

Jan. 11, 1966

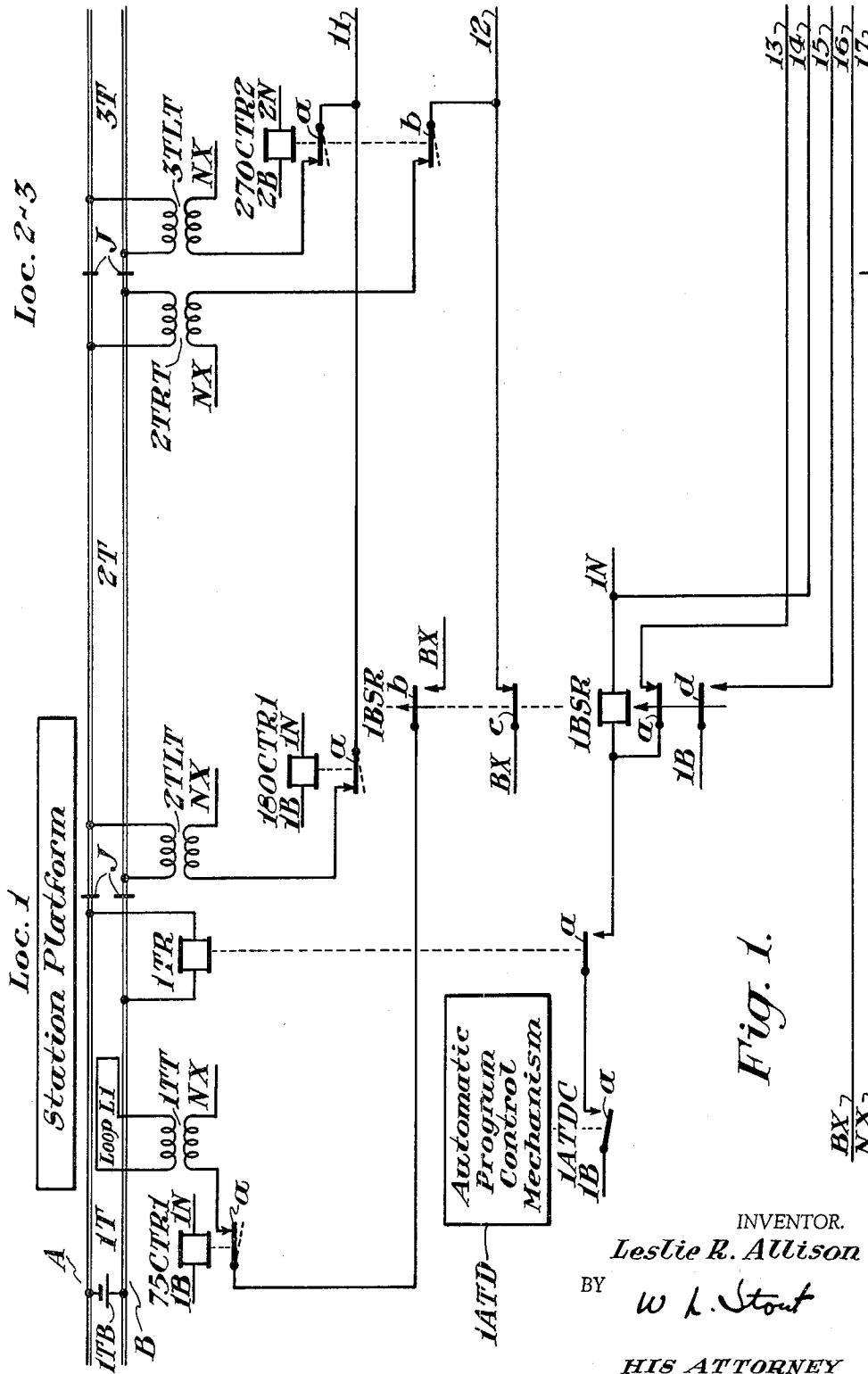
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3,229,086

AUTOMATIC TRAIN OPERATION SYSTEMS

Filed Nov. 8, 1960

7 Sheets-Sheet 1



Jan. 11, 1966

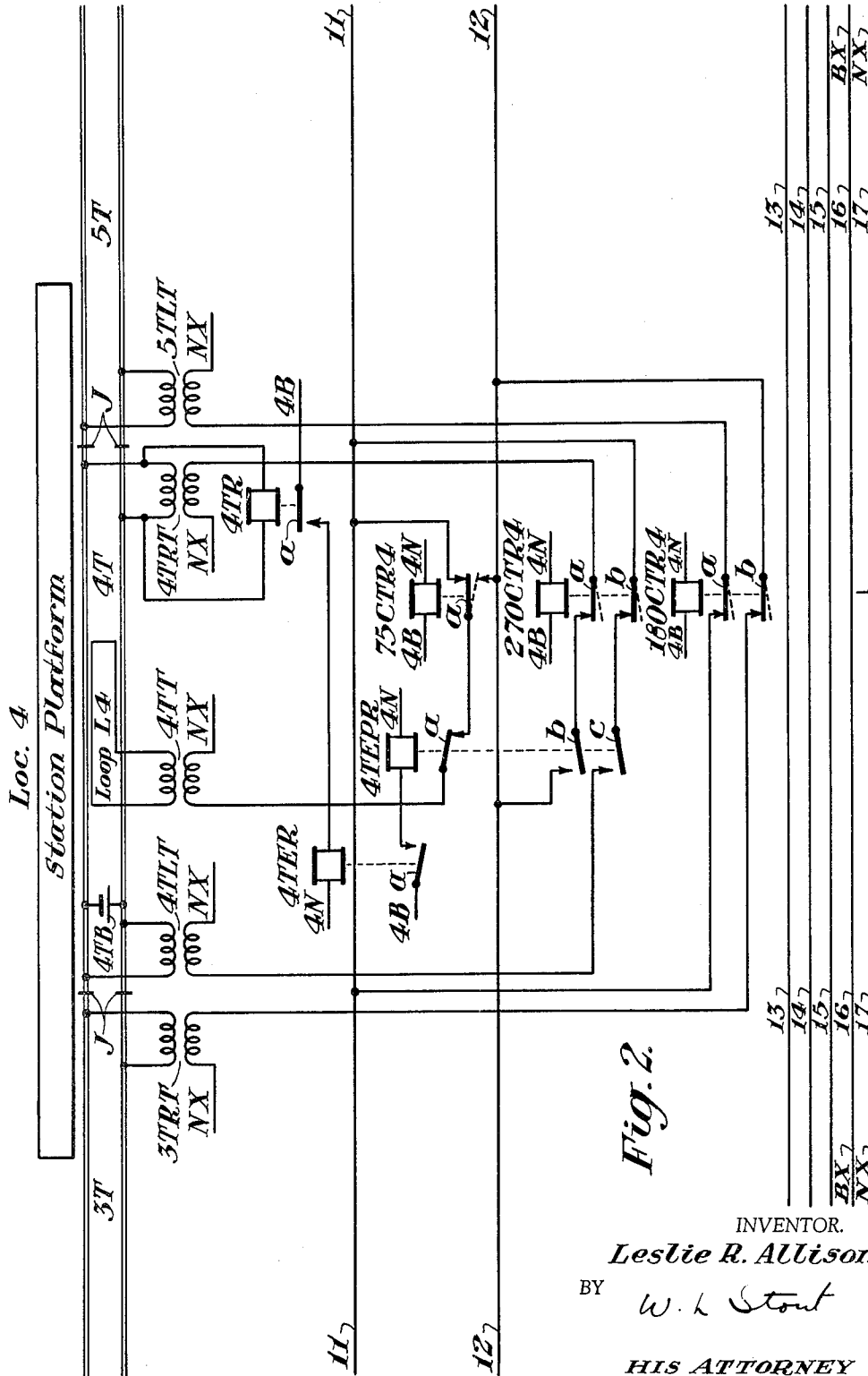
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AUTOMATIC TRAIN OPERATION SYSTEMS

Filed Nov. 8, 1960

7 Sheets-Sheet 2



Jan. 11, 1966

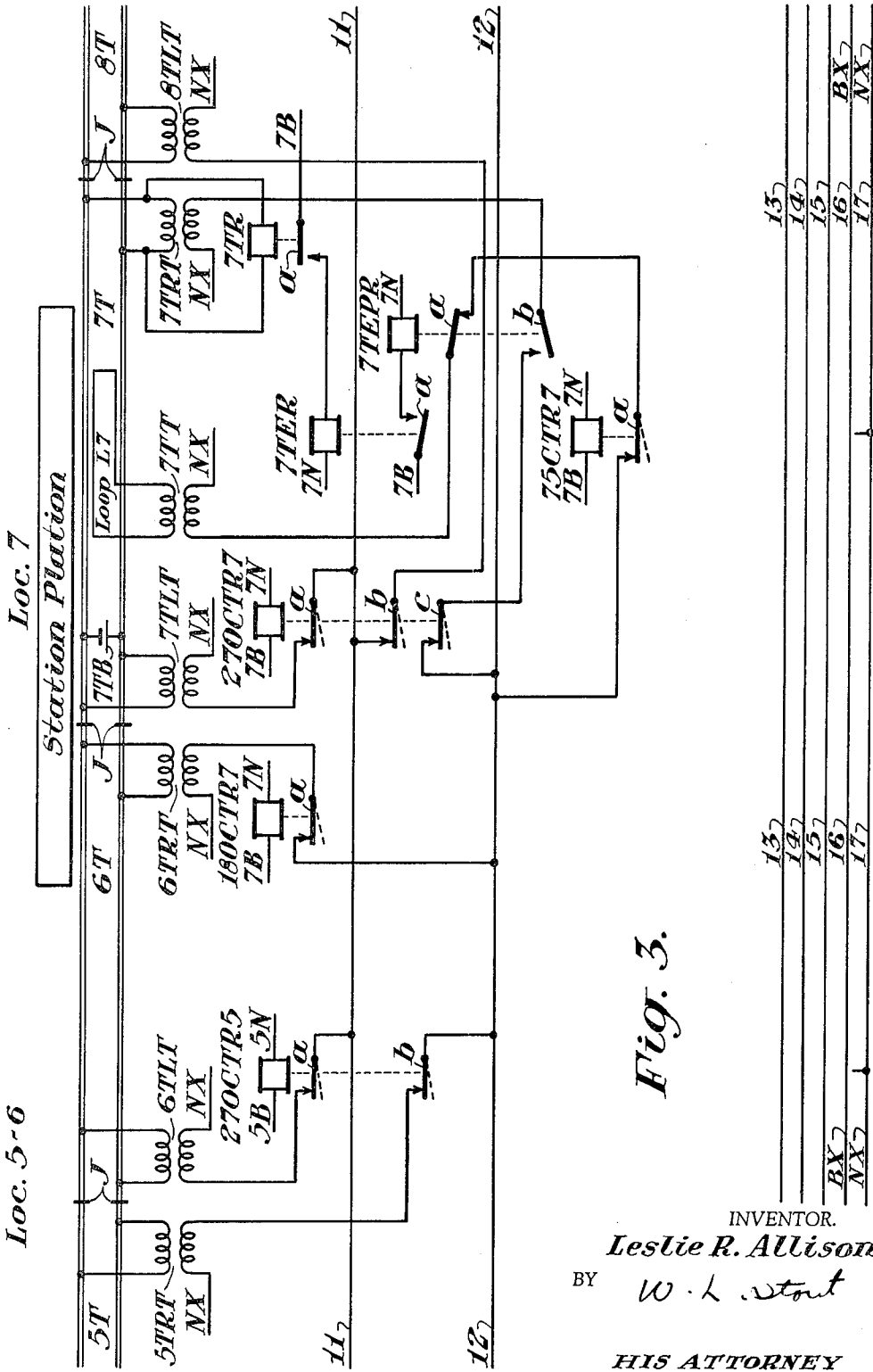
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AUTOMATIC TRAIN OPERATION SYSTEMS

Filed Nov. 8, 1960

7 Sheets-Sheet 3



Jan. 11, 1966

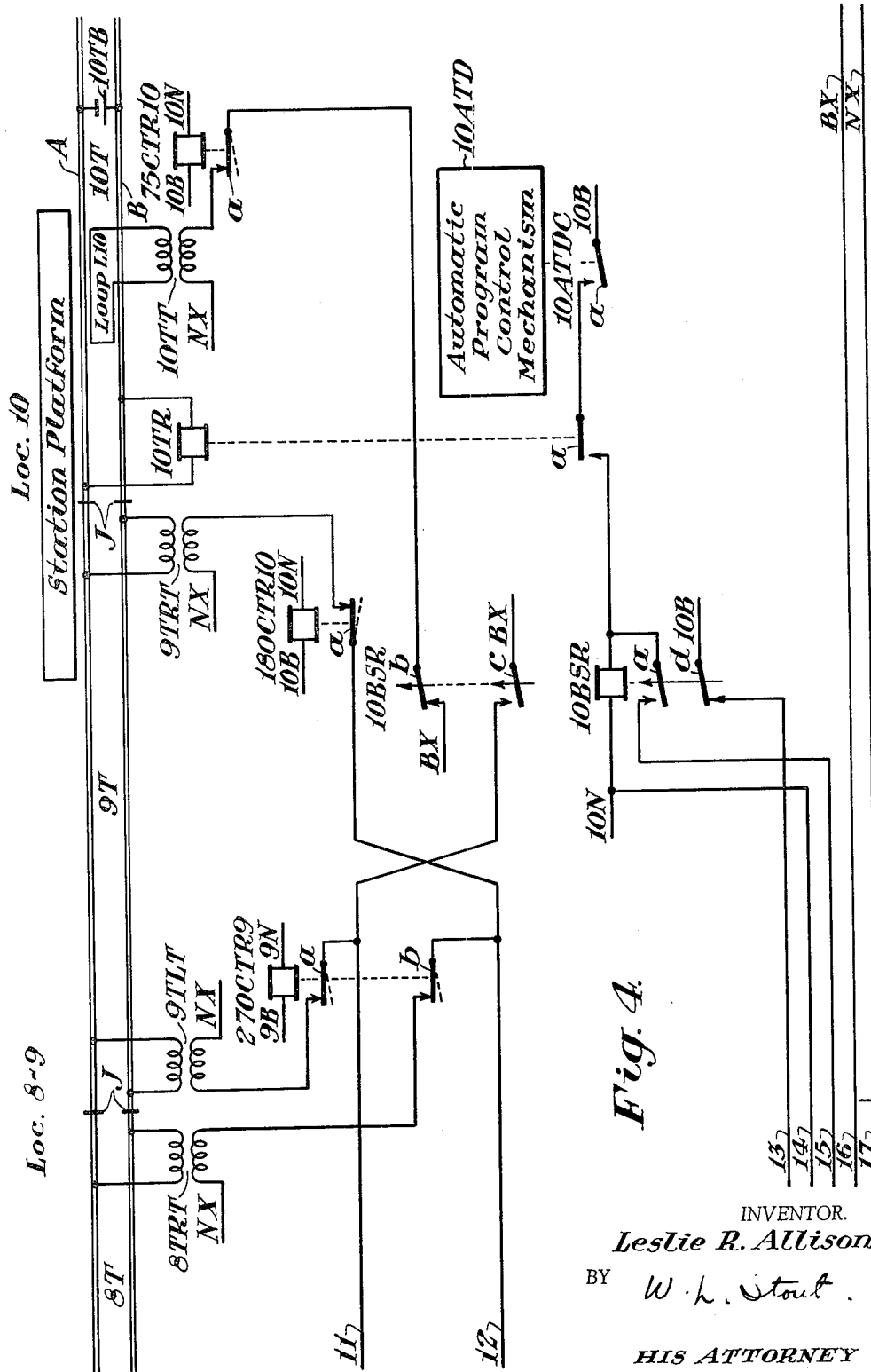
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AUTOMATIC TRAIN OPERATION SYSTEMS

