# United States Patent [19]

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[54] **TRAIN SPEED CONTROL SYSTEM**


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[52] **U.S. Cl.**........ **246/63 C,** 246/34 CT, 246/187 B

[51] **Int. Cl.**.............................................. **B61l 3/10**

[58] **Field of Search**.........246/34 CT, 63 C, 63 R, 187 B, 246/36; 303/21 P, 20


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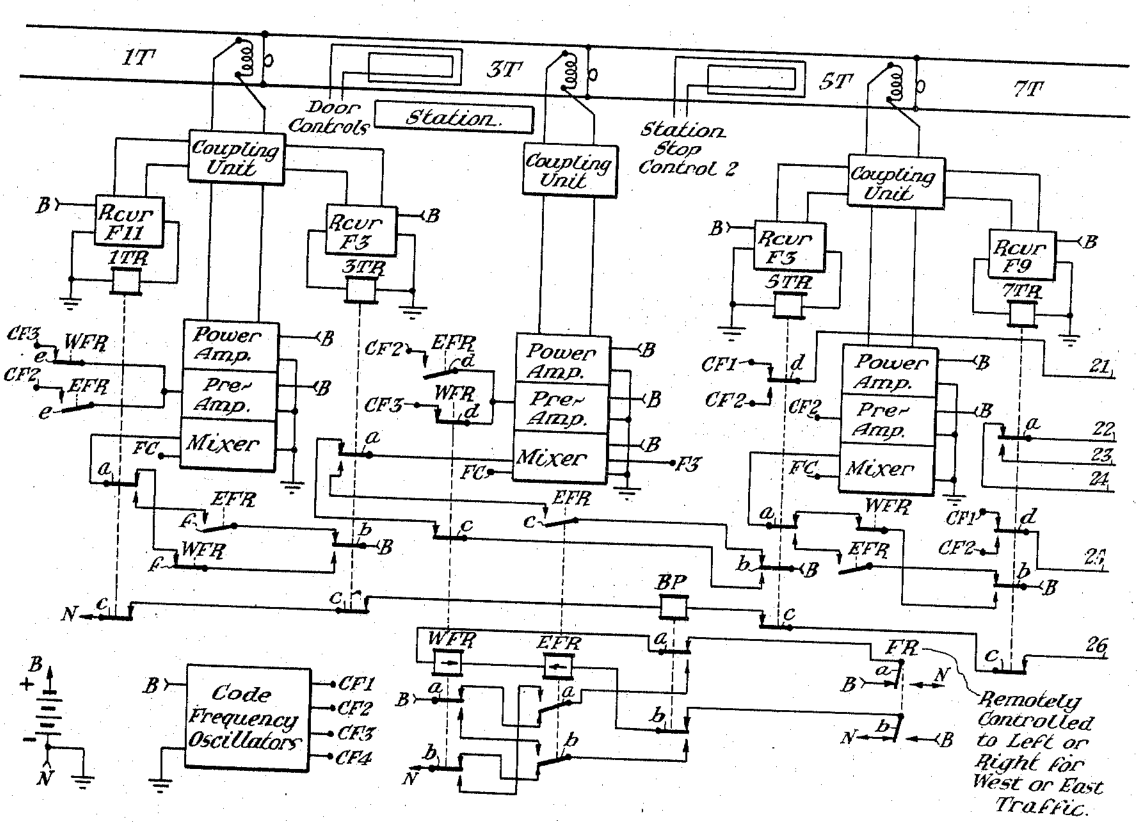
[57] **ABSTRACT**


High frequency detector track circuits are coupled to the rails at crossbonds which divide the track stretch into sections without insulated joints. The HF transmitters supply track energy both directions from alternate bonds into each track section of the adjoining pair. Correspondingly tuned receivers at the other end of each section control track relays which indicate the track occupancy condition. Successive pairs of track sections have different frequencies selected on a random basis from a predetermined plurality. Train control energy of a different, single frequency is supplied to the rails at the exit end of each section and is modulated by one of a plurality of low frequency code rates selected in accordance with the track occupancy condition of advance sections as determined by the track circuits. Each train is equipped with train control apparatus including at least cab signals and overspeed protection. Receivers inductively coupled to the rails pick up and supply the speed signals through a demodulator and active filters to register an allowed speed indication in accordance with the detected code rate. Train speed sensing apparatus registers the actual train speed. Overspeed detection apparatus then compares allowable and actual speeds, detects an overspeed condition, and actuates an automatic braking action if the train operator does not initiate a speed reduction within a preset time limit.


**9 Claims, 4 Drawing Figures**



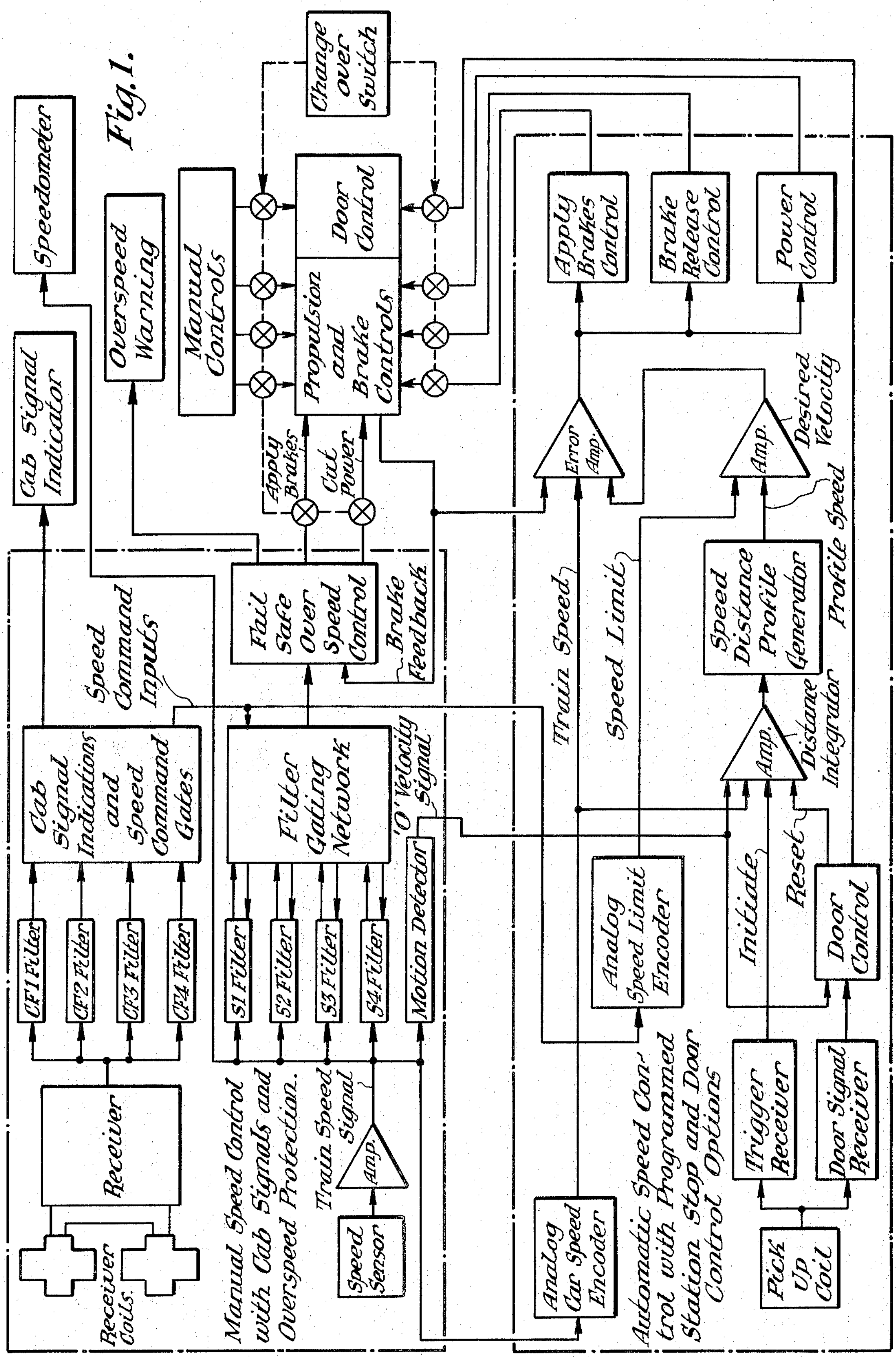

Speedometer
Cab Signal Indicator
Overspeed Warning
Manual Controls
Change over Switch
Door Control
Propulsion and Brake Controls
Apply Brakes
Cut Power
Apply Brakes Control
Brake Release Control
Power Control
Error Amp.
Amp.
Desired Velocity
Profile Speed
Fail Safe Over Speed Control
Brake Feedback
Speed Command Inputs
Train Speed
Speed Limit
Speed Distance Profile Generator
Distance Integrator
Cab Signal Indications and Speed Command Gates
Filter Gating Network
'O' Velocity Signal
Initiate
Reset
CF1 Filter
CF2 Filter
CF3 Filter
CF4 Filter
S1 Filter
S2 Filter
S3 Filter
S4 Filter
Motion Detector
Analog Speed Limit Encoder
Door Control
Receiver
Receiver Coils
Manual Speed Control with Cab Signals and Overspeed Protection.
Train Speed Signal
Amp.
Speed Sensor
Analog Car Speed Encoder
Automatic Speed Control with Programmed Station Stop and Door Control Options
Trigger Receiver
Door Signal Receiver
Pick Up Coil

Fig. 1.

