of a small battery of 3 volts. This is earthed to one side, the other side being connected through the switch to the operating coil of a controlling relay situated in the box alongside the track at the site of the ramp, the other side of the coil completing the circuit to earth. The contacts of the relay, in turn, control the current from a battery in the relay box. This battery has the negative end earthed to the rails, the other end being connected to the ramp through the relay contacts and a switch on the signal arm.

The required current on the ramp is about 500 milliamps, but to feed this through about 1,200—1,600 yards of wire from signal-box to ramp, such as would be the case if the controlling switch were at the signal box, would require a large battery. By means of the small relay battery at the signal box and the contact relay (whose operating current is only a few milliamps) at the ramp site, a much smaller battery is required to energise the ramp than would be otherwise the case.

The purpose of the contact on the signal arm is to ensure that even though a signalman may have pulled his lever to drop the Distant signal arm, the ramp must, nevertheless, not be energised until the arm of the signal is actually dropped to the recognised "proceed" position, viz., 20-70° below horizontal.

It will be clearly seen that any failure of contacts, wires or batteries, will result in the ramp being left dead, and consequently only "caution" signals will be given in all circumstances should any failures occur.

The normal current is about 500 milliamperes through an external resistance of 25 ohms. This requires a voltage of 12.5 or more between the ramp and the running rails (i.e. the earth). The source of supply can be primary or secondary cells, rectifiers, etc.

The essential portion of the engine apparatus is a shoe (Fig. 5) which has a lift of 1 inch every time the engine passes over the ramp. This shoe has two functions, one depending on its mechani-

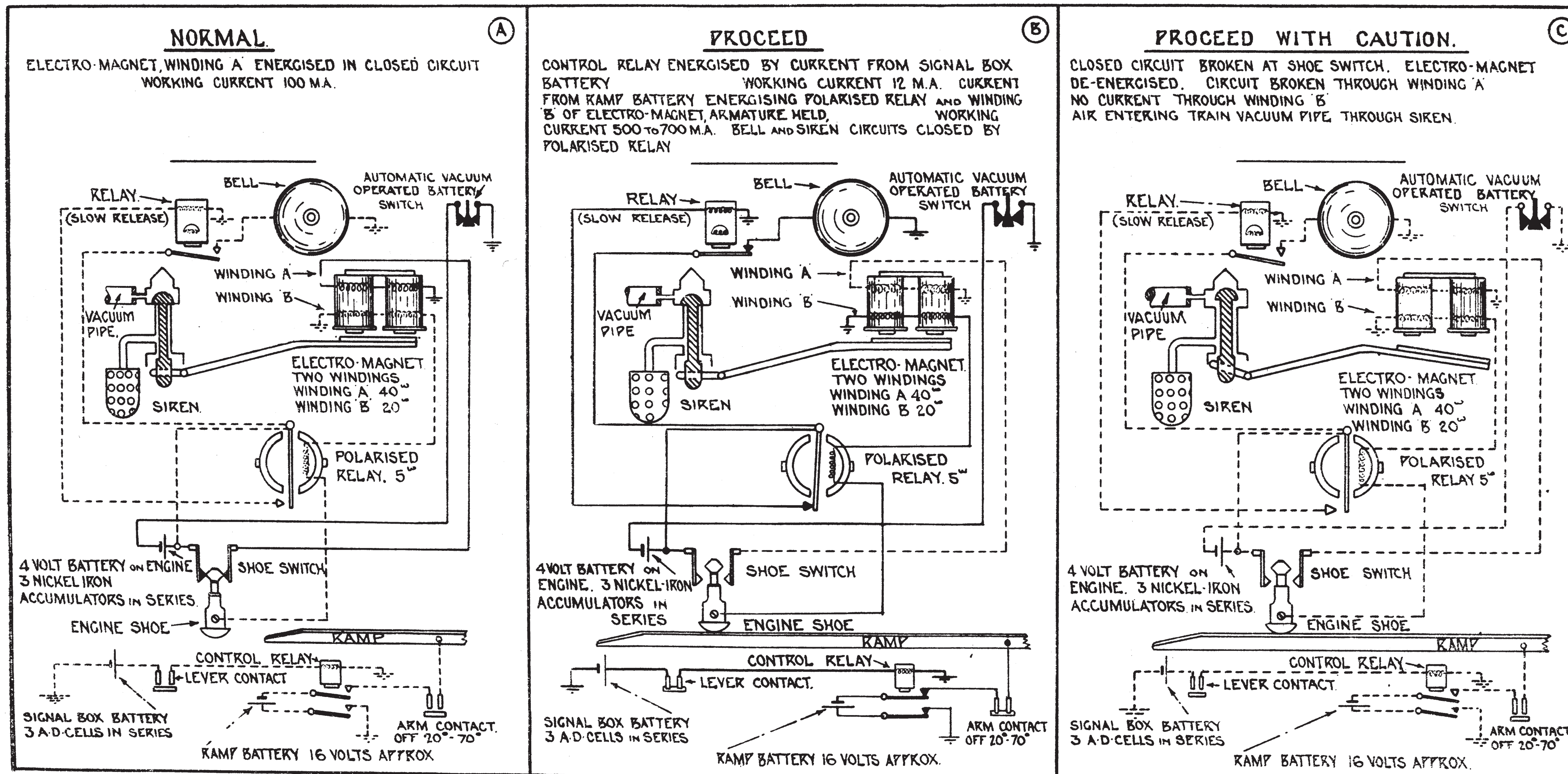

NORMAL.
A
ELECTRO-MAGNET, WINDING 'A' ENERGISED IN CLOSED CIRCUIT
WORKING CURRENT 100 M.A.
RELAY.
(SLOW RELEASE)
BELL
AUTOMATIC VACUUM OPERATED BATTERY SWITCH
WINDING 'A'
WINDING 'B'
VACUUM PIPE.
SIREN.
ELECTRO-MAGNET TWO WINDINGS WINDING 'A' 40 WINDING 'B' 20
POLARISED RELAY. 5
4 VOLT BATTERY ON ENGINE 3 NICKEL IRON ACCUMULATORS IN SERIES.
SHOE SWITCH
ENGINE SHOE
RAMP
CONTROL RELAY
LEVER CONTACT
SIGNAL BOX BATTERY 3 A-D CELLS IN SERIES
ARM CONTACT. OFF 20°-70°
RAMP BATTERY 16 VOLTS APPROX
PROCEED
B
CONTROL RELAY ENERGISED BY CURRENT FROM SIGNAL BOX BATTERY WORKING CURRENT 12 M.A. CURRENT FROM RAMP BATTERY ENERGISING POLARISED RELAY AND WINDING 'B' OF ELECTRO-MAGNET, ARMATURE HELD, WORKING CURRENT 500 TO 700 M.A. BELL AND SIREN CIRCUITS CLOSED BY POLARISED RELAY
RELAY
(SLOW RELEASE)
BELL
AUTOMATIC VACUUM OPERATED BATTERY SWITCH
WINDING 'A'
WINDING 'B'
VACUUM PIPE
SIREN
ELECTRO-MAGNET. TWO WINDINGS WINDING A 40 WINDING B 20
POLARISED RELAY. 5
4 VOLT BATTERY ON ENGINE. 3 NICKEL-IRON ACCUMULATORS IN SERIES
SHOE SWITCH
ENGINE SHOE
RAMP
CONTROL RELAY
LEVER CONTACT.
SIGNAL BOX BATTERY 3 A.D. CELLS IN SERIES
ARM CONTACT OFF 20°-70°
RAMP BATTERY 16 VOLTS APPROX.
PROCEED WITH CAUTION.
C
CLOSED CIRCUIT BROKEN AT SHOE SWITCH. ELECTRO-MAGNET DE-ENERGISED. CIRCUIT BROKEN THROUGH WINDING 'A' NO CURRENT THROUGH WINDING 'B' AIR ENTERING TRAIN VACUUM PIPE THROUGH SIREN.
RELAY.
(SLOW RELEASE)
BELL
AUTOMATIC VACUUM OPERATED BATTERY SWITCH
WINDING 'A'
WINDING 'B'
VACUUM PIPE
SIREN
ELECTRO-MAGNET TWO WINDINGS WINDING 'A' 40 WINDING 'B' 20
POLARISED RELAY 5
4 VOLT BATTERY ON ENGINE. 3 NICKEL-IRON ACCUMULATORS IN SERIES.
SHOE SWITCH
ENGINE SHOE
RAMP
CONTROL RELAY
LEVER CONTACT.
SIGNAL BOX BATTERY 3 A-D CELLS IN SERIES
ARM CONTACT OFF 20°-70°
RAMP BATTERY 16 VOLTS APPROX.

Fig. 4.

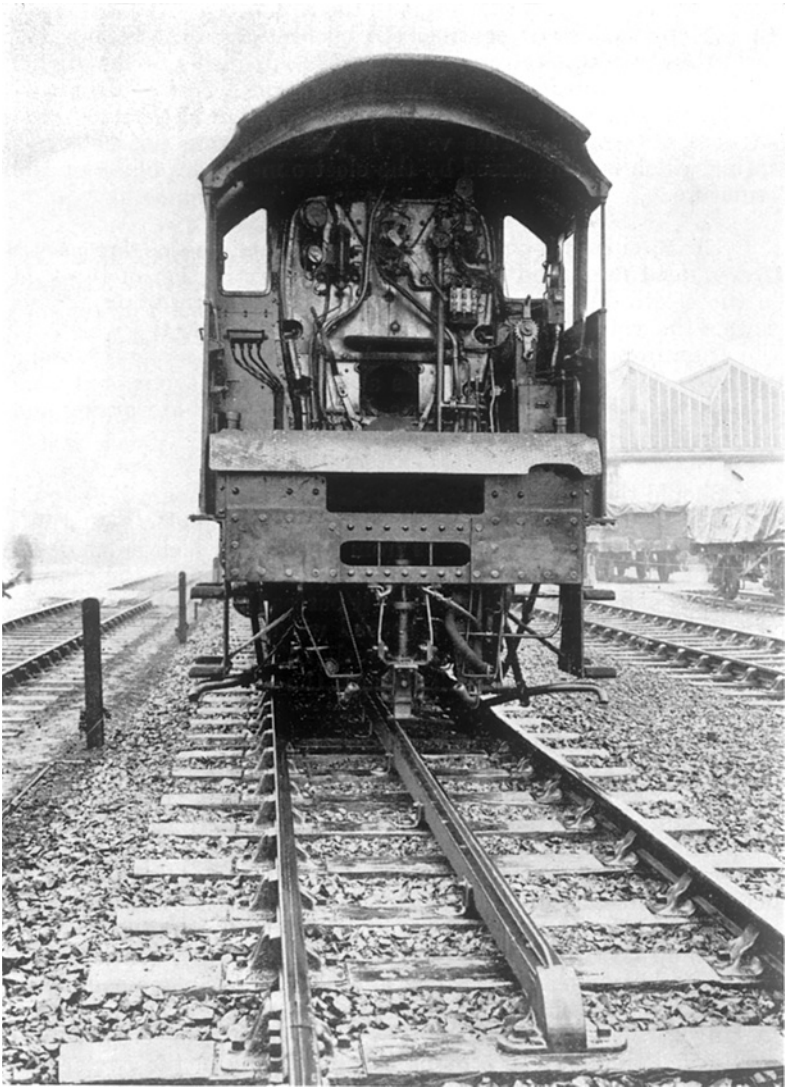


Fig. 5.

cal lift and the other depending on its ability to act as an electrical conductor while the ramp is energised.

Dealing first with the mechanical aspect of the shoe. To it is attached a suitably designed switch which is opened every time the shoe is lifted. The switch is in the circuit of a battery carried on the engine, and it controls the battery current which is fed through a pair of electro-magnets in the apparatus in the engine cab. These electro-magnets hold in position a horizontal hinged armature, which, in turn, controls the movement of a valve in the vacuum brake pipe. This valve is pressed on to its seat by a spring which is compressed by the electro-magnets pulling on the armature.

The circuit is broken at the switch when the engine passes over a dead ramp and this results in the destruction of the field in the electro-magnets, consequently the armature drops. This causes the valve to be pushed off its seat both by the weight of the armature and also by the inrush of air into the vacuum brake system. The entering air passes a spinner type syren producing a shrill whistle, and thus giving a distinctive audible warning and at the same time applying the brake.

Should the ramp be energised, however, the shoe will not only be lifted mechanically but it will also pick up the electric current from the ramp. Suitable leads from the shoe, which is insulated from the mass of the engine frame, carry the current to the apparatus in the cab of the engine. Here it passes through the field coils of a polarised relay, then to a second winding on the same poles as the brake electro-magnet previously referred to, and finally it completes the circuit to earth through the mass of the engine.

The effect of the ramp current is to replace the field of the local engine battery in the brake electro-magnets, thereby maintaining the armature horizontal and suppressing the danger signal. At the same time it produces a field in the polarised relay to which it is connected. In this field is a permanent magnet so mounted on a spindle that the production of the field causes the magnet to deflect. Attached to the magnet is a spring contact which is closed when the magnet deflects. This contact operates a further relay known as the "slow releasing relay," which consists of a coil of 5 ohms resistance, which is wound on the same spindle as another coil of 25 ohms, the ends of the latter being joined together making a "snub" winding. Current from the engine battery is fed through the 5 ohms coil by closing of the contact on the polarised relay, and the gravity controlled armature of the slow release relay is therefore lifted, closing a further pair of contacts. The field induced in the 20 ohms coil by the "make" is opposite in sense to the field of the 5 ohms coil but its magnitude is less. When the field in the 5 ohms coil is broken, however, the induced field in the 20 ohms coil due to the break is in the same direction as that which had been in the 5 ohms coil when it was energised, consequently the armature of the slow releasing relay is retained closed for longer than the duration of the current in the 5 ohms coil, due to the current induced in the 20 ohms coil by the break. This prolongs the effect of the ramp current beyond its actual duration. Since the ramp current could not always be relied on to be sufficiently strong by itself to ring the bell, the slow release relay contacts bring the stronger local engine battery current into circuit to do this, at the same time giving a longer ring than could the ramp current alone.

