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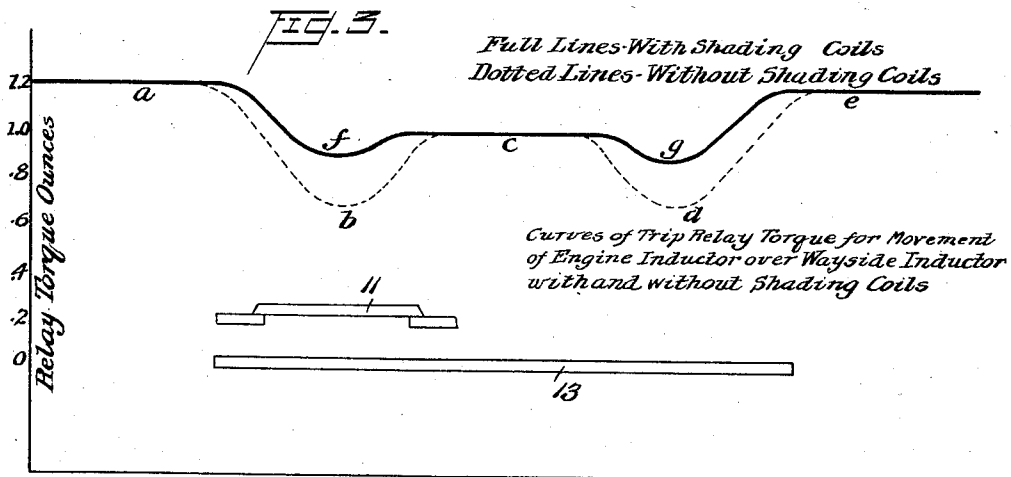
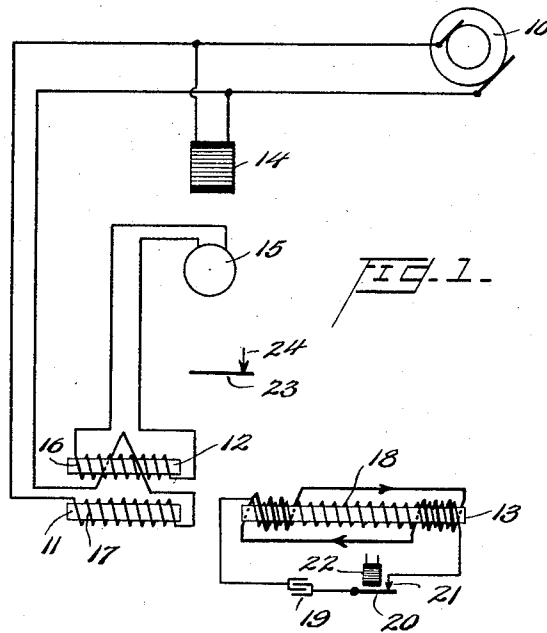
T. BODDE

1,783,491

TRAIN CONTROL SYSTEM

Filed Oct. 30, 1926

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 2.

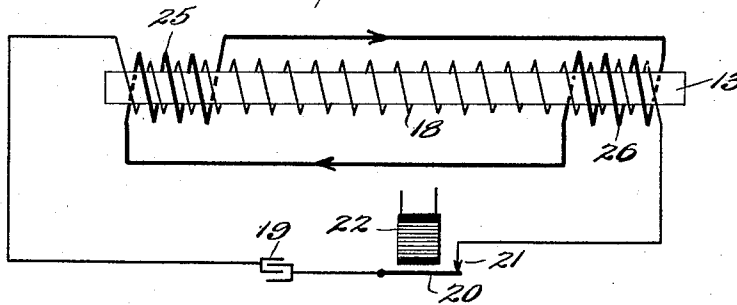


FIG. 4.

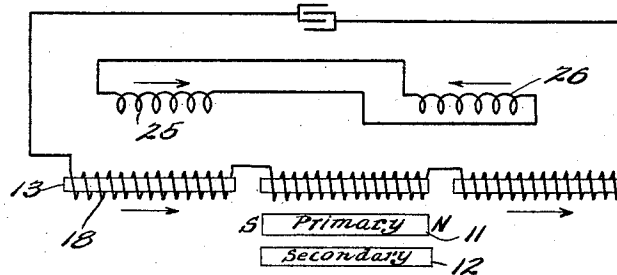
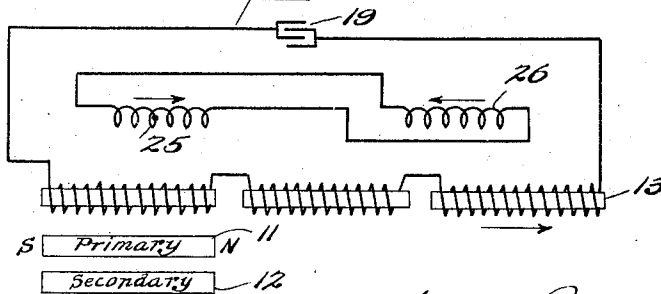


FIG. 5.