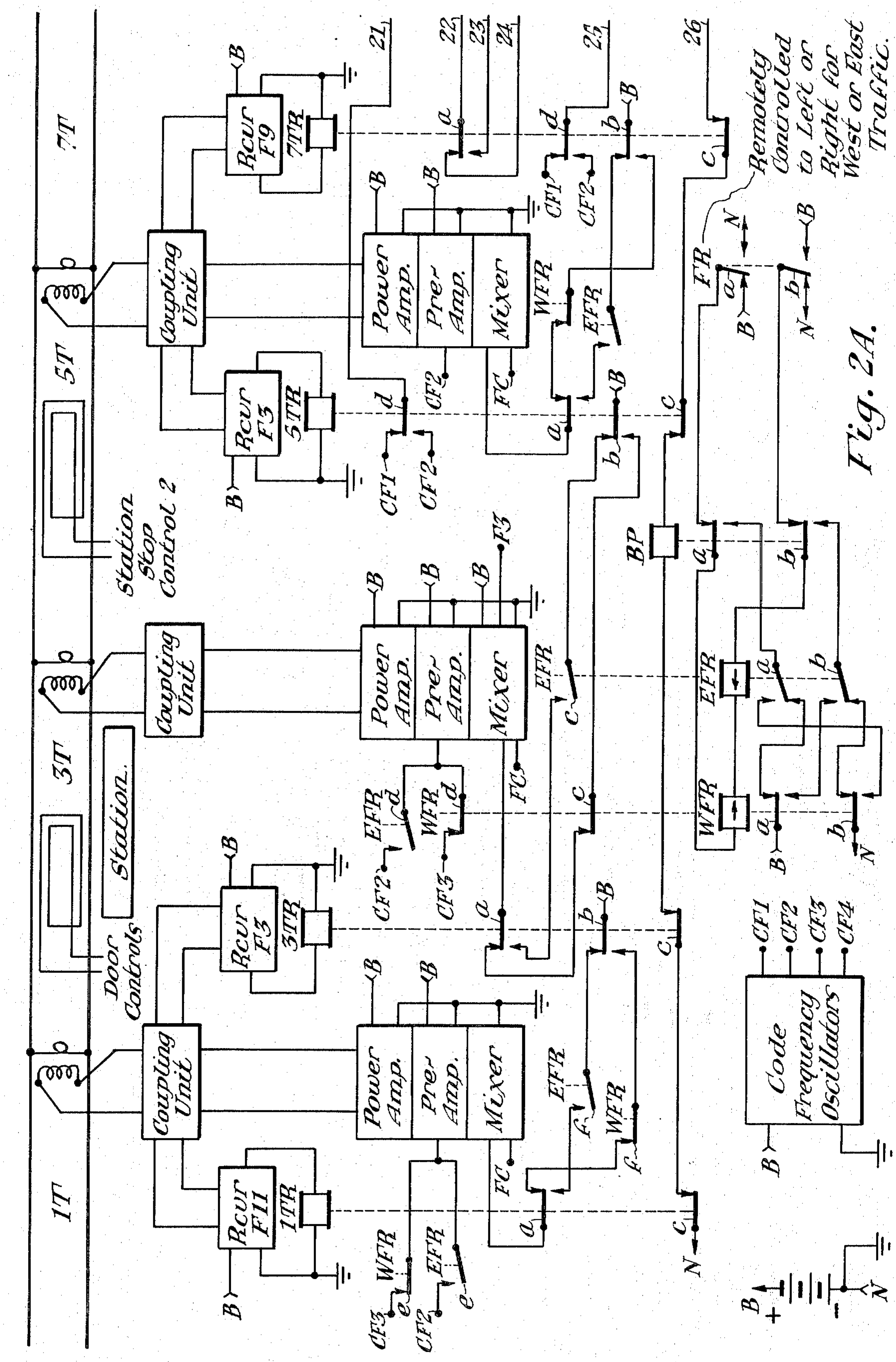

1T
3T
5T
7T
Coupling Unit
Coupling Unit
Coupling Unit
Rcvr F11
Rcvr F3
Rcvr F3
Rcvr F9
1TR
3TR
5TR
7TR
Power Amp.
Pre Amp.
Mixer
Power Amp.
Pre Amp.
Mixer
Power Amp.
Pre Amp.
Mixer
Door Controls
Station.
Station Stop Control 2
EFR
WFR
BP
FR
Code Frequency Oscillators
CF1
CF2
CF3
CF4
21
22
23
24
25
26
Remotely Controlled to Left or Right for West or East Traffic.

Fig. 2A.

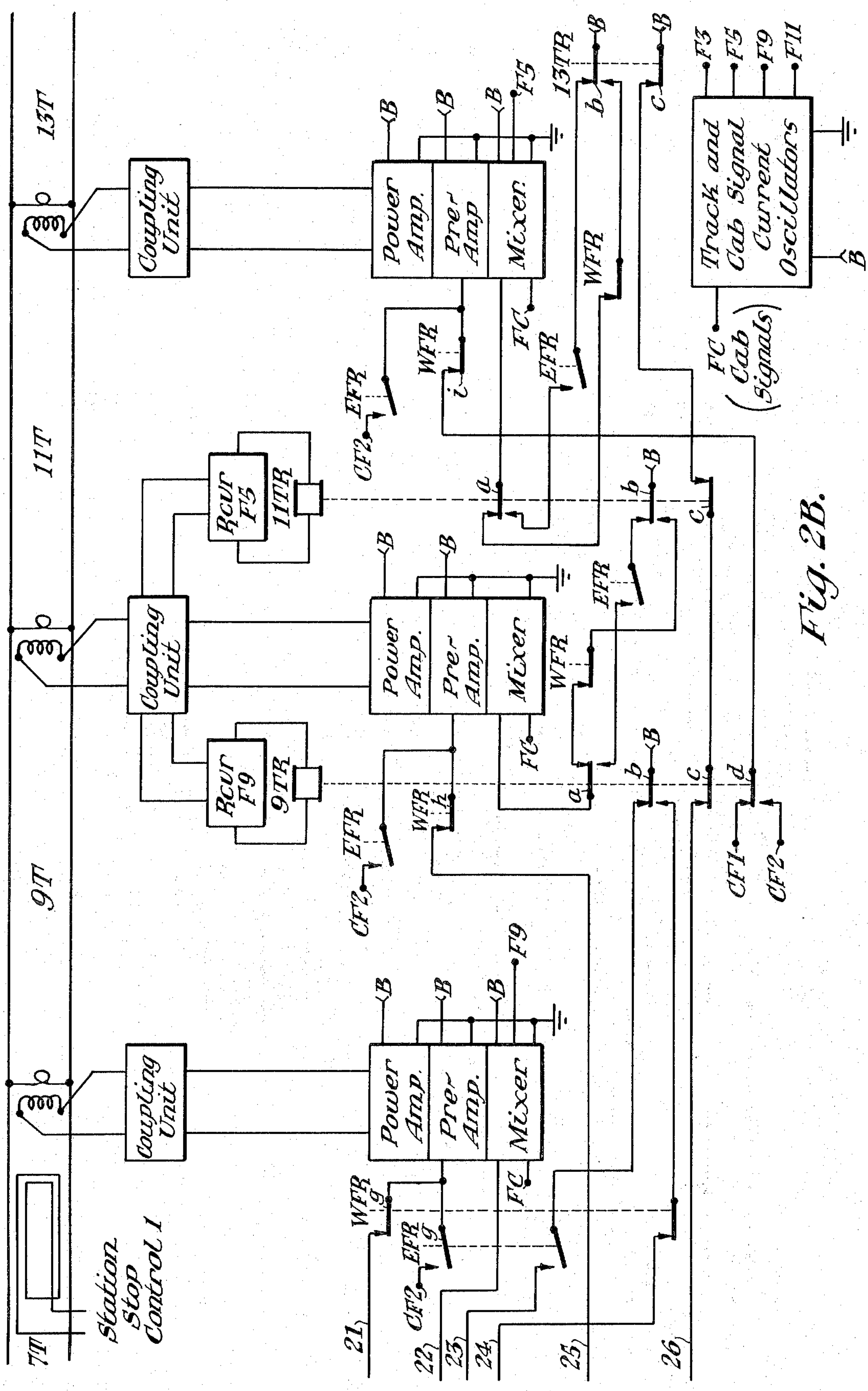

7T
9T
11T
13T
Station Stop Control 1
Coupling Unit
Coupling Unit
Coupling Unit
Power Amp.
Pre-Amp.
Mixer
Rcvr F5
11TR
Rcvr F9
9TR
13TR
WFR
EFR
CF2
CF1
FC
F5
F9
F11
F3
B
Track and Cab Signal Current Oscillators
FC (Cab Signals)
21
22
23
24
25
26

Fig. 2B.

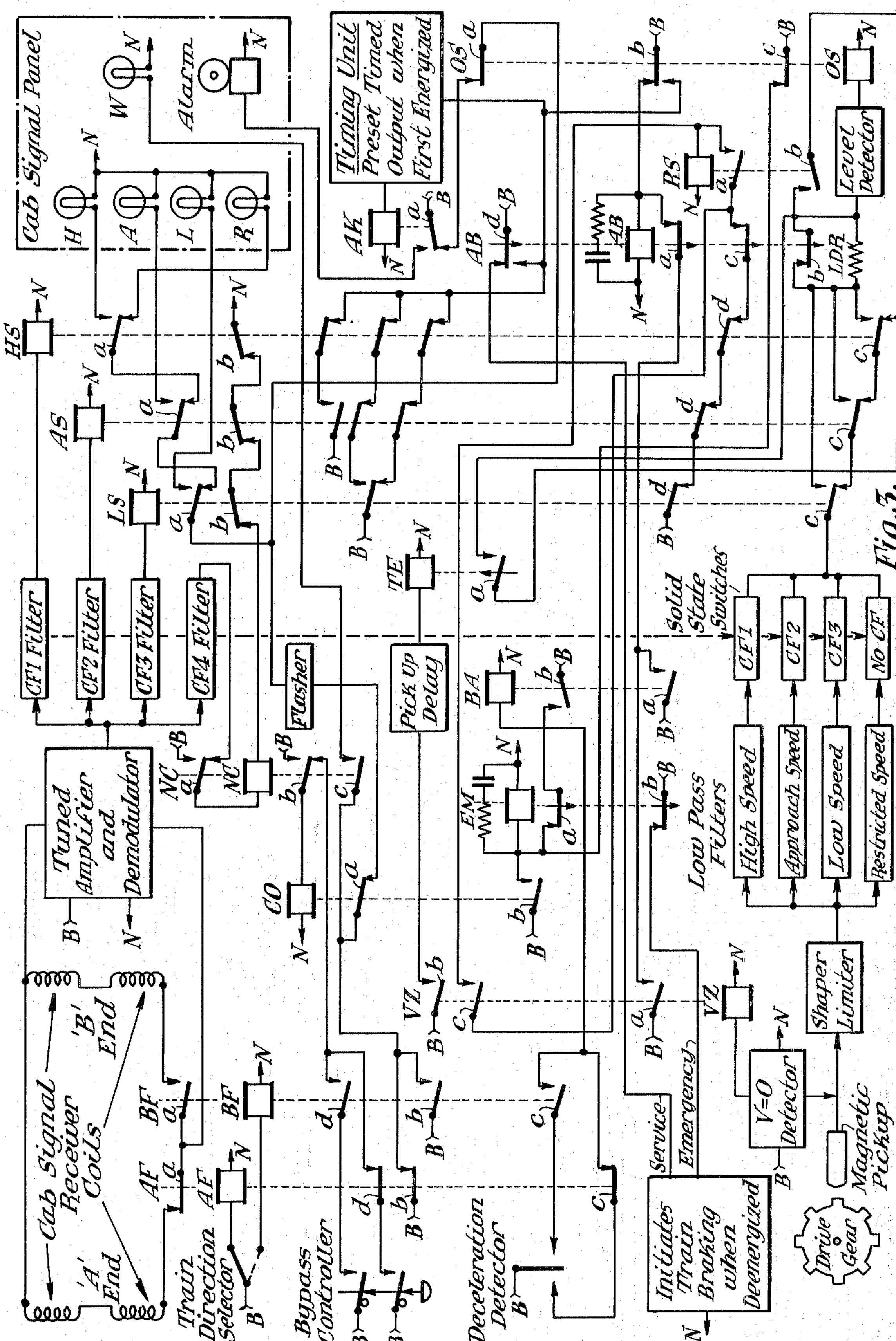

Cab Signal Panel
Alarm
Timing Unit
Preset Timed
Output when
First Energized
Level Detector
CF1 Filter
CF2 Filter
CF3 Filter
CF4 Filter
Tuned Amplifier and Demodulator
Flasher
Pick Up Delay
Solid State Switches
Low Pass Filters
High Speed
Approach Speed
Low Speed
Restricted Speed
Shaper Limiter
V=0 Detector
Magnetic Pickup
Drive Gear
Initiates Train Braking when Deenergized
Service
Emergency
Deceleration Detector
Bypass Controller
Train Direction Selector
Cab Signal Receiver Coils
'A' End
'B' End

Fig. 3.

