

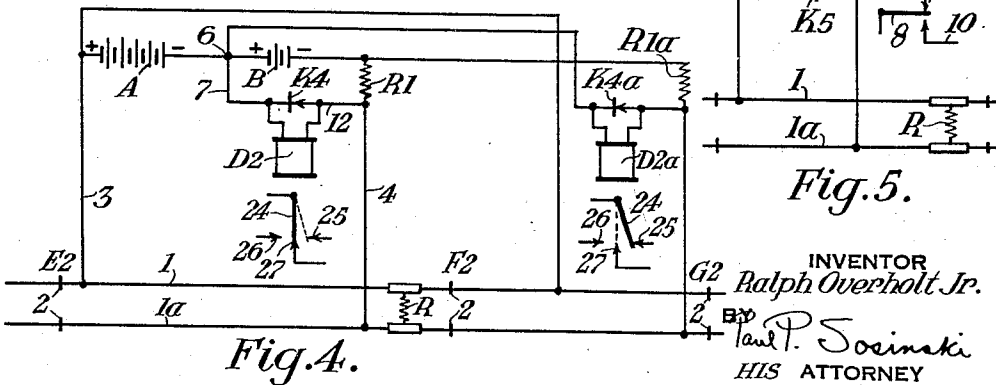
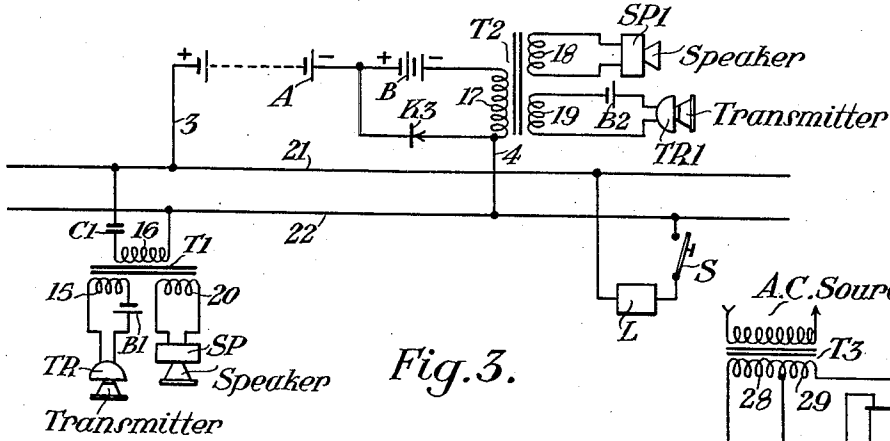
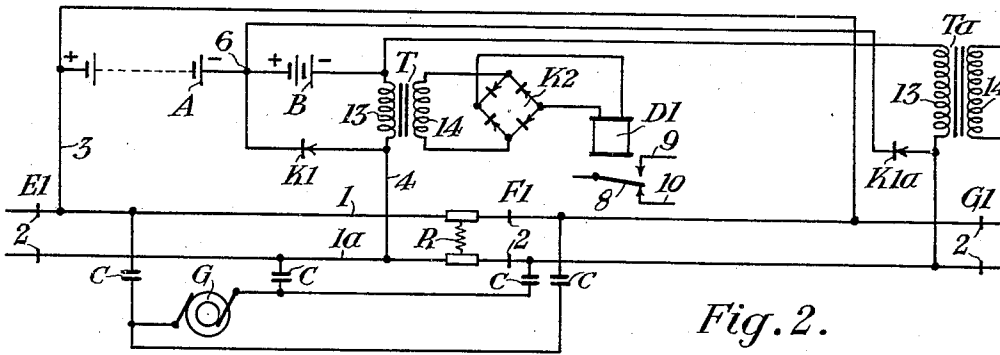
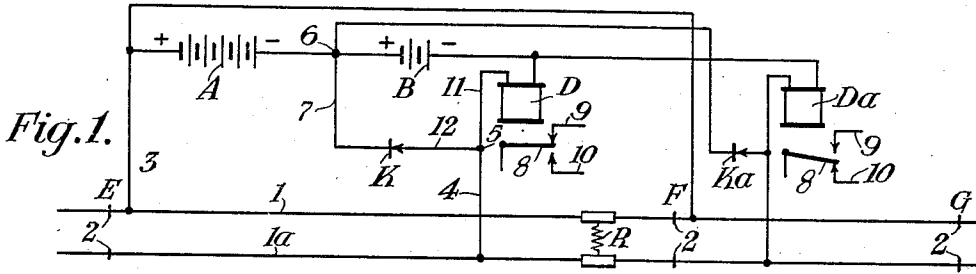
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ELECTRICAL APPARATUS

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ELECTRICAL APPARATUS

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My invention relates to electrical apparatus and more particularly, to apparatus for providing a constant check that a normally inactive circuit or one carrying only a small current is continuous and contains no defects such as would render the circuit inoperative at a time when the circuit is called upon to function and to carry a relatively much larger current. My invention is also directed to means for causing the current supplied to a load to take a given path as long as the load current is at or below a predetermined value, and automatically and abruptly to take a different path when the current exceeds such predetermined value.

More specifically stated, my invention provides the electrical equivalent of a mechanical by-pass valve whereby up to a certain point, the valve remains closed and the flow is confined to a given channel but when the flow increases above this point, the valve opens suddenly and automatically by-passes the excess flow. Looking at the invention from still another viewpoint, the apparatus may be considered as an automatic switch without moving parts which, of its own accord, makes available a high current shunt path when the load increases above a predetermined value. The apparatus embodying my invention is therefore capable of automatically and reliably distinguishing between a light and a heavy load at a location which may be removed from the point at which the load is applied and provides the sensitivity which is inherent in apparatus designed for low current operation while at the same time retaining the low impedance characteristics which are necessary for carrying substantial amounts of current without undue voltage drop or excessive power loss.