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TRAIN-CONTROL SYSTEM

Application filed October 30, 1926. Serial No. 145,191.

This invention relates broadly to railway signalling and train control systems. More particularly, the present invention is directed to railway induction signalling and control systems.

The present invention constitutes an improvement on the system disclosed and claimed in Patent No. 1,521,332 to A. G. Shaver. This patent discloses an induction signalling and control system, in which a train carried device comprising two inductively coupled elements, one of which constitutes a primary and the other a secondary, cooperate with the roadside inductor. The roadside inductor comprises a body of magnetic material disposed in the path of travel of a passing train in such a manner that the primary of the train carried devices will pass immediately over the roadside device. The roadside inductor is, finally, provided with a winding and with circuit means whereby said winding may be open circuited or short circuited depending upon the traffic condition of the immediate block.

It is the object of the present invention to improve the operating characteristics of the system and to obviate any possibility of obtaining an erroneous indication.

The invention will be more clearly understood by reference to the accompanying drawing and a description thereof.

In the drawings,

Figure 1 is a diagrammatic illustration of the basic elements of the system embodying the present invention;

Figure 2 is a showing of the roadside inductor embodying the present invention;

Figure 3 shows the operating characteristics of the system with and without the present improvement;

Figures 4 and 5 are diagrammatic showings of the theory of operation of the system embodying the present improvement.

Referring to Figure 1, 10 is a source of alternating current and 11 and 12 constitute the primary and secondary respectively of the train carried device which is adapted to cooperate with the roadside inductor 13 to pick up the indication of the traffic condition of the immediate block. The train also carries

a two part relay comprising the element 14 which is permanently connected to the source 10 and the rotatable element which is connected to the winding 16 of the train carried secondary 12. The winding 17 of the train carried primary is also connected to the source of current 10. The roadside inductor is provided with a winding 18. A condenser 19 is connected in series with the winding and the circuit of the winding may be closed by means of the arm 20 and cooperating contact 21 which are under the control of the relay 22. The relay 22 is energized or deenergized in accordance with the traffic condition of the immediate block. The circuit of the winding 18 of the roadside inductor will be open when the relay 22 is deenergized and will be closed when the relay 22 is energized.

In broad terms the operation of the system so far described and which is fully disclosed in the patent referred to above is as follows: The inductors 11 and 12 are carried by the train and are so disposed that the inductor 11 passes directly over the roadside inductor 13. If the winding of the roadside inductor 13 is open circuited the electromagnetic relationships of the train carried elements will be disturbed and the trip control relay 15 will operate to open the contacts 23, 24 and thereby effect an application of the brakes or give any other desired indication. If, however, the circuit of the winding 18 of the roadside inductor is closed at the time the train passes thereover, the electromagnetic relationships will not be disturbed and the train carried system will remain unaffected.

The elements 14 and 15 of the trip relay are both normally energized, and under normal conditions, the element 14 exerts a torque upon the element 15 so that the contacts 23, 24 are maintained closed. This torque is the result of the attractive forces that exist between the currents carried by these elements and, the size of the torque is influenced by the amount of current in each of the elements and by the phase relationship between such currents. One view of the operation of the system, therefore, is that when the train carried devices pass over the roadside inductor hav-

ing its winding open circuited, the torque between the elements 14 and 15 will be diminished to such an extent that the element 15 will rotate and open the contacts 23, 24. It has been commonly assumed hitherto that when the train carried devices pass over a short circuited roadside inductor the torque between the elements 14 and 15 does not substantially diminish. Measurements of the torque, however, have shown that while there is no substantial diminution of the torque over the greater part of the time it takes the train carried inductor to pass over the roadside inductor, there is a substantial diminution of the torque at the time when the train carried inductor first enters a space overlying the roadside inductor. Figure 3 of the drawings is a graphic illustration of the torque measurements obtained under such conditions. The curve *a-b-c-d-e* which includes the dotted portions shows the manner in which the torque varies as the train carried inductor passes over the roadside inductor.