## TRAIN SPEED CONTROL SYSTEM

Our invention pertains to a train speed control system. More particularly, the invention is an arrangement in which the actual speed of a train moving along a stretch of track is compared to the allowable speed established by traffic conditions in advance, and the train is controlled to bring the speed within the existing allowable speed limits.

In all railroad systems, including those specifically defined as being rapid transit systems, the matter of safe control of train speed is of prime importance. Various speed control systems, in use and known to the art, provide selected degrees of sophistication of control. In general, each such system is designed specifically to provide the desired degree of speed control. All such systems require wayside means to detect the presence of the trains moving through the stretch and their location within predetermined sections. All systems further require wayside means which can transmit this information onto the train to establish the speed at which it may move based on the position of trains in advance along the track and/or existing track hazards. These means for transmitting speed information onto the train may or may not be the same apparatus as used for the detection of train position. Further, each train is equipped with apparatus for receiving and decoding the speed indications received from the wayside and for providing a corresponding signal for the train operator or control apparatus. Each train requires some means for measuring and registering its own speed and for comparing this registered speed with the maximum allowable speed. Having completed the comparison, apparatus is then needed to actuate the necessary controls or to indicate to the operator when an overspeed condition exists. Due to the multiplicity of the present systems, depending upon the sophistication of the control desired, a basic system which provides the listed features and is also adaptable to any degree of train control sophistication will be advantageous in the art. In other words, a single basic system is desirable which is compatible with all systems from simple overspeed protection with manually operated control to the full automation of train operation.

Accordingly, an object of our invention is an improved speed control system for railroad trains.

Another object of the invention is an improved speed control arrangement for railroad trains compatible with any desired degree of automation in the train operation.

A further object of the invention is a speed control system for a stretch of railroad track including a simplified train detection apparatus, a superposed signal system for transmitting a speed signal onto trains traversing the stretch, and efficient train-carried means for comparing the allowed and actual train speeds to actuate the necessary controls for maintaining but not exceeding the allowed speed.

Still another object of our invention is a train control system for a stretch of track including high frequency track circuits for train detection, a single selected frequency, code modulated in accordance with advance traffic conditions, for transmitting allowed speed signals to trains traversing the stretch, and train-carried apparatus for receiving the allowed speed signals, recording the actual speed of the train, and comparing the speeds to actuate overspeed control measures when such conditions are detected.



A still further object of the invention is a train speed control system including high frequency track circuits for detecting trains occupying a stretch of track, superposed code modulated, single different frequency track circuits for transmitting the allowed speed signals, and, on each train, signal receivers inductively coupled to register the allowed speed signal from the track, speed sensing apparatus to determine the train speed, and signal comparison apparatus for comparing the allowed and actual speed registered signals to control the overspeed protection apparatus to actuate braking procedures to maintain the train speed equal to or less than the allowed speed.

Other objects, features, and advantages of our invention will become apparent from the following specification, accompanying drawings, and appended claims.

## SUMMARY OF THE INVENTION

In practicing our invention, a stretch of railroad track is divided into sections by crossbonds connected between the rails at the junction locations between desired track sections. No insulated joints are inserted in the rails at these points, thus maintaining a continuous rail for propulsion return where electrified operation is in effect, particularly as in rapid transit systems. Train detection throughout the stretch is provided by high frequency track circuits. The high frequency energy transmitters are coupled to the rails through the crossbonds at alternate bond locations and feed in both directions into the rail. Thus, each pair of adjoining track sections or track circuits has the same frequency. However, the successive track circuit pairs are assigned different frequencies which are shown as generated at centralized oscillator units, amplified, and then coupled to the rails at the proper section junctions. Two track circuit receivers are coupled to the rails at the intervening bond location between the transmitters, one receiver for each adjoining track circuit. Each such receiver is tuned to respond only to the track circuit frequency of the associated transmitter at the other end of the corresponding track section.

A separate energy transmitter with a different frequency is also coupled to the rails at each bond location to provide train control track energy. A single oscillator unit generates a selected single frequency for the train control track circuits. Such an oscillator may be part of the same bank of oscillators which provide the basic energy for the detector track circuits but having a different selected frequency. The train control track circuit energy is supplied also from the central location for the stretch to each bond location and is activated to supply such energy to the rails at the exit end of the section only when a train enters at the opposite end. For each section, the train control, or speed control, energy is modulated by a code frequency selected in accordance with the advance traffic conditions throughout the stretch as detected and determined by the high frequency detector track circuits. The code frequency is selected at the instant the train enters the track section although the selection may change in accordance with changes in the advance traffic conditions while the train is traversing that particular track section. Each code frequency represents a preset different maximum allowed speed for train movement. These code frequencies representing speed limits are generated at the central location for the stretch, and the modulation is determined by the detector track circuit apparatus in accordance with train occupancy. The actual modulation selection is accomplished over contacts of track relays which are actuated by the track circuit receivers. Such relays are used in order to provide a final degree of fail-safe operation to the track circuits. It is emphasized that in our inventive arrangement, for a particular stretch of railroad track, all apparatus except crossbonds is concentrated at a central location, that is, the frequency oscillators, amplifier transmitters, track receivers, coupling units, and track relays. From this central location, direct connections are made to the crossbonds for coupling the energy to or from the rails of a specific track section, the crossbond apparatus connected between the rails being the only device located at the actual junction between the track sections.

Each train traversing the stretch of track is equipped with train control apparatus which is capable of receiving an allowed speed signal from the rails and displaying a corresponding indication, comparing the actual train speed and the allowed speed, and controlling the speed of the train in accordance with the relationship. The speed control provided may be of any one of several degrees of sophistication, from a mere overspeed warning to full automatic train operation. The train-carried receiving apparatus is inductively coupled to the rails and tuned to receive only the modulated cab signal or train control energy transmitted through such rails. The received energy is amplified and demodulated and then filtered in accordance with the existing code or modulation frequency to energize a selected speed indication relay corresponding to the received code frequency and thus to a designated maximum allowable speed. Through a matrix of contacts of these relays, the corresponding speed indication is selected for display on a signal panel. The actual train speed is measured by a magnetic pickup from the driving gears which generates an alternating current voltage whose frequency varies in accordance with the actual train speed. This alternating current developed as a measure of train speed is then shaped and passed through various low pass filters, one filter being provided for each maximum speed range represented by the signals picked up from the rails. These low pass filter outputs are passed through solid state switches, one to each filter which is closed only when the corresponding speed signal received from the rails represents an allowable speed corresponding to the actual speed signal passed by that filter. The output from the solid state switches is passed through a checking circuit matrix, composed primarily of speed relay contacts, to a voltage level detector to check that the actual speed of the train corresponds to the received allowable speed signal. The level detector output energizes an overspeed relay. This relay releases if an overspeed condition occurs so that the output through the low pass filter and corresponding switch decreases below the level at which the level detector will provide sufficient relay energization. Release of the overspeed relay actuates automatic train braking apparatus if there is no action by the train operator. Various check and timing arrangements are provided to allow the train operator a preselected time in which to take action and further to assure that braking is actually occurring. An added zero velocity detector provides, through the filter and switch circuit paths, an alternating current frequency sufficient to hold the overspeed relay energized when the train is stopped. This allows the train to start again when a proceed signal is received from the track.

## BRIEF DESCRIPTION OF THE DRAWINGS

Prior to defining the novel features of our invention in the appended claims, we shall describe now the system apparatus in more detail, referring from time to time to the accompanying drawings in which:

FIG. 1 is a block diagram of the train-carried apparatus illustrating, in addition to the parts provided by our invention, options of automatic train operation which may be added to the basic arrangement.

FIGS. 2A and 2B, when placed adjacent, provide a diagrammatic illustration of the wayside apparatus for a stretch of track which cooperates with apparatus similar to that of FIG. 1 to complete a speed control system for the trains embodying the arrangement of our invention.

FIG. 3 illustrates, in a diagrammatic manner, a specific train-carried apparatus which cooperates with the wayside circuits of FIG. 2 to provide a complete basic speed control system embodying our invention.

Where possible, similar reference characters designate equivalent or similar apparatus in each of the drawings. In FIG. 3, where energy is required for the operation of specific apparatus, connections to the positive and negative terminals of a suitable source of direct current energy are designated by the references B and N, respectively. The specific direct current energy source for FIG. 3 apparatus is not shown since several suitable sources are known in the art, any one of which may be used. In the parts of FIG. 2, a source of direct current energy for operating all the apparatus is shown as a battery, designated by a conventional symbol in the lower left of FIG. 2A, with positive and negative terminals again designated by the references B and N, respectively. Where these references appear elsewhere in FIGS. 2A and 2B, they designate a connection to these terminals of the battery. The negative or N terminal of the battery is also connected to a common ground for the wayside system designated by a conventional symbol. Therefore, a connection elsewhere in these circuits to the ground terminal is an actual connection also to terminal N of the source.

## DETAILED DESCRIPTION OF BASIC SYSTEM APPARATUS

Referring now to FIG. 1, a block diagram of train-carried apparatus is illustrated embodying our invention and including some options which may be added for more sophisticated control of the train speed. The upper dot-dash rectangle includes, as noted, the apparatus which provides cab signals and overspeed control when manual operation of the train is in effect, either selected by positioning the changeover switch shown at the far right or by providing none of the additional options available. The lower dot-dash rectangle includes the apparatus which would be added, either partially or in whole, to provide automatic speed control, station-stop control, and door control so that the entire package of apparatus on the train would provide for automatic train operation. The conventional blocks shown outside the dot-dash rectangles represent the train propulsion apparatus and associated controls including cab signal indicators, a speedometer, and an overspeed warning device. As previously mentioned and as illustrated, even if all of the apparatus is chosen for automatic train operation, provision is still made for manual control selection by a changeover switch which converts between manual and automatic operation as may be necessary. These controls are illustrated at the right of FIG. 1 by the changeover switch block and the dotted line indicating the various changeover connections, depending upon the control selected by the switch position.