One application in which my invention has special utility is in connection with track circuits for miniature or model railways for indicating the presence of a train on the track circuit. Another application is in connection with the transmission of intelligence, such as telephone transmission, over an available power or communication circuit. It will be in connection with these specific applications that I shall describe my invention in order that its features and advantages may become more fully apparent. It will be apparent, however, that such description in connection with a model railroad track circuit or power line channel is presented by way of illustration only and is not intended to limit the scope of the invention which is broadly useful in connection with any electrical supply circuit

in which diversion of current to a second path is desirable when the current exceeds a predetermined value,

I shall describe several forms of apparatus embodying my invention, and shall then point out the novel features thereof in claims.

Fig. 1 of the accompanying drawing is a diagrammatic view showing one form of apparatus embodying my invention, as applied to a model railroad track circuit. Figs. 2, 4, and 5 are diagrammatic views also embodying my invention and showing modified forms of the apparatus of Fig. 1. Fig. 3 is a diagrammatic view embodying my invention in which the invention is used to provide communication over an existing load circuit.

Similar reference characters refer to similar parts in each of the several views.

One difficulty in providing a simple and reliable track circuit for a model railroad is caused by the relatively high resistance of the train shunt due to the light weight of the rolling stock. If the signaling current is obtained from the rails which also carry the propulsion current, then a further difficulty arises due to the fact that ordinarily the propulsion current must be of different character from the track circuit current in order that the track relay will not be falsely energized by the propulsion current with a train occupying the block. Moreover, even if the propulsion current is direct, the signaling current being alternating, there is still some possibility of false energization of the signaling apparatus due to the effect of pulsations or impulses in the propulsion current. All of these difficulties are overcome in a simple and effective manner in the apparatus embodying my invention. That is to say, the track relay responds positively to the application of a model railroad train shunt even though the shunt is of very high resistance, and remains definitely unresponsive when the track is unoccupied. Moreover, the propulsion current in the apparatus embodying my invention need not necessarily be of different character from the track circuit current but may be furnished either from a battery, a transformer, or other suitable source similar to that which energizes the track relay. Furthermore, any suitable number of track circuits may be energized from a single propulsion battery and a single track circuit battery, or from a single transformer, as will appear hereinafter. Accordingly, the apparatus embodying my invention not only eliminates the necessity for a third rail to carry the propulsion current as the usual two

rails suffice for carrying both the propulsion and track circuit energy but it also eliminates the added cost and maintenance involved in the use of individual batteries or transformers for each track circuit section. The foregoing features and advantages will be best understood from a description of the apparatus and operation of an illustrative track circuit such as that shown in Fig. 1 of the drawing.

Referring to Fig. 1, the reference characters 1 and 1a designate the two rails of a stretch of track which is divided into track circuit sections by means of the insulated rail joints 2. Only two track circuit sections are shown in the drawing. The rails 1 and 1a may, of course, represent the supply conductors of any suitable electrical or transmission circuit across which may be connected any suitable load R. As shown, the load R represents the shunt resistance load of a model railroad train as the train proceeds over the track section.

Across the rails 1 and 1a is connected a battery or other suitable source of unidirectional current A, through an asymmetric unit K. Source A is the propulsion battery which energizes the train load R. The asymmetric unit K is so poled with respect to the battery A that a low resistance path for the flow of propulsion current is provided which path may be traced as follows: starting from the positive terminal of battery A, through wire 3, rail 1, load R, rail 1a, wire 4, asymmetric unit K, and wire 7, to the negative terminal of battery A. The asymmetric unit K may conveniently be a dry disc copper oxide rectifier such, for example, as disclosed in Letters Patent of the United States No. 1,640,335, granted to Lars O. Grondahl on August 23, 1927. On account of the high ratio of resistance in the reverse current direction as compared with the resistance in the forward current direction in the copper oxide rectifier, I have found this rectifier to be particularly effective in providing the desired operation. It will be obvious, however, that any suitable asymmetric unit having an appreciable resistance ratio as well as a suitable current-carrying capacity may also be used.

Across the terminals 5-6 of the asymmetric unit K is connected a second source of unidirectional current B, in series with a relay D. The relay D may perform any of the usual functions of a track relay such as controlling signals or other signaling or control apparatus over its contacts 8-9 8-10. The particular circuits and apparatus controlled by relay D form no part of my invention and since these are well known, they have not been illustrated in the drawing in order to simplify the disclosure. One circuit for relay D (which however does not pick up the relay unless the section is occupied, as described hereinafter) may be traced from the positive terminal of battery B, wire 7, asymmetric unit K in the reverse or high resistance direction, wires 12 and 11, and winding of relay D, to the negative terminal of battery B. If desired, the battery B may be eliminated and an equivalent voltage obtained from the propulsion battery A by connecting the conductor 7 to a suitable tap on this battery.

With the track section E-F unoccupied (no load connected across the supply conductors 1 and 1a), no propulsion current will flow through the unit K in the forward direction and the only current in relay D will be that supplied by battery B through unit K in the high resistance direction. The apparatus is so proportioned that

this current is insufficient to cause the relay to pick up under the unoccupied or no load condition. If now a load is connected across the conductors 1 and 1a, the two batteries A and B will aid in supplying a certain amount of current to relay D over a circuit passing from the positive terminal of battery A, through wire 3, rail 1, load R, rail 1a, wires 4 and 11, winding of relay D, through the battery B, to the negative terminal of battery A. The relay D may or may not pick up, depending upon whether the load resistance R is below or above the predetermined value, as established by the voltage of battery A and the remaining constants of the apparatus. Entry of a train will, of course, pick up the relay because the resistance of the load R under this condition will be below the predetermined value.

As the load resistance R decreases below the predetermined value, relay D will pick up and will remain picked up thereafter without becoming substantially overenergized, even though the load resistance should continue to decrease further and reach a very low value. That is to say, up to a certain point, all of the current will flow through the circuit which includes relay D, and no current will flow through the rectifier K in the forward or low resistance direction. Suddenly, however, as a critical point in the load current is reached, any further increase in the load current will cause current to begin to be by-passed through the rectifier in the forward or low resistance direction so that very little, if any, of the additional current will flow through relay D. This operation may be explained by stating that the apparatus behaves as though the circuit of relay D were capable of accepting only a predetermined amount of current, up to its saturation point, but when this point is reached and the circuit is "filled," substantially all of the additional current will be by-passed automatically over the low resistance shunt path including rectifier K. The action of the rectifier K in by-passing the additional current due to increased load will not affect the current flowing in relay D to any appreciable extent so that relay D will remain energized continuously during the time that the track section E-F is occupied or an appreciable load R is effective.