The need for a slow releasing relay will be more clearly realised when it is remembered that the passage of an engine over the ramp at a speed of 60 miles per hour takes half a second from one end of the ramp to the other. The effective portion of the ramp is not 44 feet 3 inches long, however, but is only 25 feet 8 inches. The passage over this at the same speed take place in 0.32 second, during which time the whole of the phenomena above described takes place.

As with the electrical arrangement on the ramp, so also with the engine apparatus, it will be seen that failure of any of the electrical gear will result in the destruction of the field in the brake electro-magnets, which will produce a "caution" signal, because the brake valve armature will thereby be dropped, causing the vacuum valve to open, sounding the syren and applying the brakes. Moreover, mechanical failure of the shoe apparatus is similarly detected, because if a shoe fails to return to its proper working position after passing over a ramp, the shoe switch will be left open, and no current will be flowing in the brake valve electro-magnets.

In a similar manner should contact with a live ramp be faulty and no current be picked up, the result will be a "caution" signal in all circumstances.

It will thus be clear that all failures always result in "caution" signals and, further than this, no wrong side failures, viz., the production of "proceed" signals on the engine with the Distant arm in the horizontal position, are possible with the Great Western type of Automatic Train Control apparatus. The accompanying illustrations show a drawing and corresponding photograph of the cab apparatus (Figs. 6 and 7), and the position of the apparatus in the engine cab (Fig. 8).

It may be convenient at this stage to draw attention to the fact that current flows from the engine battery through the brake electro-magnets all the time the engine is in traffic, with the exception, of course, of those times when it is broken at the shoe switch when passing over a ramp.

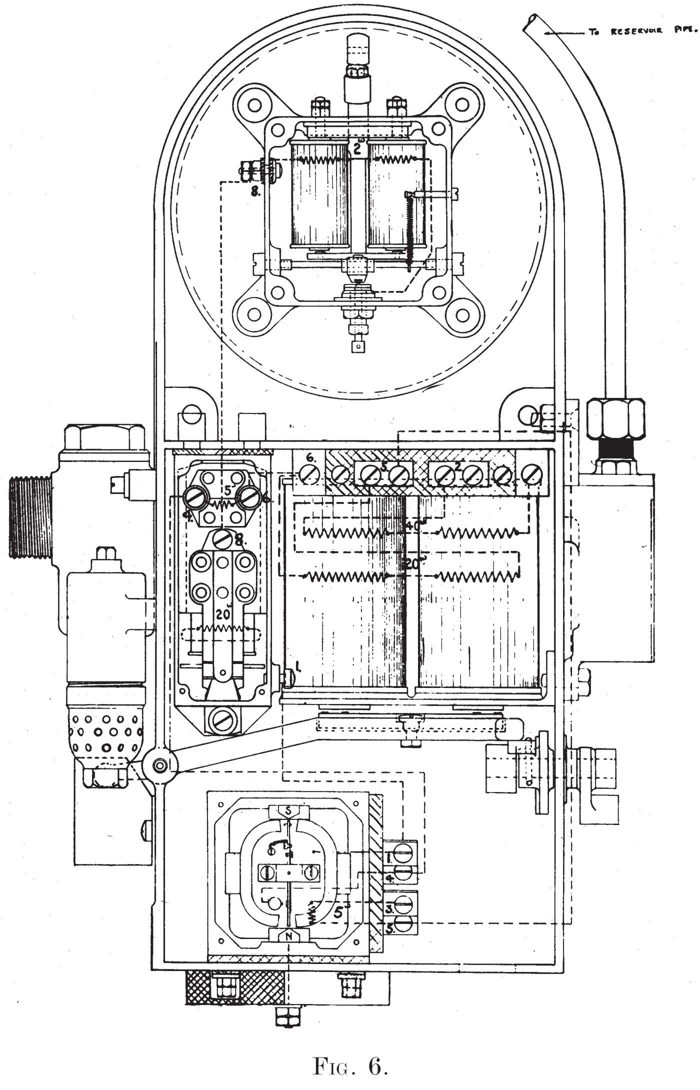


FIG. 6.

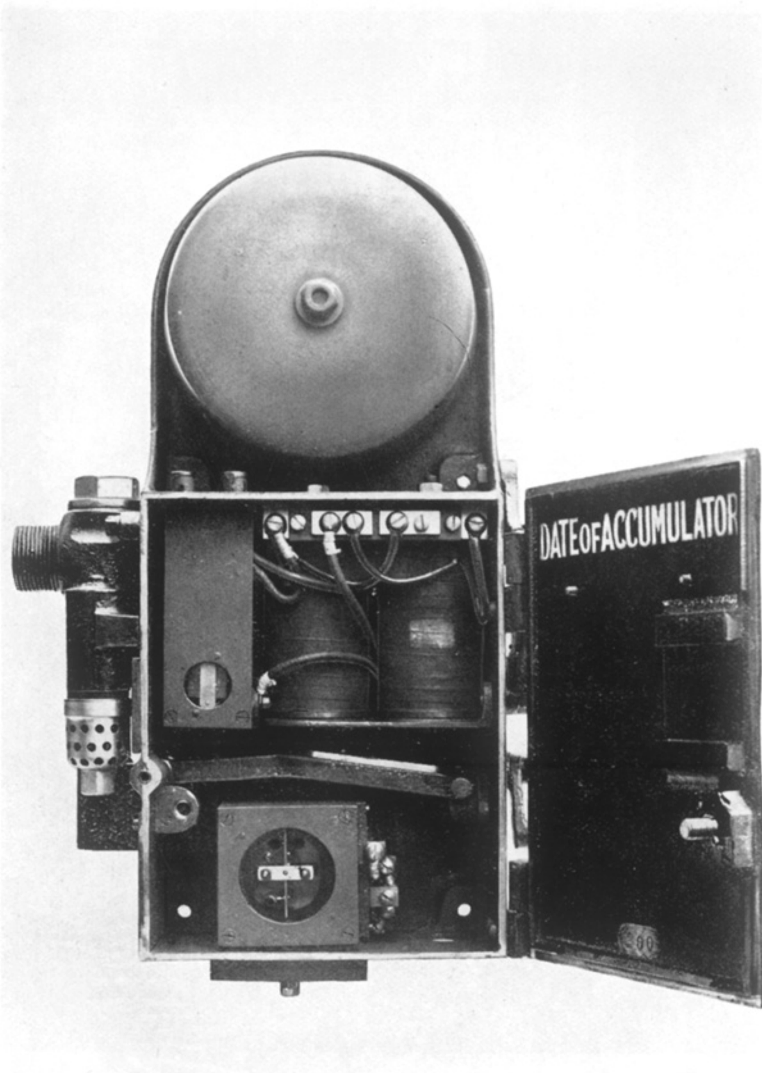


Fig. 7.

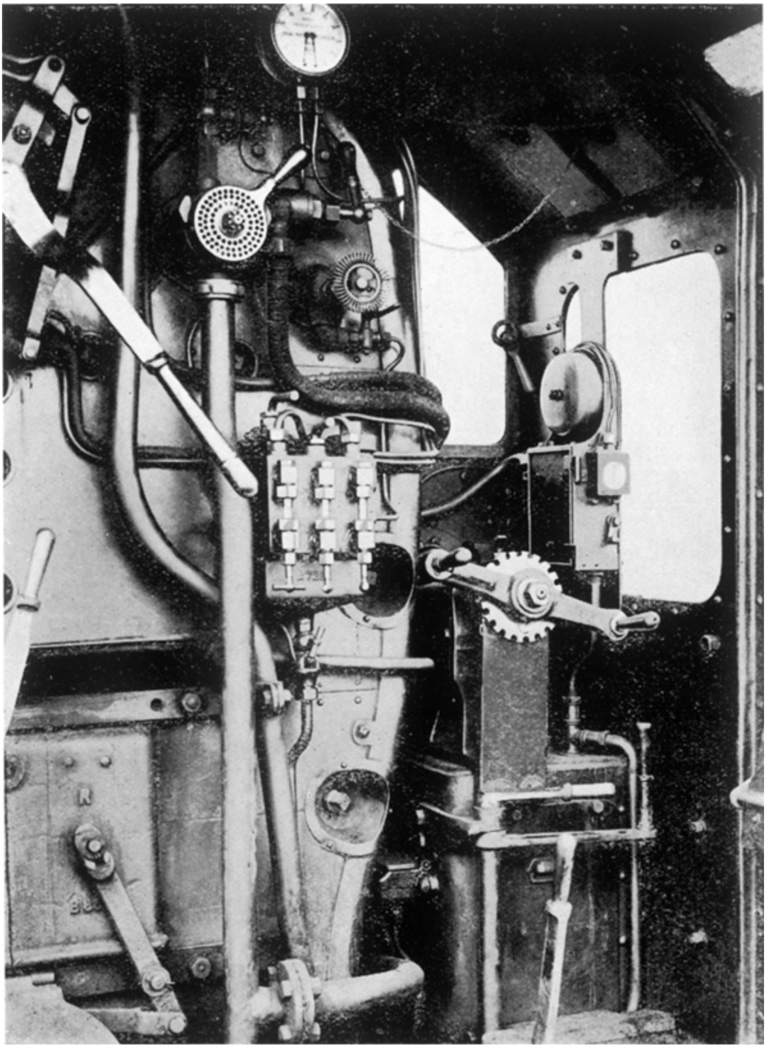


Fig. 8.

When the engine is stabled at the engine shed, however, there is no need for this steady drain on the battery to continue. To economise the battery power, a simple device has been adopted known as the Automatic Vacuum Operated Battery Switch. This consists of a small vertical cylinder with a fairly close fitting piston. The top of the cylinder is connected by a $\frac{3}{8}$ inch bore copper pipe to the vacuum reservoir of the engine, the bottom of the cylinder being open to the atmosphere. To the piston is attached a small piston rod on which is carried an electric contact which bridges two spring blades. The negative end of the engine battery is connected to the mass of the engine through the vacuum switch. When the vacuum in the reservoir is created it sucks the piston to the top of the cylinder. When the vacuum in the reservoir is destroyed however, the weight of the piston and its attached rod and contact causes it to fall, thus breaking the circuit through the spring blades. Since the vacuum reservoir falls to zero after about half-an-hour has elapsed from the time of stabling of the engine, the current from the battery is, by this device, cut off throughout practically the whole time during which the engine is stabled.

The foregoing description applies to the A.T.C. apparatus as fitted to the majority of Great Western engines for main line working.

When engines are required to work over the electrified lines in the London area, however, a modification of this apparatus is necessary, and a short account of the development of this gear may be of interest.

The conductor for the current on the electrified lines is a third rail in the centre of the track directly under the position of the A.T.C. shoe. The voltage in the third rail is about 660 volts, and the effect of the A.T.C. shoe making contact with the live conductor rail would be very serious. When it is desired to run engines fitted with A.T.C. over the electrified lines it is necessary, therefore, to ensure that no contact can take place between the shoe and the conducting rail. This has a nominal height of $1\frac{1}{2}$ inches above the running rail, however, and should thus have a clearance of 1 inch under the A.T.C. shoe. Owing to the fact that the A.T.C. shoes were originally mounted on the engine frame, which is spring borne, the nominal clearance of 1 inch is reduced if the engine is low on its springs. Moreover, any downward movement of the frame while running would also reduce the clearance.

In order to obviate this difficulty and to ensure that the shoe height is maintained, the shoe must be mounted on an unsprung portion of the engine, e.g., the axleboxes or the axle, and when arrangements were originally made to work steam engines over the electrified lines into Paddington Suburban station, it was thought that a suitably designed A.T.C. shoe mounted on such an unsprung portion of the engine would ensure that the nominal clearance of 1 inch between the underside of the shoe and the top of the third rail would obtain. One engine was actually so fitted with an unsprung shoe gear, but before being put in service some consideration was given to the question whether the third rail did at all times conform to the nominal figure of $1\frac{1}{2}$ inches above the running rail level. In order to settle this point a means was devised to measure the height of the third rail throughout the whole of the road likely to be traversed by steam engines.

The apparatus was situated on an engine and in an attached experimental car and consisted of a multiple bladed switch (Fig. 9) which was put in place of the standard switch in the switch box of the experimental unsprung shoe apparatus fitted to the engine. On this multiple switch were eight blades; one was connected to the positive side of a battery, its end resting in all positions of the switch on a flat contact plate which slid beneath it. This plate extended the full width of the remaining seven blades, and its edge was serrated so that successive increases of $\frac{1}{8}$ inch in the height of the shoe above rail level brought into contact successively the blades opposite the respective serrations (see Fig. 9).

The contacts were connected to a series of seven electrically operated pens situated in the vehicle attached to the engine, the pens being mounted over a moving strip of paper, which was driven at a constant speed by an electric motor. There were thus seven pens indicating the height of the shoe. An eighth pen on the table was operated by an observer closing an ordinary pear push on passing stations, mile posts and the like. When the shoe had reached $2\frac{1}{2}$ inches above the rail, an electric horn sounded in the vehicle and remained sounding so long as the shoe was more than $2\frac{1}{2}$ inches above the rail.

By means of this arrangement a continuous record (Fig. 9) was made of the height of the centre rail over a single track length of about 12-15 miles on those roads which were likely to be used by steam trains.

In order to make this record, occupation had to be obtained of the lines when the current was switched off, and this entailed some interesting journeys through the tunnels of the Metropolitan Railway on weekdays between 2 and 4 a.m. and on Sunday mornings between 3 and 5.30.