Considering now the basic apparatus, a train control signal supplied in the rails is received through inductive coupling by the receiver coils shown in the upper left and fed into a receiver unit. This receiver, shown conventionally, amplifies and demodulates the received signal and a single code or modulation frequency output is applied to the bank of code frequency filters, each turn to pass an indicated signal. The resulting filter output activates a selected gating arrangement to establish a circuit for displaying a cab signal indication designating the maximum allowable train speed under the existing traffic conditions. Simultaneously, the train speed is sensed and an amplified signal representing the speed is applied to a bank of low pass filters, each representing a particular speed range used in the operation, the output being applied to a filter gating network. This gating network is also responsive to the received speed signal from the rails to allow a comparison between the actual and allowed speed ranges. If the actual train speed is within the allowable limits determined from the track signal pickup, the overspeed control is maintained in the condition to permit the train to continue its movement along the rails. If an overspeed condition is detected, the overspeed control apparatus actuates a braking action and removes the propulsion power from the train. If the train is in manual operation under control of a train-carried operator, either because the changeover switch is so positioned or because that type of control has been installed, such operator exercises the manual controls in accordance with the cab signals, the speedometer indication, and the overspeed warning to avert emergency stops. In exercising such control, certain reaction time delays are applied to the automatic braking applications to allow the operator time to institute the proper braking and propulsion controls to bring the train speed within the allowable limits.

If automatic train operation is provided and is selected by the changeover switch, the actual and allowed speed signals are applied to encoders shown within the lower dot-dash rectangle. The allowed speed limit signal is then applied through a comparing amplifier to develop a desired velocity signal. This desired signal, together with a signal representing the actual train speed, and a brake feedback signal are compared in the error amplifier to develop the proper signal to control the train propulsion apparatus. In accordance with the character of this signal, a brake applying or brake release control and various types of power propulsion controls are applied through corresponding devices to the train propulsion and brake apparatus. The resulting control of the train movement brings the speed of the train within the allowable limits designated by the signal picked up from the rails and already processed.

If the full automatic train operation provided includes the station stop and door control options, an additional pickup coil mounted on the train receives a station stop signal from the wayside at locations in approach to the station platform, as illustrated in FIGS. 2A and 2B and which will be discussed in some detail in connection with the wayside apparatus. When the station stop control signals are picked up and recognized by the trigger receiver, they are applied to an amplifier which serves as a distance integrator. The actual train speed signal is also applied to this amplifier together with a zero velocity signal when the train is actually stopped. This distance integrator amplifier provides a signal of the train location with respect to the station location in advance to a distance profile generator. This latter unit outputs a profile speed to the desired speed amplifier which, also comparing it with the allowable speed limit, controls the desired velocity signal in order to assure a station stop under a full automatic control of the train propulsion and braking apparatus. A door control signal is received by this same pickup coil within the station platform area, as illustrated in FIG. 2A. The zero speed signal and the door signal actuate a door control device which outputs a signal to cause the opening of the train doors at the station platform. The door control also resets the distance integrator since a station stop has been made and the speed distance profile generator may be reset for a subsequent station stop operation. The door opening and closing, that is, the actual time open, may be on a preset time basis or may be terminated by the operator actuating a closing control. The train then resumes its automatic train operation mode and moves away from the station under control of the allowable speed signals received from the track circuits. This automatic train operation apparatus is not a specific part of the present invention but this conventional illustration is provided to show how it might be interfaced with the basic apparatus provided by the arrangement embodying our invention. Several types of such automatic operation apparatus are available and thus the conventional block diagram illustration is here used, it being only necessary to know that the actual train speed signal and an allowable train speed signal need be provided for purposes of the train movement control together with trigger signal pickups from the track to initiate station stop procedures and door opening controls.

We shall now described the wayside apparatus which is part of our inventive system to provide the train detection and train control signals necessary for the operation of the train-carried apparatus. Reference will be made to FIGS. 2A and 2B, when placed adjacent with FIG. 2A to the left and the corresponding connecting lines matched, during the description of the wayside apparatus. When these two drawings are thus positioned, across the top in conventional double line representation is shown a stretch of railroad track. Although our invention is not limited to specific systems, it is herein assumed that this track is part of a rapid transit system in which the trains operate by electric propulsion. Such trains normally move from right to left in the drawing, which direction will be designated as the westbound direction. However, when so directed and established by the dispatcher in charge, trains may on occasion move in the reverse direction over the stretch of track shown. The track stretch is further divided into track sections by crossbonds connected between the rails. Each section thus established is designated by the reference T with a numerical prefix, odd numbers in succession from left to right. Thus, the section at the left is designated as section 1T and the numbers increase numerically in odd-numbered progression so that section 13T is shown at the right.

The crossbonds effectively join the two rails into a single propulsion return path since no insulated joints are used. In other words, each rail is a continuous electrical circuit path and the bonds, by connecting them together at periodic intervals, equalize the return current flowing in each rail. Each bond is illustrated as comprising a single turn primary winding which actually connects between the two rails and a multi-turn secondary winding coupled thereto and to which the wayside apparatus is connected. Although several types of such bonds exist, a specific example is that illustrated in Letters Patent of the U.S. Pat. No. 3,268,843, issued to Ralph Popp on Aug. 23, 1966 for Electric Induction Apparatus. The connections from the secondary of each crossbond to the other wayside apparatus are through coupling units which are shown by conventional blocks since the circuit design of such coupling units is well known in the art. Actually the circuitry within each coupling unit varies in accordance with the type and amount of wayside apparatus which is being coupled to a particular crossbond. It is herein assumed that all the wayside apparatus for the stretch of track shown, except for the crossbonds themselves, is located in some form of central housing. The connections from each coupling unit to the associated crossbond are then made by a direct pair of wires or a pair in a cable extending along the wayside. In rapid transit system operation, where relatively short track sections are used, such central housing of the apparatus for a particular stretch is possible and practical. It is also assumed that the stretch shown is that between the station whose platform is shown adjacent track section 3T and the immediately preceding station for the normal traffic direction which is adjacent to the next track section 15T off the right-hand of the drawing. Section 13T, a portion of which is shown, is actually a part of the preceding stretch of track but is here shown to complete the overall operating concept.

Each track section is provided with a high frequency track circuit for train detection purposes. In each such circuit, the energy source is at one end of the section and the receiver apparatus with a final track relay, designated by the reference TR, at the other end. For purposes of track circuit energy supply, the sections are paired in succession along the stretch of track and a single common track circuit energy source, of a frequency distinct from that of adjacent pairs, provided at the adjoining ends of each pair of sections with receivers being at the opposite ends. Said another way, in effect each pair of track circuits is provided with a common center fed track circuit with the energy source at the junction of the adjacent ends of the pair and the two tracks relays located at the distant ends of the pair. Each track section is also provided with a track circuit for train control or speed control signaling purposes. This is also a high frequency track circuit but the same high frequency energy, different than used in any detector track circuit, is used for each section to enable the train apparatus to have a single type of tuning and thus be of a more simple nature than if different frequencies were used. For the train control track circuits, energy is supplied to the rails at the exit end of each track section in accordance with the selected direction of train operation. This energy is coded or modulated in order to provide more than one speed signal or instruction representing allowable train speeds. The receiver for such train control energy is on the train, to be later discussed, and no wayside receivers for this train control frequency track circuit are used. It will be noted that all track circuit energy, that is, all energy provided to the rails, is coupled to the rails through the previously described cross-bonds. In addition, at each junction point between track sections where track energy is supplied, the coupling unit provides an additional interface between the wayside apparatus and the track crossbond.

Before specifically describing in detail the track circuit and train control energy circuits, we shall describe the central apparatus for generating the selected frequencies for the various track circuits and the code or modulation frequency source for such circuits. Since it is assumed that a central housing for wayside apparatus along each stretch is provided, a central source for the track circuit and train control frequencies is entirely practical. In the lower right of FIG. 2B, illustrated by conventional block, are the oscillators for the high frequencies used for the track circuits, different frequencies being used to obtain separation and non-interference between the track circuits for adjacent pairs of track sections. Any type of oscillator which will provide reliable service may be used and the details are not part of our inventive concept. The block is shown as providing four detector track circuit high frequency outputs, designated as F3, F5, F9, and F11, and a single train control or cab signal frequency output designated as FC. The frequency of the output FC is the same not only for all track sections within this stretch but for all stretches of track for the overall assumed transit system in which cab signal or speed control is provided. The intervening high frequency outputs in the numerical succession will be used in other stretches. Each such central oscillator unit may provide all frequencies so that ready interchange of a single unit between different stretches of track is possible. In one specific case, the high frequency range for the detector track circuits was from 2.5 to 6.0 KHz. In the same installation, the cab signal or train control frequency was selected at 990 Hz, in other words, on the order of 1KHz.

The single, central code or modulation frequency source is shown by a similar conventional block in the lower left of FIG. 2A. This group of oscillators provides four outputs shown as being the code frequencies CF1, CF2, CF3, and CF4, but additional code frequencies may be used if additional instructions for speed control are required. These are conventional oscillator circuits known in the art, any of several types being useable which will provide a square wave output at the selected code frequency. In the specific system previously mentioned, the code frequencies were selected in the range from 5.0 to 16.8 Hz. It is herein specifically assumed also that code frequency CF1 designates a 50 mph allowable maximum speed; frequency CF2, 25 mph; and frequency CF3, 15 mph. These three speed limits are otherwise designated as high, approach, and low speed limits. Code frequency CF4 is a special cutout signal which, when received on board the train, locks out the speed control equipment when a train departs from speed control territory into a stretch of track in which cab signals and/or speed control is not provided. Such lockout enables manual operation without automatic emergency braking provision and the principle of such lockout operation is known in the prior art. It is further obvious that the specific high frequency, the train control frequency, and the code frequency ranges given are examples only and not limitations on the system embodying our invention.

There is one other item of central apparatus, the traffic direction selection arrangement. Traffic direction is registered by the traffic relay WFR for westbound traffic, and relay EFR for eastbound traffic. These are biased relays, as indicated by the arrow within the relay winding symbol, and are properly energized to pick up and close front contacts only when current flows through the relay winding in the direction of the arrow. The circuits for these relays are basically controlled by a traffic controller contactor FR which, as indicated by the note, is remotely controlled by the dispatcher of the system and operated to its left or right position for westbound or eastbound traffic direction, respectively. Since westbound traffic is normal, the contact arms of controller FR are normally in their left-hand position. The block repeater relay BP, associated with this traffic direction circuitry, releases to repeat the occupancy of any section of the stretch of track. A circuit for controlling this relay will be described later but basically the relay is picked up when there is no train occupying any portion of the stretch of track illustrated.

Under normal traffic conditions, a circuit for properly energizing relay WFR extends from terminal B of the source over FR contact *a* in its left-hand position, front contact *a* of relay BP, the windings of relays WFR and EFR in series, front contact *b* of relay BP, and FR contact *b* in its left position to terminal N. The conventional flow of current in this circuit is obviously such to properly energize relay WFR to close its front contacts while relay EFR is energized by reverse current and thus its contacts remain released. If reverse direction traffic is desired, controller FR, by remote control, is placed in its right-hand position so that a circuit may be traced from terminal B over FR contact *b* in its right-hand position, front contact *b* of relay BP, windings of relays EFR and WFR in series, front contact *a* of relay BP, and FR contact *a* in its right position to terminal N. This reverses the flow of current in the traffic direction relay windings so that relay EFR will pick up and relay WFR releases.