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7 Sheets-Sheet 4



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AUTOMATIC TRAIN OPERATION SYSTEMS

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7 Sheets-Sheet 5

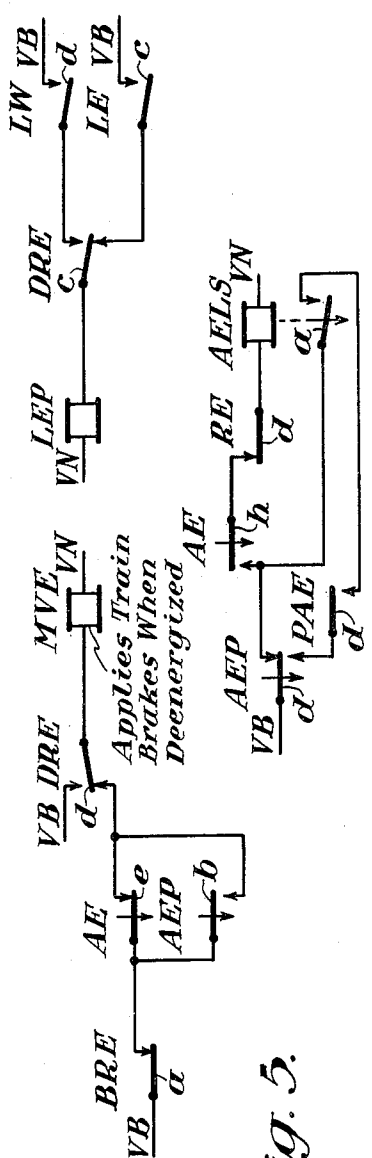
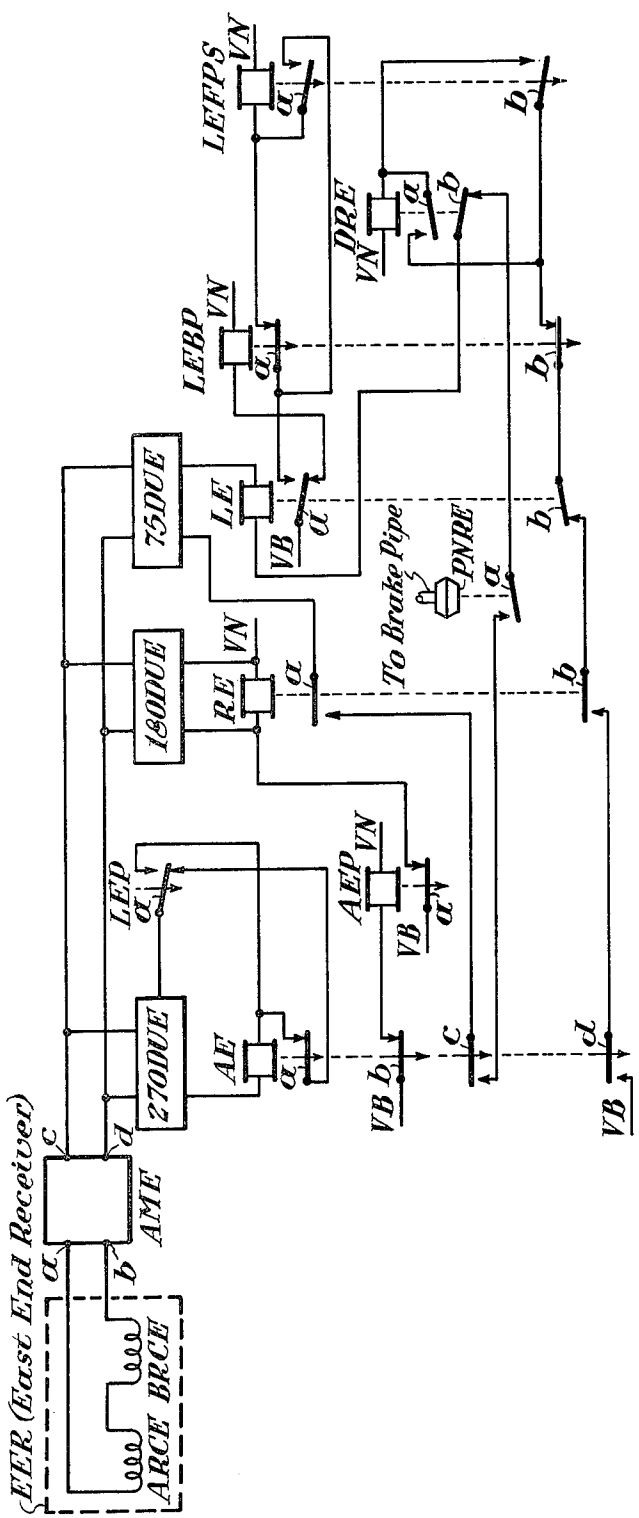


Fig. 5.

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AUTOMATIC TRAIN OPERATION SYSTEMS

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7 Sheets-Sheet 6

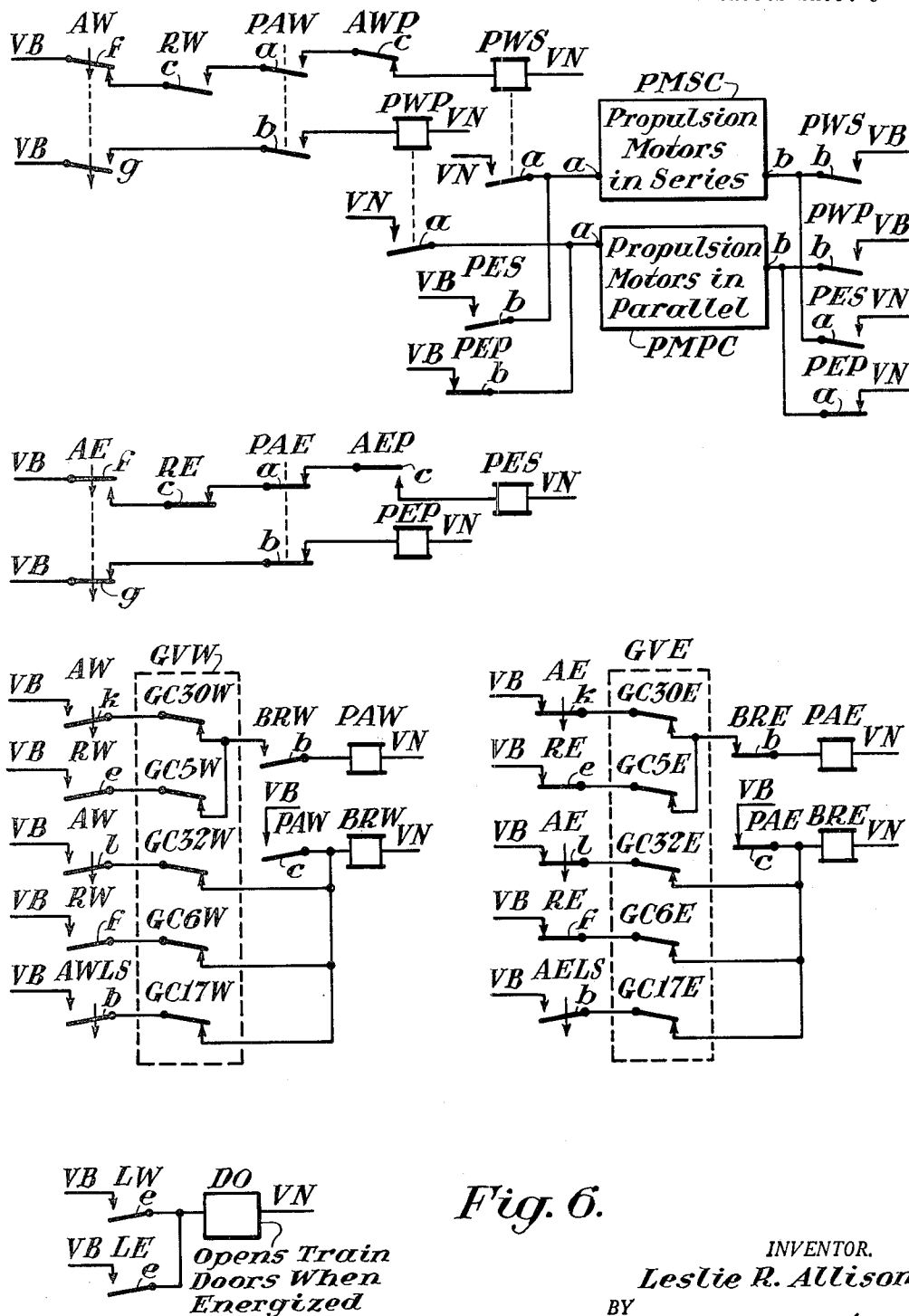


Fig. 6.

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AUTOMATIC TRAIN OPERATION SYSTEMS

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7 Sheets-Sheet 7

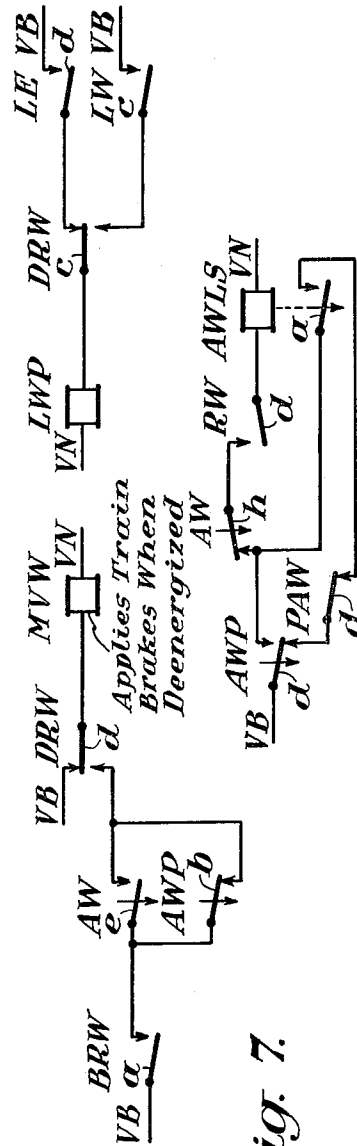
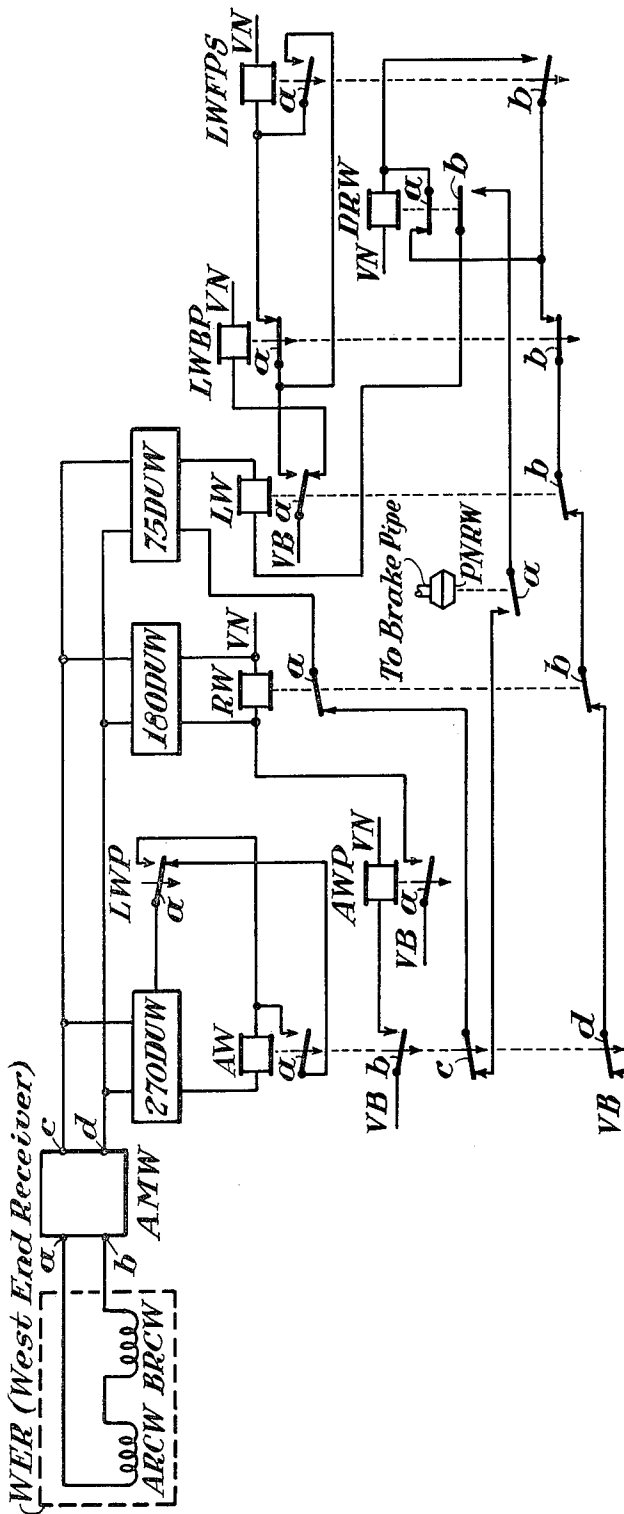


Fig. 7.