It is the object of the present invention to modify the system in such a manner as to obviate the dips shown by the dotted portions of the curve and to prevent any substantial reduction of the torque when the roadside inductor is short circuited. This object is accomplished in the present invention by providing a roadside inductor with one additional winding at each end which will be hereinafter referred to as shading coils. These coils are indicated by the reference numerals 25 and 26. They are wound in opposition to each other and are short circuited on each other. When the roadside inductor is provided with shading coils the curve *a-f-c-g-e*, which is obtained, it will be seen, practically eliminates the dips in the curve which exist when the old type of roadside inductor is used.

In order to facilitate the understanding of the principle underlying the present invention a theory of operation of the entire system is submitted herewith.

Normally, that is, at such times when there is no roadside inductor in proximity with the train carried inductors, inductors 11 and 12 constitute a primary and a secondary respectively of a transformer. The cores of these two inductors are separated by air gaps. A flux generated in the inductor 11, therefore, has two external paths. One of these paths leads through the core of the secondary 12 and the other leads through the surrounding air. The flux in the primary 11 is determined by the electromotive force impressed upon its winding and is constant regardless of the reluctance of the magnetic circuit outside the element 11.

A certain definite magnetomotive force is consumed in the core of the element 11. The other part of the magnetomotive force is

spent in passing the flux through the two external paths described above. In view of the fact that the flux within the core of the element 11 remains constant, and in view of the fact that the reluctance of that core remains constant, the portion of the magnetomotive force that is spent in this part of the magnetic circuit remains constant. The magnetomotive force that is spent on the external circuit is applied to two parallel magnetic paths, one path being entirely through the air and the other path being through the air gaps that exist between the elements 11 and 12 and through the core of the element 12.

We will now introduce the roadside inductor 13 and for the first case, we will assume that its winding is open. Conditions are as follows:

Inasmuch as the voltage applied to the element 11 is constant, the flux passing through the element is the same. The reluctance of the external magnetic circuit is lowered by reason of the introduction of the roadside inductor 13. The reluctance of the path which includes the core of the element 12 is the same. The total reluctance of the magnetic paths external to the element 11 has, therefore, been decreased and the magnetomotive force required to set up the flux in these external circuits has decreased which in turn results in a decrease of the flux which passes through the core of the inductor 12. The effect of this reduction in flux through the element 12 is to decrease the voltage and current in the circuit which includes the trip relay 15.

We will next assume that the roadside inductor has been wound and short circuited but we will assume that the condenser 19 is not included in the circuit. It is to be noted at this point that the train carried inductors are a good deal shorter than the roadside inductor and are approximately one-third the length of the roadside inductor. In view of this fact, the train carried inductor overlies only that part of the roadside inductor which lies directly below the train carried inductor and which constitutes a secondary with relation to the element 11, while the remainder of the roadside inductor merely constitutes the highly inductive load on the secondary. When the train carried inductor overlies approximately the middle portion of the roadside inductor, this middle portion constitutes an induced secondary while the end portions constitute a load upon the secondary. A current will flow in the winding 18 of the roadside inductor which will set up a flux in opposition to the flux set up at the primary 11. The current taken by the element 11 will increase by an amount sufficient to set up an additional flux equal and opposite to that set up by the roadside inductor so that the resultant flux set up by the element 11 is the same as that previously considered. Were there no other fac-

tors considered, the flux passing through the element 12 would be the same as when the roadside inductor was in open circuit. At this point, however, magnetic leakage comes into play. As is well known, when the secondary of a transformer is loaded a leakage flux is produced both by the primary and secondary which in ordinary transformers takes a leakage path partly through the air. In a transformer of the kind under consideration where there are large air gaps between the iron cores and also because of the presence of the low reluctance path through the element 12, the leakage flux will be considerable. The primary leakage flux will be in phase with the total primary current while the secondary leakage flux will be in phase with the secondary current. Part of this leakage flux will take a path through the element 12, thus increasing the flux in this element. This will serve to increase the voltage introduced in the winding of the element 12 and thereby increase the current in the relay 15. Further, since the inductance of the external circuit for the roadside inductor is much greater than for the element 12, the leakage flux will not be in phase with the regular flux in the element 12 so that the resultant current in 12 will not be due to the arithmetical sum of the two fluxes. It must be remembered that the trip relay is a two element relay and when the resultant current in 15 is in a different phase from the current previously flowing, the proper phase relation between the two elements of the relay will be disturbed and the torque will be reduced.

We now introduce the condenser 19 in the circuit of the roadside inductor. This condenser has two effects. The first effect is to increase the current flow in the winding of the roadside inductor due to the reduction in the impedance of its circuit. This increased current will increase the leakage flux previously referred to. The condenser will also have the effect of changing the phase of the current flowing in the circuit of the roadside inductor so as to produce a leakage flux which will be more nearly in phase with the regular flux passing through the element 12. For maximum results, the condenser should be of such value as to bring the leakage flux and the regular flux in the element 12 exactly in phase. The result now obtained is to increase the flux in the element 12, the total flux now being equal to the flux which passed through the element 12 under the first conditions assumed plus the leakage flux. This increases the voltage induced in the winding of the element 12 and increases the current flowing in the trip relay 15, and maintains this current at substantially the same level as under normal conditions. The phase of this current remains the same as under normal conditions. Under such conditions, there-

fore, the torque between the elements 14 and 15 will increase.

The above discussion explains the full line portion of the curve in Figure 3. We shall now proceed with an explanation of the dotted line portions *b* and *d* of the curve. The portion *b* of the torque curve arises at the time when the element 11 is coming into correspondence with the roadside inductor. Under such conditions only a small end portion of the winding 18 constitutes a secondary of the transformer while all of the remaining portion of the winding constitutes a load upon that secondary. Comparing these conditions with the conditions discussed herein above, when the train carried inductor overlies substantially the middle portion of the roadside inductor, the secondary winding generates a considerably smaller voltage and the load upon this secondary is considerably greater than under the conditions first discussed. Figure 4 illustrates diagrammatically the conditions that exist when the train carried inductor overlies substantially the middle portion of the roadside inductor while Figure 5 illustrates diagrammatically the conditions that exist when the train carried inductor overlies one side of the roadside inductor.

In Figures 4 and 5 the primary inductor is represented at a certain moment when it has a polarity N—S as shown. In both cases the polarity will induce in the roadside inductor winding a current which will produce poles opposite to the primary train inductor. In the absence of the auxiliary or shading coils 25, 26 the poles induced on the roadside inductor when the parts are as shown in Figure 5 will be very weak as compared with the strength of the poles induced on the roadside inductor when the parts are as shown in Figure 4. The reason for this difference in strength lies in the fact that the load upon the secondary under conditions shown in Figure 4 consists of two coils, one on each side of the secondary, each having half the number of turns of the one continuous coil which constitutes the load upon the secondary under conditions shown in Figure 5. The inductance of a coil varies approximately with the square of the number of turns in the coil.

For this reason, the inductance of the load coil under conditions shown in Figure 5 is about twice as great as the inductance of the two coils which constitute the load on the secondary under conditions shown in Figure 4. The air gaps shown in Figures 4 and 5 between the various parts of the roadside inductor are only for the purpose of the diagrammatic illustration and do not actually exist in the device as constructed and used.

The condenser having been adjusted for maximum effect under the condition when the train carried inductor overlies the mid-

dle portion of the roadside inductor, it fails to have the same effect for the condition when the train carried inductor overlies an end portion of the roadside inductor. In the absence, therefore, of any compensating means such as the shading coils which constitute the present improvement, a substantial decrease in the flux in the element 12 would be produced as previously explained. This decrease would be only partially compensated by the leakage flux, which leakage flux would not be of the proper phase. Due to these facts, therefore, the current carried by the relay 15 is substantially reduced at the time when the train carried inductors enter into correspondence with the roadside inductor and also at the time when they leave such correspondence. During such operations of the passage of the train carried inductor over the roadside inductor, therefore, the torque between the elements 14 and 15 is substantially reduced as shown by the dotted portions *b* and *c* of the torque curve in Figure 3.

The shading coils 25 and 26 are introduced in order to compensate for the undesirable effects indicated above. These coils consist of but a few turns so that their inductance is very low. As the train carried inductor 11 comes into correspondence with the roadside inductor 13 a large current will be induced in the shading coil 25 which will set up a leakage flux of approximately the proper phase and cause an increased flux to pass through the element 12. The same phenomenon will take place when the train carried inductor leaves the roadside inductor. The two coils 25 and 26 are so interconnected that when the train carried inductor is in a position overlying substantially the middle portion of the roadside inductor, the induced currents in the coils 25 and 26 will oppose and neutralize each other so that they will be ineffective.