When relay BP releases to repeat the occupancy of the stretch by a train, holding circuits are completed for maintaining the traffic direction relays in their existing positions. For example, with westbound traffic established, the release of relay BP completes a circuit for holding relay WFR picked up which is traced from terminal B over front contact *a* of relay WFR, back contact *a* of relay EFR, back contact *a* of relay BP, the windings of relays WFR and EFR, back contacts *b* of relays BP and EFR, and front contact *b* of relay WFR to terminal N. Flow of current in this circuit obviously holds relay WFR picked up. An equivalent circuit is established if eastbound traffic is in existence when relay BP releases, the easily traced circuit including back contacts *a* and *b* of relay WFR and front contacts *a* and *b* of relay EFR to maintain the proper flow of current to the winding of relay EFR. Other contacts of relays WFR and EFR are shown elsewhere in the wayside circuit drawings, each designated by the relay reference and a lower case letter for a specific contact reference to distinguish it from other contacts.

We are now ready to discuss the train detector track circuits and the train control or cab signal energy circuits. At alternate bond locations where track circuit energy is received for train detection, two track circuit receiver units are coupled to the rails, one receiver for the track section in each direction from the junction location, the coupling being through the corresponding crossbond and associated coupling unit. Each track receiver is tuned to accept only coded track circuit energy of the frequency being transmitted through the section with which it is associated. Each receiver unit shown by conventional block includes a further designation indicating the track circuit frequency to which it is tuned. This tuning is broad enough to receive the basic track circuit frequency modulated with any of the code frequencies in use in the particular system. Such track receivers, in response to the reception of track circuit energy, demodulate the energy, provide various checks for the received energy, and energize the associated track relay only when the coded energy is of the proper carrier frequency. The details of these receiver units are not shown since any conventional circuits for tuning, amplification, demodulation, and detector arrangements may be used, preferably of course of solid state or integrated circuit type. The associated track relays are designated by the reference TR with a prefix in accordance with the track section with which they are associated. Thus, at the junction of sections 5T and 7T, at the right of FIG. 2A, are track relays 5TR and 7TR associated respectively with track sections 5T and 7T. It is to be noted that the track receivers at these locations are tuned for the basic track frequencies F3 and F9, respectively. Each track relay is energized by the associated receiver and picked up when the corresponding track section is not occupied by any part of a train. Conversely, the relay releases when one or more wheel and axle units of a train occupy any part of the corresponding track section.

Each crossbond location, that is, the location of each track section division, is provided with a bank of apparatus to provide track energy at the selected frequency and code rates provided by the common oscillator devices previously discussed. Each set of apparatus includes mixer and preamplifier sections and a final power amplifier to provide energy of sufficient level for track circuit operation. Each section or sub-unit incorporates conventional solid state or integrated circuit elements to perform the designated functions. Thus, each unit is shown by conventional block since the circuit details are not part of our invention and various specific circuit elements to provide the desired functions may be used.

Each mixer unit receives an input at the train control or cab signal frequency FC from the central oscillator. At alternate locations, that is, where detector track circuit energy is to be supplied, the mixer unit also receives a track circuit high frequency input from the same central oscillator unit. Each mixer unit also receives a code frequency input through a switching portion of the preamplifier element which in turn receives the code frequency from the code frequency central oscillator unit. The coded input actuates the alternate connection of the detector track circuit and cab signal frequencies to the mixer output at the selected code frequency. The alternate mixer outputs occur only when the corresponding energy connection to terminal B of the local source is complete. For example, for the mixer element of the apparatus associated with the junction between sections 3T and 5T, a permanent connection from terminal B to the right side of the mixer is provided for energizing the supply of track circuit energy at frequency F3. However, the connection to the left side of the mixer for the cab signal frequency energy is completed to terminal B only when one of two circuit paths is complete. The first includes front contact *a* of relay 3TR, front contact *c* of relay WFR, and back contact *b* of relay 5TR. This circuit is obviously complete when westbound traffic direction is established, section 3T is not occupied, and section 5T is occupied by a train. A second path includes back contact *a* of relay 3TR, front contact *c* of relay EFR, and front contact *b* of relay 5TR. This circuit path is active when eastbound traffic direction is established, section 5T is unoccupied, and a train first occupies section 3T.

At locations where detector track circuit energy is supplied, such as that just described, the corresponding mixer connection to terminal B is continuous. Where no detector track circuit energy is supplied, there is no such connection from the mixer element to terminal B nor to any HF terminal of the central oscillator unit. In such cases, although the alternate connections are made during the code frequency application, obviously no detector track circuit energy output from the mixer occurs, only the cab signal energy output portion being active. The output of the mixer section at whatever frequency and modulation, is supplied directly to and amplified in the preamplifier section to a level to properly drive the power amplifier portion. This power amplifier section further increases the signal energy to drive the detector track circuit and to also provide a sufficient level of track energy for cab signal receiver inductive pickup.

It will be noted, of course, that the same detector track circuit frequency is used for a pair of adjoining track sections, one each way from each track circuit supply location. However, a different frequency is used in the next pair in each direction and the shift is not in the successive order supplied by the track current oscillators but is variable. Such random selection assures that there will be no interference between adjacent center fed track circuits. As previously mentioned, the same cab signal frequency is used or supplied at each crossbond location in order to simplify the tuning and operation of the train-carried receiver elements. The code or modulation frequency is selected in accordance with the established traffic direction and the advance track section occupancy conditions. For a reverse traffic move, that is, in the eastbound direction, a single speed is fixed so that code frequency CF2 is always selected over a front contact of relay EFR when such traffic direction is established. For example, for the previously discussed apparatus supplying energy to the crossbond at the junction between sections 3T and 5T, the code frequency input to the preamplifier, and thus to the mixer element, over front contact *d* of relay EFR is from terminal CF2 of the code frequency oscillator. It will be noted, however, that this modulated cab signal energy at this code rate will not be supplied to section 3T for an eastbound move unless the power energy connection for the mixer element to terminal B is completed over front contact *b* of relay 5TR to assure that section 5T is not occupied by a train. Cab signal energy is also supplied only after the approaching eastbound train occupies section 3T, causing the release of relay 3TR to close its back contact *a*.

For westbound traffic, random traffic and/or hazard oriented speed selection is normally used in establishing the code frequency of the cab signal energy in the rails. However, near station locations, fixed maximum speed limits for westbound traffic are also used similar to the fixed limit for eastbound traffic. For example, for section 3T, the cab signal energy applied at the exit end of the section, the far left crossbond shown, is modulated at the fixed code frequency CF3 selected over front contact *e* of relay WFR for application to the preamplifier section. This provides the low speed limit, sufficient to start a train from the station location shown within section 3T. Nevertheless, this train is not permitted to leave the station, that is, section 3T, if advance section 1T is occupied by a preceding train. This check is assured by applying cab signal energy from terminal B to the mixer element over a connection including back contact *b* of relay 3TR, which is released with the train occupying the station area, front contact *f* of relay WFR, and front contact *a* of relay 1TR. Obviously, if section 1T is occupied, front contact *a* of relay 1TR will be open to interrupt the supply of energy from terminal B to the mixer element. However, if front contact *a* of relay 1TR is closed, then cab signal energy at frequency FC and modulated at code frequency CF3 is applied from the mixer unit through the preamplifier and power amplifier elements to track section 3T, the connections to the crossbond at the exit end of the section being as usual through a coupling unit. The westbound speed limit for section 5T is also fixed at the low speed, code frequency terminal CF3 being selected for application of coded energy to the preamplifier unit over front contact *d* of relay WFR. Again, the connection to terminal B for the associated mixer element is checked over front contact *a* of relay 3TR so that a train in section 5T is forced to stop if section 3T is also occupied.

Since the westbound speed limit for section 7T is fixed at the approach speed, a single connection from the preamplifier unit to terminal CF2 is sufficient, there being no selection necessary over contacts of the traffic relays since eastbound traffic in section 5T is also limited to this approach speed. However, the connection to terminal B for the mixer element of the associated units at this location, in order to generate a modulated cab signal energy, is checked over front contact *a* of relay 5TR for westbound traffic and over front contact *b* of relay 7TR for eastbound traffic so that west and eastbound traffic in sections 7T and 5T do not receive any cab signal energy if the advance track section for that traffic direction is already occupied. This connection to terminal B for the mixer element at this location over the multiple paths, depending upon the established traffic direction, is similar to that already discussed for the energy supply units at the junction of sections 3T and 5T. In fact, the mixer element at each location is connected to terminal B, to supply a modulated cab signal current, over a similar type circuit network. Obviously, such connections serve for either direction of traffic to apply a cab signal energy only upon the entry of a train into the section to which cab signal energy is being supplied.

At the junction between sections 7T and 9T, code frequency CF2 is selected over front contact *g* of relay EFR for modulating the cab signal energy applied to section 7T for reverse moves. However, the cab signal energy for section 9T for westbound traffic selects between code frequency CF1 and CF2. As usual, the connection to terminal B for the mixer element, which generates the cab signal energy at frequency FC and modulated at a selected code rate, is checked over front contact *a* of relay 7TR to assure that the immediately preceding advance track section is not occupied by a train. Obviously, no energy at frequency FC is applied into section 9T if this front contact is open indicating occupancy of section 7T by a train. However, if section 7T is clear, further selection between code frequencies CF2 and CF1 is made in accordance with the occupancy condition of section 5T. This selection circuit, tracing from the preamplifier unit, includes front contact *g* of relay WFR, closed for the usual westbound traffic condition, and thence over the interdrawing connection line **21.** Terminal CF1 or CF2 is selected, respectively, as front or back contact *d* of relay 5TR is closed to indicate no occupancy or occupancy of section 5T. Thus, a train entering section 9T will receive a high or approach speed cab signal indication depending upon the occupancy condition of section 5T if section 7T is checked clear.

Similar code frequency selections are made for the cab signal energy applied to sections 11T and 13T for westbound moves. The code frequency selection for the preamplifier unit at the junction between sections 9T and 11T, when westbound traffic is established and thus front contact *h* of relay WFR is closed, is made, tracing over interdrawing connector **25,** by contact *d* of relay 7TR, this being the track relay for the second section in advance of section 11T. If the section is clear, front contact *d* of relay 7TR selects code frequency CF1, but if the section is occupied, back contact *d* selects code frequency CF2. Of course, the application of any cab signal energy is dependent upon front contact *a* of relay 9TR being closed. For section 13T, assuming that front contact *a* of relay 11TR is closed to indicate no occupancy of the immediate preceding advance section, code frequency selection for the preamplifier unit is made over front contact *i* of relay WFR and thence over front contact *d* of relay 9TR to apply a code frequency CF1, or if section 9T is occupied, over back contact *d* of relay 9TR to select a code frequency CF2.

Although each track section T illustrated in FIGS. 2A and 2B appears of relatively equal length, actually the track sections closer to the station location in section 3T are of shorter length so that the lower maximum speed limit does not adversely affect the average speed for train operation throughout the entire system. These shorter track section lengths are practical since the lower maximum speed allowed permits shorter train stopping distances if emergency braking is necessary. It is obvious too that the specific speed selections for the various sections for westbound moves and the single speed selection for eastbound moves illustrated herein are by way of example only. Actual installations embodying our invention are not limited to such specific speed selections but cab signal application of allowable speed limits will be in accordance with the characteristics and requirements of any particular installation.