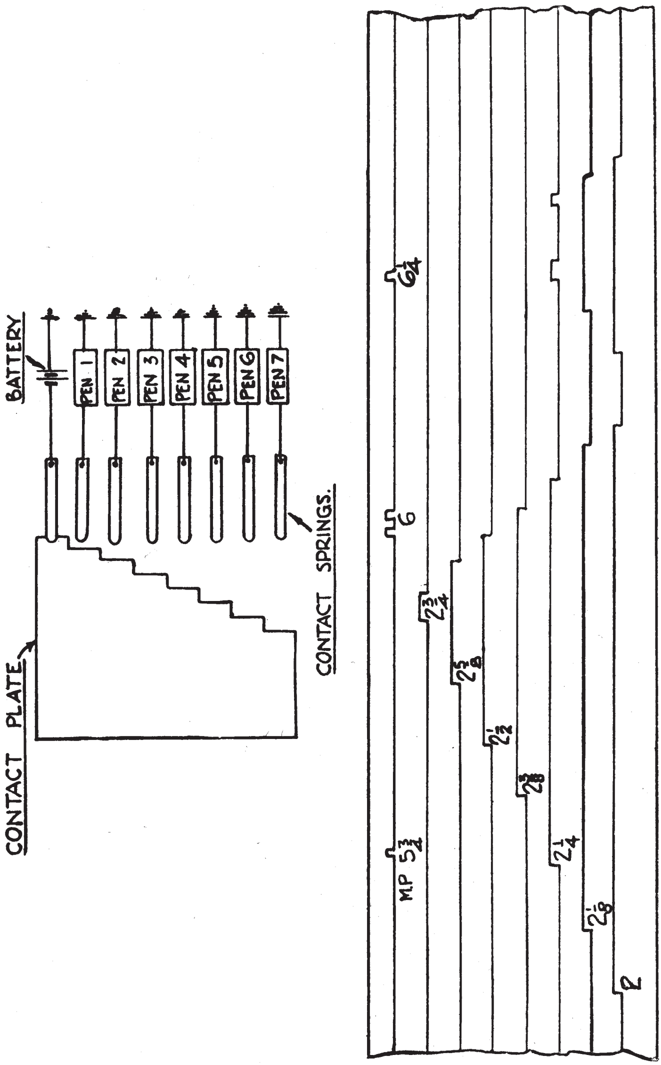

CONTACT PLATE
BATTERY
PEN 1
PEN 2
PEN 3
PEN 4
PEN 5
PEN 6
PEN 7
CONTACT SPRINGS.
M.P 5 3/4
6
6 1/4
2 3/4
2 5/8
2 1/2
2 3/8
2 1/4
2 1/8
2

Fig. 9.

As a result of these tests it was found that the height of the third rail was very frequently more than the nominal figure of $1\frac{1}{2}$ inches, often reaching as high a figure as $2\frac{1}{2}$ inches and occasionally even more. This big difference was due to the method of mounting the third rail, which is only anchored to the track at each end of its 44 feet length, the centre being left merely resting on channel section supports. The passage of the engine over the track would thus depress the running rails, whilst leaving the third rail undeflected. To overcome this difficulty for A.T.C. purposes would involve either a complete alteration in the method of mounting the third rail, or would entail redesigning the shoe apparatus on the engine so that the shoe could be suitably clipped up out of the way when operating in these areas.

The suggestion to alter the mounting of the third rail was quite impracticable for two reasons. In the first place, the cost of the alteration over the length of the track involved would be prohibitive, and, secondly, the great proportion of the road in question was not under the control of the G.W.R. For these reasons attention was directed to some method of raising the shoe on the engine out of the range of possible contact with the third rail. Early suggestions to this end included hand operated gear to lift the shoe, which placed on the engineman the responsibility for

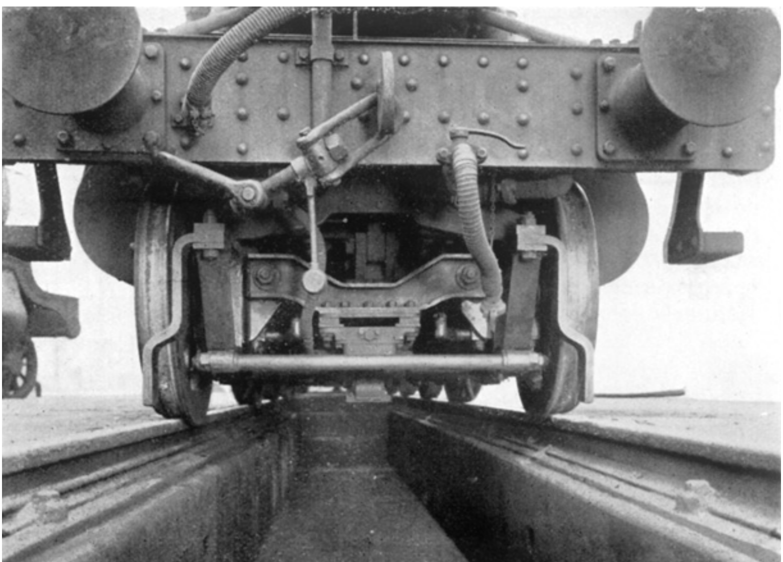


Fig. 10.

the shoe being lifted. The results of failure by the driver to lift the shoe at the correct place were deemed to be so serious, however, that it was subsequently decided to place the operation completely out of his control, and clip the shoe up and drop it automatically at the appropriate places. This is achieved by fashioning a portion of the shoe gear in such a manner that on the shoe being lifted to the required height, a spring bolt drops behind a catch and the shoe is held clipped up in this raised position. The height selected was 4 inches because in no case was the height of the electric third rail found to exceed $3\frac{1}{4}$ inches, and this in very few circumstances. (Fig. 10) shows the shoe gear as mounted on the axle-boxes, and (Fig. 11) shows the drawing of the gear and also the wiring diagram.

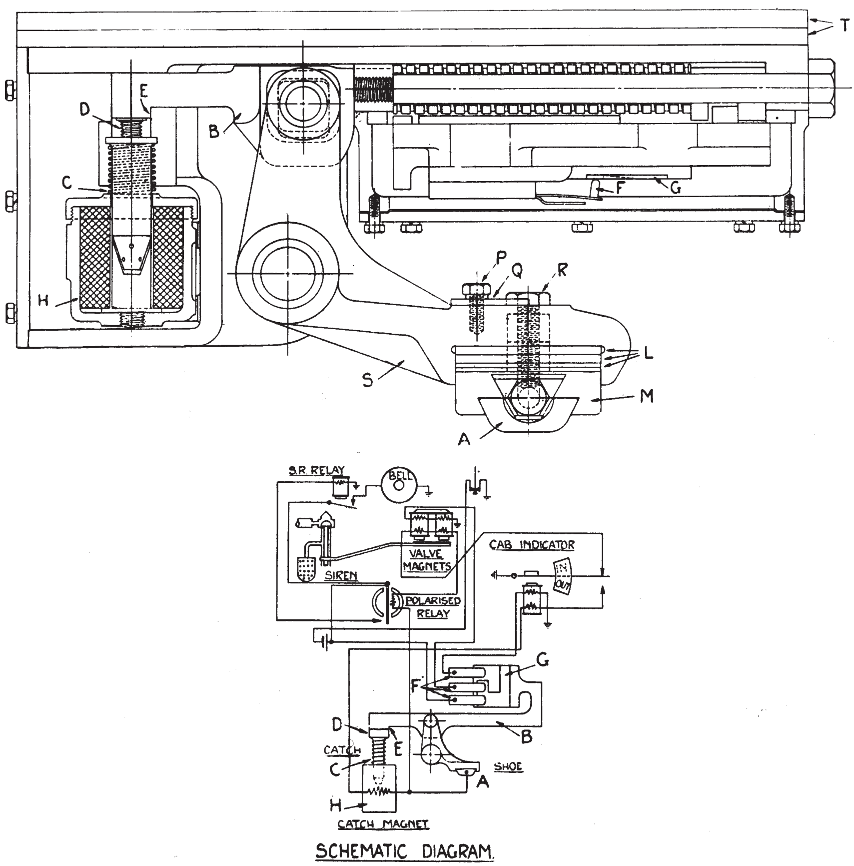


Fig. 11.

The method of operation is as follows:—On approaching an electrified area the engine passes over a dead ramp $4\frac{1}{2}$ inches high, which lifts the shoe "A" $1\frac{3}{4}$ inches and consequently the stirrup "B" moves $1\frac{5}{16}$ inches, allowing the spring "C" to push the catch "D" behind the shoulder "E" on the stirrup. At the same time the switch is moved to the position when the three contact blades "FFF" are all resting on the brass plate "G." The circuit through the brake valve magnets is thus restored, allowing the valve to be kept shut. This position of the switch also energises the coils of a shoe position indicator in the engine cab, the flag of the indicator moving to position "Shoe catch in," at the same time taking the earth off the 20 ohm brake valve coils of the cab apparatus and earthing the electro-magnets "H" in the shoe apparatus. The head of the catch "D" is $1\frac{1}{8}$ inches wide, hence the shoe on leaving the ramp drops to 4 inches above rail.

On leaving the electrified area, the engine passes over a live ramp $4\frac{1}{4}$ inches high. The shoe "A" is first lifted to $4\frac{1}{4}$ inches and at the same time the ramp current energises the electro-magnet "H" and also the 2 ohm coil in the cab indicator. The electro-magnet "H" withdraws the catch "D," hence as the engine leaves the ramp the shoe drops to normal $2\frac{1}{2}$ inches above rail and the switch is returned to normal position, with only two of the three contact blades "FFF" resting on the brass plate "G." This breaks the circuit through the main coils of the cab indicator, but the flag does not move to the "Shoe catch out" position until the shoe "A" leaves the ramp, since the ramp current passing through the 2 ohm coil of the indicator holds the flag in the "In" position, maintaining the earth on to the catch magnet "H." The catch "D" is thus held out during the whole time the shoe is on the ramp, ensuring that the shoe is free throughout its passage over the ramp to drop down to its normal position. On leaving the ramp the indicator flag drops to the "Shoe catch out" position, restoring the earth to the 20 ohm brake valve coils of the cab apparatus and taking the earth off the electro-magnet "H." The apparatus is then in the normal working position.

The height of the shoe is adjusted by altering the total thickness of the liners "LL" above the slipper piece holder "M." If it is desired to raise the shoe more than the removal of all the liners "LL" will permit, the whole shoe apparatus must be dropped from the supporting plates, and one, or both, of the $\frac{1}{2}$ inch packing pieces "TT" removed.

It will be seen from the above that a special switch with three blades is used instead of the standard with two blades only. In addition, the contact plate of the switch is made key-shaped and not straight as is the standard.

The need for this special switch is twofold. In the first place, it is necessary to give some visual indication of the position of the shoe to the driver, and this is done by means of the electric flag-indicator in the engine cab. When the shoe is clipped up the third blade of the switch completes a circuit through the sliding key-shaped plate contact and energises the coils of the indicator. Secondly, when the shoe is clipped up, the circuit to the brake electro-magnets through a standard switch would be broken and a continuous brake application would result. By means of the second contact position on the contact plate corresponding to the clipped up position of the shoe, the electro-magnets are energised and the engineman suppresses the brake application by means of the re-setting lever in the ordinary way.

It is interesting to point out that when clipping up over a dead ramp a danger signal is received, as would be expected, but in addition, when resetting by the picking up of a current from a live ramp, a danger signal is again received. This is different, of course, from the result of picking up a current from a ramp in the main line, which results in a bell signal. The reason for this difference is that on the ramp which is energised for resetting the shoe to its normal working position, the current flows in the opposite direction to that of the current when present in a main line ramp, and therefore the permanent magnet in the polarised relay is deflected away from its contact, consequently no bell signal results. Moreover, the field in the valve magnets due to the re-setting ramp current is opposed to that of the engine battery current therein, consequently the pull of the 40 ohms coil is partly neutralised by the field of the 20 ohms coil with the result that the armature is, as it were, thrown down by the current from the ramp. The reason for this reversal of current is to ensure that a bell signal is only received on the engine when passing a Distant signal in the "clear" position, and is never received under any other circumstances.

The clipping up and resetting apparatus in its original form was tried with success over ramps specially set in the main line during periods of occupation on Sundays, and at the initial attempt the shoe was successfully dropped from its clipped up position at all speeds up to about 45 miles per hour. Clipping up was successfully carried out at all speeds up to about 70 miles per hour.

Speed restrictions of about 25 miles per hour obtain at those points where steam trains would enter or leave the electrified line, but in practice this speed may be exceeded by 5 miles per hour. Therefore, it was necessary to ensure that the apparatus would work with certainty at 30 miles per hour. With the engine under test, all connections were good, the gear was in good condition and the battery was also fully charged. In order to provide a

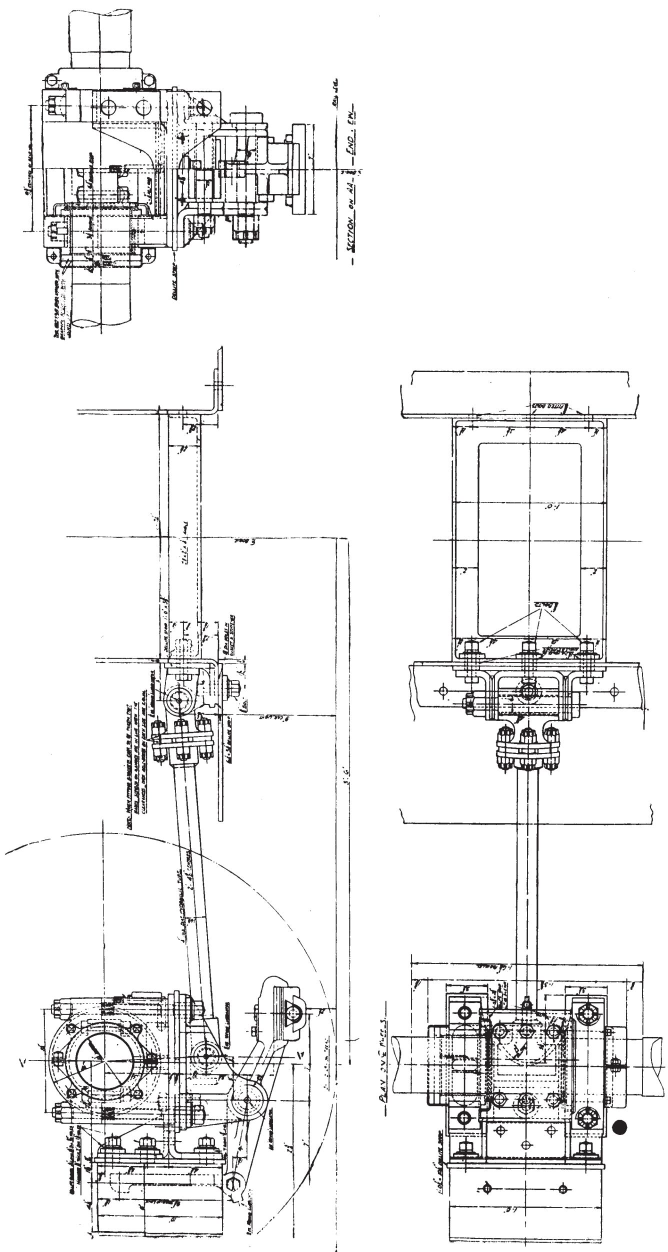


Fig. 12.

sufficient margin between everything being in new condition and the worst cases likely to arise, due to deterioration of apparatus and adverse weather conditions, it was decided to aim at 60 miles per hour as the speed at which the apparatus should work with certainty with everything in new condition.

Various modifications were, therefore, made during the course of trying out the apparatus, without in any way altering its essential details, and in its final form, the shoe was successfully released at all speeds up to 69 miles per hour.

This apparatus is now fitted to all engines working into Paddington Suburban station, and to those engines regularly working into Smithfield Market and Addison Road, together with a number of engines which may work into Addison Road with excursion trains on special occasions.

Ramps for operating this shoe gear are fitted at a number of different sites in the London area. No serious difficulty has been experienced with the device since its general adoption.

Another interesting development of A.T.C. arose with the advent of the Diesel Rail Cars with their "either-end" control. These vehicles operate on long stretches of the main line which is equipped with A.T.C. ramps, consequently it was an obvious decision to fit them with A.T.C. apparatus.

Equipping them with a shoe was no very great difficulty, since a modification of an existing design of an unsprung engine shoe apparatus enabled a suitable arrangement (Fig. 12) to be slung on to one of the axles, the principal novelty of the arrangement being the method of securing the unit from rotating with the axle. The main difficulty arose, however, due to the vehicle being controlled from either end, and it was, therefore, necessary to duplicate the cab apparatus and put one in each driver's cabin. This, in turn, necessitated the provision of some means of ensuring that only that apparatus which was appropriate to the direction of motion should be in use, the other being at such times out of use. This was achieved by special wiring (Fig. 13) of both sets of apparatus to a change-over switch, which consists of three pairs of spring blades and which is coupled to the reversing handle of the car.

In passing, it should be pointed out that these cars have gear boxes with four or five speeds and a separate reverse drive in series, giving them four or five speeds in each direction. It is to the controlling gear of the reverse drive that this change-over switch is coupled. When the car is proceeding in one direction, the spring

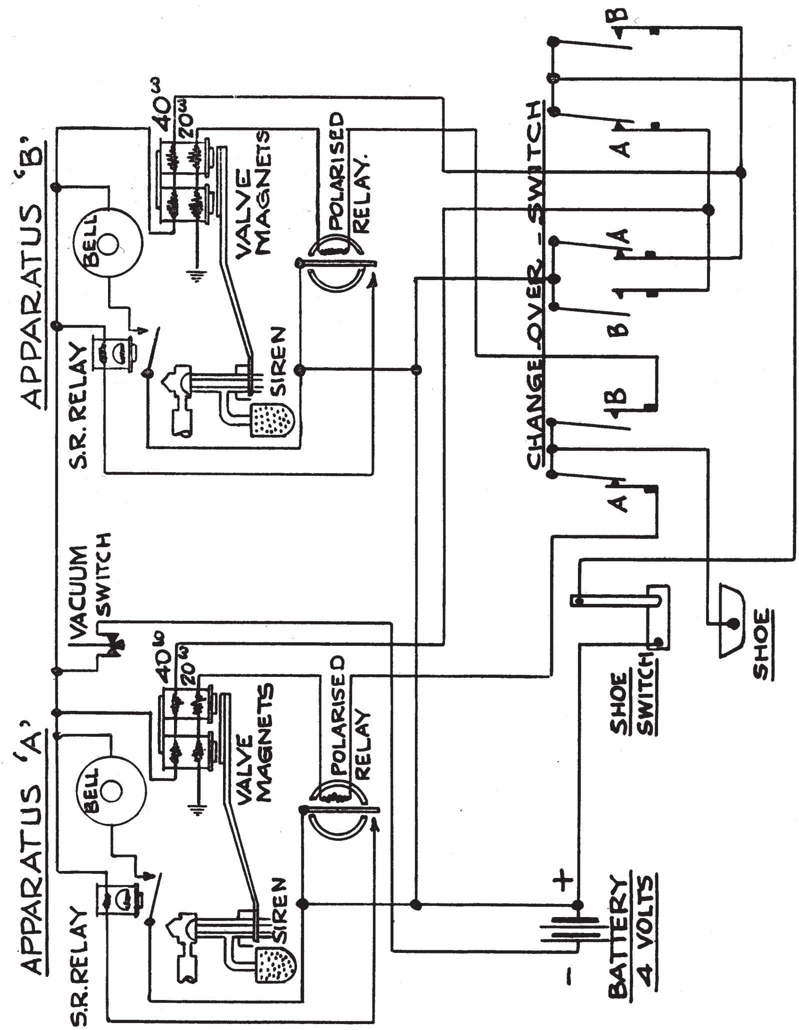


Fig. 13.

blades are all making contact on one side, and, similarly, the action of the driver in reversing the car to drive from the other end automatically changes over the contact of the spring blades to the other side. Three pairs of blades are necessary, one pair for the ramp current, another pair for the local battery current, and the third pair for the current which is fed to the brake coils from the shoe switch.

It is clear from the diagram that in that apparatus which is not appropriate to the direction of motion, the brake coils are permanently energised from the battery and no operation of the shoe switch will result in the opening of the brake valve in that apparatus.

The device is quite successful and has been fitted to all Diesel rail cars which have been purchased by the Company.

A further interesting development in the design of A.T.C. apparatus has been rendered necessary by the increasing use of "push-pull" trains or auto-trains as they are termed. These trains are equipped with gear on each vehicle or "trailer," which makes it possible for the train to be driven from an appropriate "driver's vestibule" on the end trailer of the train. Suitable rigging is provided so that the driver can from the vestibule operate the regulator valve on the engine and also blow the whistle. Control of the brake is effected by means of a standard air valve in the vestibule for application of the brake, but the brakes must be released by the fireman on the engine after application by the driver in the vestibule. Not more than four such trailers may be attached to the engine, and not more than two on each end of the engine. With this maximum arrangement there are thus five places on the train from which it is possible to arrange for it to be driven. Tail traffic is, of course, permitted on the tail of the train.

Prior to the introduction of the apparatus described below, the signals appropriate to A.T.C. received on these auto-trains were confined to the footplate of the engine. Consequently when the driver was driving from a trailer vestibule, he was quite ignorant of the signals received on the engine and had to rely on the fireman to receive and interpret the audible signals and to re-set the "caution" brake application when necessary. This unsatisfactory state of affairs has been overcome by installing in each trailer vestibule apparatus which makes possible the repetition of the audible signals and "caution" brake application in whichever vestibule the driver happens to be. By this means, both driver and fireman receive the signals when the train is driven from a trailer vestibule, and both have to re-set the "caution" brake application when necessary, thus ensuring that both are cognisant of the "caution" warning.

To achieve this, certain modifications to the standard engine cab apparatus, and a new design of apparatus for use only in the vestibules, were found to be necessary. These sets of apparatus are all linked together with electric wires extended to the full length of the train and furnished with suitable plug connections at the end of each vehicle to facilitate coupling up, etc. The wiring diagram is shown in (Fig. 14).

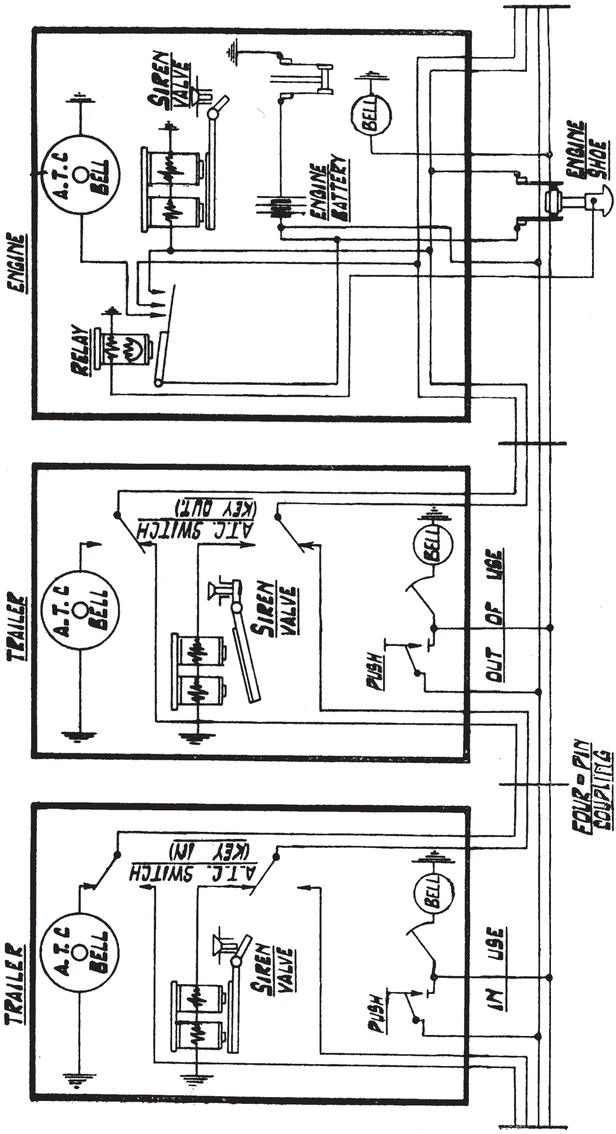

ENGINE
RELAY
A.T.C BELL
SIREN VALVE
ENGINE BATTERY
BELL
ENGINE SHOE
TRAILER
A.T.C BELL
A.T.C. SWITCH
(KEY OUT)
SIREN VALVE
BELL
PUSH
OUT OF USE
TRAILER
A.T.C BELL
A.T.C. SWITCH
(KEY IN)
SIREN VALVE
BELL
PUSH
IN USE
FOUR-PIN COUPLING

Fig. 14.

The linking of the vestibule apparatuses to the engine battery circuit ensures that the breaking of the shoe switch contacts, or the making of the bell contacts, on the engine, causes the brake valve to open, or the bell to ring, as the case may be, in both vestibule and engine cab.

It is clear that some arrangement is necessary to ensure that signals are repeated only in that vestibule from which the trailer is being driven, and to achieve this a system has been adopted which involves the use of an "Auto-Train Driver's A.T.C. Key" (Fig. 15), and the fitting of appropriate instruments in each vesti-

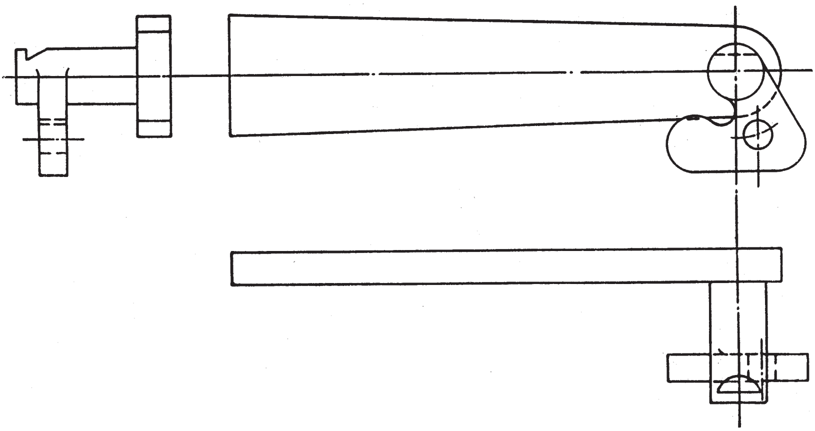


Fig. 15.

bule and on the engine footplate. This is analagous to the token system of working trains on single lines: from whatever point on the train the engineman is driving, he must there have the "token" or key inserted in the appropriate instrument, otherwise he will have some considerable inconvenience when driving his train. A further reason for the adoption of this system lies in the fact that it renders it very unlikely that an engineman will be driving in a trailer vestibule and be ignorant that the A.T.C. is not in use, if this should be the case. So much reliance is placed on the A.T.C. by the drivers that ignorance that it is out of use, if it should be so, constitutes a graver danger than its complete absence.

The instrument in each vestibule (Fig. 16) combines the functions of a change-over switch for the electric circuits for A.T.C., and a master vacuum valve which shuts off the train pipe vacuum from the driver's vacuum brake valve and also from the A.T.C. syren valve. If the key be correctly inserted into the instrument, the A.T.C. apparatus in this vestibule is brought into use and the driver's vacuum brake valve is rendered usable in the

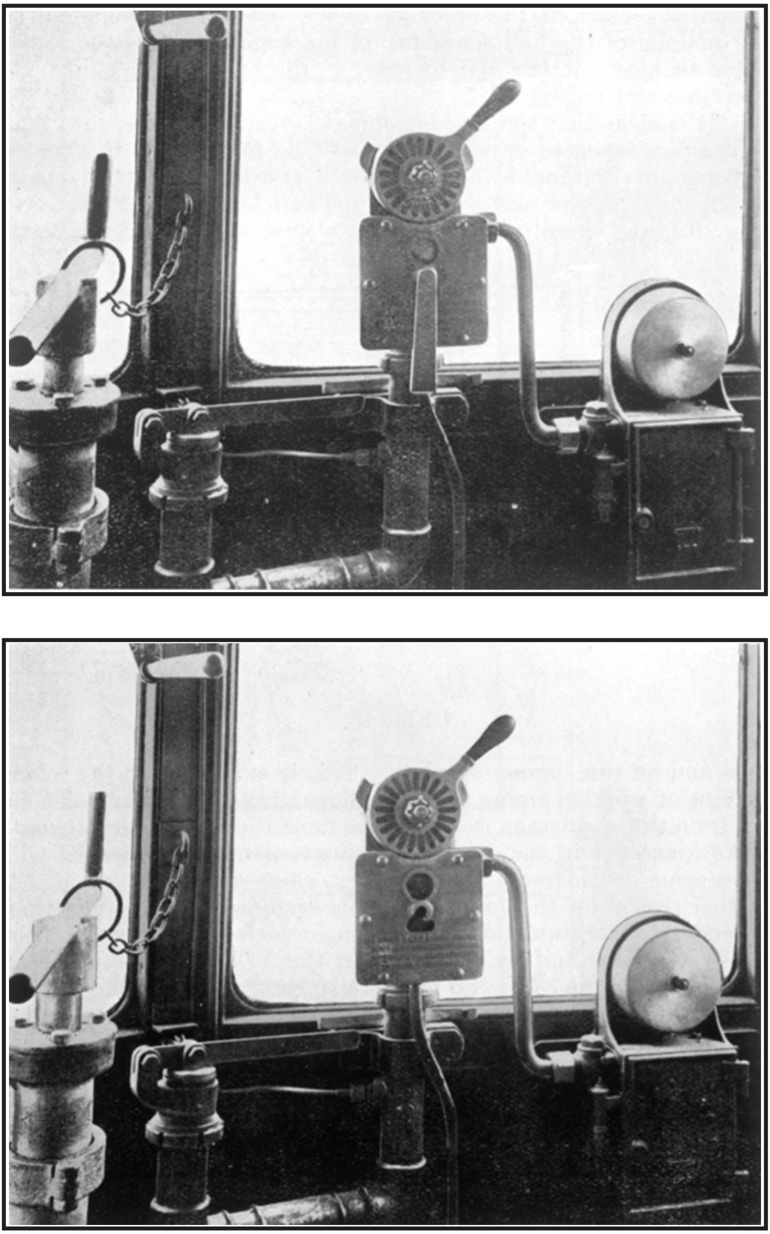


Fig. 16.

ordinary way. Should the key not be correctly inserted, however, or should it be missing, the driver will find that his vacuum brake valve is out of use, and he will have to use an emergency brake setter which is provided close handy, but which will not be at all easy to operate and will be likely to cause rough stops. This inconvenience will remind him to insert the key, and, hence the A.T.C. will thus be brought into use. The arrangement of controls in the trailer vestibule is shown in (Fig. 16).

On the locomotive the instrument (Fig. 17) takes the form

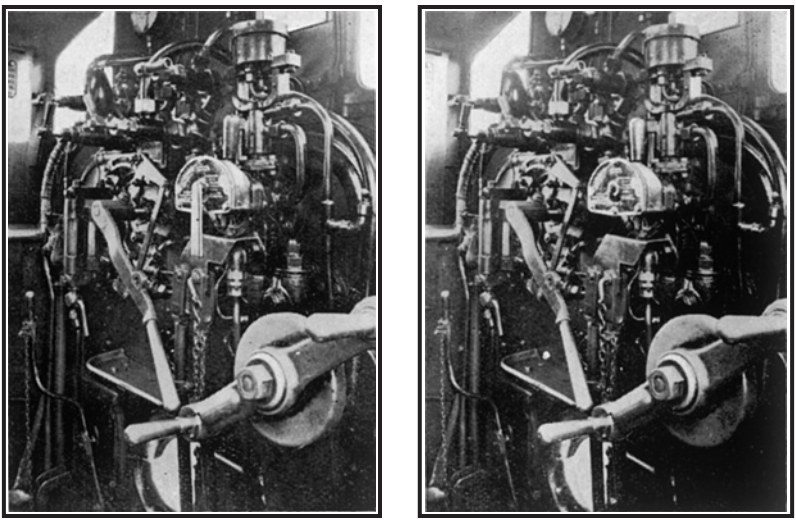


Fig. 17.

of a conditional ratchet catch on the handle of the ejector. With the key correctly inserted into this key holder, the handle can be moved in the ordinary way, both to apply the brake and to blow up a vacuum. Should the key not be correctly inserted, however, or should it be missing, the driver will find that he can make only one application of the brake, but will be prevented by the ratchet catch from subsequently blowing up a vacuum until he has correctly inserted the key. The fireman will be able, in emergency, in the absence of the driver, to apply the brake, but it will not be possible for him to release it until the driver's key is correctly inserted into the key-holder on the ejector. Even though the driver's key be not in the holder, it is made possible for the fireman to re-create the vacuum after a brake application has been made by the engineman who is driving in a trailer vestibule.

The key-holder is necessary on the locomotive to ensure that when a driver leaves the vestibule to drive the train from the footplate of the engine, he removes the key from the vestibule instrument and thus puts that A.T.C. apparatus out of use.

Although this apparatus on auto-trains is still in the experimental stage, no trouble of any kind has been experienced since the first set was fitted, and it appears likely that the use of the gear will ultimately be extended.

A little-used but extremely interesting modification of the standard A.T.C. apparatus is necessary when it is adapted for use on single lines.

The essential condition for satisfactory single line working of A.T.C. apparatus is that only such signals shall be given on the engine as apply to its direction of motion.

This is achieved on the G.W.R. system by specially interlocking with the single line train staff or token instruments, certain switches which control the current to the ramps; and also by special wiring (Fig. 18) of the engine apparatus. This modification to the engine apparatus, however, does not affect its operation when the engine is running on the main line.

On the track the following modifications are made to the standard apparatus.

When the line is clear all ramps "up" and "down" are electrified, and, therefore, some method of differentiating between them is necessary. It is, therefore, so arranged that a positive current is connected to the ramps which apply to the direction of motion and a negative current is connected to the ramps which apply to the opposite direction. This is effected by arranging that certain switches have to be closed before the tablet or staff can be released to give the driver authority to proceed.

When the line is not clear only the ramps applying to the direction of motion are dead; those applying to the opposite direction being again electrified with a negative current through the medium of switches interlocked with the token instruments.

On the engine the following modifications are made to the standard cab apparatus. There is only one winding (that from the engine battery) on the valve electro-magnets, and the standard polarised relay is replaced by another polarised relay with two tongues instead of one. Certain re-arrangement of the wiring is also necessary.

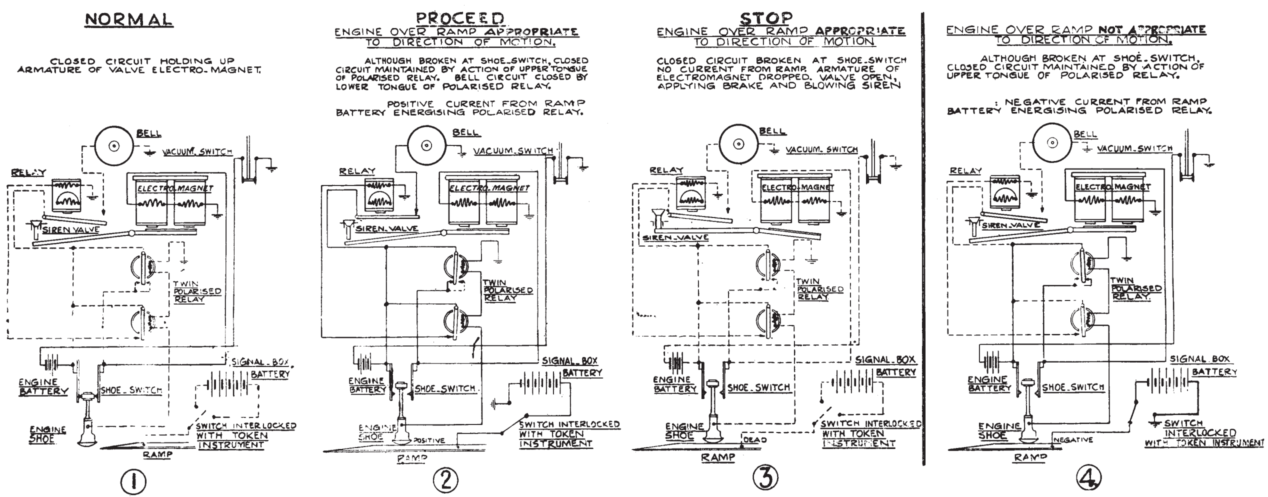

NORMAL
CLOSED CIRCUIT HOLDING UP ARMATURE OF VALVE ELECTRO-MAGNET.
BELL
VACUUM SWITCH
RELAY
ELECTRO-MAGNET
SIREN VALVE
TWIN POLARISED RELAY
ENGINE BATTERY
SHOE-SWITCH
SIGNAL-BOX BATTERY
ENGINE SHOE
SWITCH INTERLOCKED WITH TOKEN INSTRUMENT
RAMP
1
PROCEED
ENGINE OVER RAMP APPROPRIATE TO DIRECTION OF MOTION.
ALTHOUGH BROKEN AT SHOE-SWITCH, CLOSED CIRCUIT MAINTAINED BY ACTION OF UPPER TONGUE OF POLARISED RELAY. BELL CIRCUIT CLOSED BY LOWER TONGUE OF POLARISED RELAY.
POSITIVE CURRENT FROM RAMP BATTERY ENERGISING POLARISED RELAY.
POSITIVE
2
STOP
ENGINE OVER RAMP APPROPRIATE TO DIRECTION OF MOTION
CLOSED CIRCUIT BROKEN AT SHOE-SWITCH NO CURRENT FROM RAMP. ARMATURE OF ELECTROMAGNET DROPPED. VALVE OPEN, APPLYING BRAKE AND BLOWING SIREN
DEAD
3
ENGINE OVER RAMP NOT APPROPRIATE TO DIRECTION OF MOTION.
ALTHOUGH BROKEN AT SHOE-SWITCH, CLOSED CIRCUIT MAINTAINED BY ACTION OF UPPER TONGUE OF POLARISED RELAY.
: NEGATIVE CURRENT FROM RAMP BATTERY ENERGISING POLARISED RELAY.
NEGATIVE
4

Fig. 18.

The upper tongue of the polarised relay has a contact on each side of it so that it completes a circuit whichever current (either positive or negative) is passed through it. The lower tongue has one contact only, on the side to which it is deflected by a positive current. The function of the upper tongue is to short-circuit the shoe switch and thus maintain a current through the valve electro-magnets. This it does whichever way it is deflected, the contacts which it touches being electrically connected. The function of the lower contact is to complete the circuit which rings the bell, and this it does only when a positive current is passed through it.

When the engine passes over a dead ramp the usual syren warning and partial brake application are given, due to the breaking of the circuit through the valve electro-magnets.

When the engine passes over a ramp electrified with a positive current, i.e., when the Distant signal is at "Clear," the two tongues of the polarised relay make contacts, one ringing the bell and the other maintaining the current through the valve electro-magnets.

When the engine passes over a ramp electrified with a negative current, i.e., a ramp applying to the opposite direction of motion, only the upper tongue of the polarised relay makes contact, maintaining the circuit through the valve electro-magnets, and no signal is given on the engine.

In any case, failure of any of the circuits causes a "Caution" signal to be given.

When engines fitted for single line working are running on the main line, correct signals will be received, but engines fitted for main line only will not receive correct signals if working over single lines.

Although no very extensive use is made of A.T.C. on single lines on the G.W.R., it is of historical as well as of technical interest, because it was among the earliest schemes for A.T.C. which were evolved in the early development of the apparatus.

From the earliest forms of A.T.C. apparatus on the G.W.R. to its most recent developments is a natural sequence, therefore the concluding paragraphs of this paper should deal with the latest type of A.T.C. apparatus which has been produced.

All the modifications to the standard apparatus which have been described in the course of the paper have been produced to meet the demand for A.T.C. gear to suit specialised conditions of service, but the new gear, which is about to be described, is a completely new solution to the original problem. Any such alteration in the essential features of established practice can only be justified if considerable economy is effected in either first cost or maintenance, or in both. This claim is made for the new apparatus which is the patented invention of Mr. A. W. Brooker, the foreman of the Telegraph Shop at the Company's Signal Works at Reading.

Obviously the apparatus must be arranged to give signal indications in the cab of the locomotive identical with those given by the existing standard G.W.R apparatus, viz:—

Signal at "Caution": Syren sounded and brakes applied with increasing force.

Signal at "Clear" : Bell sounded.

Similarly, any failure of the apparatus must result in a "Caution" signal, exactly as with the standard apparatus. Also the apparatus must work over exactly the same ramps on the track as the existing standard apparatus.

In the case of the existing G.W.R standard apparatus, it has been made apparent above that the indications are given by means of an electric accumulator carried on the engine. With the new apparatus, however, the indications are given without the use of an accumulator on the engine.

The signals are produced on the engine by means of a shoe of the usual type, $2\frac{1}{2}$ inches above rail, which is lifted each time the engine passes over a ramp. Attached to the shoe by suitable means is a length of No. 14 S.W.G. steel wire, which passes through an insulated flexible metallic tube to the apparatus in the engine cab, the general arrangement of which is shown in (Fig. 25). Here the wire is attached to, but electrically insulated from, a flexible steel band which is wrapped around a drum within which is a convoluted spring. It is clear that each time the shoe is lifted the simple mechanical pull of the wire will cause a partial rotation of the drum, and the spring within the drum will pull the wire back when the shoe resumes its normal position on leaving the ramp.

This partial rotation of the drum is used either (a) to open a vacuum valve, applying the brake and sounding the syren, or, (b) to ring a bell; according to whether the signal is (a) "Caution," or (b) "Clear." The production of the appropriate signal depends upon the presence or absence of a current on the ramp, which current, when present, energises an electro-magnet in the apparatus, to which it is carried by the insulated flexible metallic tube, causing the brake valve to remain shut, and simultaneously ringing the bell.

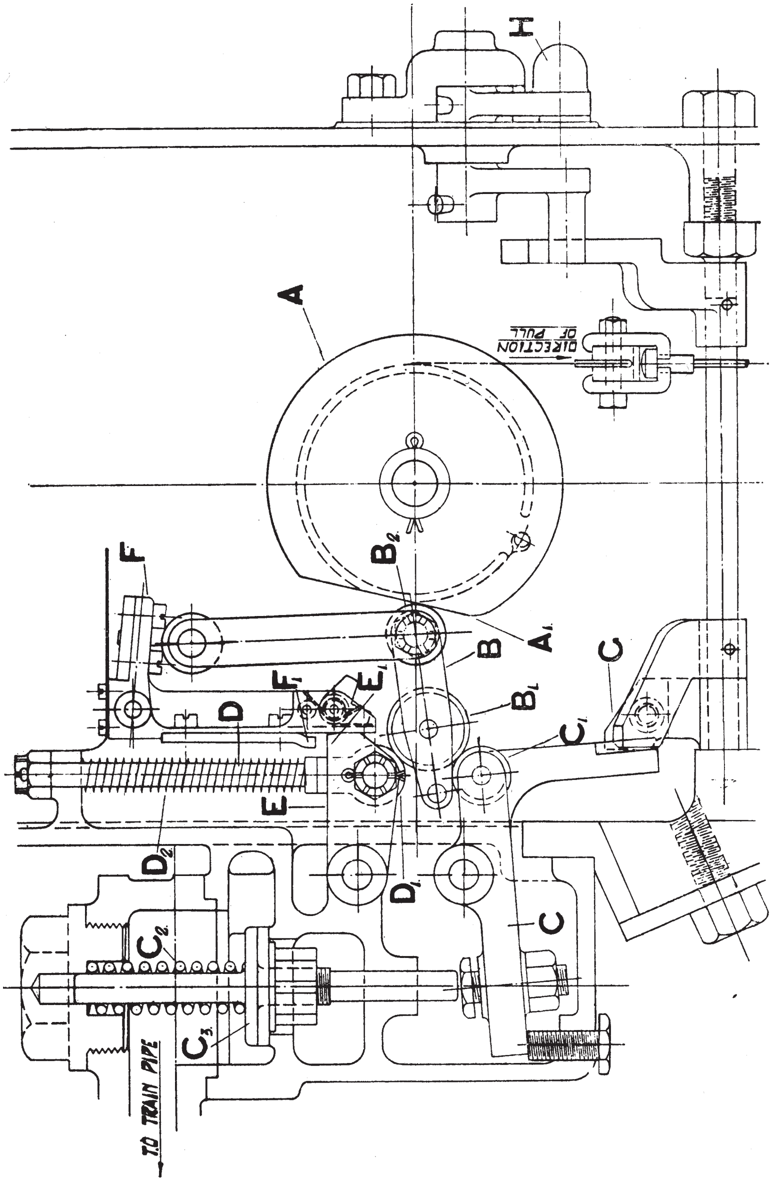

H
DIRECTION OF PULL
A
B_2
A_1
B
B_1
C
C_1
F
F_1
E_1
D
E
D_2
D_1
C
C_2
C_3
TO TRAIN PIPE

Fig. 19.

Fig. 19 shows the essential portions of the apparatus necessary to give a "Caution" signal:—Syren sounded, brakes partially applied. In these circumstances the ramp will be electrically dead, so that the passage of the engine over the ramp merely lifts the shoe. The lift of the shoe causes a partial rotation of the drum "A" as mentioned above. The edge of the drum is formed with two flanges, in the recess between which is the flexible steel band to which the wire is attached.

The front flange of the drum is formed like a cam (A1), against which a small roller (B2) works. This small roller is in the end of the driving lever (B), which carries the wedge-roller (B1). Partial rotation of the drum thus causes the wedge-roller (B1) to be driven forward between the end (D1) of the escapement rod (D) and the roller (C1) which is carried in the end of the brake valve lever (C). The escapement rod (D) is controlled by the spring (D2) and also by the escapement lever (E). The brake valve lever (C) is controlled by the spring (C2) on the brake valve (C3).

When the wedge-roller is driven between (C1) and (D1) it forces them apart, and since the spring (D2) on the escapement rod is weaker than the spring (C2) on the brake valve (C3), the escapement rod and lever move upwards until the end (E1) of the escapement lever (E) comes against the shoulder (F1) on the armature.

Further movement of the wedge-roller will then cause the downward movement of the roller (C1) and the brake valve lever (C) will thus open the brake valve (C3). Air is thus admitted to the train pipe through the reed (C4) (not shown) causing a syren sound and partial application of the brake.

When the valve is fully open the brake valve lever (C) is caught by the spring-catch (G) and the valve remains open until the driver releases it by means of the resetting handle (H).

Fig. 20 shows the essential portions of the apparatus necessary to give a "Clear" or "Proceed" signal:—Bell sounded. In these circumstances, the ramp will be electrically energised so that the passage of the engine over the ramp not only lifts the shoe, but the shoe also picks up the current from the ramp. This current causes the suppression of the "Caution" signal which would otherwise be given by the movement of the shoe, and also causes the bell to be sounded.

The current flows from the shoe through the insulated flexible metallic tube and through the coils (J) causing the spring con-

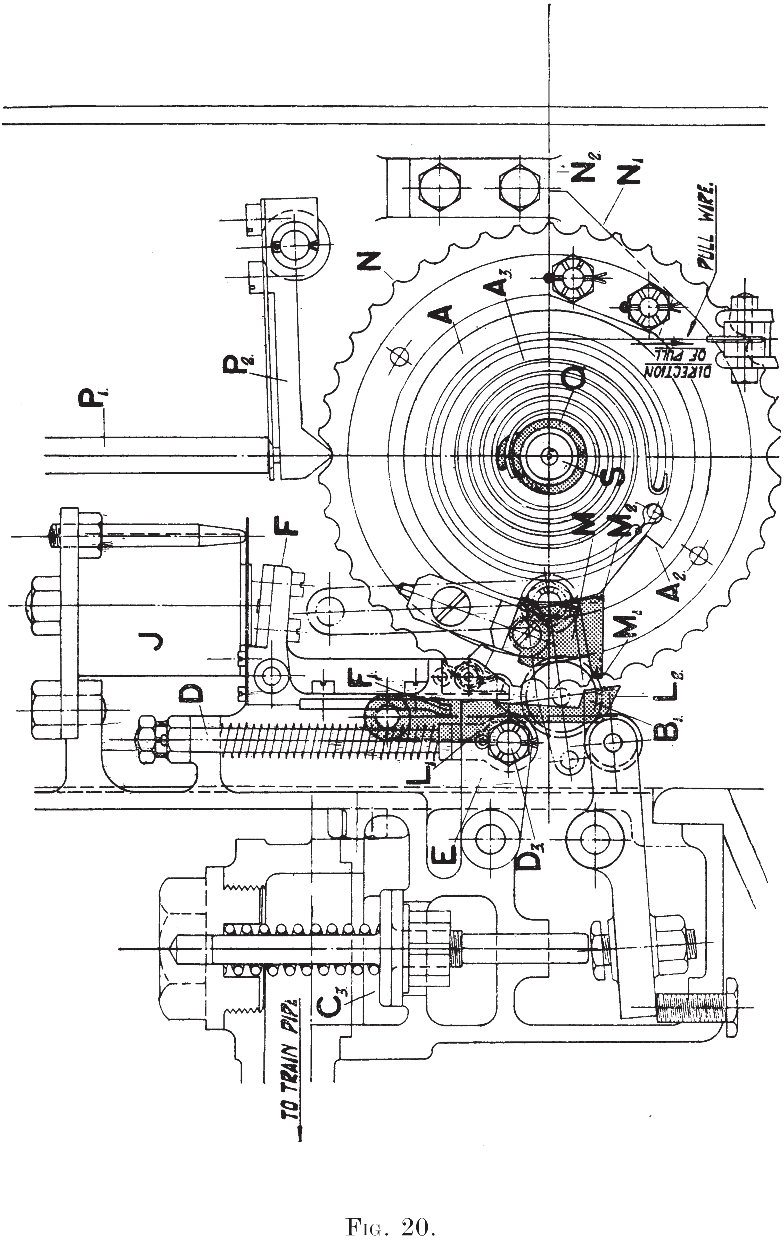

PULL WIRE.
DIRECTION OF PULL
TO TRAIN PIPE
N
N_1
N_2
P_1
P_2
A
A_2
A_3
O
S
M
M_1
M_2
L_1
L_2
B_1
F
F_1
J
D
D_3
E
C_3

Fig. 20.

trolled armature (F) to be lifted. The movement of the armature removes the shoulder (F1) from the path of the escapement lever (E), which is thus free to continue its initial upward movement to the full extent required by the travel of the wedge-roller (B1). The brake valve (C3) thus remains shut throughout and the "Caution" signal is suppressed.

The bell is sounded by means of the toothed wheel (N) which is co-axial with, but free from, the drum (A). A convoluted spring within and attached to the wheel keeps it normally in the position with the stop (N1) on wheel in contact with the stop (N2) on the case of the apparatus. On the wheel is mounted a pawl (M), shown shaded, which is in the same plane as the rear flange of the drum (A). A notch (A2) is cut in this rear flange so as to engage the pawl (M) when the toe (M2) of the pawl is moved inwards. When this occurs the toothed wheel (N) is pulled round by the drum rotating when the shoe lifts, and the bell hammer rod (P1) vibrating on the top of the spring striker (P2), which is struck by the wheel teeth, rings the bell.

The pawl (M) is actuated in the following manner, viz:—When the escapement rod (D) is driven up to the full extent, due to the armature (F) being lifted and the shoulder (F1) being removed from its path, the pin (D3) in the escapement rod (D) and lever (E) causes the bell engagement lever (L), shown shaded, to trip out, due to the pin (D3) pressing on the inclined face (L1) of the lever (L). The end (L2) of the lever (L) is in the same plane as the heel (M1) of the pawl (M), so that when the lever (L) is tripped out, the toe (M2) of the pawl (M) is moved inwards, into the notch (A2) on the drum (A). The free-wheel is thus engaged with the drum and the bell rings.

Failure of any part of an A.T.C. apparatus should be suitably detected, and this is achieved with this apparatus in the following manner:—

In Figs. 20 and 21 the convoluted spring (A3) in the drum (A) has one end fixed to the drum, while the other end is attached to the loose sleeve (Q) shown shaded, on the spindle (S) which is fixed to the case of the apparatus. On the end of this sleeve (Q) is an arm (Q1) which is clamped to the sleeve in any desired position by the bolt (Q2). In the arm is a spring loaded click (Q3) which drops into a succession of notches (Q4) on the sleeve. This click (Q3) is the winding ratchet for the convoluted spring (A3) in the drum (A).

The end of the arm (Q1) rests on the stem of a small valve (R), known as the detector valve, under which is a spring (R1)

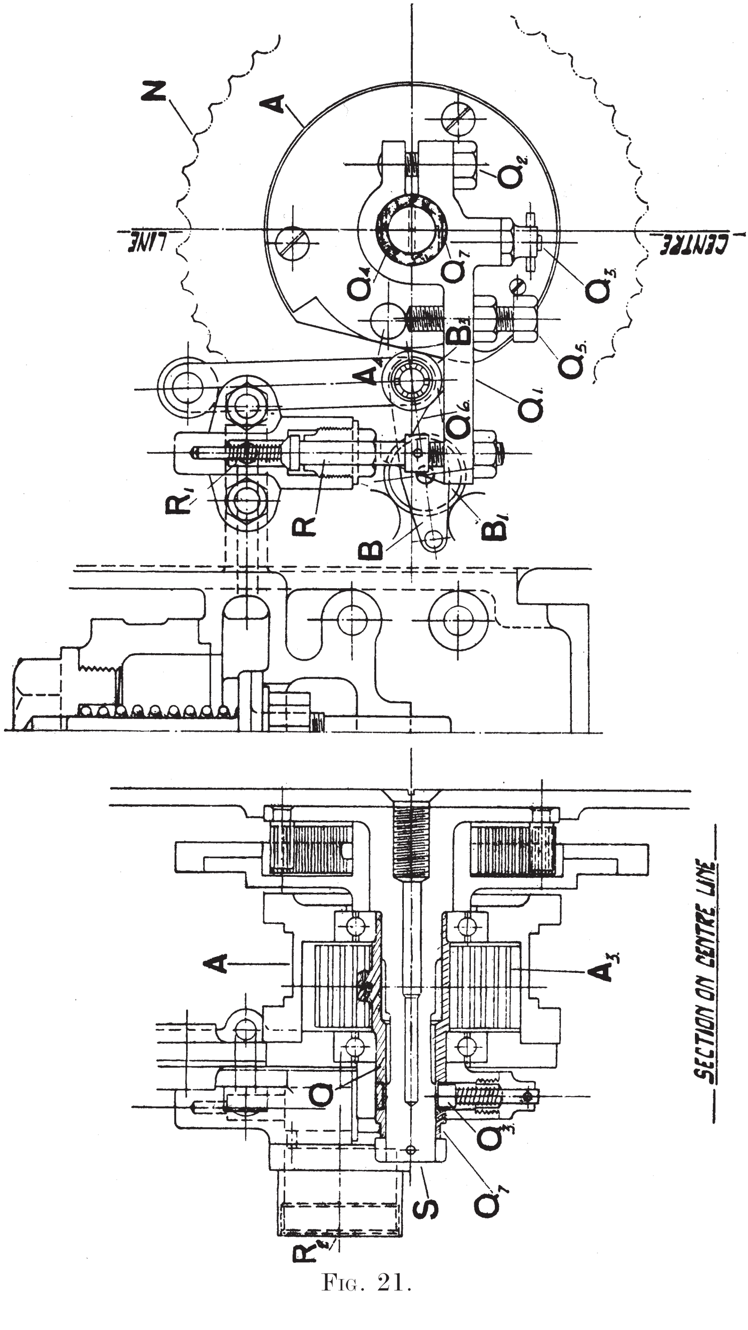


FIG. 21.

which tends to push it off its seat. When the clamping bolt (Q2) is slacked off, the sleeve (Q) can be rotated anti-clockwise, by means of a thin spanner on the flats (Q7), putting tension into the convoluted spring (A3) to any desired amount, and hence tightening the wire and flexible band. The tendency of the spring to unwind is resisted by the end of the arm (Q1) bearing on the stem of the valve (R), which is thus pushed on to its seat against the spring (R1).

Hence, if either the pull wire or the flexible band should break, the convoluted spring (A3) will unwind, and the valve (R) will be pushed off its seat by the spring (R1) assisted by gravity. Air will thus flow past the valve (R), through the detector whistle (R2) causing a shrill whistle, with a slight application of the brake. Similarly, if the convoluted spring (A3) should break, the valve (R) will open. Again, should the pull wire stretch, but not break, it will allow the drum (A) to rotate anti-clockwise, and the pin (A4) in the face of the drum will press on the set-bolts (Q5) in the arm (Q1), which will depress the arm and allow the valve (R) to open. By these means, any defect in the pull wire, etc., is fully detected, and the driver is adequately warned by the sounding of the detector whistle (R2).

Should the shoe fail to return to its normal height after passing over a dead ramp, the continuous sounding of the "Caution" syren, with partial application of the brake, and the inability of the driver to stop this by the resetting handle (H) (Fig. 19) is sufficient detection of this fault.

Should the shoe fail to return to its normal height after passing over a live ramp, giving a "Clear" signal, there is risk of repetition of the "Clear" signal at the next ramp, no matter what the state of the ramp may be. To obviate this risk and to detect this fault, the apparatus is arranged in the following manner:—

On the same spindle as the small roller (B2) in the driving link (B) (Figs. 19 and 21), is a second small roller (B3), which is in the same plane as the inclined face (Q6) on the arm (Q1). When the drum (A) rotates, which it does every time the shoe goes over a ramp, the small roller (B3) presses on the inclined face (Q6), pushing the arm (Q1) down, thus allowing the valve (R) to open as before. In the event of the shoe failing to return to its normal height after a "Clear" signal, the valve (R) will thus be kept off its seat, the detector whistle (R2) will be sounded, giving adequate warning to the driver.

The momentary opening of the detector valve every time the shoe goes over a ramp has the additional advantage that the valve and passages are thus kept in working order by regular usage.

By means of the foregoing any failure of the apparatus, which is at all likely to occur, is fully and adequately detected.

A further but extremely less likely type of fault is failure of any part of the cab apparatus to return to the normal position after giving a "Clear" signal. Failures of this type are (1) armature not falling away from poles of electro-magnets, (2) escapement rod and lever not returning to normal, (3) bell engagement lever not returning to normal. Detection of these cases is sufficiently effected by ensuring that no signal be given subsequent to their occurrence. This is done in the following manner, viz:—

In (Fig. 22) on the back of the tail of the armature (F) is a small trip piece (F2), which is in the same plane as the stop (K)

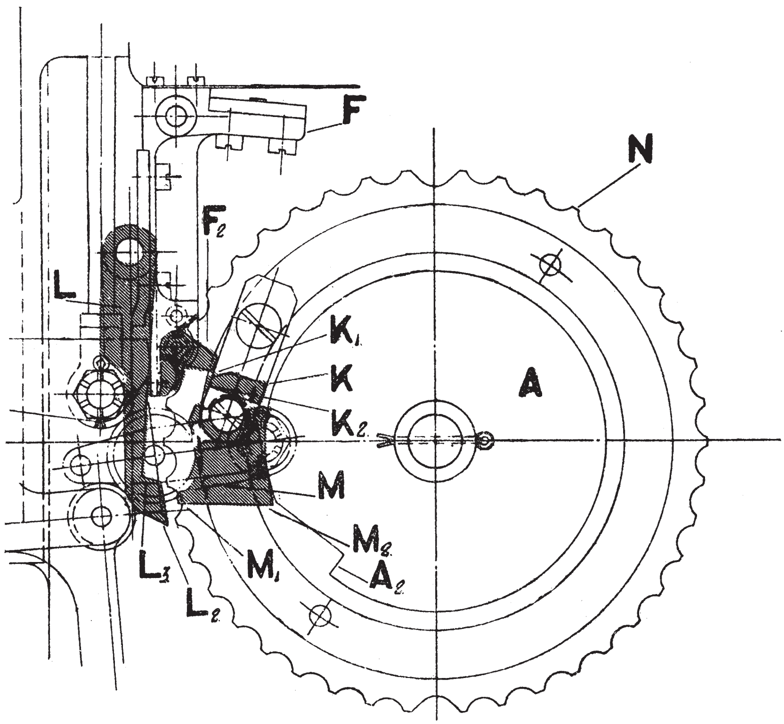


Fig. 22.

on the freewheel (N) (Figs. 20 and 22). When a "Clear" signal is received and the bell is sounded, the movement of the freewheel causes the inclined face (K1) of the stop (K) to strike this trip piece (F2) which is knocked upwards, allowing the freewheel to fly round, ringing the bell. On leaving the ramp the armature might possibly (though not at all probably) fail to return to normal, either due to some fault in the armature itself, or to failure of the escapement rod and lever to return to normal. Should this occur, the trip piece (F2) on the tail of the armature will be left jutting into the path of the return of the stop (K), so that when the toothed wheel is on its return stroke the back (K2) of the stop (K) will be caught by the trip piece (F2). This will mean that the end (L2) of the bell engagement lever will not then be in line with the heel (M1) of the pawl (M) and it will be impossible to insert the toe (M2) of the pawl (M) into the notch (A2) on the drum (A), even though the bell engagement lever may be correctly positioned to effect this.

Similarly, if the bell engagement lever fails to return to normal, for any reason other than failure of the escapement rod and lever to return to normal, the heel (M1) of the pawl (M) will then rest on the ledge (L3) on the bell engagement lever (L) itself and it will thus be impossible to insert the toe (M2) of the pawl (M) into the notch (A2) on the drum (A).

The apparatus may be put out of use for one of the two following reasons, viz. :—

1. Any failure.
2. When the shoe is automatically clipped up.

In the event of a failure the driver will be warned, in most instances by the continuous sounding of the detector valve, that some portion of the apparatus is at fault and he will then put the apparatus out of use in the following manner.

In (Fig. 23) (T) is a spindle with a cam-shaped centre (T1) around which is a square buckle (U1) on the spindle of the vacuum cut-out valve (U), fixed on a square (T3) carrying at its outer end a thumb-button (T4) and a pin (T5). The thumb-button (T4) passes through a straight slot (V1) in the movable indicator plate (V) and also through a circular slot (W1) in the fixed notice plate (W). The pin (T5) is attached to the end (X1) of the connecting link (X), the other end (X2) of which is secured inside the case of the apparatus, where it is attached to the top (Y1) of a lever (Y). The bottom end (Y2) of the lever (Y) rests against the pin (A4) on the drum (A). The end (X1) of the connecting link consists of a sleeve through which the connecting link passes, being secured by a split pin (X3), the pin (T5) being attached to the link by means of the lug (X4) which is part of the end (X1).

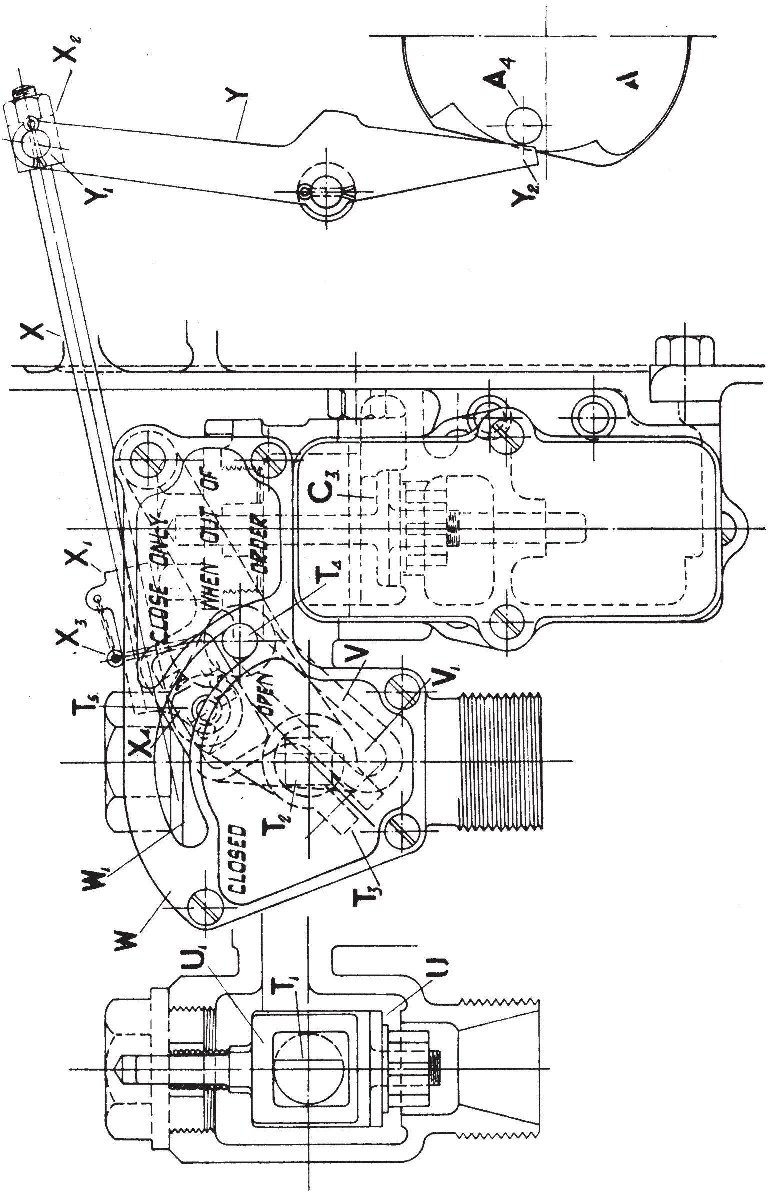


Fig. 23.

To put the apparatus out of use the driver removes split pin (X3) and he is then able to push the thumb-button (T4) from open to closed, at the same time automatically bringing into view the indicator plate "Not in use."

An advantageous feature of this gear for controlling the cut-out valve is that should the driver of a long goods train come to a stand with the engine shoe resting on the ramp he will not be able to close the vacuum valve (C3) owing to the wedge-roller being driven home, due to the shoe being lifted. Under these circumstances the brake application so caused would give him some difficulty in re-starting his train. Merely by putting the thumb-button to closed without withdrawing the split pin, however, will shut off the vacuum, and so facilitate his re-starting the train. On leaving the ramp, the shoe will return to its normal height, allowing the drum to return and the pin (A4) will push the lever (Y) to its normal position; the cut-out valve will thus be re-opened and the apparatus immediately brought into use again.

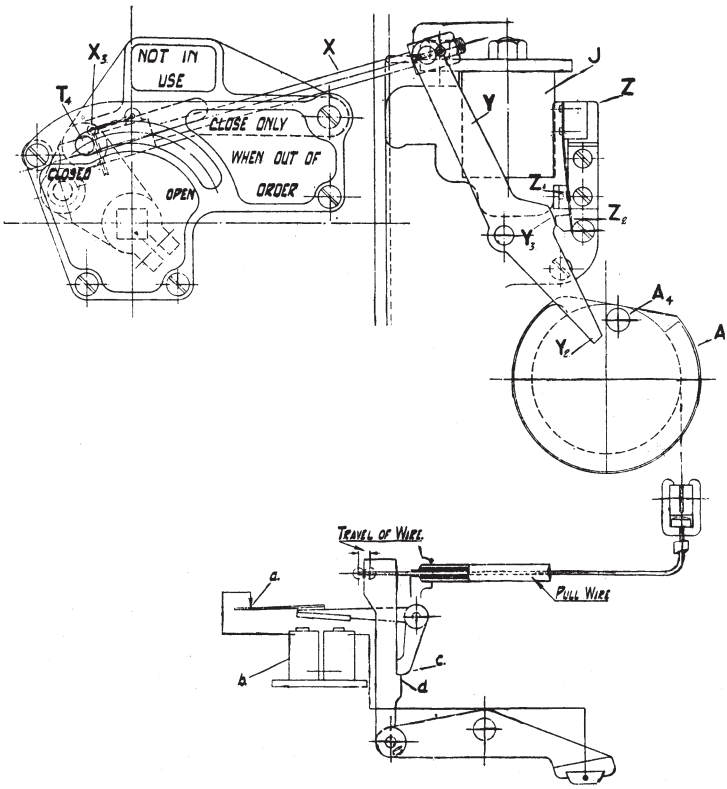


Fig. 24.

Fig. 24 shows the details necessary for automatic shoe clipping and resetting.

In the cab apparatus is a bracket (Z) carrying an electric contact (Z1). A cam-face (Y3) on the lever (Y) is in close proximity to the end of the spring contact blade (Z2) carrying the contact (Z1).

In the shoe gear is an electric contact (a) which is connected to an electro-magnet (b). A spring catch (c) is arranged so that when the shoe is lifted higher than its normal, the spring catch (c) will drop behind the shoulder (d) thus holding the shoe up. To release the shoe a current is passed from the ramp through the electro-magnet (b), the pull of which withdraws the spring catch (c) and allows the shoe to return to its normal height.

When running on the main line, the shoe electric contact (a) is open, and the cab apparatus contact (Z1), which is in series with the armature coils (J) is closed, thus passing the whole of the ramp current to the armature coils (J) in the cab apparatus.

When the shoe is to be clipped up the engine passes over an extra high (4¼ inches) dead ramp, which lifts the shoe so that the catch (c) falls and the shoe is held at 4 inches above rail. With the shoe in this position the electric contact (a) is closed and as will be seen later, the cab apparatus contact (Z1) is opened, so that the whole of the current picked up from the resetting ramp will pass through an electro-magnet (b). Also (in Fig. 20) the drum (A) in the cab apparatus is held in its extreme position of clockwise rotation with the wedge-roller (B1) driven right home between the escapement lever (E) and the brake valve lever (C), the brake valve (C3) being thus fully open, with the reed sounding continuously.

Under these circumstances, operation of the resetting handle (H) will have no effect. The driver then pushes the thumb-button (T4) to closed without removing the split pin (X3). This brings the "Not in use" flag to view and also causes the connecting link (X) to move the shaped lever (Y) so that the cam-face (Y3) presses on the spring blade (Z2), breaking the contact (Z1). Also the end (Y2) of the lever is moved over to the new position of the pin (A4). Definite action on the part of the driver thus ensures that he is made aware of the suspension of the operation of the apparatus.

To bring the shoe to its normal 2½ inches above rail and so reset the apparatus for normal working, the engine passes over an extra high (4¼ inches) live ramp carrying a current of 48 volts. This current energises the electro-magnet (b), withdrawing the catch (c), the load on which is released by the $\frac{1}{4}$ inch lift of the shoe from 4 inches to $4\frac{1}{4}$ inches on first contact with the ramp. On leaving the ramp the shoe thus drops to its normal height.

In the cab apparatus this causes the drum (A) to return to its normal position, and the pin (A4) pushes the end (Y2) of the lever (Y) back to its original position, closing the contact (Z1) and opening the vacuum cut-out valve (U) by means of the connecting link (X). The "Not in use" flag is thus automatically obscured. The return of the drum (A) to its normal position also allows the wedge-roller (E1) to withdraw from between the escapement lever (F) and the brake valve lever (C), but the brake valve (C3) remains fully open, with the reed sounding continuously, because the end of the lever (C) is held by the spring catch (G).

Under these circumstances, it will be impossible to move the thumb-button (T4) to closed without removing the split pin (X3), owing to the pin (A4) restricting the movement of the lever (Y). The driver then lifts the resetting handle (H), releasing the brake valve lever (C) and shutting the valve (C3). Definite action on the part of the driver thus ensures that he is made aware of the resumption of the operation of tile apparatus.

The original form of this apparatus was in many respects different from that herein illustrated, but no modification of any of the essential features has ever been found to be necessary. The original apparatus was subjected to a bench test in the shops, and gave a life of over 400,000 indications without any appreciable wear of the moving parts, nor was any stretch or defect detected in the wire, cable or its attachments. Following this, a modified form was made, embodying alterations designed towards cheapness of manufacture. This set was fitted to an engine and gave over two years' satisfactory service with only one failure. This set has since been withdrawn from service. Two further sets, again redesigned in detail, but unaltered in principle, were then fitted to two further engines and for nearly two years have given satisfactory service with one or two failures. The gear as described above is the final design incorporating those modifications and improvements which had been shown to be necessary by the experience gained with the three original sets. Three further sets of gear in this final form are at present in use and thus, with the two sets mentioned, a total of five sets in all are in use and none has given any serious trouble. Evident economy effected by the absence of the battery on the engine will result if the experiments with the apparatus warrant an extension of its use.

The G.W.R. system of A.T.C. has been in constant and increasing use on the Company's main lines for nearly 30 years, and within the very near future, it will be in operation throughout the whole of the main routes. It is the only Automatic Train Control in use as a standard equipment on any main line railway in the world, and it stands as effective testimony to the unflagging efforts of the Great Western Railway Company towards giving complete and satisfactory service to its clients.

The Author's thanks are due to the Authorities of the Great Western Railway for permission to use the data of the paper and for the loan of lantern slides.

DISCUSSION.

Mr. K. J. Cook said that Mr. Dymond had covered his subject with extreme thoroughness, so that at first sight there seemed little left to discuss. The paper had unfolded a very interesting tale of evolution and development, and it is clue to the experience gained during this development that the Automatic Train Control apparatus is so reliable to-day.

It was, he said, particularly appropriate that the Author should lay the emphasis he did on the faith the drivers have in the reliability of the apparatus, and on the fact that this faith rests on the confirmation which is given to the signals received at the apparatus by the visual observation of the semaphore arms on the track. The fact that the apparatus functions correctly in the great majority of instances, with but few cases of failure on the right, or "safety" side, and none at all on the wrong or "danger" side, builds up an unshakeable confidence in the apparatus.

The story of the development of shoe clipping and resetting on electrified lines was of much interest, particularly in view of the peculiar difficulties which beset the problem at the outset. It had been a benefit to have the Author's own description of the evolution and perfection of the gear which it was his job to design, and to overcome its difficulties. It may confidently be said that the design was satisfactory, as the gear is working with the utmost satisfaction at the present time.

The Author, in reply, said Mr. Cook rightly stressed the fact that the apparatus in its present form was the result of a continuous process of development and he (the Author) thought it was true to say, as Mr. Cook had suggested, that the early designers' most optimistic hopes for its future had now been more than realised.

Another point stressed by Mr. Cook and emphasised in the paper, was the confidence in the apparatus which was felt by the men, and which was due to the apparatus being constantly in use. In the great majority of cases the driver saw the Distant signal and heard the Automatic Train Control audible signal almost at the same instant, and as the one corroborated the other in nearly every case, the drivers' confidence, when visibility was bad, was unshaken.

Mr. H. G. Johnson stated that it was sometimes wrongly supposed that the use of audible signals in the cab was of benefit only in foggy weather. That such was not the case, however, was obvious to those who ride on the footplate, where failure to observe a signal may be due to steam from another engine, complexity of signal arrangements and, of course, darkness. These are a few of the circumstances which justify the adoption of any means to lighten the drivers' task of correct interpretations of the semaphore signals. The Author's description of the new electro-mechanical apparatus was of great interest and the elimination of the battery was certainly a big point in its favour. A further advantage lies in the fact that it is impossible for the driver to suppress the caution indication entirely, as was possible with the standard electrical apparatus. He added that the electro-mechanical apparatus was much simpler than might appear at first sight from the diagrams. It was fitted to several of the Company's locomotives and had proved itself well able to stand up to service conditions.

In these days of high speeds and dense traffic the subject of cab signalling and train control was of great importance and he thought that the Author's paper would be a valuable addition to the Society's publications.

The Author, in answer to Mr. Johnson, said with reference to the new electro-mechanical apparatus that he was glad that he (Mr. Johnson) had emphasised that the gear was not complicated. It was extremely simple and had the further merit of being fairly cheap to manufacture. It was also advantageous that no repression of the caution signal was possible, but nevertheless the Author had had no experience of illegal wedging up of the resetting handle. Indeed, he ventured to state that every driver on the system would acclaim the Automatic Train Control gear as the most important advance from their point of view that had ever been made.

Mr. S. A. Gawad asked whether the driver knew if the shoe was clipped up on entering electrified areas, and if so, by what means? What were the precautions taken if the shoe failed to clip up? Further, could the apparatus be extended to cover cases where fouling points in adjacent roads were not cleared?

In reply to Mr. Gawad's reference to the possibility of the shoe failing to clip up on entering an electrified line, the Author stated that if it did so the cab-indicator would reveal this and the driver would have to stop and take whatever steps he considered necessary. One or two cases did occur in the early history of the gear, but these were put down to causes connected with the lack of experience in the manufacture and fitting of the apparatus.

Referring to the fouling point detection by the Automatic Train Control apparatus, the Author said that this was a matter which had not yet been brought to their notice for consideration, but doubtless some suitable modification could be devised to meet the case.

Mr. C. T. Cuss congratulated the Author on the clarity with which he presented the paper, and recalled a similar paper being presented to the Society some twenty-five years ago and was amazed at the progress made during the period. In particular, confidence in the apparatus, which in those days did not exist, was to-day its chief asset. Moreover, the adaptations of the apparatus for duties far outside its original scope had exceeded the ambitions of the early designers.

He wished, however, to ask the Author if failures did occur, and if so, what was their nature and further, what percentage of the total number of signals received was incorrect?

The Author, in reply, stated that failures did occur, but they all gave signals of the danger aspect in place of correct clear signals, so that there was no danger to the safety of the train. They might be due to low battery current on the ramp, to dirty ramps or shoes, to ice and snow on the ramp tops or to other reasons. There were no figures available giving the percentage of such failures.

Mr. B. H. Coleby (A Visitor) said that he was extremely interested in the paper, more especially as he was not a railwayman and was only vaguely familiar with the Automatic Train Control apparatus. He desired to ask the Author if it was at all possible for the shoe to miss striking the ramp. He believed that the distance out of the ramp varied according to the position of the Distant signal. When the Distant signal was moved out, he would like to know if the ramp was also moved out too. Again, where the Distant signal was electrically operated, was the ramp circuit quite distinct from the operating circuit? He understood that on ordinary trains the syren was sounded by means of the vacuum and he desired to know how this vacuum was created on the Diesel cars. Continuing, he said that he was particularly interested in multi-directional indications being obtained from one ramp, and he would like to know what steps would be taken to apply Automatic Train Control to multi-aspect signals? Would the Automatic Train Control system work with the Westinghouse Brake, as he understood that another railway were using this type of brake and also were experimenting with Automatic Train Control apparatus.

Finally, could the Author give any figures of the cost of the engine apparatus and also as a consequence of the almost universal use of the Automatic Train Control system on the Great Western Railway, would the Company eventually dispense with fogmen?

Answering Mr. Coleby's questions on multi-aspect signals, The Author stated that as yet this was an eventuality not yet encountered, but in the event of more indications than three being required off one fixed ramp, there would need to be some form of tuned circuit, in which event the number of indications possible was fairly large. These refinements could, however, only be achieved at a cost. With reference to the question of the possibility of missing contact with the ramp by the engine shoe, the Author stated that the shoe was 7 inches wide and no cases of missed contact had ever come to his notice. The distance of the ramp from the signal was governed by the gradient obtaining at the site; and is so positioned that in the event of the automatic application of the brake being called upon to bring the train to a stand without the agency of the driver, it would do so before the stop signal was reached. This had been successfully achieved on test on several occasions. The operation of distant signals by electrical means did not alter the wiring for the ramp in any material aspect, the ramp being energised from an entirely separate battery or rectified supply.

Replying to the questions on the Diesel cars, the Author said that the design of brake gear varied on different railcars. On the earlier cars a vacuum was produced in a reservoir by means of rotary blowers on the engines and gearboxes. The brake was held off by means of a spring and the production of a vacuum on one side of the operating piston applied to the brake. The audible signal was produced by an enclosed reed being caused to vibrate, due to the passage of the air from the cylinder to the vacuum reservoir on opening of the electro-magnet valve. On the base of the reed the end of a small spill made light contact, while the other end of the spill rested against an air-tight plate diaphragm. When the reed vibrated the spill moved in sympathy and the diaphragm was thus vibrated, giving a distinct audible warning. The later cars had a vacuum brake very similar in general principle to the standard Great Western vacuum brake and the signal was produced in the ordinary way. He added that by means of certain modifications to the syren valve, the apparatus could be made to work quite successfully with the Westinghouse Brake.

The Author stated that fogmen could be dispensed with, but the Company still retained their services, as they were regarded as an additional security.

In conclusion, he said that no satisfactory figures could be given as to the cost of the apparatus, as the prices varied so considerably with the market prices of material.

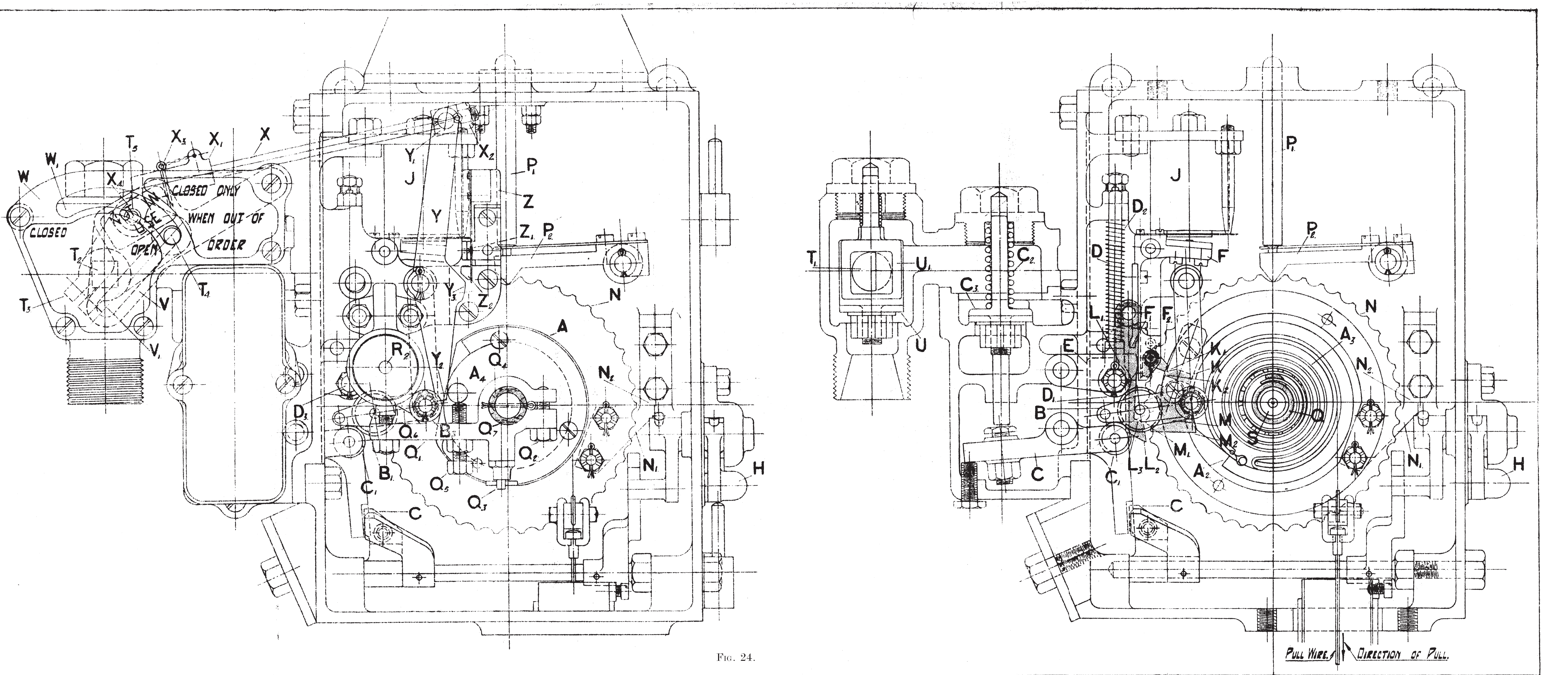

CLOSED ONLY
WHEN OUT OF
ORDER
CLOSED
OPEN
NOT IN USE
PULL WIRE.
DIRECTION OF PULL.

Fig. 24.