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3,229,086

AUTOMATIC TRAIN OPERATION SYSTEMS

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7 Claims. (Cl. 246—187)

My invention relates to a system for operating trains automatically, that is, to a completely automatic train control system.

In the railway signaling art the term "Automatic Train Control System" is generally accepted as meaning a cab-signaling system, that is, a system in which a visual signal is provided in the cab of the engine of a train and is controlled to display, similar to the wayside signals usually provided, preselected aspects indicative of traffic conditions in advance of the train or of the proper speed for the train. The cab-signal is usually actuated by electrical control signals inductively transmitted to the train from the trackway or the rails of the track over which the cab-signal equipped train travels, but may also be actuated by other forms of control signals such as sound or radio signals, etc., transmitted to the train through space.

Such automatic train control systems have heretofore been employed in conjunction with train-carried speed responsive devices or governors to provide what are generally termed, in the railway signaling art, "Automatic Speed Control Systems." In these speed control systems the train-carried cab-signal control apparatus operates in conjunction with the governor to effect an automatic application of the train brakes and, in some systems, an interruption of the propulsion or motive power of the train if the engineman fails to sufficiently reduce the speed of the train within a predetermined period of time following a change from a less restrictive to a more restrictive cab-signal indication, such change indicating lower speed conditions existing in the route for the train.

In accordance with my present invention I provide an automatic train control system including apparatus for completely controlling automatically the starting, the speed, the stopping, and car door opening and closing of a crewless train, or a train having no operator or engineman. In view of the generally accepted interpretation of the term, automatic train control system, as pointed out above, I have chosen to entitle my invention, "Automatic Train Operation Systems," in order to differentiate it from the generally accepted meaning of said term, automatic train control system. However, in this description and in the claims which follow, these terms may at times be employed interchangeably.

Accordingly, the main object of my invention is to provide a system for automatic control of the movements and speed of a train having no operator or engineman.

Another object of my invention is to provide means for automatically controlling the stopping and starting of a crewless train at desired stations spaced along a stretch of railway track over which the train travels.

A third object of my invention is to provide means for automatically controlling acceleration of a crewless train after leaving each station stop.

A fourth object of my invention is to provide means for automatically controlling deceleration of a crewless train when approaching each station stop, so that the train may be stopped within a prescribed area of the station platform.

A still further object of my invention is to provide means for insuring that a crewless train makes a station stop for a predetermined minimum period of time before it is permitted to start in response to its automatic controls.

A sixth object of my invention is to provide means for controlling the movements and speed of a crewless shuttle-train, that is, a train which shuttles back and forth between two spaced stations located at the opposite ends of a railway.

Other objects and characteristic features of my invention will become apparent as the description proceeds.

In practicing my invention I employ, in conjunction with apparatus for at times supplying signals in the form of pulses of energy at various code rates to the rails of the track stretch over which the crewless train is to travel, train-carried apparatus selectively responsive to said energy pulses, and a train-carried governor responsive to the speed of the train; means for automatically starting, stopping, and operating the train within prescribed speed ranges, by controlling the motive power to the propulsion motors of the train and controlling the brakes of the train in response to the operation of said train-carried apparatus and governor.

I shall first describe one form of apparatus embodying my invention and shall then point out the novel features thereof in claims.

In the accompanying drawings, FIGS. 1 through 4 when arranged numerically from left to right comprise a diagrammatic view of a track layout equipped with one form of wayside apparatus with which the train operation system of my invention may be employed.

FIGS. 5, 6 and 7 illustrate diagrammatically the train-carried apparatus of my invention for a train which is to traverse a length of railway track such as that shown in FIGS. 1 through 4.

Referring to FIGS. 1 through 4 of the drawings, there is shown a length of railway track comprising rails A and B extending between an extreme left-hand or west station location designated Loc. 1 and an extreme right-hand or east station location designated Loc. 10. Two additional station locations are shown between Loc. 1 and Loc. 10, with the station nearer Loc. 1 being designated Loc. 4 and that nearer Loc. 10 being designated Loc. 7. Station platforms for the convenience of passengers boarding or leaving trains are as usual provided at the station locations, as shown in the drawings.

Insulated rail joints J, employed in the rails A and B at points within the station platform areas and at points between said areas, divide the length of railway tracks into a succession of electrically insulated track stretches or sections designated from left to right 1T through 10T, respectively. The point between Loc. 1 and Loc. 4 at which the joints are provided is designated Loc. 2-3, the point between Loc. 4 and Loc. 7 is designated Loc. 5-6, and that between Loc. 7 and Loc. 10 is designated Loc. 8-9. The factors involved in the selection of the points at which insulated rail joints are to be provided in the track will be discussed hereinafter.

It is deemed expedient to point out at this time that in FIGS. 1 through 4 a suitable source of current for control of apparatus other than track circuits is provided at each location, each source being preferably a battery of proper voltage and capacity. For the sake of simplicity these sources are not shown in the drawings but the positive and negative terminals of each source are identified by reference characters B and N, respectively, prefixed by numerical characters associated with each source location designation. In FIGS. 5, 6 and 7 the positive and negative terminals of the train-carried source of current are designated VB and VN, respectively. This will be readily apparent from an examination of the drawings.

The winding of each of the relays employed in my invention is shown in the drawings by a rectangle in the conventional manner, and the contacts controlled by the neutral type relays employed are in most instances dis-

3

posed below or above the rectangle representing the relay winding and are indicated as controlled thereby by a dotted line extending from each respective winding to the associated contacts. Where contacts of relays are not so disposed, the relay by which each contact is controlled is identified by the reference character for the relay being placed on the drawings above each such contact or groups of contacts. Several of the neutral relays may be slow-acting, that is, slow to release, slow to pick up, or both. The contacts of such relays are indicated by an arrow drawn through the movable position of each contact with the head or heads of the arrow pointing in the direction in which the relay, and therefore the contact, is slow-acting. Neutral type relays are a conventional type and are well known in the railway signaling art.

A plurality of code transmitter relays are employed in FIGS. 1 through 4 and are designated in the drawings as CTR followed by a numerical character suffix associated with the location of the respective relay, and having a prefix designating the code rate of the relay. For example, the 75 code rate code transmitter relay at Loc. 1 is designated 75CTR1. Similarly, the 270 code rate code transmitter relay at Loc. 2-3 is designated 270CTR2. Such code transmitter relays are also well known in the railway signaling art and the code rate of such a relay refers to the number of closures per minute of the front or back contacts of the relay when the winding of the relay is energized. As shown in the drawings, the windings of the code transmitter relays are continuously energized by connecting the positive and negative terminals of the battery at the respective location to the relay windings and, therefore, the contacts of each relay are continuously operating at the respective code rate of the relay. The contacts of such relays are, therefore, illustrated by showing solid lines for the movable portion of the contacts closed against the front contact points, thereby indicating that the windings of the relays are continuously energized; and by showing dotted lines for the movable portions of the contacts in the open condition of the front contacts, thereby indicating that, although the relays are continuously energized, the contacts are intermittently operating at their respective code rates. This is believed apparent from an examination of the drawings.

Track stretches 1T, 4T, 7T and 10T are each shown provided with a conventional type track circuit including a track relay and track battery both connected across the rails of their respective stretch so that the relay is energized, in the manner well known in the art, when its respective track stretch is unoccupied by the wheels of a train. The track relays and track batteries are designated TR and TB, respectively, preceded by a prefix designating their respective track stretches. For example, the track relay and track battery for track stretch 1T are designated 1TR and 1TB, respectively.

A plurality of seven conductors are shown extending between Loc. 1 and Loc. 10 and thus past all the intermediate locations. These conductors are designated 11 through 17, and conductors 16 and 17 are employed for conducting an alternating current from terminals BX and NX, respectively, of an alternating current source not shown in the drawings. The source of the alternating current may in actual practice be at any one of the locations or at some location not shown, the only requirement for the apparatus arrangement shown in the drawings, FIGS. 1 through 4, being that current from terminals BX and NX of the same alternating current source is available at each location shown. Actually only connections to conductor 17, which is connected to terminal NX of the alternating current source, need be provided at each of the locations in FIGS. 1 through 4 except Loc. 1 and Loc. 10. This will become apparent as the description proceeds.

When a train, provided with the automatic train operation apparatus of my invention, as hereinafter described, moves in a direction from east to west or right to left in the track layout shown in FIGS. 1 through 4, energy from terminal BX of the alternating current source is supplied

4

in a manner hereinafter described, from Loc. 10 to each of the other locations over the conductor 11 extending between Loc. 1 and Loc. 10. Similarly, when such a train moves in a direction from west to east or left to right in the track layout, energy from terminal BX of the alternating current source is supplied in a manner hereinafter described, from Loc. 1 to each of the other locations over the conductor 12 extending between Loc. 1 and Loc. 10. This will become more apparent hereinafter.

Conductors 13, 14 and 15, extending between Loc. 1 and Loc. 10 are employed for controlling a very basic form of traffic circuit for controlling the direction of movements of trains between said locations, conductor 14 being connected to the negative terminals 1N and 10N of the sources of control current at Loc. 1 and Loc. 10 respectively, thereby providing a common return conductor for energy from said sources. This traffic circuit will be described in detail later.

An automatic programming device or program control mechanism is shown in block diagram form at Loc. 1 and Loc. 10. These mechanisms as employed in my invention are sometimes termed automatic train dispatchers and at Loc. 1 and Loc. 10 are designated 1ATD and 10ATD, respectively. Such program mechanisms are well known in the art and for the purposes of this description they may be assumed to be, but do not necessarily need to be, similar to that shown and described in Letters Patent of the United States No. 2,318,048, issued May 4, 1943, to W. N. Bodkin for Automatic Program Control Mechanism.

There is disposed below each of the block diagrams representing the mechanisms 1ATD and 10ATD a normally open contact *a* of circuit controllers designated 1ATDC and 10ATDC, respectively. Each of these controllers is operated to close its respective contact *a* for a preselected period of time and at set time intervals by the photoelectric relay described in the Bodkin patent. For a detailed description of the mechanisms reference should be made to said patent, but it is believed that a brief discussion of the timing cycles of the mechanisms 1ATD and 10ATD as employed in conjunction with my invention will be helpful in an understanding of this description.

A train equipped with the apparatus of my invention is intended to make trips back and forth or "shuttle" between Loc. 1 and Loc. 10 over the track layout shown in FIGS. 1 through 4. After having stopped a predetermined period of time at one of said locations and the train doors have opened and closed, the train is then to reverse its previous direction of movement and travel to the other location, continuing such movements in accordance with the timing cycles of the automatic train dispatchers. Therefore, in actual practice, clocks in the dispatcher mechanisms are synchronized with each other, and the program tapes controlling the actuation of the controllers 1ATDC and 10ATDC must be so arranged that the contacts of the controllers are not operated to closed positions except following time intervals of sufficient length to insure that the train has arrived at the respective location of the actuated controller. Thus, the length of time required for the train to travel between Loc. 1 and Loc. 10, including allowances for intermediate station stops as hereinafter described, must be considered in selecting the minimum timing cycles of the program tapes of the dispatcher mechanisms. These requirements will become more apparent as the description proceeds.

Referring further to FIGS. 1 through 4, it may be seen that trackway loops, designated loops L1, L4, L7 and L10, are provided in track stretches 1T, 4T, 7T and 10T, respectively. Each of these loops comprises conductors located in the trackway of the respective track stretch parallel to the track rails so as to be in inductive relationship with train-carried coils or receivers to be hereinafter described. The arrangement of such loop

5

conductors is well known in the art and the ends of the conductors forming loops L1, L4, L7 and L10 are connected across the terminals of the secondary windings of transformers designated 1TT, 4TT, 7TT and 10TT, respectively. Control signals in the form of code pulses of current from the previously mentioned alternating current source are, as hereinafter set forth, at times supplied to the primary winding of each said transformer at the 75 code rate. The purpose of the arrangement will appear hereinafter.

The terminals of the secondary winding of each of a plurality of additional transformers are connected with the opposite rails at each end of each of the track stretches 2T through 9T. Each of these transformers is designated by the reference character for the respective track stretch followed by a suffix LT or RT indicating the left-hand or right-hand end, respectively, of the track stretch. For example, the transformer having its secondary winding connected across the rails at the left-hand end of track stretch 2T is designated 2TLT, and the transformer having its secondary winding connected across the rails at the right-hand end of track stretch 2T is designated 2TRT. The reference characters designating the transformers for the remainder of said track stretches is readily apparent from these examples. Control signals in the form of code pulses of current from said alternating current source are, as hereinafter set forth, supplied to the primary windings of each of said plurality of transformers at prescribed times and at predetermined code rates.

It is believed it will be expedient to describe at this time the operation of the apparatus shown in FIGS. 1 through 4 in supplying control signals in the form of train control current to the rails of the track layout and the aforesaid trackway loops. However, it should first be pointed out that a train intended to travel the track layout and equipped with the apparatus of my invention will be provided with two control signal or train control energy receivers, one located at each end of the train and each comprising, in the manner well known in the art, two magnetizable cores, each core of a receiver being carried in inductive relation with a different one of the track rails or said loop conductors. Each core is provided with a winding and the windings of the cores of each receiver are connected in series in such manner that the voltages induced therein by coded alternating train controlling current flowing in the opposite directions in the two track rails in advance of the train are additive. It is apparent that, since the train control current will be shunted by the wheels and axles of the train, each receiver will be responsive only to energy supplied to the track rails from a source located in advance of the train. Therefore the receivers must be located in advance of the forward axle of the train, that is, each receiver must be located in advance of the axle which is the forward axle for the respective direction of travel of the train for that receiver. By providing a receiver on each end of the train it is, therefore, possible to operate the train with either end as the "head-end."