It is to be noted that the circuit network for connecting terminal B of the energy supply to the cab signal energy side of the mixer element at the junction between sections 11T and 13T includes front and back contacts *b* of track relay 13TR. The winding for this relay is not shown since it would be located at the central housing for the next track stretch to the right of drawing FIG. 2B. Such a track relay would be controlled by supply of track circuit frequency F5 energy to the rails of section 13T through the coupling unit and crossbond connections at the junction between sections 11T and 13T. It may be noted also at this point that the circuit for block repeater relay BP, previously mentioned, includes, in series, front contacts *c* of each track relay TR for the stretch of track shown, including front contacts of relays 1TR and 13TR. Obviously release of this relay repeats the occupancy of any track section within the stretch shown as well as the occupancy of section 13T. As previously described, the release of relay BP completes circuits for holding the FR relays in their existing traffic condition during the time that the stretch is occupied by a train moving in either direction.

Although not a specific part of the system of our invention, the relation of an automatic station stop control operation to our system is illustrated. In section 7T, a predetermined distance in approach to the station platform located within section 3T, a wayside coil or loop is positioned to provide a first stop control signal to a westbound train. This signal actuates the apparatus such as included in the bottom apparatus block of FIG. 1. As previously explained, the reception of this station stop signal by a special pickup coil on the train actuates the station stop program preset into the train apparatus. It may be noted that the maximum allowable train speed in section 7T for westbound trains is the approach speed, as established by the use of code frequency CF2 to modulate the cab signal energy. This assists in developing a proper station stop since the train will be slowing from a maximum or high speed level. A second coil or loop in section 5T, at a second predetermined distance in approach to the station, provides a second signal to correct the station stop program to allow for slight variances in train response. One specific form of such wayside loops and stop program apparatus is disclosed in Letters Patent of the U.S. Pat. No. 3,493,741, issued February 3, 1970, to J. W. Lubich, for an Object Stopping System. Another form of such station stop apparatus which may be used with the system of our invention is disclosed in the copending application for Letters Patent of the United States, Ser. No. 166,033, filed Feb. 17, 1971, by R. H. Grundy and D. R. Little, for Station Stop Control Arrangement for Self-Propelled Vehicles, now U.S. Pat. No. 3,731,088, issued May 1, 1973, the present application having the same assignee. The final loop at the end of the station platform in section 3T provides a door opening control signal, received on the train by the same extra pickup coil when the train arrives and stops over the loop. It is to be also noted that, to assist in the station stopping, the maximum allowable speed in sections 5T and 3T is the low speed provided by modulating the cab signal energy at code frequency CF3.

We shall turn now to the basic train-carried apparatus, as specifically shown in FIG. 3, which cooperates with the wayside apparatus embodying our invention. The cab signal or speed control energy from the rails is picked up by a selected set of train-carried coils, two pairs of which are shown in the upper left of FIG. 3. This provides for either direction opertion of the train. However, most of the apparatus on the train is provided single unit only, that is, is not duplicated, and serves for either direction operation of the train. Although only one cab signal panel appears in the upper right within the dot-dash rectangle, actually one such indication panel will be provided at each operator's position and the lamps and alarm apparatus connected in parallel. Also, the single bypass controller switch, shown at the left center, may be duplicated at each operator's location, if so desired. In order to select a direction of operation and actuate the proper receiver coils, a train selection detector, shown at the left of the drawing, is placed in the desired position to select the A or B end of the train as the leading end for operation. Such a selector switch may take any one of several forms, but for convenience a lever having a single arm or contactor is illustrated. Relay AF or BF is energized by an obvious circuit in accordance with the selection of the A or B end of the train by the lever arm. For the remainder of the description, we shall assume that the A end of the train has been selected in accordance with the lever position specifically shown and the A forward relay AF is picked up.

The receiver coils, actually the pair at each end but here the pair at the A end specifically, are so mounted as to be in inductive relation or coupled to the rails. Thus the coils pick up inductively the cab signal energy flowing in the rails modulated by a code frequency selected in accordance with the traffic in advance or as specifically selected by the location along the track. The signal produced in these coils is applied over front contact *a* of relay AF to a tuned amplifier, demodulator unit shown by a conventional block. The details of the circuitry within this amplifier demodulator unit are not shown since they are not specifically part of our invention and conventional and known circuitry, preferably of solid state or integrated circuit type, may be used to detect, amplify, and demodulate the cab signal frequency energy. It may be noted that the tuned amplifier will receive and detect only energy at the cab signal frequency CF and demodulates the received energy to produce a code frequency output in accordance with the modulation frequency of the received energy.

The output from the demodulator element, which will be one of the four code frequency signals discussed in connection with the wayside apparatus, is applied to the bank of active filter units. These units are so tuned, one for each code frequency signal, that they pass only that signal. Conventional circuitry may be used for these active filter units and thus is not shown in detail, each conventional block being marked to designate the frequency which it will pass, that is, CF1 to CF4. The output from each filter, when present, energizes an associated allowed speed registry relay S, or, for filter CF4, a No Control relay NC used for cutout purposes, to be described later. The allowed speed registry relays may be specifically defined as the high speed relay HS, the approach speed relay AS, and the low speed relay LS, associated respectively with filters **CF1**, **CF2**, and **CF3**. The first three filter outputs also actuate associated vital solid state switches, shown conventionally in a bank at the bottom with the control being conventionally indicated by the heavy dashed line connecting the two banks of apparatus. When an output exists from a particular filter, the correspondingly designated solid state switch provides a completed circuit to pass an input from its left to the output at its right. Since only a single filter is active to provide an output at any one time, only the single corresponding solid state switch is activated at the same time. If there is no output from any of the filters **CF1**, **CF2**, or **CF3**, the No CF switch is actuated.

Whenever one of the speed relays is energized and picked up, the corresponding allowed speed indication lamp in the cab signal panel is also illuminated. This, of course, occurs only one lamp at a time since only the one speed relay is properly energized at any one time. The lamp circuits include a common portion beginning from terminal B at back contact *a* of the alarm indication relay AK and extending over front contact *a* of overspeed relay OS, thence, if relay LS is picked up, over its front contact *a* and through the filament of lamp L to terminal N. If relay AS is picked up instead, the circuit extends over back contact *a* of relay LS and front contact *a* of relay AS through the filament of lamp A to terminal N. Likewise, the circuit for lamp H includes, in addition to the common portion, back contacts *a* of relays LS and AS and front contact *a* of relay HS. If all three speed relays are released, the series circuit extends over back contact *a* of each of these relays through the filament of lamp R to terminal N. Lamp R is a restricted speed indication which requires that the train be brought to a stop and then proceed at a restricted speed which is less than the allowable low speed. Since it was previously established that speeds of 50, 25, and 15 may be specifically assigned to the high, approach, and low ranges, the restricted speed would be on the order of 10 to 12 mph so that the train could be readily stopped short of an obstruction. As will become evident shortly from a further description, the stop and proceed action will be enforced by the automatic overspeed and emergency apparatus also provided.

An alternate source of energy for lamp illumination which exists at times extends from the multiple connection to terminal B over front contacts *b* of relays AF and BF, one of which is closed, and thence over back contact *a* of cutout relay CO and through a flasher unit to contact *a* of relay LS. This circuit becomes effective any time that relay AK picks up or overspeed relay OS releases and causes a flashing indication at a preset rate to appear in the cab signal panel to call the operator's attention to the changed condition or emergency warning.

The circuit for initially energizing No Control relay NC extends from the output of filter **CF4** over back contact *a* and the winding of relay NC, and thence over back contacts *b*, in series, of relays LS, AS, and HS to terminal N. When filter **CF4** is active, producing an output, relay NC thus picks up and completes a stick circuit over its own front contact *a* which includes back contacts *b* of the speed relays and bypasses the filter output. The closing of front contact *b* of relay NC completes an obvious circuit for the winding of relay CO which then picks up and holds as long as relay NC remains energized. Under these conditions, a circuit for illuminating lamp W exists from terminal B at front contact *b* of either relay AF or relay BF over front contact *c* of relay NC and through the filament of lamp W to terminal N. As was previously described, code frequency **CF4** is used when the train is to leave the speed control area and enter territory in which no cab signals or speed control is provided. Lamp W thus indicates to the operator that he is to control his train in accordance with wayside indications only or special train orders depending upon the circumstances. Obviously, as soon as the train reenters a controlled territory, the energization of any one of the speed relays to open its back contact *b* deenergizes relay NC which releases. This also releases relay CO and restores the various control circuits and operation of the apparatus.

The remaining device on the cab signal panel is an alarm bell or buzzer which is energized under alarm conditions by a circuit including front contact *a* of relay AK. As will become apparent shortly, this alarm device is actuated or energized for a preset time period only sufficient to allow the operator to react to a signal change or emergency condition otherwise existing. All of the apparatus in the cab signal panel is provided to give the operator information under manual operating conditions as to the allowed speed and the established condition of operation by the illumination of one of the lamps. In addition, the speed relays establish a condition, that is, a preset maximum speed limit which the overspeed portion of the train-carried apparatus must meet, as will now be described.

To monitor the actual speed and actuate the overspeed detection apparatus, a magnetic or electromagnetic pickup device is positioned near the main driving gear for the train propulsion equipment, as shown in the lower left of FIG. 3. This magnetic pickup device produces an output, the frequency of which is proportional to train speed. A shaper-limiter unit of any conventional circuit design receives this frequency signal and produces an output of proper wave shape and amplitude to apply to the low pass filter bank. The output of each low pass filter is fed to an associated allowed speed solid state switch. Each such switch has a low resistance only when the corresponding allowed speed signal is being received by the cab signal apparatus. In other words, the circuit path through a particular solid state switch, e.g., a silicon controlled rectifier, is completed when the designated code frequency CF is modulating the received cab signal energy of frequency FC. As previously described, if the CF1 signal is modulating the received cab signal energy, the CF1 filter is active to pass the demodulator output and solid state switch CF1 is actuated. When any specific low pass filter passes the output of the shaper-limiter unit, other higher speed LP filters also pass this input signal. Thus if the train is moving at the approach speed but the allowed speed is at the high range, i.e., signal CF1 received, solid state switch CF1 is actuated to pass the output of the high speed LP filter which also passes the approach speed frequency signal.