From the above it will be seen that the condenser 19 serves the double function of reducing the total impedance of the roadside inductor circuit and to bring about the proper phase relationship between the currents in the elements 14 and 15 of the trip relay, when the train carried inductor overlies substantially the middle portion of the roadside inductor. Under such conditions the shading coils 25 and 26 oppose each other and serve no function. When, however, the train carried inductor overlies an end portion of the roadside inductor, the shading coils function in a manner to increase the leakage flux in the primary train carried inductor 11 thereby increasing the flux passing through the secondary train carried inductor 12, which in its turn brings about an increase in the current in the tripping element 15. Moreover, the shading coils also serve to bring the current in the tripping element 15 into proper phase relationship with the current in the tripping element 14.

Having described the invention, it is not to be limited to the specific embodiment shown in the specification and drawings.

What is claimed is:

1. A roadside tripping apparatus for an induction train control system comprising an element of magnetic material, a winding on said element, a circuit devoid of an energy source for said winding, means for opening and closing said circuit, and an auxiliary compensating or shading winding on an end of said element.

2. A roadside apparatus for an induction train control system comprising an element of magnetic material, a winding on said element, a circuit for said winding, means for opening and closing said circuit, and oppositely wound auxiliary compensating or shading windings on the ends of said element.

3. A roadside apparatus for an induction train control system comprising an element of magnetic material, a winding on said element, a circuit for said winding, means for opening and closing said circuit, and oppositely wound auxiliary compensating or shading windings on the ends of said element, said shading windings having a low inductance.

4. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils, roadside apparatus comprising an inductor embodying a circuit operable in accordance with wayside conditions for magnetically shunting the vehicle carried apparatus when said circuit is open and for permitting an uninterrupted operation of said vehicle carried apparatus when said circuit is closed and means cooperating with said roadside apparatus to prevent any substantial magnetic shunting when said circuit is closed.

5. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an induction element for producing an indication in said vehicle carried coupled coils, circuit means associated with said element for producing another indication in said vehicle carried coupled coils and means associated with said element for supplementing the operation of said circuit and aiding in the production of the other indication.

6. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an induction element for producing a danger indication in said vehicle carried coupled coils, circuit means associated with said element for producing a clear indication in said vehicle carried coupled coils and means associated with said element for supplementing the operation of said circuit and aiding in the production of the clear indication.

7. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an element of magnetic material, a winding on said element, a circuit for said winding, means whereby said circuit may be opened to produce a danger indication in said inductively coupled coils and closed to produce a clear indication and means on said element ineffective when said circuit is open and effective for supplementing the operation of said circuit and to aid in the production of the clear indication when said circuit is closed.

8. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an element of magnetic material cooperating directly with said inductively coupled coils, a winding on said element, a circuit devoid of an energy source for said winding, means for opening and closing said circuit, and auxiliary shading windings on said element.

9. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an element of magnetic material cooperating directly with said inductively coupled coils, a winding on said element, a circuit devoid of an energy source for said winding, means for opening and closing said circuit, and auxiliary shading windings on the ends of said element.

10. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an element of magnetic material, a winding on said element, a circuit for said winding, means for opening and closing said circuit, and oppositely wound auxiliary shading windings on the ends of said element.

11. In an induction train control system, the combination of vehicle carried apparatus comprising inductively coupled coils and a roadside apparatus comprising an element of magnetic material, a winding on said element, a circuit for said winding, means for opening and closing said circuit, and oppositely wound auxiliary shading windings on the ends of said element, said shading windings having a low inductance.

12. An induction train control system, the combination of vehicle carried apparatus comprising a pair of inductively coupled coils, a source of energy connected to one of said coils and a relay connected to the other of said coils, and roadside apparatus inductively cooperating with said vehicle carried apparatus comprising an inductor embodying a circuit operable in accordance with wayside conditions to reduce the cur-

rent in said relay when the circuit is open and to maintain the current in said relay when the circuit is closed and means cooperating with said roadside apparatus aiding in the maintainance of the current in said relay.

13. In an induction train control system, the combination of vehicle carried apparatus comprising a coil, a source of energy connected to said coil, a second coil inductively coupled to said first coil, and roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long element of magnetic material having an entrant end and an exit end, a winding on said element, a circuit for said winding operable in accordance with roadside conditions for reducing the flux in said second coil when said circuit is open, and means cooperating with said element and said winding for maintaining the flux in said second coil when the circuit is closed.

14. In an induction train control system, the combination of vehicle carried apparatus comprising a coil, a source of energy connected to said coil, a second coil inductively coupled to said first coil, and roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long element of magnetic material having an entrant end and an exit end, a winding on said element, a circuit for said winding operable in accordance with roadside conditions for reducing the flux in said second coil when said circuit is open, and means on said element cooperating with said element and said winding for maintaining the flux in said second coil when the circuit is closed.

15. In an induction train control system, the combination of vehicle carried apparatus comprising a coil, a source of energy connected to said coil, a second coil inductively coupled to said first coil, and roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long element of magnetic material having an entrant end and an exit end, a winding on said element, a circuit for said winding operable in accordance with roadside conditions for reducing the flux in said second coil when said circuit is open, and auxiliary windings cooperating with said element and said winding for maintaining the flux in said second coil when the circuit is closed.

16. In an induction train control system, the combination of vehicle carried apparatus comprising a coil, a source of energy connected to said coil, a second coil inductively coupled to said first coil, and roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long element of magnetic material having an entrant end and an exit end, a winding on said element, a circuit for said winding operable in accordance with roadside conditions for

reducing the flux in said second coil when said circuit is open, and auxiliary windings on the ends of said element cooperating with said element and said winding for maintaining the flux in said second coil when the circuit is closed.

17. In an induction train control system, the combination of vehicle carried apparatus comprising a coil, a source of energy connected to said coil, a second coil inductively coupled to said first coil, and roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long element of magnetic material having an entrant end and an exit end, a winding on said element, a circuit for said winding operable in accordance with roadside conditions for reducing the flux in said second coil when said circuit is open, and oppositely wound auxiliary windings cooperating with said element and said winding for maintaining the flux in said second coil when the circuit is closed.

18. In an induction train control system, the combination of vehicle carried apparatus comprising a pair of inductively coupled coils, a source of energy connected to one of said coils, a two element relay having one of its elements connected to said source of energy and having the other of its elements connected to the other of said coils whereby a constant torque is exerted by one element upon the other, roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long body of magnetic material, a winding on said body, a circuit for said winding, means operable in accordance with roadside conditions for opening and closing said circuit and means cooperating with said winding when its circuit is closed whereby the torque upon said element is maintained substantially constant.

19. In an induction train control system, the combination of vehicle carried apparatus comprising a pair of inductively coupled coils, a source of energy connected to one of said coils, a two element relay having one of its elements connected to said source of energy and having the other of its elements connected to the other of said coils whereby a constant torque is exerted by one element upon the other, roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long body of magnetic material, a winding on said body, a circuit for said winding, means operable in accordance with roadside conditions for opening and closing said circuit and means disposed on the ends of said body cooperating with the winding on said body for maintaining said torque substantially constant when the circuit of said winding is closed.

20. In an induction train control system, the combination of vehicle carried apparatus comprising a pair of inductively coupled

coils, a source of energy connected to one of said coils, a two element relay having one of its elements connected to said source of energy and having the other of its elements connected to the other of said coils whereby a constant torque is exerted by one element upon the other, roadside apparatus inductively cooperating with said vehicle carried apparatus comprising a relatively long body of magnetic material, a winding on said body, a circuit for said winding, means operable in accordance with roadside conditions for opening and closing said circuit and means on said body cooperating with the winding when its circuit is closed to maintain the magnitudes and phase relationships of the currents in said elements substantially in their normal condition.

21. In an induction train control system, the combination of vehicle carried apparatus comprising a pair of inductively coupled coils, a source of energy connected to one of said coils, a relay connected to the other of said coils, a roadside inductor cooperating with said vehicle carried apparatus comprising a relatively long body of magnetic material, a winding on said body, a circuit for said winding, means for opening and closing said circuit in accordance with roadside conditions and means for preventing any substantial reduction of the torque of said relay when the vehicle carried coils overlie the entrant or the exit ends of the roadside inductor.

22. In an induction train control system, the combination of vehicle carried apparatus comprising a pair of inductively coupled coils, a source of energy connected to one of said coils, a relay connected to the other of said coils, a roadside inductor cooperating with said vehicle carried apparatus comprising a relatively long body of magnetic material, a winding on said body, a circuit for said winding, means for opening and closing said circuit in accordance with roadside conditions and oppositely wound auxiliary coils on the ends of said body cooperating with the winding when its circuit is closed to prevent any substantial reduction in the torque of the relay when the vehicle carried inductors overlie the entrant or exit ends of the roadside inductor.

Signed at Niagara Falls in the county of Niagara and State of New York this 7th day of October, A. D. 1926.

THEODORE BODDE.