For the purpose of the description of the apparatus of FIGS. 1 through 4, a train traveling the track layout shown will, at this time, be assumed to respond as described to the receipt of control signals in the form of cab-signal or coded train control current. It is believed that the operation of the wayside apparatus can be best described in this manner, and the train-carried apparatus for controlling such response and the operation of such apparatus will be described in detail hereinafter.

The wayside apparatus is shown in the drawings in the condition it occupies when the traffic circuit has been conditioned for a train movement from left to right through the track layout and the train has departed from Loc. 1. It will, therefore, be further assumed that the train is in track stretch 2T and is moving towards Loc. 10.

6

At this time a stick relay 1BSR, to be hereinafter described (FIG. 1), is maintained picked up by a stick circuit which extends from terminal 10B of the battery at Loc. 10 (FIG. 4) over back contact *d* of relay 10BSR, conductor 13 to Loc. 1, front contact *c* of relay 1BSR (FIG. 1), the winding of relay 1BSR, and conductor 14, to terminal 10N of the battery at Loc. 10. The purpose of the slow pickup feature of relay 1BSR will become apparent later. (It should also be noted that the similar stick relay 10BSR at Loc. 10 is in its released position.) A circuit for supplying alternating current to conductor 12 at this time extends from terminal BX of the alternating current source over front contact *c* of relay 1BSR (FIG. 1). As described below, alternating current at one or the other of two code rates is being supplied to the primary windings of transformers 2TRT, 3TRT, 5TRT, 6TRT, 8TRT and 9TRT at this time.

The circuit for supplying alternating current to the primary winding of transformer 2TRT extends, as shown in FIG. 1, from conductor 12 over front contact *b* of code transmitter relay 270CTR2 and through said winding to terminal NX of the alternating current source. It is thus apparent that alternating current at the 270 code rate is being induced in the secondary winding of transformer 2TRT and is being supplied therefrom to the rails of track stretch 2T at the right-hand end thereof.

A similar circuit for supplying alternating current to the primary winding of transformer 3TRT extends (FIG. 2) from conductor 12 over front contact *b* of code transmitter relay 180CTR4 and through said winding to terminal NX of the alternating current source. Thus alternating current at the 180 code rate is being induced in the secondary winding of transformer 3TRT and is being supplied therefrom to the rails of track stretch 3T at the right-hand end thereof.

Similar circuits operate at this time to supply to the rails at the right-hand ends of track stretches 5T and 8T, pulses of alternating current at the 270 code rate; and to the rails at the right-hand ends of track stretches 6T and 9T, pulses of alternating current at the 180 code rate. No detailed description of these circuits is believed necessary at this time in view of the similarity of the circuits to those just traced for track stretches 2T and 3T.

The pulses of alternating current at the 270 code rate are employed for controlling the speed of the train to a high speed range and the pulses of alternating current at the 180 code rate are employed for controlling the speed of the train to a low speed range. Thus the 270 code pulses are supplied to the train when leaving a station and traveling between stations to a point within a predetermined minimum distance from a station platform at which a stop is to be made. At that point the code rate is changed to 180 code and the speed of the train is to be reduced to the low speed range so that it can make the required stop at the station. Thus, the points at which the insulated rail joints are to be provided at Loc. 2-3, Loc. 5-6 and Loc. 8-9 depend on authorized speed in said high speed range, the minimum deceleration of the train when its propulsion or motive power is interrupted, and the retardation effect on the train of the application of the train brakes. It is apparent that these last two factors depend on various parameters pertaining to the train and the track, such as the weight of the train, the grade and curvature in the respective track stretches, the type of brakes employed, etc. In other words, the point at which Loc. 2-3 is located must be such that the train can be smoothly controlled from its authorized high speed to a stopped condition at the station platform at Loc. 4 during an eastward movement of the train and, similarly, such that the train can be smoothly controlled from its authorized high speed to a stopped condition at the station platform at Loc. 1 during a westward movement of the train. Thus, in actual practice, an additional track stretch or stretches not shown may be provided

7

between Loc. 1 and Loc. 4 in order that the train may proceed at its authorized high speed for the greatest possible distance before the train control current supplied to the train is changed to the 180 code rate when the train is approaching a station. This discussion applies equally well to the number of track stretches to be provided between Loc. 4 and Loc. 7. However, in the arrangement shown in FIGS. 1 through 4, the train is to make a station stop at Loc. 7 only when it is making an eastward train movement, and, therefore, the location of the insulated rail joints at Loc. 8-9 depends only on the distance required for the train to smoothly reduce its speed so as to make the required station stop at Loc. 10.

As the train proceeds through track stretch 2T the receiver on the right-hand end of the train is receiving coded pulses of current at the 270 code rate and the train is therefore controlled to proceed at the speed of its high speed range. When the train enters track stretch 3T the coded current supplied to said receiver is changed to the 180 code rate and the speed of the train is reduced to the low speed range so that it may be brought to a smooth stop at the station at Loc. 4.

When the right-hand end of the train first enters track stretch 4T, the right-hand end receiver receives no code and a brake application results causing the train to come to a stop with said receiver over the portion of the trackway provided with the conductors forming the loop L4 connected to the secondary winding of transformer 4TT, and the receiver is then supplied with code pulses at the 75 code rate. When the train has completely stopped, the receipt of the 75 code by the receiver operates to open the doors of the train. The circuit for supplying 75 code to the primary winding of transformer 4TT extends from conductor 12 over the back point of contact *a* of code transmitter 75CTR4, back contact *a* of a relay 4TEPR, to be described, and through said primary winding to terminal NX of the alternating current source. Thus code pulses at the 75 code rate are induced in the secondary winding of transformer 4TT.

There is shown in FIG. 2 a time element relay 4TER and the aforementioned relay 4TEPR which repeats the operation of the time element relay. Such time element relays are well known in the railway signaling art and it is sufficient for purposes of this description to point out that such relays are arranged to close a front contact, such as front contact *a* of relay 4TER, a predetermined period of time following the energization of the control winding of the relay. The circuit for energizing the control winding of relay 4TER extends from battery terminal 4B over back contact *a* of track relay 4TR and through the winding of relay 4TER to battery terminal 4N. Thus, the control winding of relay 4TER is energized when the train enters track stretch 4T.

When relay 4TER closes its front contact *a*, following the time delay period of the relay, a pickup circuit for relay 4TEPR is closed. This circuit extends from battery terminal 4B over front contact *a* of relay 4TER and through the winding of relay 4TEPR to battery terminal 4N. Relay 4TEPR thus becomes picked up and opens its back contact *a* and closes its front contact *b*. The opening of back contact *a* of relay 4TEPR opens the previously described circuit to the primary winding of transformer 4TT and the 75 code pulses are no longer supplied to the train receiver from the track loop L4. The closing of front contact *b* of relay 4TEPR supplies pulses of alternating current at the 270 code rate to the primary winding of transformer 4TTRT. This circuit extends from conductor 12 over front contact *b* of relay 4TEPR, front contact *a* of code transmitter 270CTR4, and through the primary winding of transformer 4TTRT to terminal NX of the alternating current source. Pulses of energy at the 270 code rate are thus induced in the secondary winding of transformer 4TTRT and are supplied to the rails of track stretch 4T at the right-hand end thereof. The removal of the pulses of train control current at the 75

8

code rate from the train loop operates to close the doors of the train and, following their closing, the 270 code rate pulses supplied to the rails of track section 4T operate to start the train and control its speed to the high speed range.

It is to be noted that the insulated rail joints defining the westward limits of track stretch 4T must be so located that the train is stopped, by an automatic brake application, with its right-hand end receiver over track loop L4, when the receipt of train control current is temporarily interrupted upon the entrance of the train into track stretch 4T in its eastward train movement. Similarly, the insulated rail joints defining the eastward limits of track stretch 4T must be so located that the train is similarly stopped during a westward train movement to be herein-after discussed.

When the train enters track stretch 5T its right-hand end receiver continues to receive train control current at the 270 code rate and the train continues to accelerate to its high speed range if it has not already attained that speed. This train control current is supplied to the rails of track stretch 5T from the secondary winding of transformer 5TTRT, the primary winding of that transformer being energized by a circuit extending from conductor 12 over front contact *b* of code transmitter 270CTR5 and through said primary winding to terminal NX of the alternating current source.

When the train enters track stretch 6T its right-hand end receiver receives code pulses at the 180 code rate, in a manner similar to when it entered track section 3T, and the speed of the train is again controlled to its low speed range.

At Loc. 7, a time element relay 7TER, a repeater relay 7TEPR, track relay 7TR, and the code transmitter relays 75CTR7 and 270CTR7 operate in a manner similar to that described for Loc. 4. Thus, when the train enters track stretch 7T the train is controlled to stop and, following the opening and closing of its doors during a predetermined time delay, is again controlled to start and to accelerate to the speed of its high speed range. The operation of the apparatus at Loc. 7 at this time is identical to that described for the corresponding apparatus at Loc. 4 and, therefore, no detailed tracing of the control circuits is believed necessary.

When the train enters track section 8T the train continues to receive train control energy at the 270 code rate, this energy being supplied to the rails of track stretch 8T from transformer 8TTRT at the right-hand end thereof, the primary winding of transformer 8TTRT being energized at this time by a circuit extending from conductor 12, over front contact *b* of code transmitter 270CTR9 at Loc. 8-9 and through said primary winding to terminal NX of the alternating current source.

When the train enters track stretch 9T its right-hand end receiver receives pulses of train control energy at the 180 code rate supplied to the rails of the stretch from the secondary winding of transformer 9TTRT. The primary winding of 9TTRT is energized at this time by a circuit extending from conductor 12 over front contact *a* of code transmitter 180CTR10 and through the primary winding of transformer 9TTRT to terminal NX of the alternating current source.

Loop L10 at Loc. 10 must be so located within track stretch 10T that the receiver on the right-hand end of the train will be over the loop when the train has come to a stop at Loc. 10. Also it is required that the left-hand end of the train remains in track stretch 9T at this time so that the left-hand end receiver can receive train control energy from the rails of track stretch 9T, as hereinafter described. These requirements dictate the location of the insulated rail joints defining the westward end of track stretch 10T.

When the train enters track stretch 10T in its eastward movement the code pulses of train control energy at the 180 code rate are cut off, an automatic brake application

results and the train comes to a stop with its left-hand end receiver over the rails of track section 9T and its right-hand end receiver over the conductors of trackway loop L10. Train control energy at the 75 code rate is supplied to loop L10 from the secondary winding of transformer 10TT. The circuit for energizing the primary winding of transformer 10TT at this time extends from terminal BX of the alternating current source over back contact *b* of relay 10BSR, front contact *a* of code transmitter 75CTR10, and through said primary winding to terminal NX of the alternating current source. As hereinafter discussed the doors of the train are thus controlled to open.

The entrance of the front wheels and axles of the train into track stretch 10T releases track relay 10TR. The closing of back contact *a* of relay 10TR prepares at back contact *a* of that relay a pickup circuit for stick relay 10BSR. When the automatic train dispatcher 10ATDR indicates, by actuating its controller 10ATDC, that the train schedule on the tape in the dispatcher mechanism calls for the train to return to Loc. 1 the pickup circuit for relay 10BSR is completed. This circuit may be traced from battery terminal 10B over contact *a* of said controller 10ATDC in its actuated position, back contact *a* of track relay 10TR, and through the winding of relay 10BSR to battery terminal 10N. Relay 10BSR thus becomes energized, opening its back contacts *b* and *d* and closing its front contacts *a* and *c*. The opening of back contact *b* of relay 10BSR interrupts the previously described circuit to the primary winding of transformer 10TT, and the train control energy at the 75 code rate is no longer supplied to the right-hand end receiver of the train and the doors of the train are, therefore, controlled to close. The opening of back contact *d* of relay 10BSR interrupts the stick circuit for relay 1BSR at Loc. 1 (FIG. 1) and relay 1BSR releases. The release of relay 1BSR opens at its front contact *c* the circuit for supplying alternating current to conductor 12. The closing of back contact *d* of relay 1BSR completes a stick circuit for relay 10BSR. This circuit extends from terminal 1B of the battery at Loc. 1, back contact *d* of relay 1BSR, conductor 15, front contact *a* of relay 10BSR, and through the winding of relay 10BSR and over conductor 14 to terminal 1N of the battery at Loc. 1. Relay 10BSR is thus maintained in its picked up position. The closing of front contact *c* of relay 10BSR supplies alternating current from terminal BX of the source to conductor 11 extending between Loc. 1 and Loc. 10. The slow pickup feature of relay 10BSR (and also 1BSR at Loc. 1) insures that the train will have sufficient time for its doors to open, before making its return journey, in the event the controller contact of the automatic program control mechanism has been actuated to its closed position prematurely due to faulty timing or some other similar fault in the program mechanism.

Train control energy is supplied to the rails of track stretch 9T at this time from the secondary winding of transformer 9TTLT, the receiver on the left-hand end of the train receives the energy and, following the closing of the train doors, the train starts and accelerates to its high speed range. The circuit for supplying current to the primary winding of transformer 9TTLT extends from conductor 11 over front contact *a* of code transmitter 270CTR9 and through said primary winding to terminal NX of the alternating current source. No train control energy is now being supplied to the right-hand ends of the track stretches since, as pointed out, the circuit for supplying alternating current to conductor 12 is open at front contact *c* of relay 1BSR (FIG. 1).

When the train enters track stretch 8T, the receiver on the left-hand end of the train will receive from the rails of track stretch 8T pulses of train control current at the 270 code rate since the train is not to make a station stop at Loc. 7 in its westward move. These pulses of energy are supplied to the rails at the left-hand end of

track stretch 8T from the secondary winding of transformer 8TTLT. The primary winding of that transformer is energized at this time by a circuit extending from conductor 11 over front contact *b* of code transmitter 270CTR7 and through said primary winding to terminal NX of the alternating current source.

When the train enters track stretch 7T relay 7TR will release and the time element relay 7TER will be energized. However, no energy is supplied to the primary winding of transformer 7TT for loop L7 since conductor 12 is deenergized and no circuit is provided for so supplying energy from conductor 11. Thus the energization of time element relay 7TER at this time is immaterial.

Train control energy at the 270 code rate is supplied to the rails of track stretch 7T from the secondary winding of transformer 7TTLT and thence to the left-hand end receiver of the train. The primary winding of transformer 7TTLT is energized by a circuit extending from conductor 11 over front contact *a* of code transmitter 270CTR7 and through said primary winding to terminal NX of the alternating current source.

The primary winding of transformer 6TTLT is energized by a circuit extending from conductor 11 over front contact *a* of code transmitter 270CTR5 and through said primary winding to terminal NX of the alternating current source. The train control current induced in the secondary winding of transformer 6TTLT at the 270 code rate is supplied to the rails of track stretch 6TTLT at the left-hand end thereof and, when the train enters that track stretch, the left-hand end receiver continues to receive train control energy at the 270 code rate.

When the train enters track section 5T, the left-hand end receiver will receive train control energy at the 180 code rate since the train is to make a stop at Loc. 4. These pulses of energy are supplied to the track rails of track stretch 5T, at the left-hand end thereof, from the secondary winding of transformer 5TTLT. The circuit for energizing the primary winding of transformer 5TTLT extends from conductor 11 over front contact *a* of code transmitter 180CTR4 and through said primary winding to terminal NX of the alternating current source. The train will reduce its speed to the low speed range when traversing track stretch 5T and, when it enters track stretch 4T, the train control energy to the left-hand end receiver will be temporarily interrupted, the brakes of the train will be applied and the train will come to a stop with its left-hand end receiver over the length of rails provided with the conductors forming track loop L4.

The entrance of the train into track stretch 4T also releases track relay 4TR and closes at back contact *a* of that relay the previously described energizing circuit for relay 4TER. After the expiration of the time delay period of relay 4TER, that relay will close its front contact *a* and pick up relay 4TEPR over its previously described pickup circuit. The closing of front contact *c* of relay 4TEPR closes an energizing circuit to the primary winding of transformer 4TTLT. This circuit extends from conductor 11, through front contact *b* of code transmitter relay 270CTR4, front contact *c* of relay 4TEPR, and through the primary winding of transformer 4TTLT to terminal NX of the alternating current source. The left-hand end receiver of the train again receives train control energy at the 270 code rate and the train again starts and accelerates to its high speed range.

Train control energy at the 270 code rate is supplied to the rails of track stretch 3T, at the left-hand end thereof, from the secondary winding of transformer 3TTLT and thus to the left-hand end receiver of the train when the train enters track stretch 3T. The primary winding of transformer 3TTLT is energized at this time by a circuit extending from conductor 11 over front contact *a* of code transmitter 270CTR2 and through said primary winding to terminal NX of the alternating current source.

When the train enters track stretch 2T, the left-hand end receiver again receives train control energy at the

11

180 code rate from the pulses supplied to the rails from the secondary winding of transformer 2TLT. The circuit to the primary winding of transformer 2TLT extends from conductor 11 over front contact *a* of code transmitter 180CTR1 and through said primary winding to terminal NX of the alternating current source. The train is thus controlled to its slow speed range.

When the train enters track stretch 1T the train control energy to the left-hand end receiver is cut off and an automatic brake application causes said receiver to stop over track loop L1. The receiver then receives train control energy at the 75 code rate from said loop, the circuit for energizing the primary winding of transformer 1TT extending from terminal BX of the alternating current source over back contact *b* of relay 1BSR, front contact *a* of code transmitter 75CTR1, and through said primary winding to terminal NX of the alternating current source. The doors of the train are controlled to open and remain so until the train is to return again to Loc. 10.

When automatic train dispatcher 1ATD indicates that the schedule calls for a return trip for the train, controller 1ATDC is actuated and closes a pickup circuit for relay 1BSR. This circuit extends from battery terminal 1B over contact *a* of controller 1ATDC in its actuated position, back contact *a* of track relay 1TR, and through the winding of relay 1BSR to battery terminal N. Relay 1BSR thus becomes picked up closing its front contact *a* and preparing its stick circuit. The opening of back contact *d* of relay 1BSR opens the stick circuit for relay 10BSR at Loc. 10 and that relay releases completing at its back contact *d* the stick circuit for relay 1BSR including conductor 13. The closing of front contact *c* of relay 1BSR again supplies alternating current to conductor 12 from terminal BX of the alternating current source. The opening of back contact *b* of relay 1BSR interrupts the energizing circuit to the primary winding of transformer 1TT, the receiver on the lefthand end of the train no longer receives train control energy at the 75 code rate, and the train doors are controlled to close. When the doors of the train have closed the code pulses at the 270 code rate, received by the receiver on the right-hand end of the train from the rails of track stretch 2T, operate to start the train on its trip towards Loc. 10 and to accelerate the train to its high speed range. The train thus moves through track stretch 2T proceeding towards Loc. 10 in the manner previously described. When the train has vacated track stretch 1T, relay 1TR becomes picked-up and opens at its back contact *a* the pickup circuit for relay 1BSR. However, relay 1BSR is maintained picked-up over its stick circuit previously described.

Having thus described the operation of the wayside apparatus employed in my invention, I will now describe the train-carried apparatus for controlling the response of the train to the control energy supplied to the rails of the track stretch shown in FIGS. 1 through 4.

Referring to FIGS. 5, 6 and 7, FIG. 5 shows the previously mentioned control signal or train control energy receiver mounted on the east or right-hand end of the train and the apparatus associated with that receiver, and FIG. 7 shows the previously mentioned receiver mounted on the west or the left hand end of the train and the apparatus associated with that receiver. FIG. 6 shows apparatus associated with the receivers, and controllers actuated, at different times, by each set of apparatus. This will become more apparent as the description proceeds.

Referring first to FIG. 5, there is shown the east end receiver designated EER and comprising the two pickup coils or inductors ARCE and BRCE which are mounted on the east end of the train, as previously mentioned, so as to be in inductive relationship with rails A and B, respectively, of the track stretch shown in FIGS. 1 through 4. The inductors ARCE and BRCE are connected in series with each other and to the input terminals *a* and *b* of an amplifier AME. Output terminals *c*

12

and *d* of amplifier AME are connected in multiple through decoding units designated 270DUE, 180DUE, and 75DUE to the control windings of decoding relays AE, RE and LE, respectively, through circuits to be hereinafter discussed. FIG. 7 shows a similar arrangement of apparatus associated with the west end receiver designated WER comprising pickup coils or inductors ARCW and BRCW carried in inductive relationship with rails A and B, respectively, and connected to the input terminals *a* and *b* of an amplifier AMW. Output terminals *c* and *d* of amplifier AMW are connected in multiple through decoding units designated 270DUW, 180DUW, and 75DUW to the control windings of decoding relays AW, RW and LW, respectively, through circuits to be described.

The details of the receivers, amplifiers, decoding units, and associated circuitry form no part of my present invention but are well known in the railway signaling art. For example, for the purpose of this description, each of the arrangements of such components shown in FIGS. 5 and 7 may be considered to be similar to that shown and described in FIG. 1 of Letters Patent of the United States No. 2,336,766, issued December 14, 1943, to Leslie R. Allison and Carl Volz for Railway Traffic Controlling Apparatus, except that decoding units 75DUE and 75DUW in my present application are tuned so as to be responsive only to energy supplied thereto at the 75 code rate. The manner of so tuning such units is well known in the art and is taught by the tuned circuits controlling the A and R relays of FIG. 1 of said patent. It is, therefore, considered sufficient for the purpose of this description to point out that decoding units 270DUE, 180DUE, and 75DUE, shown in FIG. 5, operate to produce a current output for energizing relays AE, RE, and LE, respectively, when code pulses at the 270, 180, and 75 code rates, respectively, are induced in the inductors ARCE and BRCE of receiver EER, this apparatus operating in manner similar to that shown and described in said patent. Similarly, decoding units 270DUW, 180DUW, and 75DUW, shown in FIG. 7, operate to produce a current output for energizing relays AW, RW, and LW, respectively, when code pulses at the 270, 180, and 75 code rates, respectively, are induced in the inductors ARCW and BRCW of receiver WER. The circuits for supplying said current outputs to the control windings of the respective relays will now be described.

Referring to FIG. 5, the output from decoding unit 270DUE is supplied to the control winding of relay AE over a circuit including the front point of contact *a* of a slow release relay LEP, to be described; and once relay AE is energized it is maintained energized, so long as the current output from unit 270DUE continues, over a stick circuit including the back point of contact *a* of relay LEP and front contact *a* of relay AE. Thus relay AE is energized when receiver EER receives code pulses at the 270 code rate and relay LEP is energized, and once so energized is maintained energized until receipt of the code pulses at the 270 code rate is terminated.

The output from decoding unit 180DUE is supplied directly to the control winding of relay RE and, therefore, relay RE is energized whenever receiver EER receives coded pulses at the 180 code rate. Relay RE is also provided with a pickup circuit extending from terminal VB of the train-carried battery over front contact *a* of a relay AEP, to be described, and the winding of relay RE to terminal VN of the vehicle-carried battery. Thus relay RE is also energized whenever relay AEP is energized, and relay AEP being a front contact repeater of relay AE, as discussed below, relay RE is energized whenever relay AE is energized. As stated, relay AEP is a front contact repeater of relay AE and has a pickup circuit extending from battery terminal VB, through front contact *b* of relay AE, and the winding

of relay AEP to battery terminal VN. The purpose of relay AEP will be pointed out hereinafter.

The output from decoding unit 75DUE is supplied to the control winding of relay LE through a circuit including a back contact *a* of relay RE, back contact *c* of relay AE, front contact *a* of a pneumatically operated relay PNRE, to be described, and back contact *b* of a relay DRE, to be described. Thus relay LE is energized whenever receiver EER receives code pulses at the 75 code rate and it has been checked that relays AE, RE and DRE are released and that contact *a* of relay PNRE is closed. The purpose of relay PNRE will be discussed hereinafter.

There is associated with relay LE a slow release back contact repeater relay LEBP and a slow release front contact repeater stick relay LEFPS. Relay LEBP has a pickup circuit extending from battery terminal VB, through the back point of contact *a* of relay LE, and the winding of relay LEBP to battery terminal VN. Thus relay LEBP is energized whenever relay LE is released and remains picked up, due to its slow release feature, for a brief period following the picking up of relay LE. Relay LEFPS has a pickup circuit extending from battery terminal VB, through the front point of contact *a* of relay LE, front contact *a* of relay LEBP, and the winding of relay LEFPS to battery terminal VN. Relay LEFPS has a stick circuit extending from battery terminal VB, through the front point of contact *a* of relay LE, front contact *a* of relay LEFPS, and the winding of relay LEFPS to battery terminal VN. Relay LEFPS is thus picked up when relay LE is picked up following a period of deenergization of relay LE and, once so picked up, remains picked up for a brief period following the release of relay LE, that is, for its own slow release period.

The previously mentioned relay DRE is a relay employed to indicate direction, as will be apparent hereinafter. Relay DRE has a pickup circuit extending from battery terminal VB, through back contact *d* of relay AE, back contact *b* of relay RE, back contact *b* of relay LE, front contact *b* of relay LEBP, front contact *b* of relay LEFPS, and the winding of relay DRE to battery terminal VN. Relay DRE has a stick circuit including its own front contact *a* in shunt around said contact *b* of relay LEFPS. Relay DRE is thus picked up whenever relays AE and RE are released and following the period of the deenergization, the energization, and again the deenergization of relay LE. This operation and its purpose will become apparent hereinafter. Once relay DRE is picked up as described, it will remain picked up so long as relays AE, RE, and LE remain released.

The above-mentioned pneumatically controlled relay PNRE shown in FIG. 5 is connected by the conduit shown at the top of the geometric figure representing the relay, to the brake pipe as indicated. The relay is so constructed that its contact *a* is open whenever the train brakes are in their released position and is closed whenever the brakes are fully applied, that is, whenever the air supplied to the train brakes for their release is exhausted from the brakes to cause an application thereof. Such relays and their operation are well known in the art.

There is also shown in FIG. 5 the previously mentioned relay LEP and a stick relay designated AELS. Relay LEP has a first pickup circuit extending from battery terminal VB, through front contact *c* of relay LE, the back point of contact *c* of relay DRE, and the winding of relay LEP to battery terminal VN. Relay LEP has a second pickup circuit extending from battery terminal VB, through front contact *d* of relay LW, to be described, the front point of contact *c* of relay DRE, and through the winding of relay LEP to battery terminal VN. Relay LEP is thus energized whenever relay LE is picked up and directional relay DRE is released, or whenever relay LW is energized, as hereinafter discussed, and relay DRE is picked up.

Stick relay AELS is provided with a pickup circuit extending from battery terminal VB, through the front point of contact *d* of relay AEP, back contact *h* of relay AE, front contact *d* of relay RE, and through the winding of relay AELS to battery terminal VN. The stick circuit for relay AELS extends from battery terminal VB, through the back point of contact *d* of relay AEP, back contact *d* of a relay PAE, to be discussed, front contact *a* of relay AELS, back contact *h* of relay AE, front contact *d* of relay RE, and the winding of relay AELS to battery terminal VN. Relay AELS is thus picked up in the interval between the release of relay AE and the release of its slow release repeater relay AEP, and once so picked up is maintained picked up after the release of relay AEP so long as relays PAE and AE remain released and relay RE remains picked up. The purpose of relay AELS will be set forth in detail later.

There is also shown in FIG. 5 a magnet valve designated MVE which controls the release and application of the train brakes. That is, magnet valve MVE releases the train brakes when energized and applies the brakes when deenergized. Magnet valve MVE has a first energizing circuit extending from battery terminal VB, through the front point of contact *d* of directional relay DRE, and the winding of MVE to battery terminal VN. The valve MVE has a second energizing circuit extending from battery terminal VB, through front contact *a* of a relay BRE, to be discussed, front contact *e* of relay AE, and back contact *b* of relay AEP in multiple with each other, the back point of contact *d* of relay DRE, and the winding of relay MVE to battery terminal VN. The operation of these control circuits for magnet valve MVE will be discussed in detail hereinafter. (A similar magnet valve MVW is shown in FIG. 7, and also controls the release and application of the train brakes, as will be hereinafter discussed.)

The circuits and apparatus associated with receiver WER on the west or left-hand end of the train and shown in FIG. 7 are similar to those just described and no detailed description of such circuits and apparatus is believed necessary, it being considered sufficient to point out the relays AWP, LWBP, LWFPS, DRW, LWP, and AWLS in FIG. 7 correspond to relays AEP, LEBP, LEFPS, DRE, LEP, and AELS in FIG. 5 and are controlled by circuits similar to those described for these latter relays. Pneumatic relay PNRW in FIG. 7 is identical in construction and operation to relay PNRE discussed above and, as previously mentioned, magnet valve MVW controls the release and application of the train brakes in a manner similar to valve MVE. However, it should be pointed out that the apparatus of FIG. 5 operates to control the train when the train moves in a direction from west to east over the track layout shown in FIGS. 1 through 4, and the apparatus of FIG. 7 operates to control the train when the train moves in a direction from east to west over said layout. An operational example of both sets of apparatus will be given later.

There is shown in FIG. 6 a first set of relays designated PAE, BRE, PES, and PEP and a second set of corresponding relays designated PAW, BRW, PWS, and PWP. These first and second sets of relays control the supply of propulsion power to the motors of the train and control the actuation of the brakes of the train when the train is moving in eastward and westward directions, respectively, as will be described. The supply of propulsion power to the motors of the train is controlled by two controllers designated PMSC and PMPC, controller PMSC controlling the supply of power to the train motors in series for low speed movements, and controller PMPC controlling the supply of power to the train motors in parallel for high speed movements. The direction of rotation of the motors of the train is controlled in accordance with the polarity of current supplied to the controllers and thus the controllers operate to control the movements of the train in eastward or westward directions according as

current of a first or second polarity is supplied to the controllers. This will become more apparent as the description proceeds.

It should be pointed out at this time that the doors of the train are normally biased to a closed position and are actuated to and maintained in an open position only when energy is supplied to a door opening controller. This controller is indicated in FIG. 6 by a rectangular geometric figure designated DO. Such door opening apparatus is well known in the art and, since the details thereof form no part of my present invention, no detailed description of the controller itself is believed necessary.

An eastward and a westward speed responsive device comprising train axle driven governors are also shown in FIG. 6. These governors are designated GVE and GVW, respectively, and are employed in conjunction with the eastward and westward sets of control apparatus, respectively. Such governors are well known in the railway signaling art and for purposes of my invention may be any of the well known types such as centrifugal type governors, or that known as the electric or frequency generator type. For purposes of this description, however, it will be assumed that each of the governors is of the type shown and described in Letters Patent of the United States, No. 2,211,554, issued August 13, 1940, to Herbert L. Bone and John W. Livingston for Speed Responsive Device.

Each of the governors is provided with a plurality of contacts which are normally biased to a closed position against a back contact point as shown in FIG. 6, that is, normally closed when the train is at rest, and each of which is operated to an open position when the speed of the train reaches a predetermined speed to which the respective contact is adjusted. The contacts on governor GVE are designated GC5E, GC6E, GC17E, GC30E, and GC32E, and are adjusted to open when the speed of the train reaches the speeds of 5 m.p.h., 6 m.p.h., 17 m.p.h., 30 m.p.h. and 32 m.p.h., respectively. When each contact is operated to its open position it remains open so long as the speed of the train remains at or above the respective speed to which the contact is adjusted. Similarly, the contacts on governor GVW are designated GC5W, GC6W, GC17W, GC30W, and GC32W, and are controlled in a manner similar to the corresponding contacts on governor GVE. Although I have chosen to show and describe my invention using two governors or speed responsive devices, one for each end of the train, it is to be understood that a single governor could be employed since the contacts on governors such as that shown in said Bone et al. patent operate identically for either direction of movement of a train and the rotation of its axles.

Since each of the eastward and westward sets of apparatus shown in FIG. 6 operates in a similar manner, except as pointed out below, it is deemed expedient for purpose of simplification of this description to trace in detail the control circuits for the eastward set of apparatus only. The operation of the westward set of apparatus will be readily understood from the operational description given hereinafter.

Relay PAE (FIG. 6) has a first pickup circuit extending from battery terminal VB, through front contact *k* of relay AE, contact GC30E of governor GVE, front contact *b* of relay BRE, and the winding of relay PAE to battery terminal VN. Relay PAE has a second pickup circuit extending from battery terminal VB, through front contact *e* of relay RE, contact GC5E of governor GVE, front contact *b* of relay BRE, and the winding of relay PAE to battery terminal VN. Relay PAE is thus energized whenever relay AE is energized and the speed of the train is below 30 m.p.h., or whenever relay RE is energized and the speed of the train is below 5 m.p.h.

Relay BRE has a first pickup circuit extending from battery terminal VB, through front contact *c* of relay PAE, and the winding of relay BRE to battery terminal VN. Relay BRE has a second pickup circuit extending

from battery terminal VB, through front contact *l* of relay AE, contact GC32E of governor GVE, and the winding of relay BRE to battery terminal VN. Relay BRE has a third pickup circuit extending from battery terminal VB, through front contact *f* of relay RE, contact GC6E of governor GVE, and the winding of relay BRE to battery terminal VN. Relay BRE has a fourth pickup circuit extending from battery terminal VB, through front contact *b* of relay AELS, contact GC17E of governor GVE, and the winding of relay BRE to battery terminal VN. Thus relay BRE is energized whenever relay PAE is energized, or whenever relay AE is energized and the speed of the train is below 32 m.p.h., or whenever relay RE is energized and the speed of the train is below 6 m.p.h., or whenever relay AELS is energized and the speed of the train is below 17 m.p.h.

Relay PES has a pickup circuit extending from battery terminal VB, through back contact *f* of relay AE, front contact *c* of relay RE, front contact *a* of relay PAE, back contact *c* of relay AEP, and the winding of relay PES to battery terminal VN. Relay PES is, therefore, energized whenever relay AE is released, relay RE is picked up, relay PAE is picked up, and relay AEP is released.

Relay PEP has a pickup circuit extending from battery terminal VB, through front contact *g* of relay AE, front contact *b* of relay PAE, and the winding of relay PEP to battery terminal VN. Relay PEP is thus energized whenever relays AE and PAE are energized.

Controller DO has two energizing circuits, the first extending from battery terminal VB over front contact *e* of relay LE, and the control winding of controller DO to battery terminal VN; and the second extending from battery terminal VB over front contact *e* of relay LW, and the control winding of controller DO to battery terminal VN. Thus the doors of the train are controlled to their open positions by the actuation of controller DO whenever relay LE or relay LW is energized.

Motor controller PMSC has first and second actuating circuits for actuating that controller to supply propulsion energy to the motors of the train in series. The first of these circuits extends from battery terminal VB, through front contact *b* of relay PES, terminal *a* of controller PMSC, terminal *b* of controller PMSC, and front contact *a* of relay PES to battery terminal VN. The second circuit extends from battery terminal VB, through front contact *b* of relay PWS, terminal *b* of controller PMSC, terminal *a* of controller PMSC, and front contact *a* of relay PWS to battery terminal VN. Thus controller PMSC may be actuated by energy of a first polarity or of a second polarity to cause the motors of the train to rotate in a first or second direction, respectively, and thereby propel the train in eastward or westward directions, respectively.

Motor controller PMPC has first and second actuating circuits for actuating that controller to supply propulsion energy to the motors of the train in parallel. The first of these circuits extends from battery terminal VB, through front contact *b* of relay PEP, terminal *a* of controller PMPC, terminal *b* of controller PMPC, and front contact *a* of relay PEP to battery terminal VN. The second circuit extends from battery terminal VB, through front contact *b* of relay PWP, terminal *b* of controller PMPC, terminal *a* of controller PMPC, and front contact *a* of relay PWP to battery terminal VN. Thus controller PMPC may be actuated by energy of a first polarity or a second polarity to cause the motors of the train to rotate in a first or second direction, respectively, and thereby propel the train in eastward or westward directions, respectively.

It has been assumed previously that a train equipped with apparatus of my invention has just left Loc. 1 (FIG. 1) and is traveling in track stretch 2T towards Loc. 10, and the condition and operation of the apparatus shown in FIGS. 1 through 4 have been described in connection therewith. The condition and operation of the apparatus

of FIGS. 5, 6, and 7 will now be described in connection with such assumption and the further assumption that the train travels to Loc. 10 and then returns to Loc. 1, etc. The apparatus is shown in FIGS. 5, 6, and 7 in the condition existing when the train is traveling in said track stretch 2T towards Loc. 10. In FIG. 5, relay AE is energized by the receipt of pulses of current at the 270 code rate by receiver EER, relay AEP is energized, thereby energizing relay RE; relays LE, LEFPS, DRE, LEP and AELS are all released; and relay LEBP is energized over the back point of contact *a* of relay LE. In FIG. 7, relays AW, AWP, RW, LW, LWFP, LWP, and AWLS are all released, and relays LWBP and DRW are energized. It is to be noted that magnet valve MVW is energized at this time over the front point of contact *d* of relay DRW and, therefore, insofar as magnet valve MVW is concerned, the brakes are released. In FIG. 6, relay BRE is energized and, assuming the speed of the train to still be below 5 m.p.h., relays PAE and PEP are energized and relay PES is released. (Relays BRW, PAW, PWS and PWP are all released at this time but their condition is immaterial since these relays are inactive and ineffective to control an eastward train movement. Relay PAE is energized at this time over both its previously described pickup circuits including contacts GC30E and GC5E of governor GVE. Relay BRE is energized over its first, second, and third, previously described pickup circuits. Relays BRE and AE being energized and relay DRE being released, magnet valve MVE (FIG. 5) is energized and the train brakes are released. Energy is being supplied to motor controller PMPC (FIG. 6) over front contacts *a* and *b* of relay PEP and the controller, therefore, supplies energy to the motors of the train in parallel and of a polarity to propel the train in an eastward direction.

I will now assume that the train continues to accelerate in response to the energy supplied to its motors in parallel, passes its 5 m.p.h. speed, and accelerates towards its high speed range of 30–32 m.p.h. When the speed of the train reaches 5 m.p.h., contact GC5E of governor GVE opens thereby opening the second pickup circuit for relay PAE. The first pickup circuit for relay PAE continues to remain closed, however, and no further action takes place at this time. When the speed of the train reaches 6 m.p.h., contact GC6E of governor GVE opens, thereby opening the third pickup circuit for relay BRE. However, the first and second pickup circuits for relay BRE remain closed, relay BRE remains energized, and no further action takes place. When the speed of the train reaches 17 m.p.h., contact GC17E of governor GVE opens, but this action has no effect at this time.

When the speed of the train reaches 30 m.p.h. contact GC30E opens, interrupting the first and remaining pickup circuit for relay PAE, and that relay releases. The release of relay PAE releases relay PEP which, in turn, removes energy from motor controller PMPC and thereby interrupts the propulsion power being supplied to the train motors thereby causing the train to coast. If the speed of the train thereafter falls below 30 m.p.h., contact GC30E of governor GVE will again close, energizing relay PAE and consequently relay PEP. The energization of relay PEP will again supply energy to controller PMPC which will operate to again supply propulsion energy to the train motors to accelerate the train to above 30 m.p.h., at which speed relay PAE again releases. Should the speed of the train increase to above 32 m.p.h., contact GC32E of governor GVE opens, interrupting the second and remaining pickup circuit for relay BRE. Relay BRE will, therefore, release and open the energizing circuit for magnet valve MVE (FIG. 5) and cause a train brake application. When the train brakes have again reduced the train speed to below 32 m.p.h. contact GC32E of governor GVE will close and relay BRE will again become picked up to energize magnet valve MVE and release the train brakes. In this manner the speed of the train is controlled within upper and lower speed limits of

a high speed range (30–32 m.p.h.) whenever the train is receiving pulses of coded current at the 270 code rate and the train is traveling in an eastward direction. Contacts GC30W and GC32W of governor GVE control the speed of the train in a similar manner when the train is traveling in a westward direction and is receiving code pulses at the 270 code rate.

When the train enters track stretch 3T in its eastward journey, receiver EER no longer receives code pulses at the 270 code rate, and receives code pulses at the 180 code rate supplied to the rails of track stretch 3T from transformer 3TRT (FIG. 2) in the manner previously described. The interruption of the receipt of the 270 code pulses deenergizes relay AE which releases after the expiration of its slow release period. The release of relay AE deenergizes relay AEP which releases after the expiration of its slow release period. Relay RE is energized by the receipt of the 180 code pulses prior to the release of relay AEP and, therefore, remains picked up at this time.

The release of relay AE deenergizes relay PAE, if energized at this time, and also deenergizes relay BRF. The release of relays AE and PAE releases relay PEP, if energized, and insures the interruption of power to the train motors. Front contact *b* of relay BRE insures the release of relay PAE. The release of relay AE also opens the energizing circuit to magnet valve MVE, which causes an immediate application of the train brakes, and the release of relay BRE insures the continued deenergization of valve MVE when relay AEP closes its back contact *b*.

Relay AELS (FIG. 5) is energized, when relay AE releases and before relay AEP releases, and is then maintained energized over the back point of contact *d* of relay AEP. Relay AELS is made slow to release to insure that it will bridge the transfer time of contact *d* of relay AEP from its front to its back contact points. The energization of relay AELS prepares, at its front contact *b*, the fourth pickup circuit for relay BRE and, when the speed of the train is reduced to below 17 m.p.h., contact GC17E of governor GVE closes to complete such pickup circuit. Relay BRE picks up, closes the energizing circuit to magnet valve MVE and releases the train brakes.

Due to the time delay, inherent in brake systems, between the initiation of the release of the train brakes (energization of magnet valve MVE) and the full release of the brakes, it has been found that initiation of the release of the brakes, upon a change from 270 code to 180 code, must be made at a speed higher than a low speed range (5–6 m.p.h.) in order that the brakes do not operate to bring the train to a full stop due to their inherent time delay. In one braking system it has been found that the speed at which the release of the train brakes should be initiated under such conditions is 17 m.p.h. and, accordingly, in this example of the operation of my invention relay AELS is controlled to effect initiation of release of the train brakes when the speed of the train is reduced from the high speed range to 17 m.p.h. upon a change in code from the 270 code rate to the 180 code rate. Relay AELS is energized only upon such a code change. Relay AWLS operates in a similar manner for a westward movement of the train and for similar reasons.)

When the speed of the train has decreased to below 5 m.p.h., contact GC5E of governor GVE and front contact *e* of relay RE complete the second pickup circuit for relay PAE which becomes energized and opens the stick circuit for relay AELS. Relay AELS releases following its slow release time interval. The picking up of relay PAE also completes at this time the pickup circuit for relay PES including back contact *f* of relay AE, front contact *c* of relay RE and back contact *c* of relay AEP. The picking up of relay PES supplies energy to controller PMSC which is then actuated to supply pro-

pulsion power to the train motors in series and of a polarity to continue the eastward movement of the train.

Contact GC5E of governor GVE in the second pickup circuit for relay PAE, and contact GC6E of governor GVE in the third pickup circuit for relay BRE now operate to maintain the speed of the train within upper and lower limits of the low speed range (5-6 m.p.h.) in a manner similar to that, previously described, in which contacts GC30E and GC32E operate to maintain the speed of the train within the high speed range. That is, whenever the speed of the train falls below 5 m.p.h., contact GC5E closes and completes the second pickup circuit for relay PAE which picks up and in turn energizes relay PES to control the supply of propulsion energy to the motors. When the train speed exceeds 6 m.p.h., contact GC6E again opens deenergizing relay BRE and again applying the train brakes by deenergizing magnet valve MVE. Thus, during the movement of the train through track section 3T in its eastward journey, the speed of the train is at first reduced to a low speed range and is then maintained within that range until the train enters track section 4T.

When the train enters track section 4T, the receipt of code pulses by receiver EER is interrupted since no energy is supplied to the primary winding of transformer 4TRT at this time (FIG. 2). Such interruption of the receipt of coded current causes the release of relay RE, which in turn releases relays PAE and BRE if those relays are energized. The release of relay PAE, if energized, releases relay PES, actuates controller PMSC and interrupts the supply of propulsion power to the train motors. The release of relay BRE deenergizes magnet valve MVE and causes a train brake application. As previously pointed out, insulated joints J between track stretches 3T and 4T are so located that the application of the train brakes, when the train is within its low speed range and enters track section 4T in its eastward journey, causes the train to come to a stop with the pickup coils of its east end receiver EER located over and in inductive relation with the length of rails provided with train loop L4 (FIG. 4). At this time loop L4 is being provided with train control current at the 75 code rate from the secondary winding of transformer 4TT, the primary winding of that transformer being energized at the 75 code rate over the previously described circuit including back contact *a* of time element repeater relay 4TEPR. The release of relay RE, when the train enters track stretch 4T, and the closing of contact *a* of pneumatic relay PNRE, following the application of the train brakes, prepares the previously described pickup circuit for relay LE and, when the 75 code pulses are supplied to receiver EER as mentioned above, relay LE becomes energized. The energization of relay LE closes, at front contact *e* of that relay, the actuating circuit for the door opening controller DO (FIG. 6) and the doors are thereby controlled to open. The energization of relay LE also closes the energizing circuits for relay LEP (FIG. 5) and relay LWP (FIG. 7) and those relays become picked up. The energization of relay LWP at this time is immaterial but the energization of relay LEP prepares the pickup circuit for relay AE which is subsequently completed as discussed below.

The energization of relay LE, upon receipt of the 75 code pulses by receiver EER, closes the pickup circuit for relay LEFPS before the slow release period of relay LEBP expires and relay LEFPS thus becomes picked up completing its stick circuit (FIG. 5). Relay LEFPS then remains energized so long as relay LE remains picked up. Following the time delay period provided by relay 4TER (FIG. 2) relay 4TEPR is energized and opens, at its back contact *a*, the circuit for supplying code pulses at the 75 code rate to the primary winding of relay 4TT and consequently to loop L4. The energization of relay 4TEPR also closes, at front contact *b* of that relay, the circuit for supplying code pulses of current at the

270 code rate to the primary winding of transformer 4TRT and consequently to the rails of track stretch 4T. The interruption of the 75 code pulses to loop L4 causes relay LE to release and to temporarily close the pickup circuit for relay DRE which picks up closing its stick circuit. However, relay AE is energized by the receipt of the 270 code pulses by receiver EER and relay DRE is immediately released by the opening of back contact *d* of relay AE. Therefore, the operation of relays LEBP, LEFPS, and DRE at this time is actually immaterial.

The release of relay LE also opens the energizing circuit to door opening controller DO and that controller is deenergized permitting the aforementioned biasing means to close the train doors. Relay LEP is deenergized when relay LE is released but remains picked up, due to its slow release feature, for a sufficient length of time to permit relay AE to become energized closing its front contact *a* in its stick circuit. Relay LEP subsequently releasing completes, at the back point of contact *a* of relay LEP, the stick circuit for relay AE and that relay remains energized on the continued receipt of the 270 code pulses. The energization of relay AE again energizes relay AEP and consequently relay RE, and relays PAE and BRE. The energization of relay BRE closes the energizing circuit to magnet valve MVE thereby releasing the brakes of the train. The energization of relay PAE energizes in turn relay PEP which actuates controller PMPC to again supply energy to the motors of the train in parallel to start the train and accelerate it to its high speed range in its eastward journey. The train-carried apparatus now operates in the manner described when the train was traversing track section 2T and no detailed repetition of such description is believed necessary. However, it should be pointed out that the east end receiver EER continues to receive code pulses at the 270 code rate when the train enters track section 5T and, therefore, the speed of the train while traversing track section 5T is controlled within the high speed range in the manner previously described, that is, by the operation of contacts GC30E and GC32E of governor GVE. It should also be pointed out that when the rear wheels and axle of the train vacate track stretch 4T, time delay relay 4TER is released due to the opening of back contact *a* of track relay 4TR, and consequently relay 4TEPR also releases to interrupt the supply of 270 code pulses to the rails of track stretch 4T and supply code pulses at the 75 code rate to loop L4. The apparatus at Loc. 4 is then in the condition existing prior to the entry of the train into track section 4T.

The actuation of the train-carried equipment and the control of the train, when the train enters track stretch 6T and subsequently track stretch 7T at Loc. 7, is identical to that described when the train entered track stretches 3T and 4T, respectively, and no detailing of the operation is necessary. Also the operation of the equipment and control of the train following its stop at the station platform at Loc. 7 is identical to such operation following its stop at Loc. 4 and no detailing of this operation is necessary. It is sufficient to point out that the speed of the train is reduced to its low speed range by the receipt of 180 code pulses when the train enters track stretch 6T, the train is controlled to stop at Loc. 7 with its receiver EER over loop L7 following its entrance into track stretch 7T and the resulting interruption of the receipt of code pulses by receiver EER, and the doors of the train are then controlled to open by the receipt by receiver EER of the 75 code pulses supplied to loop L7. Following such station stop, the doors are again controlled to close by the interruption of the 75 code pulses and the train is then started and controlled to its high speed range by the 270 code pulses supplied to the rails of track stretches 7T and 8T, and subsequently to its low speed range by the 180 code pulses supplied to the rails of track section 9T. When the train enters track section 10T, the receipt of the 180 code pulses is interrupted, the train is con-

trolled to stop with its east end receiver coils over loop L10 and the doors of the train are controlled to open by the 75 code pulses received from that loop. This operation is also similar to that described in detail when the train entered track stretch 4T and repetition of such detailed description is unnecessary.

As previously set forth, when the train stops with the coils of its east end receiver over loop L10, the west end of the train remains in track stretch 9T and, therefore, the coils of the west end receiver are in inductive relation with the rails of track stretch 9T. Referring to FIG. 7 it will be noted that directional relay DRW is energized and held energized over its stick circuit during the eastward train movement. Therefore, when relay LE picks up upon receipt of the 75 code pulses from loop L10 relay LWP is energized and closes at the front point of its contact *a* the pickup circuit for relay AW. In FIG. 5, the pickup circuit for direction relay DRE is prepared at front contact *b* of relay LEFPS, since relay LEFPS became picked up over the front point of contact *a* of relay LE and is maintained picked up over its stick circuit.

When the train has remained at Loc. 10 for a predetermined period of time controlled by the automatic program control mechanism 10ATD (FIG. 4) contact *a* of controller 10ATDC is actuated to its closed position and relay 10BSR is energized over its previously described pickup circuit. The opening of back contact *d* of relay 10BSR opens the stick circuit for relay 1BSR at Loc. 1 (FIG. 1) and that relay releases, removing energy from conductor 12. The opening of back contact *b* of relay 10BSR interrupts the alternating current supplied to the primary winding of transformer 10TT and the code pulses at the 75 code rate are no longer supplied to loop L10. The closing of front contact *c* of relay 10BSR supplies energy from the alternating current source to conductor 11, as previously discussed. Pulses of current at the 270 code rate are now supplied to the primary winding of transformer 9TLT and consequently to the rails of track section 9T at the left-hand end thereof.

In FIG. 5, the release of relay LE upon the interruption of the code pulses to loop L10 completes the pickup circuit for relay DRE and that relay picks up, closing its stick circuit. The energization of relay DRE closes at the front point of its contact *d* the first energizing circuit for magnet valve MVE and the brakes are released insofar as that magnet valve is concerned. The receipt of the 270 code pulses from track section 9T by the west end receiver on the train energizes relay AW (FIG. 7) and opens, at back contact *d* of that relay, the circuit to directional relay DRW which then releases and transfers the energizing circuit for magnet valve MVW to its energizing circuit including front contact *a* of relay BRW and front contact *e* of relay AW. The release of relay LE as set forth above deenergizes relay LWP but the slow release feature of relay LWP maintains it picked up for a sufficient period of time for relay AW to become energized. Relay LWP then subsequently releases and completes at the back point of its contact *a* the stick circuit for relay AW. The release of relay LE also deenergizes controller DO (FIG. 6) and the doors are controlled to close. Relay AE remains deenergized at this time because no code pulses are supplied to the receiver on the east end of the train.

Referring to FIG. 6, relay BRW is now energized over its pickup circuit including front contact *l* of relay AW and contact GC32W of governor GVW in its closed position. Relay PAW is energized over its pickup circuit including front contact *k* of relay AW, contact GC30W of governor GVW in its closed position, and front contact *b* of relay BRW. In FIG. 7, magnet valve MVW is energized over its previously mentioned energizing circuit including front contact *e* of relay AW and front contact *a* of relay BRW. The brakes of the train are, therefore, released.

Returning to FIG. 6, the energization of relays AW and PAW closes at front contacts *g* and *b*, respectively, of those relays the pickup circuit for relay PWP and that relay is energized. The picking up of relay PWP closes an actuation circuit for motor controller PMPC. This circuit as previously traced extends from battery terminal VB, front contact *b* of relay PWP, terminal *b* of controller PMPC, terminal *a* of controller PMPC, and front contact *a* of relay PWP to battery terminal VN. It will be noted that this circuit is of opposite polarity to that completed when relay PEP was energized and, therefore, controller PMPC is actuated to control the motors of the train to rotate in a direction to cause the train to move westwardly. The train is thus controlled to start and accelerate to its high speed range in a westwardly direction, that is, from Loc. 10 towards Loc. 1. The governor contacts GC30W and GC32W of governor GVW control the speed of the train within its high speed range so long as receiver WER is receiving code pulses at the 270 code rate and in a manner similar to that described for the eastward train movement, and no detailed description of this operation of the apparatus is, therefore, believed necessary.

As previously set forth, the train in its westwardly train movement does not make a stop at Loc. 7 and, therefore, the west end receiver WER continues to receive code pulses of current at the 270 code rate while the train traverses track sections 9T, 8T, 7T, and 6T, and the train continues its westward train movement at its high speed range until it enters tracks stretch 5T. No code pulses are supplied to loop L7 at Loc. 7 during the westward movement of the train because no alternating current is being supplied to conductor 12 at this time, and the actuation of relays 7TR, 7TER, and 7TEPR when the train traverses track section 7T in its westward movement is immaterial.

When the train enters track section 5T, receipt of code pulses at the 270 code rate is interrupted and code pulses at the 180 code rate are received from the rails of track section 5T. Consequently relay AW is released and relay RW remains picked up. The release of relay AW releases relays PAW, BRW, and consequently relay PWP, and energy to the motors of the train is interrupted and magnet valve MVW is deenergized to cause a train brake application. Relay AWLS (FIG. 7) is energized at this time over its pickup circuit including the front point of contact *d* of relay AWP, back contact *h* of relay AW, and front contact *d* of relay RW. Relay AWP subsequently releases and closes the stick circuit for relay AWLS including the back point of contact *d* of relay AWP and back contact *d* of relay PAW. When the speed of the train is decreased below 17 m.p.h., relay BRW is energized by a circuit including front contact *b* of relay AWLS and contact GC17W of governor GVW to initiate release of the train brakes. However, the speed of the train, due to the aforesaid inherent time delay in release of the brakes, is reduced to just below 5 m.p.h. before the brakes become fully released. This is similar to the operation of relay AELS and governor contact GC17E in the previously described eastward train movement.

When the speed of the train is reduced below 5 m.p.h., relay PAW is energized over its pickup circuit including front contact *e* of relay RW and contact GC5W of governor GVW. The energization of relay PAW at this time closes the pickup circuit for relay PWS including back contact *f* of relay AW, front contact *c* of relay RW, front contact *a* of relay PAW, and back contact *c* of relay AWP. Relay PWS is thus energized and supplies energy to motor controller PMSC to actuate it to supply propulsion power to the train motors in series and of a polarity to rotate the motors in a direction to continue the westward train movement. As previously described, this actuating circuit for controller PMSC extends, at this time, from battery terminal VB, front contact *b* of

relay PWS, terminal *b* of controller PMSC, terminal *a* of controller PMSC, and front contact *a* of relay PWS to battery terminal VN. The energization of relay PAW also opens the stick circuit for relay AWLS which subsequently releases to interrupt the pickup circuit to relay BRW including front contact *b* of relay AWLS and contact GC17W of governor GVW.

While the train is traversing track section 5T in its westward movement, the speed of the train is maintained within its lower speed range of 5-6 m.p.h. by contacts GC6W and GC5W of governor GVW, these contacts actuating relays BRW and PAW according as the speed of the train exceeds 6 m.p.h. or falls below 5 m.p.h. This actuation of relays BRW and PAW is similar to the control of the corresponding relays BRE and PAE when the train is making an eastward train movement in a track stretch supplied with train control current at the 180 code rate.

When the train enters track stretch 4T at Loc. 4, the supply of train control current to the west end receiver WER is temporarily interrupted, and relay RW releases causing an application of the train brakes and bringing the train to a stop with the pickup coils of receiver WER over loop L4. The receiver receives pulses of current at the 75 code rate, supplied to loop L4 over a circuit extending from conductor 11 and including the front point of contact *a* of code transmitter relay 75CTR4, and relay LW (FIG. 7) is energized over its pickup circuit including contact *a* of pneumatic relay PNRW which insures that the brakes are fully applied. The energization of relay LW closes the actuating circuit for door opening controller DO (FIG. 6) and the doors are controlled to open. Following the time delay period provided by time element relay 4TER, relay 4TEPR is energized interrupting the supply of energy at the 75 code rate to loop L4 and supplying, over front contact *c* of relay 4TEPR and contact *b* of code transmitter relay 270CTR4, alternating current from conductor 11 to the primary winding of transformer 4TLT. The secondary winding of transformer 4TLT, therefore, supplies pulses at the 270 code rate to the rails of track stretch 4T at the west end thereof. The interruption of the receipt of the 75 code pulses and the release of relay LW removes energy from controller DO and the doors again close. The receipt of the 270 code pulses again starts the train westwardly and accelerates it to its high speed range. A completely detailed description of the operation of the apparatus is not necessary as it is similar to the operation of the eastward control apparatus described for the train in its eastward movement through Loc. 4.

When the train enters track section 3T the train continues to receive code pulses at the 270 code rate and continues at the speed of its high speed range towards Loc. 1. When the train enters track section 2T, the receipt of the 270 code pulses is again interrupted and pulses of current at the 180 code rate are received by receiver WER. This code change operates, as previously described for such a code change, to reduce the speed of the train to its low speed range in preparation for stopping the train when it enters track section 1T.

The entrance of the west end of the train into track section 1T causes an interruption of the receipt of the train control current, the release of relay BRW, and the deenergization of magnet valve MVW, thereby causing an application of the train brakes. The train is thus controlled to stop with the pickup coils of its west end receiver WER over the track loop L1, and relay LW and consequently relay LWP become energized. The doors of the train are controlled to open by relay LW, as previously described. The east end of the train remains in track section 2T with the pickup coils of receiver EER in inductive relation with the rails of that track section.

Following the prescribed stopping period for the train at Loc. 1, automatic program control mechanism 1ATD operates controller 1ATDC to close its contact *a* and

energize relay 1BSR, which in turn opens the stick circuit for relay 10BSR at Loc. 10 and releases that relay. The energization of relay 1BSR and the opening of back contact *b* of that relay interrupts current at the 75 code rate to loop L1 and relay LW of the train-carried apparatus is released. The opening of front contact *c* of relay 10BSR at Loc. 10 interrupts the supply of alternating current to conductor 11, and the closing of front contact *c* of relay 1BSR at Loc. 1 supplies alternating current to conductor 12 thereby supplying energy at the 270 code rate to the rails of track section 2T at the east end thereof. Relay AE now becomes energized in the manner previously described. The pickup and subsequent release of relay LW actuates relays LWFPS and LWBP, in a manner similar to the actuation of relays LEFPS and LEBP by relay LE, and relay DRW becomes picked up completing its stick circuit. Magnet valve MVW is now steadily energized over its pickup circuit including the front point of contact *d* of relay DRW. The picking up of relay AE releases relay DRE and the control circuit for magnet valve MVE is transferred from the front point of contact *d* of relay DRE to the back point of the contact. Valve MVE is then thereafter actuated by relays BRE and AE to control the application and release of the train brakes in an eastward train movement. The energization of relay AE also operates to again control the supply of energy to the train motors in parallel and of a polarity to start and accelerate the train towards Loc. 10, the train being accelerated to its high speed range in the manner previously described. The train thereafter continues to make shuttle movements between Locs. 1 and 10 according to the timing cycles of the program control mechanisms 1ATD and 10ATD.

From the foregoing description it is apparent that, with the apparatus of my invention as shown in the drawings of this application, I have provided means for completely automatically controlling the movements and speed of a train alternately between two extreme locations, and the stopping of the train and the opening of its doors at each said locations, and at other preselected locations between the extreme locations.

While I have shown and described only one form of apparatus embodying my invention, it should be 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. An automatic train operation system for a train traveling through railway territory provided with a plurality of stations at preselected locations within the territory and each including a station platform area, said system comprising, in combination, means for transmitting to the train a first distinct signal when the train is within any one of first prescribed track stretches between said stations, means for transmitting to the train a second distinct signal when the train is within any one of second prescribed track stretches each in approach to a station platform area, means for transmitting to the train a third distinct signal when the train is within any one of third prescribed track stretches each within a station platform area, a timing device for each said third track stretch, means controlled by the entrance of the train into each said third track stretch for initiating the timing cycle of the timing device for that track stretch, means controlled by each said timing device at the end of its timing cycle for interrupting the transmission to said train of said third signal and transmitting to the train said first signal; signal receiving apparatus on said train selectively responsive to the receipt of said first, second, and third distinct signals; a speed responsive governor on said train, means controlled by said signal receiving apparatus and said governor for controlling the speed of said train to and maintaining it within a first

distinct speed range when said first signal is received, means controlled by said signal receiving apparatus and said governor for controlling the speed of said train to and maintaining it within a second distinct speed range when said second signal is received, and means controlled

2. An automatic train operation system for controlling a train to alternately traverse a stretch of railway track in opposite directions between first and second station platform areas, said system comprising, in combination, first and second sets of signal responsive apparatus on said train, first and second synchronized programming devices at said first and second areas respectively, means controlled by said first programming device for transmitting preselected signals to said first set of signal responsive apparatus during alternate non-overlapping periods of time and until said train enters said second area, means controlled by said second programming device for transmitting preselected signals to said second set of signal responsive apparatus during the other alternate non-overlapping periods of time and until said train enters said first area, means controlled by the first set of signal responsive apparatus for controlling the movement of the train from said first area to said second area when that set of apparatus is receiving said preselected signals, means controlled by the second set of signal responsive apparatus for controlling the movement of the train from said second area to said first area when that set of apparatus is receiving said preselected signals, means controlled by the signal responsive apparatus for applying the brakes of the train when the receipt of said preselected signals is interrupted, means controlled by said programming devices for transmitting signals distinct from said preselected signals to the signal responsive apparatus subsequent to the entrance of the train into a station platform area, and means controlled by said signal responsive apparatus for controlling the opening of the doors of the train following the application of the train brakes and the subsequent receipt of said distinct signals.

3. An automatic train operation system for controlling the movements of a shuttle-train over a stretch of railway track extending between first and second selected stations, said system comprising, in combination, first and second signal receiving apparatus on first and second ends of said train respectively and inductively responsive to signals supplied in advance of the train to the rails of said track stretch, first and second synchronized program mechanisms at said first and second stations respectively, means controlled by said first mechanism for supplying preselected inductive signals to the rails of said track stretch in advance of said first end of the train for a first predetermined period of time and following a predetermined time interval after the arrival of the train at said first station, means controlled by said second mechanism for supplying preselected inductive signals to the rails of said track stretch in advance of said second end of the train for a second predetermined period of time following a predetermined time interval after the arrival of the train at said second station, a speed control governor on said train, means controlled by said first signal receiving apparatus and said governor for controlling the movement and speed of the train between the first and second stations when that receiving apparatus receives said preselected signals, means controlled by said second signal receiving apparatus and said governor for controlling the movement and speed of the train between the second and first stations when that receiving apparatus receives said preselected signals, means controlled by said program mechanisms for selectively transmitting to said receiving apparatus inductive signals distinct from said preselected signals during each said predetermined time interval after the arrival of the train at a station, and means controlled

by said signal receiving apparatus for controlling the opening of the doors of the train upon receipt of said distinct signals.

4. An automatic train operation system for controlling the movements of a crewless shuttle-train over a stretch of railway track extending between first and second selected stations, said system comprising, in combination, first signal receiving means on said train selectively responsive to each signal of a plurality of distinct signals, second signal receiving means on said train selectively responsive to each signal of said plurality of distinct signals, automatic programming apparatus, means controlled by said programming apparatus for selectively transmitting said plurality of signals to said first signal receiving means and said second signal receiving means respectively during alternate non-overlapping periods of time and until the train enters a station area, a speed responsive device on said train, means controlled by said first receiving means and said speed responsive device for controlling the movement and speed of the train from said first station to said second station according to the selected signal received by that receiving means, means controlled by said second receiving means and said speed responsive device for controlling the movement and speed of the train from said second station to said first station according to the selected signal received by that receiving means, means controlled by said receiving means for controlling an application of the train brakes when the receipt of said signals is terminated, additional transmitting means at each said station for transmitting to said receiving means for a period of time and subsequent to the arrival of the train at such station another signal distinct from said plurality of distinct signals, a door controller on said train, and means controlled by said receiving means for actuating said door controller to open the doors of the train and maintaining the doors opened upon and for the duration of the receipt of said other signal.

5. In an automatic train operation system including train-carried receiving means responsive to current coded at first and second different code rates for selectively controlling first and second decoding relays to control the speed of the train to and within high and low speed ranges respectively, the combination comprising; a train operated speed governor having first and second contacts biased to a closed position and operated to open positions when the train exceeds lower and upper speed limits respectively of said low speed range, and a third contact biased to closed position and operated to an open position when the train exceeds a preselected speed intermediate said speed ranges; a stick relay, means controlled by said first and second decoding relays for energizing said stick relay only when said receiving means responds to a change from said first to said second code rate, means controlled by said second decoding relay and said first governor contact for maintaining said stick relay energized so long as said receiving means responds to said second code rate and said first governor contact is open, means controlled by said first decoding relay for controlling an application of the brakes of the train when said receiving means responds to a change from said first to said second code rate; means controlled by said stick relay in its energized position and by said third governor contact in its closed position for initiating the release of said train brake application, said predetermined intermediate speed at which said third governor contact opens being so selected that the inherent delay time between initiation of release and full release of the brakes will result in the reduction of the speed of the train to just below said lower speed limit of said low speed range; and means controlled by said second decoding relay and said first and second governor contacts for thereafter maintaining the speed of the train within said lower speed range so long as said receiving means responds to said second code rate.

6. An automatic train operation system for controlling a shuttle-train traversing a stretch of railway track extending between first and second locations, said system comprising, in combination, first and second track sections in said stretch at said first and second locations respectively, first and second approach track sections in said stretch in approach to said first and second track sections respectively, a first set of receiving apparatus on a first end of said train selectively responsive to current coded at different code rates supplied to the rails of said track stretch in advance of said first end of the train, a second set of apparatus on the second end of said train selectively responsive to current coded at different code rates supplied to the rails of said track stretch in advance of said second end of the train, timing apparatus having first and second timed cycles; means controlled by said timing apparatus for supplying current coded at a first code rate to the rails of said first approach track section and to the rails of the track stretch between said approach sections, and current coded at a second code rate to the rails of said second approach track section, all such coded current being supplied during the first part of first and second parts of said first timed cycle and in advance of said first end of the train; means controlled by said timing apparatus for supplying current coded at said first code rate to the rails of said second approach track section and to the rails of the track stretch between said approach sections, and current coded at said second code rate to the rails of said first approach track section, all such coded current being supplied during the first part of first and second parts of said second timed cycle and in advance of said second end of the train; means located within said second track section and controlled by said timing apparatus for supplying to said first set of receiving apparatus on the train during said second part of the first timed cycle current coded at a third code rate, means located within said first track section and controlled by said timing apparatus for supplying to said second set of receiving apparatus on the train during said second part of the second timed cycle current coded at said third code rate, a train-carried device selectively responsive to the speed of the train, means controlled by said first set for receiving apparatus and said speed responsive device for supplying propulsion power of a first polarity to the motors of the train when such set of receiving apparatus is receiving current coded at said second code rate and the speed of the train is below a lower limit of a low speed range; means controlled by said first set of receiving apparatus and the speed responsive device for controlling an application of the train brakes when such set of receiving apparatus is receiving current coded at said first code rate and the speed of the train is above an upper limit of said high speed range, and when such set of receiving apparatus is receiving current coded at said second code rate and the speed of the train is above an upper limit of said low speed range; means controlled by said first set of receiving apparatus and the speed responsive device for controlling an application of the train brakes when such set of receiving apparatus is receiving current coded at said first code rate and the speed of the train is above an upper limit of said high speed range, and when such set of receiving apparatus is receiving current coded at said second code rate and the speed of the train is above an upper limit of said low speed range; means controlled by said second set of receiving apparatus and said speed responsive device for supplying propulsion power of a second polarity opposite to said first polarity to the motors of the train when such set of receiving apparatus is receiving current coded

at said first code rate and the speed of the train is below said lower limit of said high speed range, and when such set of receiving apparatus is receiving current coded at said second code rate and the speed of the train is below said lower limit of said lower speed range; means controlled by said second set of receiving apparatus and said speed responsive device for controlling an application of the train brakes when such set of receiving apparatus is receiving current coded at said first code rate and the speed of the train is above said upper limit of said high speed range, and when such set of receiving apparatus is receiving current coded at said second code rate and the speed of the train is above said upper limit of said low speed range; and means controlled by each said set of receiving apparatus for opening the doors of the train when such set of apparatus is receiving current coded at said third code rate.

7. A system for automatically controlling the movement of crewless train over a stretch of railway track, said system comprising, means for transmitting to the train a first distinct signal when the train is standing at a first point in the stretch, means on the train responsive to the receipt of said signal for releasing the brakes of the train and controlling the motive power of the train to start the train and accelerate it to a first speed range and for thereafter maintaining the speed of the train within said speed range so long as said signal is received, means for interrupting the transmission of said signal and transmitting to the train a second distinct signal when the train reaches a second point in said stretch, means on the train responsive to the interruption of said first signal for applying the brakes of the train to reduce the speed of the train to a second speed range, means on the train responsive to the receipt of said second signal for thereafter controlling the motive power of the train and the brakes of the train to maintain the speed of the train within said second speed range so long as said second signal is received and for applying the train brakes when the receipt of the second signal is interrupted; and means for interrupting the transmission of said second signal when the train reaches a third point in said stretch, said third point being located in advance of a prescribed stopping area in said stretch and being so chosen in accordance with the speed of the train at that point and the retardation effect of the train brakes that the train will stop with a prescribed portion of the train within said prescribed stopping area.

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