When any one of the speed relays is picked up to close its front contact *c*, a path is complete through the circuit network to apply any output of the solid state switches, connected in multiple, over front contact *b* of the automatic braking relay AB to the level detector unit and thence to the winding of relay OS. The level detector, which is designed as a vital circuit unit, will deliver a direct current voltage to overspeed relay OS as long as the input is of sufficient magnitude. Each low pass filter is designed to have a sharp cutoff of output voltage at the maximum allowable speed corresponding to its speed assignment. In other words, at the maximum allowable speed for the high speed filter, assumed to be 50 mph, the output of the low pass filter will decrease, if this speed limit is exceeded, to just below the detection point of the level detector and thus would deenergize the overspeed relay. Thus, when the input to the level detector is of sufficient magnitude, it indicates that the vehicle or train is moving at less than the maximum allowable speed. Of course, the output from the high speed low pass filter will be applied to the level detector only if a corresponding cab signal or speed signal indication is being received so that filter CF1 is active and thus has actuated solid state switch CF1 as well. Each of the low pass filter units operates in a similar manner but with the output decreasing when the corresponding speed is exceeded. Thus relay OS will be held energized by the output of the level detector as long as the train speed remains at or below that of the low pass filter whose output is applied to the level detector because the corresponding solid state switch is actuated by the reception of the corresponding speed signal by the cab signal apparatus.

When the vehicle is stopped there is, of course, no output from the magnetic pickup which would normally cause relay OS to be deenergized, thus locking the brakes. In order to prevent a lockout condition when the train is ready to start again, a zero velocity (V=O) detector unit is provided. When the train is stopped, this detector checks the integrity of the pickup circuit and produces a sufficient output which may be passed through the filter bank to the vital level detector to keep the overspeed relay OS energized. When there is any train motion, the V=O detector stops oscillating and the circuitry acts on the output of the magnetic pickup, as already explained. If desired, a second output from the shaper-limiter unit may be differentiated and averaged to provide a direct current proportional to the speed which would then be used to actuate a speedometer to advise the train operator of his actual speed. This is not shown in FIG. 3 since such is conventional practice. The V=O detector apparatus is shown by a conventional block since such elements are known in the art and need not be shown in detail. An output from this detector also energizes the velocity zero relay VZ during the time that the train is stopped.

Various other relays and apparatus are also associated with this overspeed control arrangement. An automatic braking relay AB, already mentioned, is normally held energized by a simple circuit including front contact *b* of relay OS. Relay AB has a stick circuit which includes its own front contact *a* and either front contact *a* of brake assurance relay BA or front contact *a* of relay VZ. Relay AB is provided with a capacitor-resistance shunt of its winding to produce a selected period of slow release, for example, on the order of 2.5 seconds, for purposes of allowing reaction time for the train operator. This slow release characteristic is further designated by the conventional downward pointing arrows drawn through the relay contact armatures to denote the slow acting direction.

The brake assurance relay BA is controlled by a deceleration detector, shown at the left of the drawing, which detects deceleration of the train to close its left or right normally open contact, depending upon the direction of movement, and thus complete a connection from terminal B through that contact. With the train operating with A end forward, deceleration will cause the left contact of the deceleration detector to close and complete a circuit including front contact *c* of relay AF to energize the winding of relay BA, which then picks up. Front contact *c* of relay BF is included in the circuit for energizing relay BA if the opposite direction of movement is in effect. Front contact *a* of relay BA, when closed, completes a stick circuit already traced for relay AB. Front contact *b* of relay BA, upon closing, completes a stick circuit for the emergency relay EM which includes also front contact *a* and the winding of this latter relay. Relay EM is normally held energized by a simple circuit including front contact *c* of relay OS. An alternate circuit for holding relay EM energized under speed control cutout conditions includes front contact *b* of relay CO. Relay EM is provided with a capacitor-resistor snub of its winding to establish a slow release period slightly longer than that of relay AB, e.g., on the order of 4.0 seconds.

A time element relay TE is energized upon the expiration of a preselected delay period after the closing of front contact *b* of relay VZ. Various types of pickup and delay elements may be used to delay the pickup of relay TE and thus only a conventional block is shown. In a specific example, the time delay may be on the order of 10 seconds before relay TE picks up after the energization of the delay element. Of course, if desired, the delay period may be incorporated within the winding and mechanism of relay TE itself.

A restricted speed relay TS is provided to enforce the stop and proceed action when a restricted signal is received by the cab signal apparatus, that is, a lack of any code frequency modulation occurs and lamp R is illuminated. Relay RS is normally deenergized and is energized by a pickup circuit including back contacts *d*, in series, of each of the speed relays S, front contact *c* of relay AB, front contact *c* of relay VZ, and the winding of relay RS. When relay RS picks up, it closes its own front contact *a* to complete a stick circuit which bypasses fron contact *c* of relay VZ.

Relay AK is energized for a predetermined time interval each time an existing allowed speed or cab signal is replaced by a lower allowed speed limit. This relay is also energized for the same predetermined period if relay AB or OS releases. The predetermined interval of energization is preset to be the same as the release time of relay AB. This allows the operator to judge his reaction time to actuate the braking of a train upon a lower speed signal occurrence. Various means of providing the predetermined energizing period are available in the art so that only a conventional block is shown with an explanatory note as to its operation. Energy is supplied to this block over several multiple circuits. Two of these circuits include, respectively, back contact *d* of relay AB and back contact *b* of relay OS so that the release of either one of these relays will apply energy to the timing unit to energize relay AK for the preset interval. Energy is also supplied to the timing block over a matrix of contacts of the speed relays S which complete a circuit path under the cited conditions. In other words, a circuit path through the matrix of contacts of the S relays will exist to apply energy when a particular S relay releases, and a lower speed relay S picks up, or no S relay is energized. If energization of a particular S relay is replaced by the energization of a higher speed S relay, no circuit path will exist from terminal B to the timing unit for relay AK. The normal release time of the S relays is sufficient to assure that the next relay, corresponding to either a higher or lower speed, will pick up prior to the release of the deenergized relay. Other means or methods of supplying energy to the timing unit for relay AK, when the speed limit changes, may be used and our system is not limited to the use of a circuit matrix including contacts of the S relays which is used here to illustrate the operation only.



We shall now describe the operation of the train-carried apparatus in performing its speed control functions. It is assumed that the train is moving with the A end in the lead, as previously set, and that cab signal energy is being received modulated by code frequency CF2. Thus a 25 mph maximum speed limit is in effect with relay AS energized. Lamp A in the cab signal panel is illuminated and, for this description, it is assumed that the train is under manual operation by the operator on board on the driving control position. Relay OS is energized as long as the train remains at or below the 25 mph speed, energy being provided in response to the magnetic pickup signal by the shaper-limiter through the approach speed low pass filter and solid state switch CF2 and the circuit network through the level detector and the relay winding. If the train exceeds 25 mph, plus whatever tolerance is permitted, the output cutoff characterisitic of the approach speed low pass filter reduces the energy being applied to the level detector to the point where relay OS releases. The opening of front contact *b* of relay OS deenergizes relay AB but this relay is provided with a preestablished slow release period so that it holds its front contacts closed for the present. Relay AK, however, is picked up since the closing of back contact *b* of relay OS applies energy to the timing unit and the alarm device on the cab signal panel is actuated to indicate to the operator that an overspeed condition exists. It will be noticed also that the common portion of the lamp circuit providing steady illumination is interrupted, both at back contact *a* of relay AK and front contact *a* of relay OS, so that the alternate circuit including the flasher unit is effective and lamp A begins to flash to also call the attention of the operator to the overspeed condition.

If the operator applies the brakes within his allowed reaction time, the deceleration detector will close its left contact in response to train deceleration, energizing relay BA. The closing of front contact *a* of relay BA completes a stick circuit for relay AB which thus is retained energized. When the train slows to the allowed speed limit, plus or minus the tolerance, relay OS will again be energized and pick up so that the operator may release the brakes and continue the movement of the train with or without power application as is appropriate. It will be noted that, since front contact *b* of relay AB remains closed, the full output of the low pass filter, in this case the approach speed filter, is applied to the level detector as the train speed is reduced below the allowed speed limit.

If the operator does not respond in time to establish a braking condition within the release time of relay AB, this relay releases and opens its front contact *d* to initiate an automatic service brake application. The control apparatus for this automatic brake application is illustrated by a conventional block at the left of FIG. 3. The specific apparatus may be of any known type and will vary in accordance with the specific requirements of the train braking apparatus installed. All that is necessary to understand the operation of our system is that removal of energy from either input connection to this apparatus block actuates a brake application of the type corresponding to that noted for each lead. When relay AB releases, the opening of its front contact *b* removes the shunt on the level detector resistor LDR which is now in series with the level detector and attenuates the signal applied thereto. This forces the train, under the automatic brake application, to slow down to some preselected point below the actual speed limit, for example, to 20 mph, before the output from the low pass filter is of sufficient level to provide energy to the level detector for reenergizing relay OS. Thus, a penalty of additional speed reduction is imposed if the train operator does not initiate the braking action in time when an overspeed condition occurs.

The automatic brake application, of course, causes a deceleration which is detected to energize relay BA. The closing of front contact *b* of relay BA will retain relay EM energized since this relay has a longer slow release period than does relay AB. However, relay AB will be reenergized only when relay OS, being reenergized, picks up to close its front contact *b*. It is also to be noted that relay AK releases at the end of the preset energized period, thus deenergizing the alarm. However, the flashing indication on the cab signal panel will continue until relay OS again picks up. A similar action will occur when a lower speed signal is received unless the operator reacts within the release time of relay AB to initiate a braking application to reduce the train speed to the new lower speed limit. For example, if the received code frequency changes from CF2 to CF3 so that relay AS releases and relay LS picks up, the speed of the train must be reduced below the 15 mph low speed limit before sufficient energy is passed by the low speed low pass filter through solid state switch CF3 to energize relay OS. However, an immediate braking action retains relay AB energized as previously described.

If the service brakes fail, either during a manual or an automatic application, the brake assuring circuitry will cause an emergency brake application. When relay OS releases, the opening of its front contact *c* interrupts the circuit for normally energizing relay EM. As previously indicated, this relay has a slow release period established by the resistor-capacitor winding shunt which is somewhat longer than the release time of relay AB. If a suitable braking rate is not established within this release time of relay EM, so that relay BA picks up to close its front contact *b* and retain relay EM energized by its stick circuit, relay EM releases. The opening of its front contact *b* interrupts the application of energy to the emergency input connection of the automatic brake apparatus which initiates an emergency braking condition. It is evident that, once released, relay EM cannot be reenergized until the train speed is reduced to a safe level so that relay OS reenergizes, perhaps with the train at a stop. If a cutout condition is effected, relay CO is energized and closes its front contact *b* to hold or reenergize relay EM.

The stop and proceed at restricted speed command is initiated whenever a train enters a section with no cab signal energy. Regardless of the entering speed, relay OS will deenergized because all the S relays release so that the open front contacts *c* of these relays interrupt all circuit paths to the level detector. This is true since front contact *a* of relay TE and front contact *b* of relay RS are also open at this time so that no circuit path exists over back contacts *c* of the S relays between the solid state switch output bus and the level detector. The alarm is sounded, while relay AK is energized, and lamp R flashes. If the operator initiates braking action in sufficient time, relay BA will energize and close its front contact *a* to retain relay AB energized over its stick circuit. When the train stops, relay VZ will be energized to complete the energizing circuit for relay RS which includes back contacts *d*, in series, of the S relays, front contact *c* of relay AB, and front contact *c* of relay VZ. Relay RS picks up and completes its stick circuit which bypasses contact *c* of relay VZ. With front contact *b* of relay RS now closed, a circuit exists, including back contacts *c* of the S relays, by which energy from the V=0 detector may be applied through the filters and solid state switches to the input of the level detector and thus reenergize relay OS. This permits the train to immediately proceed at restricted speed, the operator being so informed by the steady illumination of lamp R in his cab signal panel.