When the load R is decreased, the forward current through rectifier K will also decrease but no substantial change in current through relay D will occur until the forward current reaches the predetermined critical value. At that point, the voltage drop across the rectifier K will be substantially zero. Any further decrease in the load will cause the direction of the net current through rectifier K suddenly to reverse and to flow in the high resistance direction, thus causing a marked decrease in the current traversing relay D and a release of this relay. Accordingly, when the train vacates the section E-F and the load current drops to zero, relay D will release.

One way in which the foregoing operation may be more clearly understood is to assume, for purposes of explanation only, that the asymmetric unit K is a perfect valve, having infinite resistance in the reverse direction and zero resistance in the forward direction. With such an asymmetric unit, it will be apparent that starting at extremely high values of load resistance, all of the current from battery A will go through relay D, and not any will pass through the rectifier. Under this condition, practically the full voltage of battery B will be effective across the rectifier

K and will be in the reverse or opposed direction with respect to any current flow through the rectifier. The reason why the voltage of battery B will appear across the rectifier is that under the assumed condition of very high resistance load, the voltage drop across relay D will be very small and since the rectifier and battery B are in a closed circuit with relay D, the rectifier potential will be that of the battery minus the small relay drop. Accordingly, no current from battery A will flow through the rectifier and all of the current will flow through relay D.

As the load resistance is decreased in small steps, the current in relay D and the voltage drop in this relay will progressively increase, thus causing the reverse potential across the rectifier K to decrease progressively. At some point, the current through relay D will be sufficient to cause the relay to pick up, but at this point the drop across relay D will still be less than the voltage of battery B so that a certain reverse potential will still remain across the rectifier and the rectifier will still pass no current (remembering that a perfect valve has been assumed).

Finally, at a critical value of the load resistance, the voltage drop across relay D will just equal the voltage of battery B so that the potential across the rectifier will become zero. This marks the transition point in the rectifier characteristic and under the assumed condition of zero resistance in the forward direction, it is obvious that at and beyond this point, all of the increase in current from battery A will pass through the rectifier, relay D remaining energized under this condition.

Considering now an actual asymmetric unit having the usual properties which render it a somewhat imperfect valve, the same general operation as discussed above will be obtained, the only difference being that the transition point will be less sharply defined and that some current will flow in relay D from battery B even before any load is applied to the circuit 1-1a. Also, the energization of the relay D will increase slightly after the transition point is reached, due to the voltage drop across the rectifier K in the forward direction.

It is desirable to proportion the apparatus in such a manner that relay D will pick up at a current value substantially below that which the relay receives at the time the rectifier passes through its transition point and begins to by-pass the excess current. Otherwise, should the relay be designed to pick up just at the transition point, a failure to pick up might occur in the event that the voltage of battery B dropped below its normal value. This is because a drop in voltage of battery B causes the transition to occur at a lower value of load current and the pick-up current value for relay D might never be reached under this condition.

I have found in practice, for example, that with a battery B of 4 volts, a resistance for relay D of 125 ohms and a pick-up current of about 20 milliamperes, the maximum current which passes through relay D is about 50 milliamperes, all current in excess of this value and amounting to several amperes being by-passed through the rectifier. These values are, of course, merely illustrative and are not intended as limiting the proportions of the apparatus because, obviously, the apparatus is broadly useful independently of the magnitude of the current or its particular division ratio. As pointed out above, an appreciable spread

between the pick-up current and the maximum current in relay D is desirable for practical reasons in order to take care of certain factors such as battery voltage drop, lead drop, change in resistance of relay D with temperature, etc. It will also be understood that the relay D is not essential for establishing the desired current division, provided that the resistance in the portion of the circuit which includes wire 11 and battery B is sufficient to produce the necessary voltage drop as load current flows therein to reduce or eliminate the reverse voltage drop across the rectifier K.

The shunting sensitivity of the apparatus in Fig. 1 is controlled largely by the voltage of battery A. Doubling the voltage of this battery will approximately double the value of the resistance R effective for bringing about the transition in the rectifier characteristic. That is, if the battery B, rectifier K and relay D are once determined, then the load current alone will determine the transition point. An increase in the voltage of battery A will therefore permit a corresponding increase in the load resistance which is effective at the time when relay D operates. An increase in the voltage of battery B, on the other hand, increases the current sensitivity of the circuit in that it permits a high resistance, low current relay to be used. Too great an increase in the voltage of battery B is undesirable, however, because it tends to increase the reverse current through the rectifier. A practical limit is reached when the current sensitivity of the apparatus becomes so high that the reverse current through the rectifier will not permit proper release of the relay under a condition approaching no load across the rails.

It will be noted that the batteries A and B provide the propulsion and track circuit currents, respectively, not only for section E-F but also for section F-G and for as many additional sections of track (not shown) as may be desired. The operation of the apparatus for section F-G when a train enters this section is identical with that described for section E-F and will be understood without further detailed explanation. The presence of a train in one or more track circuits will not affect the apparatus in the remaining track circuits provided that the batteries A and B are chosen to have sufficient capacity so as to maintain their voltage substantially constant under the various load requirements of the apparatus.

Referring now to Fig. 2, the apparatus of this figure is similar to that of Fig. 1, with the exception that the track relay D1 is normally energized when the section is unoccupied and alternating track circuit current is used for signaling purposes. This current is supplied from an alternating current generator G connected across the rails through a pair of suitable blocking condensers C which prevent the flow of propulsion current from source A in the circuit of generator G and which prevent the rails of adjoining sections from being connected together electrically over the generator connections. Energy from the generator is normally supplied to the primary winding 13 of a transformer T, through the batteries A and B in series. The output from transformer T is delivered by winding 14 to the normally energized track relay D1, through the full-wave rectifier K2 which is connected in the usual manner.

Assuming that no train occupies the section E1-F1, alternating current from generator G will flow in winding 13, thus causing relay D1 to

remain energized. Winding 13 is designed to have an appreciable resistance but the peak value of the impulses of current flowing in this winding and necessary for maintaining relay D1 energized is insufficient to eliminate the reverse potential drop which exists across the rectifier K1 due to the battery B when the section is unoccupied or the circuit is otherwise without load. Under this condition, the rectifier K1 is incapable of passing any current in the forward or low resistance direction.

Assuming next that a very light load is connected across the track circuit, this load will cause a small current to be supplied over a circuit which may be traced from battery A, through wire 3, rail 1, load R, rail 1a, wire 4, winding 13, and battery B, back to battery A. This current will cause a voltage drop in the resistance of winding 13 which will decrease the reverse voltage drop across the rectifier K1. A further increase in load will cause the reverse voltage drop across the rectifier to decrease still further until at a certain critical load, this drop will become zero and any further increase in load current from battery A will thereafter be by-passed through the rectifier.

When the rectifier voltage drop becomes exactly zero, considering only the effect of the batteries A and B, the rectifier K1 will provide substantially half-wave rectification with respect to the current from generator G because all of the current impulses of normal polarity will be by-passed through the rectifier in the forward direction, the remaining current in winding 13 being half-wave pulsating current of reverse instantaneous polarity. If desired, relay D1 may be designed so that it will release under the above condition of load, as represented by half-wave current in winding 13. This condition may, for example, represent the maximum resistance train shunt which it is desired to detect by means of the apparatus.

If the load is increased still further, the rectifier voltage drop will become increasingly positive and will cause the pulsating current in winding 13 to decrease correspondingly. At some value of the load resistance, the positive voltage drop across the rectifier due to batteries A and B will be just sufficient to balance the peak value of the pulsating potential from generator G existing across winding 13 so that beyond this point, substantially all of the current will be by-passed by the rectifier K1 and practically no current from generator G will flow in winding 13. It is very clear, therefore, that the apparatus may be so designed and proportioned as to be highly sensitive to the entry of a train into the section or the presence of a comparatively light load across the conductors 1 and 1a.

The presence of the condensers C in the generator circuit provides an additional advantage in that when a load is applied across the rails, the impedance of these condensers causes a drop in inter-rail potential which further aids the release of relay D1.

From the foregoing, it is apparent that my invention can readily be applied to alternating current track circuits employing direct current propulsion energy (as well as alternating current propulsion energy as will appear hereinafter) and that the apparatus embodies a high degree of sensitivity to the presence of a train shunt or other light load connected across the rails or conductors. It should also be pointed out that, if desired, the batteries A and B can be replaced by the output terminals of suitable substantially

constant-potential rectifiers energized from an alternating current source. The batteries A and B may be used to energize additional track sections such as F1—G1, as in Fig. 1. Only a portion of the apparatus associated with the latter section is shown in the drawing, it being understood that the transformer Ta energizes a rectifier and relay similar to the corresponding apparatus associated with section E1—F1.

Referring now to Fig. 3, the apparatus of this figure is generally similar to that of Figs. 1 and 2 except that instead of using a track circuit and a track relay or other signaling device, I have superimposed a communication channel on the load conductors in the form of a telephone circuit which is available at all times when the load on the conductors is at or below a given value, for transmitting speech or other intelligence along the conductors in a simple, direct and inexpensive manner.

The transmitter TR at the first location superimposes voice frequency currents upon the conductors 21—22, through the medium of windings 15 and 16 of transformer T1, and condenser C1. Battery B1 is the source of energy for the voice transmission. The details of this transmitting and receiving (or speaking) apparatus have not been shown, as this apparatus is well known and, of itself, forms no part of my present invention. This transmitting apparatus corresponds generally with the generator G of Fig. 2. Similarly, the load L which may at times be connected across the conductors 21—22 by means of the switch S corresponds generally with the load R of Figs. 1 and 2. The remaining apparatus which is connected with the conductors 21 and 22 by means of wires 3 and 4 is similar to the corresponding apparatus of Fig. 2, the operation of which has been described in considerable detail. Since the essential operation is the same in both Figs. 2 and 3, it will be unnecessary to repeat this operation other than to point out the differences therein.

When there is no load on the conductors 21—22, rectifier K3 passes no current in the forward direction and the voice currents which are impressed on the two conductors are faithfully transmitted to the winding 17 of transformer T2, thus exciting the winding 18 of speaker SP1 at the second location which reproduces the transmitted intelligence. Similarly, two-way communication may be established by means of the transmitter TR1 which superimposes voice frequencies upon winding 19. These currents are transmitted by way of winding 17, through the two conductors 21—22, and winding 16, to the receiving winding 20 of the speaker SP at the first transmitting location. The apparatus may be so proportioned that at no load or at light loads, there will always be present at least a small negative voltage drop across the rectifier K3 during transmission so that under this condition no appreciable distortion of the speech will occur.

If the load is increased to a point such that the rectifier potential drop approaches zero or swings positive during transmission, a certain amount of distortion will occur due to the rectifying action of the rectifier K3 which will partly suppress impulses of one polarity in winding 17. If the load is sufficiently large, these impulses may become completely suppressed and the suppression may also be partly or wholly effective with respect to impulses of the other polarity. Under the latter condition, speech transmission may no longer be possible. However, by using

code instead of telephone transmission, greater distortion is permissible so that the operating range of the apparatus may be increased in this manner. Accordingly, it will be apparent that

I have shown in Fig. 3 a system which is capable of providing satisfactory two-way communication in a simple and inexpensive manner, up to a given value of load, over the same pair of conductors which are at times used for supplying power or are used for other purposes.

Referring now to Fig. 4, the apparatus shown in this figure is very much like that of Fig. 1 with the exception that relay D2 is of the normally energized type, as in Fig. 2, and is polarized with its armature biased to its neutral position. Normally, when the section E2—F2 is unoccupied the relay D2 is maintained energized by the reverse voltage drop across the rectifier K4 due to the flow of current from the battery B through the resistor R1 and rectifier K4 in the reverse direction. Polar contact 24—25 will be closed under this condition. The resistor R1 provides the initial reverse voltage drop (which in Fig. 1 is provided by the resistance of the winding of relay D) for opposing the flow of current from battery A through the rectifier K4 in the forward direction until the transition point is reached and the load R across the rails or the two conductors reaches a predetermined value.

When a load is connected across the rails or the section E2—F2 becomes occupied, the reverse voltage drop will be reduced sufficiently to cause the relay D2 to release, opening its contact 24—25 and closing its contact 24—27. At a critical value of load, the net current through the rectifier will be zero, and any further increase in the load will cause current to flow through the rectifier in the normal or forward direction, thus establishing a forward voltage drop across the rectifier.

Relay D2 and the remaining apparatus are so designed and proportioned that the reverse voltage across the rectifier K4 with the section E2—F2 unoccupied is sufficient to maintain the contact 24—25 closed. The resistance of relay D2 should be sufficiently high so as not to mask the rectifier characteristics in order not to reduce the sensitivity of the apparatus. At a given value of the load current corresponding to a predetermined load R, the reverse voltage drop across the rectifier K4 will be insufficient to maintain relay D2 energized so that its polar contact 24—25 will be opened. Any suitable indication or control circuits for governing signaling or other apparatus may be controlled over the contacts 24—25 and 24—27 of relay D2.

When the section E2—F2 is occupied, the load current will ordinarily be sufficient to cause the voltage drop across the rectifier to reverse and become positive. This voltage drop will not be very high because of the relatively low resistance of the rectifier K4 in the forward direction, but may be enough to cause the armature of relay D2 to swing to the left, closing contact 24—26. If desired, contacts 26 and 27 may be connected together so that the closing of either contact 24—27 or 24—26 will provide an "occupied" indication.

The circuit of Fig. 4 incorporates a number of safety features in that any failure such as an open circuit in the winding of relay D2, a short-circuit in rectifier K4, a failure of the battery B, or an open circuit in the resistor R1 will each cause a release of relay D2 to provide an indication of a fault in the circuit.

Referring now to Fig. 5, I have shown in this figure the alternating current equivalent of the apparatus of Fig. 1. The transformer T3 has its input winding energized from a suitable source of alternating current and has its output winding divided into two portions 28 and 29 which correspond respectively to the sources A and B of Fig. 1. The connections of these windings with the rectifier K5, relay D3 and rails 1—1a of the track circuit are identical with the connections of the batteries A and B in Fig. 1 and so need not be described in detail. In operation, with the section unoccupied, relay D3 will be deenergized because the potential of winding 29 is insufficient to pick up this relay over the rectifier circuit. At a predetermined value of the load R, relay D3 will pick up and will remain picked up thereafter as the load is increased still further. The unidirectional current in relay D3 has been found upon test to reach a saturation point, as in Fig. 1, so that the path through the rectifier K5 carries substantially all of the load current, as in the circuits which use the battery sources. The complete theory apparently underlying the operation of the apparatus of Fig. 5 involves considerable complication and its is believed unnecessary for an understanding of the invention to present a theoretical analysis of the operation.

The apparatus of Fig. 5 provides an operation which, though not so sharply defined as in the direct current apparatus, is generally similar to that provided by the battery operated systems. For example, using a 60 cycle transformer delivering a constant voltage of 6 volts from its winding 29 and 8.8 volts from its winding 28; a direct current relay D3 wound to a resistance of 125 ohms and having a pick-up of 7 milliamperes as read on a direct current galvanometer type milliammeter; and a half-wave rectifier K5 built up of the usual copper oxide discs, the relay current was observed to increase gradually as the load resistance was decreased, reaching a saturation value of about 18 milliamperes at a load current of about 100 milliamperes as read on direct current galvanometer type meters. Beyond this point, no increase in the relay current was observed even though the load current was increased to 500 milliamperes, thus showing that the apparatus of Fig. 5 which employs alternating current sources provides the same general type of operation as the direct current apparatus of Fig. 1. The apparatus just described would, for example, be suitable for a model railroad employing alternating current for both propulsion and track circuit control.

It will be understood that the above specific values are given solely for the purpose of illustration in order to provide a more clear understanding of the invention, and not in any limiting sense whatever because, obviously, the apparatus may be proportioned in many different ways to provide the operation contemplated by the invention, depending on the particular service which the apparatus is to perform. When used in conjunction with model railroad operation, it will be understood that the single transformer T3 of Fig. 5 may be used for energizing additional track sections such as F—G of Fig. 1 by adding a rectifier K5 and relay D3 for each additional track circuit section and connecting these with the remaining apparatus in the same manner that the corresponding rectifier K4 and relay Da of Fig. 1 are connected with the apparatus for section E—F.

From the foregoing description of the several figures, it will be apparent that an important feature of my invention is the provision of apparatus which causes a first circuit to carry substantially all of the current up to a given predetermined value and then as the current is increased above this value, suddenly and automatically to cause the excess current to be switched or by-passed into a second circuit, without employing any apparatus having moving parts for performing this operation. Moreover, the apparatus embodying my invention makes it possible to detect the flow of very small currents by means of relatively rugged and reliable apparatus which in itself is not required to be ultra-sensitive. While the current is being detected (in the low current range) the voltage effective across the load terminals exhibits all the characteristics of being fed from a source having a high resistance in series therewith. However, beyond the detection range and at the transition point as discussed hereinbefore, the characteristics of the supply circuit automatically change without the aid of any moving parts, in such a way that the load voltage at increased loads exhibits all the characteristics of being fed from a constant voltage source. By virtue of these characteristics, the apparatus provides effective means for checking the integrity of a circuit normally carrying but a small current and also provides a simple signaling channel over an available pair of load supply conductors or track rails and may be used to perform many other useful functions, as well. The apparatus may also be energized from alternating current sources and although the operation is not quite so sharply defined in such apparatus as in the systems which employ direct current sources, the important advantages of the apparatus are available in both. Obviously, these general features of operation are capable of being used advantageously in many practical applications, those described herein being chosen merely for the purpose of setting forth more clearly certain fundamental aspects of the invention, rather than in any limiting sense.

Although I have herein shown and described only a few forms of apparatus embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In combination, a pair of conductors, a main source of unidirectional current, an asymmetric unit, means including said asymmetric unit for connecting said main source across said conductors, said asymmetric unit being poled in a direction to aid the flow of current from said main source, an auxiliary source of unidirectional current, an impedance, means including said impedance for connecting said auxiliary source across said asymmetric unit, said auxiliary source being poled in a direction to oppose the flow of current from said main source through said asymmetric unit, and a load connected across said conductors and energized from said main source, said impedance having a relatively low value as compared with the resistance of said asymmetric unit in the reverse-current direction, the potential of said auxiliary source being so chosen with respect to the voltage drop caused by the flow of current to said load through said

impedance that at a predetermined value of said load current said auxiliary source potential and said voltage drop will substantially neutralize, whereby upon a further increase in the load current the asymmetric unit will by-pass the portion of said load current above said predetermined value around said impedance.

2. In combination, a pair of conductors, a load connected across said conductors, a main source of unidirectional current, an asymmetric unit, means including said asymmetric unit for connecting said main source across said conductors, said asymmetric unit being poled in a direction to aid the flow of current from said main source to said load, an auxiliary source of unidirectional current, an impedance, and means including said impedance for connecting said auxiliary source across said asymmetric unit, said auxiliary source being poled in a direction to oppose the flow of current from said main source through said asymmetric unit, the parts being so proportioned that at a predetermined value of load current, the voltage drop in said impedance due to the flow of said load current will substantially neutralize the potential of said auxiliary source, thereby permitting any further increase in the load current to be by-passed around said impedance through said asymmetric unit in its forward direction.

3. In combination, a first circuit comprising a main source of unidirectional current, a load, and an asymmetric unit poled in the direction to aid the flow of current from said main source to said load; a second circuit comprising an auxiliary source of unidirectional current, said main source, said load, and an impedance, said two sources being connected in series-aiding relation; and a third circuit comprising said auxiliary source, said impedance, and said asymmetric unit poled in a direction to oppose the flow of current from said auxiliary source to said impedance; the parts being so proportioned that at a predetermined value of current through said load, the resultant potential drop across said asymmetric unit will be substantially zero, whereby an increase in current through said load above said predetermined value will cause current to be by-passed around said impedance through said asymmetric unit.

4. Current diverting apparatus comprising, in combination, a first circuit including a main source of unidirectional current, a load, and an asymmetric unit poled in the aiding direction with respect to said main source; a second circuit including an auxiliary source of unidirectional current and said main source connected in series-aiding relation, said load, and an impedance; and a third circuit including said auxiliary source, said impedance, and said asymmetric unit connected in its blocking direction.

5. Current diverting apparatus comprising, in combination, a first circuit including a main source of current, a load, and an asymmetric unit; a second circuit including an auxiliary source of current and said main source connected in series-aiding relation, said load, and an impedance; and a third circuit including said auxiliary source, said impedance, and said asymmetric unit, the parts being so proportioned that above a predetermined value of said load substantially all of the load current will be by-passed around said impedance through said asymmetric unit.

6. Apparatus for preventing the current in a given circuit from exceeding a predetermined

value comprising, in combination, a main source of unidirectional current, an auxiliary source of unidirectional current connected in series-aiding relation with said main source, a load impedance and a bias impedance connected in series with each other and in a series circuit with said two sources, said bias impedance having one terminal connected with said auxiliary source, and an asymmetric unit connected between the junction points of said two impedances and said two sources and poled in a direction to aid the flow of current from said main source through said load impedance.

7. Apparatus for preventing the current in a given circuit from exceeding a predetermined value comprising, in combination, a main source of current, an auxiliary source of current connected in series-aiding relation with said main source, a load impedance and a bias impedance connected in series with each other and in a series circuit with said two sources, said bias impedance having one terminal connected with said auxiliary source, and an asymmetric unit connected between the junction points of said two impedances and said two sources, the parts being so proportioned that below a predetermined value of said load impedance substantially all of the load current will be by-passed around said bias impedance through said asymmetric unit.

8. In combination, a pair of conductors, a load, an asymmetric unit, means for supplying unidirectional current over said conductors to said load through said asymmetric unit in its aiding direction, an impedance traversed by a portion of the current supplied to said load, and means including said impedance for establishing a potential drop across said asymmetric unit in a direction to oppose the flow of current to said load at all values of said load below a given predetermined value, whereby substantially all of said load current will traverse said impedance below said predetermined value and whereby an increase in said load above said predetermined value will cause the excess current to be by-passed around said impedance through said asymmetric unit.

9. In combination, a pair of conductors, a load, an asymmetric unit, means including a source of unidirectional current for supplying current to said load over said conductors through said asymmetric unit poled in the aiding direction with respect to said source, an auxiliary circuit excluding said asymmetric unit and supplying current from said main source to said load, and means included in said auxiliary circuit for establishing a potential drop across said asymmetric unit in a direction to oppose the flow of current to said load through said asymmetric unit at all values of said load below a given predetermined value, whereby substantially all of said load current will traverse said auxiliary circuit below said predetermined value and whereby an increase in said load above said predetermined value will cause the excess current to be by-passed around said auxiliary circuit through said asymmetric unit.

10. An automatic switching device for causing current to be by-passed from one into another circuit when the current exceeds a predetermined value, all of the component parts of said device being stationary comprising, in combination; a first circuit including a source of unidirectional current, a load, and an asymmetric unit poled in the aiding direction with respect to said source; and a second circuit including said source and said

load but excluding said asymmetric unit; and means included in said second circuit for establishing a potential drop across said asymmetric unit in a direction to oppose the flow of current to said load through said asymmetric unit at all values of said load current below said predetermined value, thus confining said load current to said second circuit until said predetermined value is exceeded, whereupon the excess current is by-passed through said asymmetric unit into said first circuit.

11. In combination, a pair of conductors, a main source of unidirectional current and an asymmetric unit poled in the aiding direction with respect to said main source and connected in series across said conductors, a load connected across said conductors, an auxiliary source of unidirectional current connected across said asymmetric unit in a direction to oppose the flow of current from said main source to said load through said asymmetric unit, and an indicator connected in series with said auxiliary source across said asymmetric unit for indicating when the current supplied to said load exceeds a predetermined value and for causing a potential drop due to the load current passing there-through which opposes the voltage of said auxiliary source to thereby aid the flow of an increased load current through said asymmetric unit.

12. Apparatus for indicating the integrity of a circuit comprising, in combination with a pair of conductors adapted to supply current to a load, a main source of unidirectional current and an asymmetric unit all included in said circuit, an auxiliary source of unidirectional current connected across said asymmetric unit in a direction to oppose the flow of current from said main source in said circuit, and an indicator connected in series with said auxiliary source across said asymmetric unit.

13. Apparatus for indicating the integrity of a circuit comprising, in combination with a pair of conductors adapted to supply current to a load, a main source of current and an asymmetric unit all included in said circuit, an auxiliary source of current connected across said asymmetric unit in a direction to oppose the flow of current from said main source in said circuit, and an indicator connected in series with said auxiliary source across said asymmetric unit.

14. In combination, a first circuit comprising a main source of unidirectional current, a load, and an asymmetric unit poled in the aiding direction with respect to said main source; a second circuit comprising an auxiliary source of unidirectional current and said main source connected in series-aiding relationship, said load, and a control relay; and a third circuit comprising said auxiliary source, said control relay and said asymmetric unit poled in its blocking direction; and signaling apparatus governed by said control relay.

15. Means for preventing the current in a given circuit from exceeding a predetermined value comprising, in combination, a main source of unidirectional current, an auxiliary source of unidirectional current connected in series-aiding relationship with said main source, a control relay and a load connected in series with each other and also in a series circuit with said two sources, said control relay having one terminal connected with said auxiliary source, an asymmetric unit connected from the other terminal of said control relay to the junction point of said two sources

and poled in a direction to aid the flow of current from said main source through said load, and signaling apparatus governed by said control relay.

16. Apparatus for detecting the presence of a relatively small current in a load conductor which at times carries a relatively heavy current comprising, in combination with said conductor, a source of unidirectional current, an asymmetric unit, a load; means for connecting said asymmetric unit in series with said source, said load, and said conductor in a direction to aid the flow of load current from said source through said conductor; and an auxiliary path in multiple with said asymmetric unit for the flow of current through said conductor, said auxiliary path including means for establishing a reverse potential drop therein for opposing the flow of said load current through said asymmetric unit until the current in said auxiliary path reaches a predetermined value.

17. Apparatus for detecting the presence of a relatively small current in a load conductor which at times carries a relatively heavy current comprising, in combination with said conductor, a source of unidirectional current, an asymmetric unit, a load; means for connecting said asymmetric unit in series with said source, said load, and said conductor in a direction to aid the flow of load current from said source through said conductor; an auxiliary path in multiple with said asymmetric unit for the flow of current through said conductor, said auxiliary path including means for establishing a reverse potential drop therein for opposing the flow of said load current through said asymmetric unit until the current in said auxiliary path reaches a predetermined value, and detecting means energized from the potential drop across said asymmetric unit.

18. In combination with a section of railway track, a source of unidirectional current, an asymmetric unit, means for connecting said source across the rails of said section through said asymmetric unit poled in the aiding direction with respect to said source for supplying current to said rails when the section is occupied, an auxiliary path in multiple with said asymmetric unit for also supplying current from said source to said rails when the section is occupied, and means included in said auxiliary path for establishing a reverse potential drop for opposing the flow of rail current through said asymmetric unit until the current in said auxiliary path reaches a predetermined value.

19. In combination with a first and a second section of railway track, one source of unidirectional current for both said sections, a first and a second asymmetric unit for said first and said second section respectively, means for connecting said source across the rails of each section through the associated asymmetric unit poled in the aiding direction with respect to said source for supplying current to the rails of the respective section when the section is occupied, an auxiliary path in multiple with each asymmetric unit for also supplying current from said source to the rails of the respective section when the section is occupied, and means included in each auxiliary path for establishing a reverse potential drop for opposing the flow of rail current through the respective asymmetric unit until the current in the associated auxiliary path reaches a predetermined value.

20. In combination with a first and a second

section of railway track, one main source of unidirectional current for both said sections, a first and a second asymmetric unit for said first and said second section respectively, means for connecting said main source across the rails of each section through the associated asymmetric unit poled in the aiding direction with respect to said main source for supplying current to the rails of the respective section when the section is occupied, one auxiliary source of unidirectional current for both said sections, said auxiliary source being connected across each of said asymmetric units in a direction to oppose the flow of current from said main source to the rails through the respective asymmetric unit, and means associated with each asymmetric unit and connected in series with the asymmetric unit and said auxiliary source for causing a potential drop due to rail current from said main source passing therethrough which opposes the voltage of said auxiliary source to thereby aid the flow of an increased rail current through the associated asymmetric unit.

21. In combination with a first and a second section of railway track, one main source of unidirectional current for both said sections, a first and a second asymmetric unit for said first and said second section respectively, means for connecting said main source across the rails of each section through the associated asymmetric unit poled in the aiding direction with respect to said main source for supplying current to the rails of the respective section when the section is occupied, one auxiliary source of unidirectional current for both said sections, said auxiliary source being connected across each of said asymmetric units in a direction to oppose the flow of current from said main source to the rails through the respective asymmetric unit, and an impedance associated with each asymmetric unit and connected in a series circuit with the associated asymmetric unit and said auxiliary source.

22. In combination with a section of railway track, a source of unidirectional propulsion current for said section, an asymmetric unit, a circuit connecting said source across the rails of said section through asymmetric unit poled in the aiding direction with respect to said source, and an auxiliary path in multiple with said asymmetric unit for the flow of said propulsion current, said auxiliary path including means for establishing a reverse potential drop therein for opposing the flow of propulsion current through said asymmetric unit, said auxiliary path also including a control relay which is deenergized when said section is unoccupied and no current from said source flows in said auxiliary path but which becomes energized when a train enters said section and an appreciable propulsion potential drop develops across said control relay to oppose the effect of said means and to aid the flow of propulsion current through said asymmetric unit, and signaling apparatus governed by said control relay.

23. In combination with a section of railway track and a rail vehicle load thereon, a source of unidirectional current, an asymmetric unit, means for connecting said source across the rails of said section through said asymmetric unit poled in the aiding direction with respect to said source to thereby supply current from said source to said rail vehicle load, an auxiliary path in multiple with said asymmetric unit for the flow of current from said source to said load, said auxiliary path including means for establishing a re-

verse potential drop therein for opposing the flow of said load current through said asymmetric unit, and a relay also included in said auxiliary path for indicating the presence of the rail vehicle upon said section.

24. In combination with a section of railway track and a rail vehicle load thereon, a source of unidirectional current, an asymmetric unit, means for connecting said source across the rails of said section through said asymmetric unit poled in the aiding direction with respect to said source to thereby supply current from said source to said rail vehicle load, an auxiliary path in multiple with said asymmetric unit for the flow of current from said source to said load, said auxiliary path including means for establishing a reverse potential drop therein for opposing the flow of said load current through said asymmetric unit, and signaling means controlled by the current flowing in said auxiliary path.

25. In combination with a section of railway track and a rail vehicle load thereon, a main source of unidirectional current, an asymmetric unit, means for connecting said source across the rails of said section through said asymmetric unit poled in the aiding direction with respect to said main source to thereby supply current from said source to said rail vehicle load, an auxiliary source of unidirectional current, and a track relay connected in a series circuit with said auxiliary source across said asymmetric unit, said auxiliary source being poled in a direction to oppose the flow of current from said main source through said asymmetric unit until the potential drop in said track relay due to the flow of said load current therein exceeds a predetermined value.

26. In combination with a section of railway track and a rail vehicle load thereon, a main source of current, an asymmetric unit, means for connecting said source across the rails of said section through said asymmetric unit to thereby supply current from said source to said rail vehicle load, an auxiliary source of current, and a track relay connected in a series circuit with said auxiliary source across said asymmetric unit, said auxiliary source being poled in a direction to oppose the flow of current from said main source through said asymmetric unit.

27. In combination with a section of railway track and a rail vehicle load thereon, a main source of unidirectional current, an asymmetric unit, means for connecting said source across the rails of said section through said asymmetric unit poled in the aiding direction with respect to said main source to thereby supply current from said source to said rail vehicle load, an auxiliary source of unidirectional current, a resistor connected in a series circuit with said auxiliary source across said asymmetric unit, said auxiliary source being poled in a direction to oppose the flow of current from said main source through said asymmetric unit until the potential drop across said resistor due to the flow of current from said main source therein exceeds a predetermined value, and a polarized checking relay energized from the potential drop across said asymmetric unit.

28. Apparatus for indicating the integrity of a circuit comprising, in combination with a pair of conductors adapted to supply current to a load, a main source of unidirectional current and an asymmetric unit all included in said circuit, an auxiliary source of unidirectional current connected across said asymmetric unit in a direction to oppose the flow of current from said main

source in said circuit, a resistor included in the connection of said auxiliary source with said asymmetric unit, and an indicator energized from the potential drop across said asymmetric unit.

29. In combination, a first circuit comprising a main source of unidirectional current, a load, and an asymmetric unit poled in the aiding direction with respect to said main source; a second circuit comprising an auxiliary source of unidirectional current, a resistor, said load, and said main source, said two sources being connected in series-aiding relationship; a third circuit comprising said auxiliary source, said resistor, and said asymmetric unit poled in its blocking direction; and a checking relay connected across said asymmetric unit.

30. In combination with a section of railway track and a rail vehicle load thereon, a source of unidirectional propulsion current, an asymmetric unit, means for connecting said asymmetric unit in series with said propulsion source across said track in a direction to aid the flow of current from said source to said load, an auxiliary source of unidirectional current connected across said asymmetric unit in a direction to oppose the flow of current from said propulsion source through said asymmetric unit, a source of periodic current connected across said track, and signaling apparatus connected in series with said auxiliary source across said asymmetric unit and responsive to the flow of current from said periodic source at such time as the potential drop in said apparatus due to current from said propulsion source and said periodic source is insufficient to overcome the opposing potential of said auxiliary source.

31. In combination with a pair of conductors, a load adapted to receive current from said conductors, a source of unidirectional current, an asymmetric unit, means for connecting said asymmetric unit in series with said source across said conductors in a direction to aid the flow of current from said source to said load, a transformer, an auxiliary path in multiple with said asymmetric unit including said transformer, said auxiliary path including means for establishing a reverse unidirectional potential drop across said asymmetric unit for opposing the flow of said load current through the asymmetric unit, a source of periodic current connected across said conductors, and signaling apparatus controlled by current from said transformer.

32. In combination with a pair of conductors, a load adapted to receive current from said conductors, a main source of unidirectional current, an asymmetric unit, means for connecting said asymmetric unit in series with said main source across said conductors in a direction to aid the flow of current from said main source to said load, an auxiliary source of unidirectional current connected across said asymmetric unit in a direction to oppose the flow of current from said main source through said asymmetric unit, a source of periodic current connected across said conductors, and signaling apparatus connected in series with said auxiliary source across said asymmetric unit and responsive to the flow of current from said periodic source at such time as the potential drop in said apparatus due to current from said propulsion source and said periodic source is insufficient to overcome the opposing potential of said auxiliary source.

33. In combination with a pair of conductors, a main source of unidirectional current, a load adapted to receive current from said conductors,

an asymmetric unit, means for connecting said asymmetric unit in series with said main source across said conductors in a direction to aid the flow of current from said main source to said load, 5 an auxiliary source of unidirectional current connected across said asymmetric unit in a direction to oppose the flow of current from said main source through said asymmetric unit, means for impressing periodically varying signaling energy

across said conductors, a condenser connected in series with said means, and signaling apparatus connected in series with said auxiliary source across said asymmetric unit and responsive to the presence of said signaling energy at such time as the current supplied to said load from said main source is below a predetermined value. 8

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