However, if the operator does not initiate the braking action under these conditions in sufficient time, relay AB will release at the end of its slow release period, initiating an automatic brake application which continues until the train stops. Now, however, with front contact *c* of relay AB open, there is no circuit for energizing relay RS when relay VZ picks up and closes its front contact *c*. The closing of front contact *b* of relay VZ at this time initiates the pickup delay period for relay TE which, as previously mentioned, in one particular situation is a time of 10 seconds. This time compares with the situation previously discussed with release times for relay AB being 2.5 seconds and for relay EM 4.0 seconds. When relay TE picks up at the end of this delay period, the closing of its front contact *a* completes another circuit including back contacts *c* of the three S relays to apply the energy developed by the V=0 detector to the input of the level detector to reenergize relay OS. Thus, if a stop and proceed action occurs with an automatic brake application, the penalty of the pickup time delay for relay TE, for example, the 10 seconds, is enforced before the train can again proceed. This extra delay encourages prompt response on the part of the train operator.

As previously described, in the last track section before leaving cab signal or speed control territory, cab signal energy is modulated by code frequency CF4. The reception of this energy and its demodulation energizes relay NC which picks up and sticks up, the circuit including in series back contacts *b* of all the S relays. Relay CO is then energized over front contact *b* of relay NC and in turn holds relay EM energized over front contact *b* of relay CO. This in effect cuts out the overspeed protection and the alarm and cab signal indication circuits are all open. However, the wayside indication lamp W is illuminated over front contact *c* of relay NC, and the operator controls the train in accordance with wayside signals and/or train orders.

If the cab signal and speed control apparatus on the train fails, resulting in an emergency application of the brakes, a restoration of the train to manual operation without speed control is provided by a sealed bypass switch. An example of such bypass control is shown at the left center of FIG. 3. The illustration is that of a stick type pushbutton with normally open contacts. If such an emergency stops occurs and the apparatus is nonfunctional, the breaking of the seal and the operation of the pushbutton to close its normally open contacts, which then remain closed until the controller is manually returned to its normal condition, will complete a circuit, under the present conditions, over the lower contact of the bypass controller, front contact *d* of relay AF, and back contact *b* of relay NC to the winding of relay CO. Relay CO is thus energized and held in this condition and the closing of its front contact *b* reenergizes relay EM. Again, the alarm and cab signal indication circuits are interrupted and the overspeed protection is removed, but the train may be operated under published rules for such conditions to proceed to the nearest station.

The system of our invention thus provides an efficient and economical speed control arrangement for trains. Apparatus is compatible with manual operation with simple overspeed protection and with increasingly sophisticated systems up to and including full automatic train operation with its station stop and door control options. The wayside apparatus is effective to detect the presence of trains and provide cab signal and speed control signals to the trains themselves. No insulated joints are required in the rails to separate the various track sections used for train detection. All the apparatus for each distinct stretch of railroad track may be centralized for efficient maintenance and economical housing and protection. Thus, a fail-safe, efficient, and economical system of train speed control is provided.

Although we have herein shown and described but one form of train speed control apparatus embodying our invention, it is to 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 our invention.

Having thus described our invention, what we claim is:

**1.** A train control system for trains moving along a stretch of track, comprising in combination,

a. a track circuit arrangement dividing said stretch into a plurality of sections and including a center fed detector track circuit for each pair of adjacent track sections supplied by a transmitter means with energy of a distinctive frequency different from that supplied other pairs of sections in said track stretch,
   1. the track circuit for each pair of sections individually detecting the occupancy of each section by a train;

b. said track circuit arrangement further including another energy source for each track section connected at the exit end thereof for supplying to the corresponding section at times energy with a single preselected frequency different from any of said distinctive frequencies and modulated with one of a plurality of allowable speed signals, selected in accordance with the detected occupancy conditions of sections in advance,
   1. each other energy source being controlled by the associated track circuits for supplying said preselected frequency energy only when the corresponding section is occupied and at least the next advance section is unoccupied,

c. receiver means on each train inductively coupled to the track rails for receiving the modulated preselected frequency energy supplied by a second energy source to the track section then occupied by that train and responsive thereto for producing a distinctive output in accordance with the selected modulation signal,

d. registry means on each train connected for receiving the output of the associated receiver means and recording an indication of the allowable train speed,

e. speed measuring means on each train coupled to the train propulsion apparatus for registering an indication of the actual train speed,

f. overspeed detection means on each train jointly controlled by the associated registry means and the associated speed measuring means for comparing allowable and actual train speeds and further connected to the train braking apparatus for at times initiating an automatic brake application to reduce the train speed in response to a detected overspeed condition of actual speed greater than allowable speed, and

g. time delay means on each train controlled by the associated overspeed detection means and responsive to deceleration of said train for measuring a predetermined time period after an overspeed condition detection and connected for inhibiting an automatic brake application when deceleration of said train is otherwise initiated during said predetermined time period.

**2.** A train speed control system for trains moving along a stretch of track, comprising in combination,

a. a track circuit arrangement dividing said track stretch into preselected track sections and operable for detecting the presence and location of trains within said stretch,
   1. said track circuit arrangement further supplying to each section a train control signal carrying a selected one of a plurality of code frequencies each designating a different maximum allowable speed for an approaching train in accordance with the detected location of any preceding train,

b. a signal receiving means on each train coupled for responding to said train control in the occupied section to register the maximum allowable speed in accordance with the received code frequency,

c. a speed measuring means on each train coupled for registering the actual speed of the train,

d. overspeed detection means on each train connected to receive the registered train speed and controlled by the associated signal receiving means for comparing the registered actual and allowable train speeds,

e. an automatic brake application control means having a nonbraking condition and more than one different braking conditions which provide successively greater deceleration rates,

f. said brake application control means connected for actuating an initial train brake application when operated to its first braking condition and successively stronger train brake applications when succesively operated to each other braking condition,

g. said brake application control means controlled by said overspeed detection means for holding in its nonbraking condition when the actual speed is less than the allowable speed,
   1. said brake application control means operable to each successive braking condition a distinct and successively longer preselected time interval after the overspeed detection means detects that the actual speed is greater than the allowable speed if no other braking action has occurred, and

h. a brake assurance means coupled for responding to deceleration of the train to operate from a first to a second position,

i. said brake assurance means connected in its second position for retaining said brake application control means in its nonbraking condition if train deceleration occurs prior to the expiration of the least preselected time interval and in its existing braking condition if deceleration occurs prior to the expiration of the next longer time interval.

3. A speed control system as defined in claim 2 in which,

a. said automatic brake application control means has only a nonbraking, a normal braking, and an emergency braking condition and is connected for actuating a train service brake application when operated to its normal braking condition and an emergency brake application when operated to its emergency braking condition,

b. said brake application control means operates to its normal braking condition a first preselected time interval and to its emergency braking condition a second and longer preselected time interval after the overspeed detection means detects that the actual speed is greater than the allowable speed if no other braking action has occurred, and

c. said brake assurance means is connected in its second position for retaining said brake application control means in its nonbraking condition if train deceleration occurs prior to the expiration of said first time interval and at least in its normal braking condition if deceleration occurs prior to the expiration of said second time interval.

4. A speed control system for railroad trains moving along a stretch of track, comprising in combination,

a. a track circuit arrangement connected for dividing said track stretch into a plurality of sections and for normally supplying energy having a distinctive frequency, to each adjoining pair of track sections at their common junction location, to feed through the rails to the distant end of each section,

b. an occupancy detection means coupled at the distant end of each of the pair of track sections supplied with the same distinctive frequency energy for registering the occupancy condition of the corresponding section,

c. a second source of energy for each track section coupled at the exit end thereof for at times supplying energy having a selected frequency different from said plurality of distinct frequencies and the same for each section,

d. a modulating means coupled to each second source and controlled by said track circuit arrangement for modulating the second source energy by a selected one of a plurality of code frequencies in accordance with the section occupancy conditions in advance of the corresponding section,

1. each code frequency designating a predetermined maximum allowable train speed,

e. the supply of said second source energy to a particular section being further controlled by,

1. the occupancy detection means for the advance section to interrupt the energy supply when that advance section is occupied,

2. the occupancy detection means for that particular section to complete the energy supply when an approaching train occupies that section, and

f. train control apparatus on each train traversing said stretch responsive to the modulated selected frequency energy successively supplied to the sections and connected for monitoring the speed of that train and maintaining the speed below the maximum allowable speed designated by the received code frequency.

5. A speed control system as defined in claim 2 in which each train-carried apparatus further includes,

a. a zero speed detection means coupled to said speed measuring for registering a zero train speed condition,

b. said zero speed detection means producing another output when zero train speed is detected and coupled for holding said overspeed detection means in its nonactuating condition to permit that train to restart when an allowed speed is registered,

c. said zero speed detection means also connected for holding said brake application control means in its nonbraking condition when a registered zero speed condition results from other than an automatic brake application.

6. A speed control system as defined in claim 5 further including in each train-carried apparatus,

a. a stop and proceed restricted speed relay means normally occupying a first position and operable at times to a second position,

b. a timing means controlled by said zero speed detection means for measuring a predetermined delay period after zero speed is registered,

c. a first circuit means completed by said restricted speed relay means in its second position for controlling said overspeed detection means to authorize train movement at a preselected restricted speed when no code frequency is received,

d. an energizing circuit means connected for operating said restricted speed relay to its second position and completed jointly by said signal receiving means when no code frequency is being received, said brake application control means in its nonbraking condition, and said zero speed detection means when a zero speed condition is registered, and

e. a second circuit means completed by said timing means when said delay period is expired for alternately controlling said overspeed detection means to authorize train movement at said preselected restricted speed when no code frequency is received.

7. A speed control system as defined in claim 4 which further includes,

a. traffic direction means operable to a first and second positions for establishing normal or reverse direction traffic, respectively, through the track stretch,

b. remotely controlled switch means connected for operating said traffic direction means to its first or second positions as normal or reverse traffic selection commands are registered by said switch means, and

c. the supply of second source energy at each junction between sections is further controlled by said traffic direction means for supplying such energy only to that section whose exit end is at that junction in accordance with the established traffic direction.

8. A speed control system as defined in claim 7 in which

the track section limits are defined by cross-bond devices connected between the rails without insulated joints, said energy sources and detection means being coupled to the section rails by transformer windings of said crossbonds.

9. A speed control system as defined in claim 8 in which all apparatus except said crossbond devices for said track circuit arrangement for said stretch of track is located at a central housing.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,794,833 Dated February 26, 1974

Inventor(s) Frank V. Blazek, William B. Dufer, Raymond C. Franke, & Philip R. Schatzel

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 24, line 34, after "control" insert --signal--

Column 26, line 8, after "measuring" insert --means--

Signed and sealed this 13th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents