United States Patent

Malon

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[54] **APPARATUS FOR DRIVING A VEHICLE**

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Aug. 18, 1967 France....................................118334

[52] **U.S. Cl.** ....**246/182 R,** 246/187 B
[51] **Int. Cl.**..**B61l 3/18**
[58] **Field of Search** ....246/182 B, 63 C, 182 R, 187 B

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[57] **ABSTRACT**

The path of the vehicle is divided into successive intervals of space. An adjustable, periodic, pulsed reference signal is provided for each interval, and its frequency is adjusted so that the product of this frequency by the length of the corresponding interval is proportional to the speed desired for the vehicle on this interval. The number of reference pulses received by the vehicle during its travel along each interval is counted and compared with a determined fixed base number to compare the real speed of the vehicle with the desired speed.

16 Claims, 9 Drawing Figures

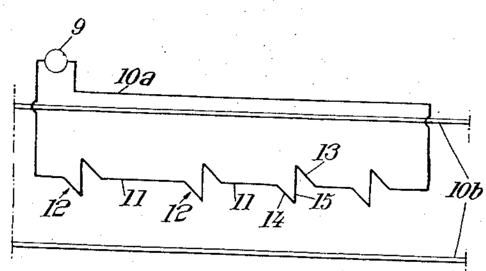

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Fig. 4.

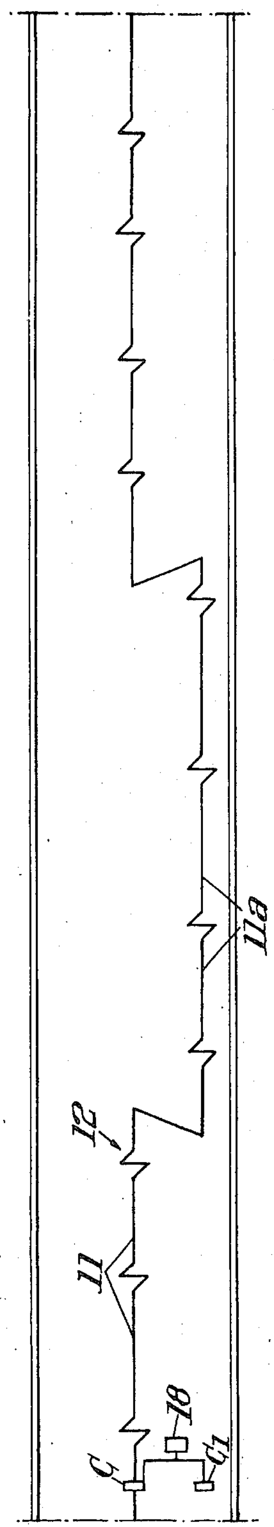


Fig. 2.

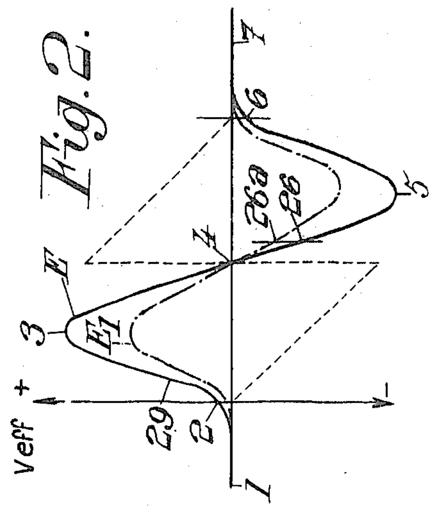
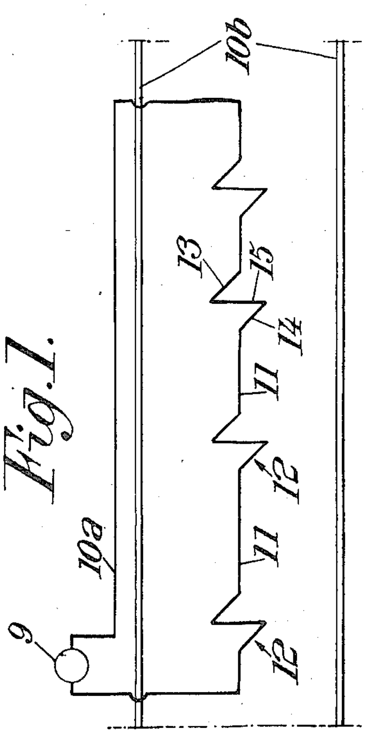


Fig. 1.



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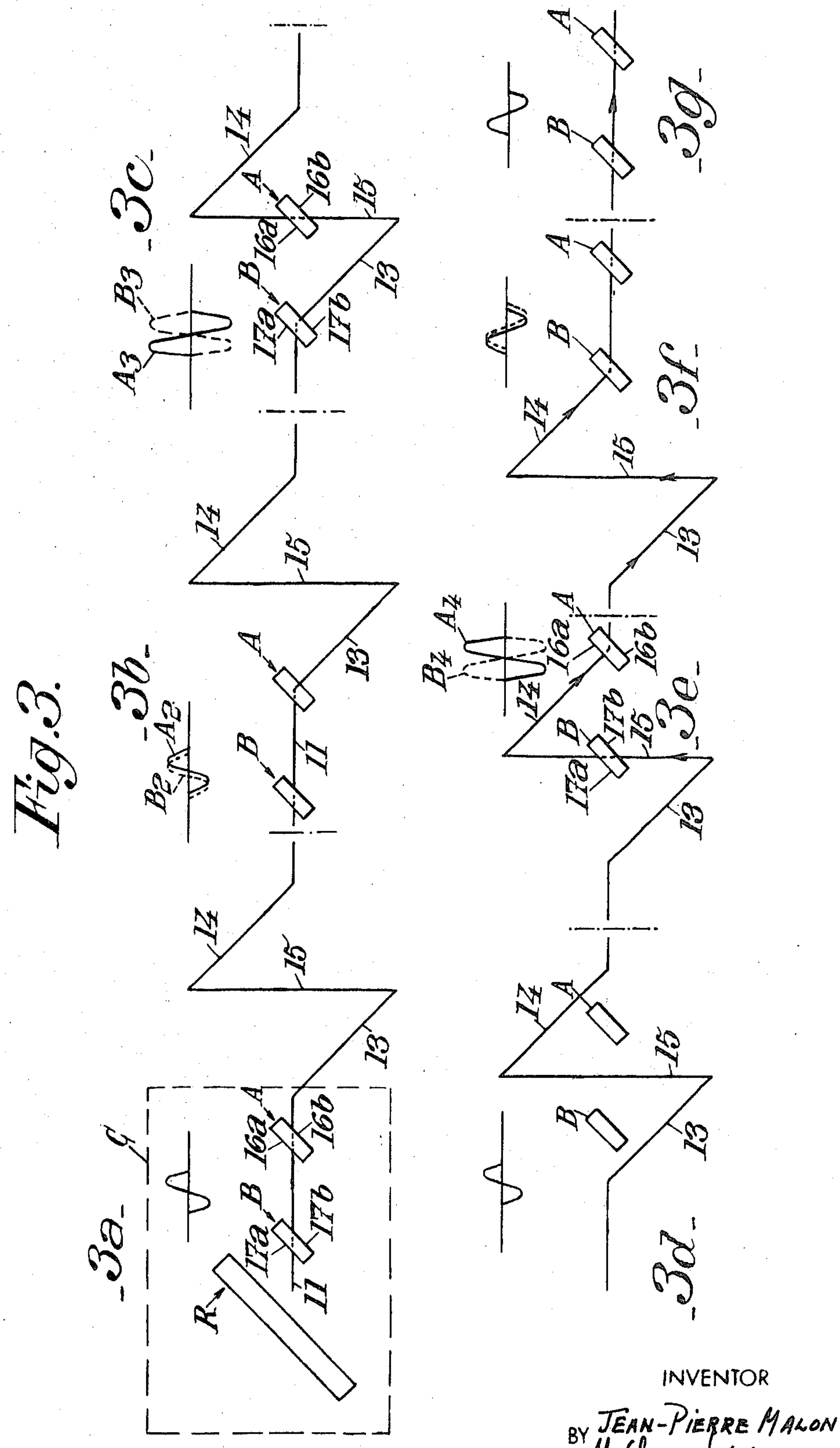

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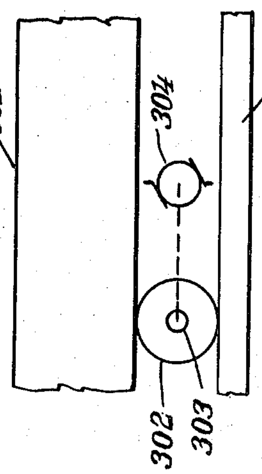

Fig. 9.

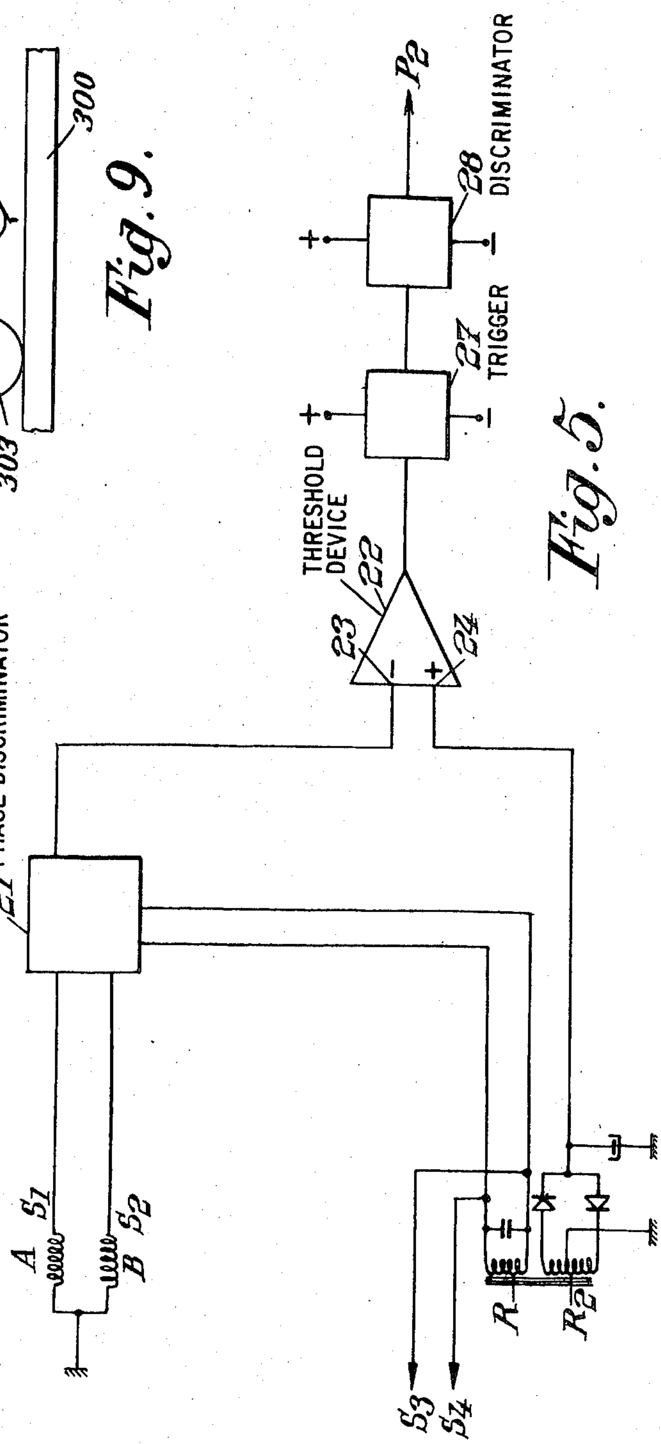

Fig. 5.

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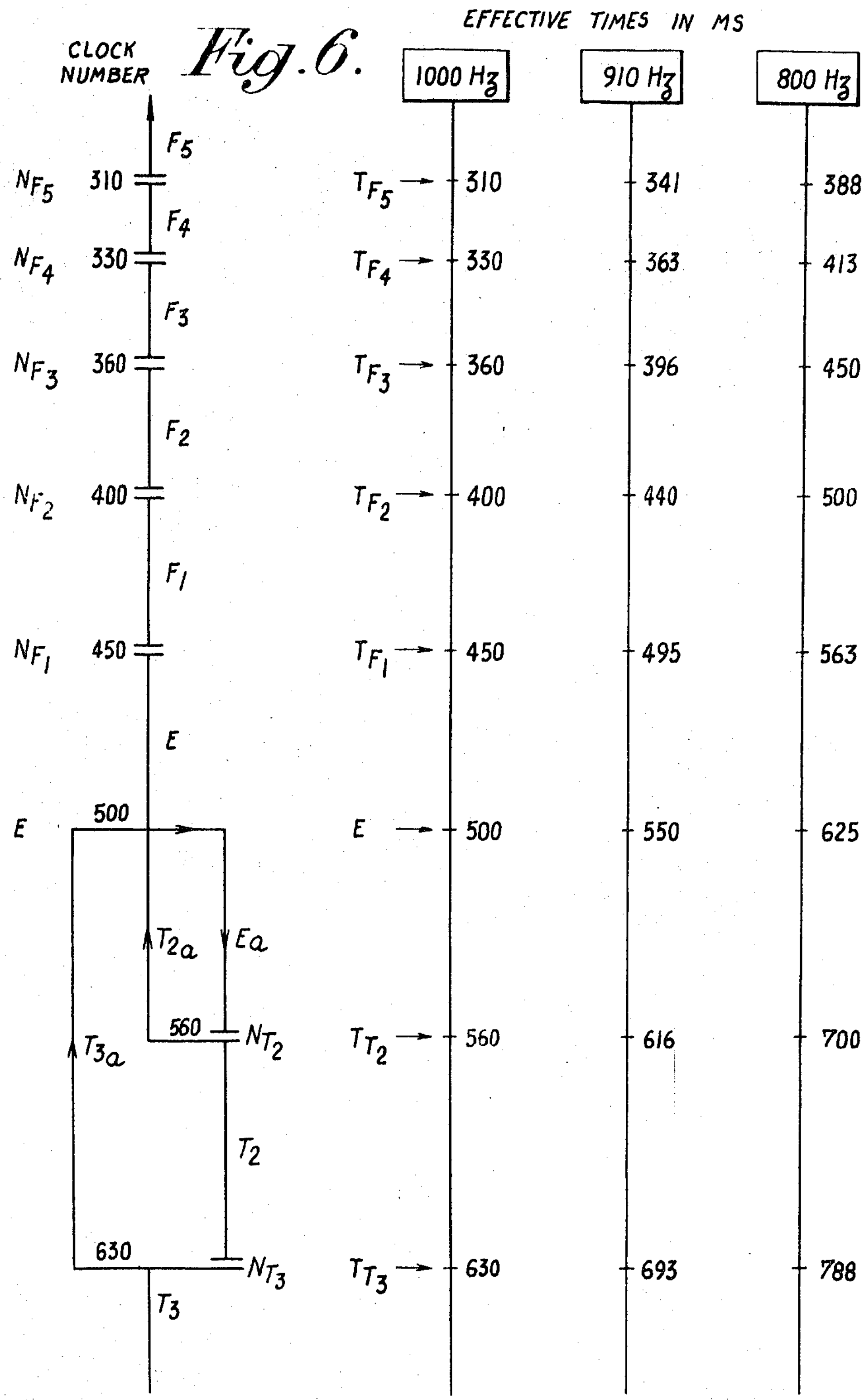
Fig. 6.



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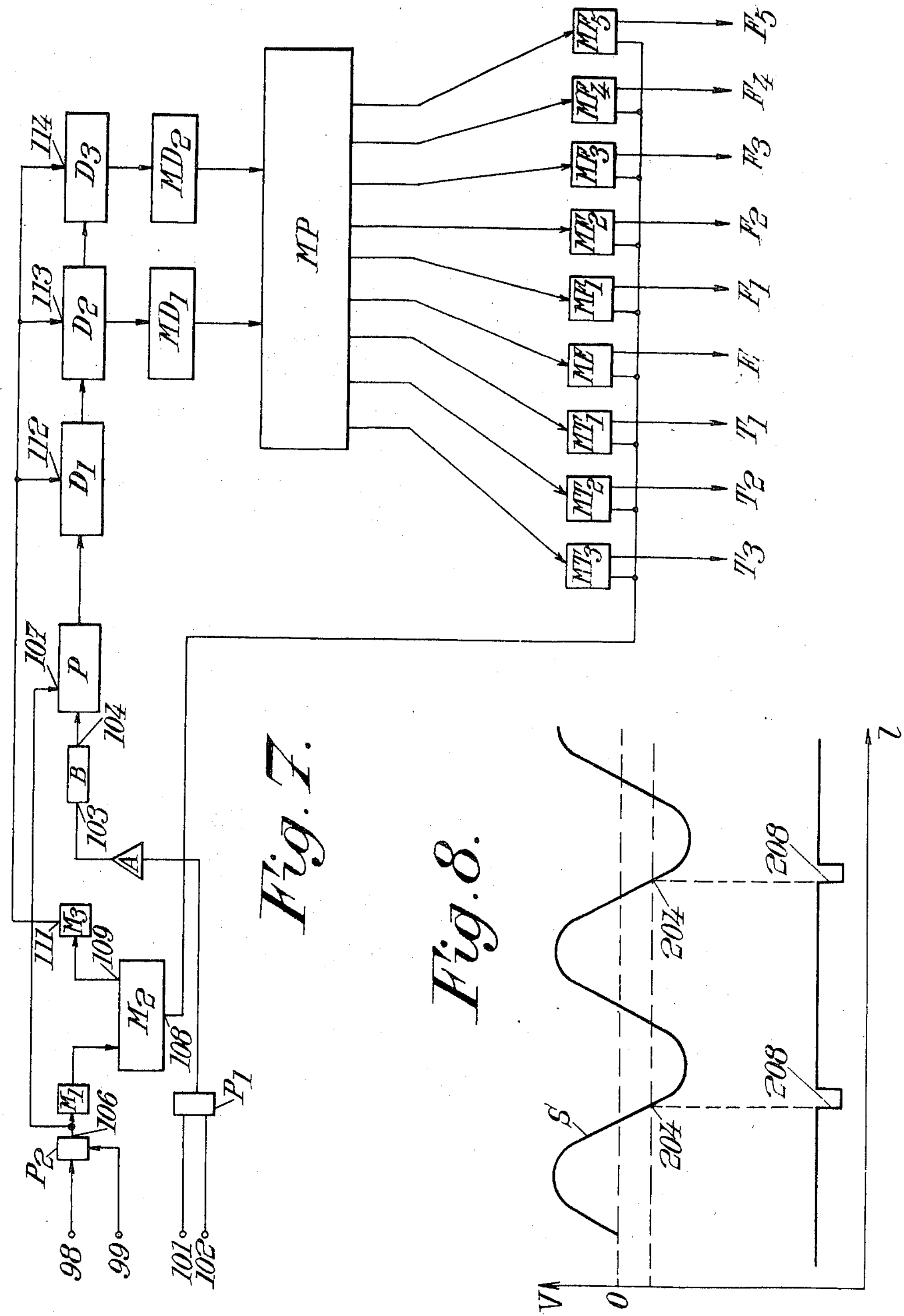

Fig. 7.

Fig. 8.

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APPARATUS FOR DRIVING A VEHICLE

This invention relates to methods and apparatuses for driving a vehicle, in particular for making its speed follow a determined program of operation. These apparatuses comprise, on at least certain parts of the path followed by the vehicle, means capable of dividing this path into successive intervals of space and of emitting at the end of the travel by the vehicle along each interval of space a space signal or information, at least one receiver of these space signals installed on the vehicle and a measuring device capable of exploiting these signals to supply magnitudes representative for example of the average speeds of the vehicle on each of these intervals of space or to translate them into orders adapted to be transmitted to the traction or braking equipment of the vehicle.

This invention concerns in particular such methods and apparatuses as applied to trains, and more particularly still as applied to underground or subway trains which are subjected to a program of operation having very variable speeds along relatively short lengths of travel and including numerous stops.

If the successive intervals of space are equal among themselves, the division mentioned above can be realized, for example, by the intermediary of measuring members carried by the train, for example by a generator driven by one of the wheels of the vehicle and producing periodic signals whose amplitude varies as a function of the speed of rotation of the wheels, the receiver then being capable of exploiting the periodic variations of amplitude of these signals. This division of the path into successive intervals of space can also be realized, more particularly in the case in which these successive intervals of space are not equal among themselves, by the intermediary of a piloting cable, through which a periodic current passes, disposed along the track in a manner such that it is adapted to produce a sequential signal adapted to be received by the receiver each time that the vehicle has completed the travel of one of these intervals of space.

It has already been proposed to realize apparatus permitting automatic driving of a vehicle, in particular of a train, in which apparatus the piloting cable is adapted to produce sequential signals each time that the train has travelled an interval of space (which, in this case, will be called hereafter "sequence") proportional to the speed desired at the region considered, these sequential signals being exploited to control the piloting device (traction or braking equipment) of the train. More particularly, these signals are exploited, in most of the known apparatuses, to give a traction order to the vehicle if the measured time T_r taken by the vehicle to travel a sequence is greater than a base time T_o, for example equal to 500 milliseconds (msec.), this traction order being more energetic as the separation between the times T_r and T_o is greater, and, reciprocally, a braking order if the measured time T_r taken by the vehicle to travel a sequence is less than the time T_o, this braking order being more energetic as the advance of the time T_r on the time T_0 is greater, the traction or braking equipment being, however, left at rest if the measured time T_r is equal to the time T_o or if the separation between T_r and T_o is less than a predetermined threshold, the train then travelling on its headway, i.e., on its forward motion preserved from previous traction.

It will be said in the following that the train travels on headway if the travel time of a "sequence" is equal to the base time T_o mentioned above or when no traction or braking step of the train is actuated.

In the apparatuses for making the speed of travel of a train follow a determined program that were the most commonly used hitherto, the receivers carried by the train are constituted by two field pickups and the piloting cable is disposed along the track in a manner such that these pickups are alternately: one pickup exposed to the electric field produced by the current of the piloting cable, in a manner to supply logic information 1 or 0 during the half-cycle considered (this pickup then being said to be in an "active position"), the other pickup protected practically from this field in order to supply the opposite logic information (this other pickup then being said to be in an "inactive position"), the permutations of the logic information produced in the two pickups being exploited to regulate automatically the speed of the train.

It is known that, in practice, the laying of this piloting cable on the track is extremely delicate, in particular for ensuring that the two pickups pass simultaneously, one from an active position to an inactive position, and the other from an inactive position to an active position, whatever be the shape of the track.

Furthermore, the realization of different speeds of travel for the trains is extremely difficult to realize from the piloting cable which defines in fact a single program of operation for all the trains, whereas it can be desirable, in particular in the case of the subway, to be able to provide a rapid rotation of the trains in the rush hours (the trains then operating at an accelerated speed), on the contrary a slow rotation of these trains (slow speed of operation) during the slack hours, and finally, at still other hours, a "normal" speed of operation. The difficulty mentioned above appears above all in the zones of the track (called hereafter "slowing-down zones") in which the braking and the stopping of the trains must be executed, in particular in the stations, and in which the piloting cable must define shorter and shorter sequences according to a decreasing law connected with the deceleration, for example equal to 0.6 meters per second ($m./sec.^2$) that it is wished to impose on the train, before the piloting cable is eliminated under the train, the absence of any field picked up by the receivers controlling the complete stop of the train. So that these sequences are always travelled by the train in the course of slowing down, but travelling on headway, in times that remain equal to a predetermined base time, for example 500 msec., practically until the stopping of the train, the lengths of the successive sequences in the slowing-down zone should decrease very rapidly, above all in the last part of these slowing-down zones and in particular as the square of the speed of the train travelling on headway. It will thus be necessary to control the actuation of more and more energetic braking steps, in order to impose on the train the above-mentioned deceleration. These braking steps will for example be actuated successively when the sequences are travelled in measured times, for example equal to:

$T_{F_1}=450$ ms
$T_{F_2}=400$ ms
$T_{F_3}=360$ ms
$T_{F_4}=330$ ms
$T_{F_5}=310$ ms

in the case in which the trains comprise for example five braking steps F_1, F_2, F_3, F_4, F_5 of increasing force.

It results from the foregoing that the train should not enter such a slowing-down zone at any speed whatsoever if it is desired to obtain progressive braking of the train, in other words if it is desired that the first braking steps are actuated directly on its entry into this slowing down zone.

Supposing that the operating program determined by the cable corresponds to conditions of "accelerated travel" (travel desired in each sequence equal to 500 msec.), it will become rapidly difficult to use in the case in which it is desired to impose on the train slow speed operating conditions. In the known driving apparatuses, such operating conditions are in general obtained by authorizing the actuation of a traction step only when the train travels a sequence of its path in a time exceeding, for example, 625 msec. It will then be observed, that when it is wished to stop the train, a large part of the slowing-down zone of the fixed piloting cable will remain unexploited for the braking, since the train travels the first sequences of this slowing-down zone in times much greater than the time required (450 msec. in the above example) to actuate the first braking step F_1. This will only be realized at the moment when the slope of the law of decrease of the lengths of the sequences is already very steep, so that the piloting system will actuate the more energetic braking steps at times which are very close together, which will have for its effect a very fierce braking, and even, in the most unfavorable conditions, the absence of stopping of the train which will continue travelling beyond the stopping point predetermined by the piloting cable.

The chief object of this invention is to eliminate to a large extent the disadvantages which have just been set out, both with respect to the possibility of modifying the speeds of travel of the vehicle when it is driven automatically, and, when this automatic driving is realized by the intermediary of a piloting cable disposed along the path provided for the vehicle and defining the fixed-piloting program, the arrangement of this piloting cable in a manner to permit precise piloting and, in addition, extremely simple laying of this cable along the track.

According to the principle feature of this invention, apparatus for driving a vehicle comprises division means for dividing the path provided for the vehicle into successive intervals of space capable of emitting sequential signals, and, on board the vehicle, at least one receiver adapted to pick up these signals at the end of the travel by the vehicle along each of these intervals, characterized by the fact that this apparatus comprises in addition a speed control device for controlling the effective speeds of the vehicle comprising a source adapted to supply, on at least certain parts of the path of the vehicle, at least one periodic reference signal whose frequency can be adjusted to a determined value, at the level of each of the intervals of space of these parts, to a value such that the product of this frequency by the length of this interval is proportional to the average speed desired for the vehicle on this interval of space, and a counting device for counting the periods of the reference signal-controlled by said receiver to count the number of pulses (clock number) received during the travel by the vehicle along each interval of space, this speed control device permitting the determination on each interval of space if the real speed of the vehicle is equal to, higher than or lower than said desired speed, according as the clock number measured on each of these intervals is equal to, lower than or higher than a determined fixed base number.

In a first, particularly advantageous embodiment of the invention, permitting the realization of completely automatic driving of the vehicle, the intervals of space constitute "-sequences" of lengths proportional to the speed desired for the vehicle at their respective locations and the reference signal has the same frequency, whose value can however be modified at will, at the location of each of these sequences, and the traction and braking equipment of the vehicle is controlled by the counting device in order to give a traction or braking order to the vehicle, according as the number of pulses counted (clock number) on each sequence is higher than or lower than a predetermined base number.

In another embodiment of the invention the successive intervals of space have lengths equal among themselves and the frequency of the reference signal is regulated to a value directly proportional to the speed desired for the vehicle at the level of each of these sequences, and detection means for detecting overspeeds of the vehicle are controlled by the counting device in order to produce, when the measured clock number falls below said base number, a signal adapted to be exploited by an alarm device or adapted to act on the braking equipment of the vehicle.

The invention comprises, apart from this principal feature, certain other features, which are preferably used at the same time, but which could, should the occasion arise, be used separately, and which will be more explicitly described hereafter, in particular a second feature according to which, on the one hand, the piloting cable comprises a plurality of cable segments disposed along the track travelled by the vehicle, as prolongations of each other, these cable segments being connected in twos by groups, similar to each other, of cable elements of discontinuous orientations with respect to the orientations of these segments, these groups extending respectively along relatively short distances of the track, each segment and one of the above-mentioned associated groups having a length each time equal to a sequence, and on the other hand, there are established on the vehicle at least one pickup exposed permanently to the field produced by the current passing through the piloting cable, and means for exploiting the relative variations of the field picked up during the passage of the vehicle above these groups in order to control the piloting device of the vehicle.

In any case, the invention will be able to be well understood with the aid of the following complementary description and the accompanying drawings, which complementary description and drawings are, needless to say, given above all by way of example.

In these drawings:

FIG. **1** is a schematic representation of a piloting cable according to a preferred embodiment of the invention, laid on the track travelled by the train;

FIG. **2** is a curve representing a sequential pickup signal obtained with the aid of a pickup having two coils cooperating with a piloting cable of the type shown in FIG. **1**;

FIG. **3** shows the different positions of such a pickup with respect to such a piloting cable, during the travel of the train above the cable parts adapted to permit the detection by the pickup of the moments of the passage of the train from one sequence to another, as well as the modifications of the field so picked up;

FIG. **4** shows a variant of the path of the cable represented in FIG. **1**;

FIG. **5** represents schematically an advantageous circuit for shaping the sequential pickup signals;

FIG. **6** illustrates a program of control of the equipment of traction, of braking and of travel on headway of the train;

FIG. **7** represents in a schematic manner the constitution of the electronic circuit of a device, controlled by the sequential pickup signals, for counting the pulses of a source of determined frequency, in order to control the above-mentioned equipment;

FIG. **8** shows a curve representing a control produced by a generator driven by an axle of a wheel of the train and a square wave signal curve resulting from the shaping of the control signal;

FIG. **9** shows in alternate form the equipment for producing the signals of FIG. **8**.

The following description relates to apparatus for the automatic driving of a train, in particular of an underground or subway, from an operational program inscribed on the track in the form of a piloting cable disposed on this track and through which an electric control current passes.

Concerning first of all the piloting cable itself, it is advantageously constituted, according to the invention, by making it comprise a plurality of cable segments **11** disposed parallel to the rails and substantially as prolongations of each other, these cable segments being connected to each other by groups **12**, similar to each other, of elements of cables of discontinuous orientations with respect to the orientation of the above-mentioned segments, extending along relatively short distances of the track, each segment **11** and one of the associated groups **12** having a length equal to one sequence, the train then being equipped with a pickup C exposed permanently to the field produced by the current passing through the piloting cable, and means, of which an advantageous embodiment will be described hereafter, for exploiting the variations of field received by the pickup, at the location of these groups of elements, to control the piloting device proper of the vehicle.

In practice, this cable is advantageously comprised by a single cable, which is made to describe a figure of discontinuity at the location provided for each of these groups. This cable extends, for example, in the case of the subway, from one station to another, its ends being connected to a periodic current supply **9**, for example by a wire **10***a* running along the rail **10***b* or by the rail itself (FIG. **1**).

According to a more particularly advantageous embodiment of the preceding feature, the groups **12** of cable elements, having a discontinuous orientation with respect to the orientation of the cable segments **11**, comprise an inclined Z whose upper and lower bars, **13** and **14**, connected to the adjacent ends of two successive segments **11**, form an angle, for example of 45°, with the segments **11**, the connection element **15** of these two bars **13**, **14** in the Z being advantageously perpendicular to the common direction of the two segments **11** considered. Each group of elements **12** thus forms a double chevron having a common bar, this group of elements being designated more simply hereafter, for convenience of the language, by the term "chevron."

Advantageously the pickup comprises two coils (only a single coil being nevertheless necessary) A, B (FIG. **3**) carried by the train, both coils being vertically in line with the segments **11** and spaced a short distance from each other, these two coils forming for example an angle of 45° with respect to the direction of the segments and being situated at a distance of approximately 8 to 12 centimeters (cm.) from these segments; advantageously this pickup also comprises a reference coil R also subjected to the field, and which, among other things, contributes to shape the signal produced by the pickup during its passage from one sequence to another, in a preferred embodiment of the shaping circuit which will be described later on. Such a signal will be called hereafter "pickup signal" for the convenience of the language.

One of the ends of the coil A is connected one end of the coil B so that the voltages induced in each of these coils are in phase, and so that the voltage appearing between the terminals S_1, S_2 (visible in FIG. **5**) constituted by their free ends is zero, when these coils both move above the piloting cable segments **11**.

When the coils arrive above a chevron **12**, the modification of the layout of the piloting cable has the effect of making a phase displacement appear between the voltages induced in the two coils, and consequently of making a differential voltage appear between the terminals S_1, S_2, which differential voltage, after demodulation, gives rise to an effective voltage which is variable as a function of the respective positions of the two coils A and B with respect to the chevron, this variable effective voltage being then capable of being exploited to pilot the train, for example, as will be described hereafter.

When the elements **13** and **14** of the chevrons form an angle of 45° with the direction of the cable segments **11** to which they are respectively connected, and the two coils A, B of the pickup are situated at a distance from each other equal to half the diagonal of the square, of which the elements **13** and **14** define two opposite sides, the effective voltage appearing at the terminals S_1, S_2 of the coils A and B varies substantially according to the curve E passing through the points **1**, **2**, **3**, **4**, **5**, **6**, **7** of FIG. **2** (the values Ueff of this voltage being shown along the ordinate) as a function of the relative position (indicated on the abscissa) of the pickup above a chevron **11** (shown in dashed lines in FIG. **2**).

This curve can be explained still more with the aid of FIG. **3**, whose parts **3***a* to **3***g* represent, on the one hand, successive positions of the coils A and B with respect to the elements **13**, **14**, **15** of a chevron, and on the other hand, the phase displacement between the resulting induced voltages, the corresponding values of the effective voltage Ueff at the terminals s_1, S_2 being given by the points **1**, **2**, **3**, **4**, **5**, **6**, **7** of the curve E of FIG. **2** (in which a reference chevron **12** is represented in dashed lines).

When the coils A, B are located in the position represented in the part **3***a* of FIG. **3**, both coils being still practically in a zone influenced solely by the segment **11**, the field penetrates into the coils A and B by their respective faces **16***a*, *17a*, the voltages induced in these coils being in phase, as shown schematically by the single curve shown above the coils A and B, and the voltage at the terminals S_1, S_2 is zero.

When the coil A arrives above the cable element **13**, as represented in the part **3***b*, the modification of its relative orientation with respect to the overall field received, makes a phase difference appear between the voltages induced in the coils A, B, and consequently, makes an effective voltage Ueff represented at **2** in FIG. **2**, appear at the terminals S_1, S_2, the coil B being exposed only to the field of the segment **11**, this phase difference also being symbolized, by the curve A_2 in solid lines for the voltage induced in the coil A and the curve B_2 in dashed lines for the voltage induced in the coil B, above the drawing shown in the part **3***b* of FIG. **3**.

This phase difference continues to increase and the voltages induced in the coils finish by being in total phase opposition (as indicated by the curves A_3, B_3), Ueff having the maximum absolute value represented by the point **3**, when these coils occupy respectively the positions represented in the part **3***c* of FIG. **3**, since, in this position, the field penetrates into the coil A by its face **16***b*, opposite to the face by which it enters, along the same angle of 45°, when the coil is located above a segment **11**, whereas the coil B is still essentially subjected to the field of the segment **11**, which enters by the face **17***a* of this coil.

This phase difference, as well as Ueff, are going to decrease again when the coils B and A continue to move towards the positions represented in the part **3***d* of FIG. **3**, in which the voltage induced in these coils are again in phase, (Ueff represented by the point **4**), in view of the symmetrical positions of the coils with respect to the element **15** of the chevron.

The phase difference and the voltage Ueff (which have however changed sign) reappear again when the pickup continues its travel, the phases being again in opposition (curves A_4, $b_4$for the position of FIG. **3***e*) and Ueff maximum in absolute value (point **5** of FIG. **2**) when the coils reach the positions represented in the part **3***e* of FIG. **3**, the coil A reentering again the zone of action of a segment **11**, this time the following segment, the field then entering this coil A again by its face **16***a*, whereas the coil B essentially enters the zone of action of the element **14**, the field penetrating into this coil by its face **17***b* (instead of **17***a* as in the case of the part **3***a* of FIG. **3**).

This phase displacement decreases again in absolute value until the moment when the coils occupy the positions represented in the part **3***f* of FIG. **3**, the phase difference and Ueff being completely eliminated when the two coils are both again exposed solely to the field of a new segment **11**. During the passage of a chevron, an induced voltage is obtained (FIG. **2**) whose law is given by the ordinate, associated with the signs + and − for showing the change of phase with respect to a reference (advantageously coming from the reference coil R).

The pickup signal thus obtained can therefore be exploited, advantageously after shaping, by the intermediary, in particular, of a preferred-shaping circuit which will be described hereafter, to determine, in an extremely precise manner, the moments in time of the passage of the train from one sequence to another; these signals can then be exploited by conventional chronometry, or preferably, by a counting device according to the invention which will also be described later on, to actuate the steps of traction, of braking or of travel on headway of the train, in conformity with the orders sent by the pickup.

The type of piloting cable that has just be described is extremely easy to lay since the major part (which can reach more than 95 percent of its length) is laid in a straight line; the chevrons can be very simply obtained by making the cable pass at the desired regions around securing members fastened to a plank laid permanently on the track.

Furthermore, this feature of the invention offers the advantage that the chevrons can be inscribed in squares of small dimension, for example 200 millimeters (mm.) to a side. In this manner there is thus also obtained a piloting cable having a real length reduced to the length of the track, with slight elongations near the cable necessary for the realization of the chevrons, and hence a reduction to a minimum of the power of the supplies of periodic current for the cable.

Another advantage resides in the possibility of shifting easily a part of the piloting cable with respect to the overall direction of the cable, for example as represented in FIG. **4**, for example from the middle of the track (central cable) to a position near to the rails (lateral cable), for example to go around a hole or a source of a considerable stray field; the train should then be equipped with a second pickup C_1 adapted to enter the zone of influence of the field of the segments **11***a* of the shifted part of the piloting cable to take the place of the pickup C, the ends of the interrupted segments **11** of the central cable and the ends of the lateral cable being interconnected in such a manner that the pickup C_1 enters the zone of influence of the segments **11***a* of the lateral cable before the pickup C leaves the zone of influence of the segments **11** of the central cable and vice versa when the central cable comes back into play, the signals produced by one or the other of these two pickups C, C_1 being applied to the inputs of an "OR"-gate **18**, the timing mechanism mentioned above then being controlled by the pickup signal appearing at the output of this gate.

The shaping envisaged above of the pickup signal is then advantageously realized as follows:

The differential pickup signal appearing at the terminals S_1 and S_2 of the two coils A and B of the pickup is applied to a phase discriminator **21** (FIG. 5), whose phase reference comes from the voltage induced in the reference coil R, this phase discriminator supplying a demodulated signal whose effective voltage varies according to the function shown schematically by the curve E in solid lines in FIG. 2. As represented in FIG. 2, this voltage has, for example, a positive half-cycle followed by a negative half-cycle with respect to the phase reference.

The demodulated signal in question is used to supply the input (−) **23** of an operational amplifier **22**, the input (+) **24** of this amplifier being supplied with a positive voltage obtained by the rectification of the signal supplied by a second winding R_2 carried by the reference coil, this voltage being lower in absolute value than the maximum amplitude of the demodulated voltage.

The operation amplifier **22** is adjusted so that a constant positive voltage (state +) is obtained at its output as long as its input (−) **23** is not supplied with a negative voltage higher in absolute value than the rectified voltage supplying its input (+) **24**.

When the negative voltage supplying the input (−) **23** of the operational amplifier exceeds this threshold established by the rectified voltage at input (+) **24** (represented by the points **26** in FIG. 2), the operational amplifier switches over to supply a negative voltage (state −) at its output.

The signal produced by the operational amplifier during this switching over is exploited to make a Schmidt trigger **27** for example pass from a state (+) to a state (−), preferably when the voltage of the output signal of the operational amplifier passes through 0.

The negative front of the signal supplied by the Schmidt trigger is then used to trigger a monostable multivibrator **28** which supplies a square wave of determined duration, for example a negative square wave of 100 microseconds, this square wave being directly exploited by the timing mechanism of the system of automatic piloting of the train to compare the times taken by the train to travel each sequence with the predetermined base time.

The use of a rectified positive voltage coming from the winding R_2 (reference) to supply the input (+) **24** of the operational amplifier is particularly advantageous in the sense that it renders the entire circuit substantially independent of the possible variations of amplitude of the intensity of the periodic current passing through the piloting cable, and in general, of the aleatory variations of the field picked up. Supposing that the intensity of this current decreases, there is obtained at the output terminals of the phase discriminator **21**, an effective voltage of lesser amplitude, presenting for example a function according to the curve E_1 represented in dot-dash lines in FIG. 2, but also a decrease in the same ratio of the rectified positive voltage supplying the input (+) **24** of the operational amplifier, so that the threshold of switching over (point **26***a* of FIG. 2) of this amplifier is also decreased in the same ratio, this switching over then being obtained at a substantially constant level of the pickup with respect to the chevron which caused the appearance of the differential signal, whatever be the intensity of the periodic current in the piloting cable.

Such a system of shaping the differential signals appearing at the terminals S_1, S_2 of the coils A, B, practically permits the elimination of the stray fields which can can be picked up separately by the coils A, B. For these stray fields to be able to disturb the shaping of the differential signal, it would be necessary not only that they influence the two coils A and B in a different manner, but also that they have the same frequency as the periodic current passing through the piloting cable, in order to pass through the phase discriminator **21**.

The square waves coming out of the monostable multivibrator can then be directly applied to a timing mechanism measuring the time taken by the train to travel each sequence, this timing mechanism being adapted to control the braking equipment or the traction equipment of the train, or again to let the train travel on headway according as the time taken by the train to travel a sequence is smaller than, greater than or of about the same magnitude as the base time, for example 500 milliseconds (msec.), which it would normally take to travel this sequence if it were travelling at the desired speed.

In particular, in the normal case in which the braking and the traction equipment comprise respectively several steps of traction T_2, T_3 etc. . . and of braking F_1, F_2, F_3, F_4 etc., the timing mechanism should be adapted to chose the appropriate traction step or the appropriate braking step according to the value of the separation between the time measured on a sequence travelled by the train and the base time.

Although the square signals obtained at the output of the shaping device described above can be supplied to any conventional timing mechanism capable of measuring and comparing the real times of passage of the train along each sequence with the time that it should theoretically have taken, in order to control the braking and traction equipment of the train to correct constantly its speed of travel, it is particularly advantageous to use the automatic driving apparatus according to the present invention. This apparatus comprises a source of pulses (reference signal), of frequency adjustable to a determined value, which can, however, be modified at will, this reference signal being advantageously supplied by the half-cycles of the current passing through the piloting cable, whose frequency is carefully adjusted to a determined value, for example to 1,000 cycles per second. It further comprises a counting device for counting the pulses received, controlled by the sequential signals supplied by the pickups, in particular by the square waves mentioned above resulting from their shaping, for counting the number of pulses (clock number) received by the train above each sequence, this counting device being adapted to control the steps of braking or of traction according as the clock number is lower than or higher than the base number, for example 500.

Supposing that the current passing through the piloting cable has a frequency of 1,000 cycles per second (piloting frequency), it will be realized that the train will travel on headway if the counting device counts 500 periods of this current during the passage of the train over each sequence. Furthermore, if means are provided for controlling the braking steps of increasing energies, for example five braking steps F_1, F_2, F_3, F_4, F_5 when the clock number measured by the counting device falls below values N_{F_1} to N_{F_5} respectively equal to:

450
400
360
330
310

during the passage of the train above each sequence, and conversely, for controlling two traction steps T_2, T_3 for example, when the measured clock number exceeds values respectively equal to:

$$N_{T_2}=560$$
$$N_{T_3}=630$$

it will be noticed that the piloting conditions are such that the train travels on headway when it travels the respective sequences in times of 500 msec., and that the various steps of the traction equipment and of the braking equipment are actuated when the effective times of passage of the train along each sequence fall below:

$$T_{F_1}=450 \text{ ms}$$
$$T_{F_2}=400 \text{ ms}$$
$$T_{F_3}=360 \text{ ms}$$
$$T_{F_4}=330 \text{ ms}$$
$$T_{F_5}=310 \text{ ms}$$

for the braking steps and exceed the times of:

$$T_{T_2}=560 \text{ ms}$$
$$T_{T_3}=630 \text{ ms}$$

for the traction steps.

Needless to say, as results from the examples given above, it is appropriate to provide a certain latitude between the various values of the clock numbers N_{F_1}, N_{F_2} . . . measured along the sequences for actuating respectively the steps F_1, F_2 . . ., so as to avoid "hunting" of the electronic piloting device when the times measured over the sequences oscillate about a critical value, which would have the effect of too rapid alternate actuation of consecutive steps.

The great advance of counting the pulses of the reference signal and of controlling the equipment for traction, for braking and for travel on headway of the train, when the clock numbers cross determined thresholds, rather than controlling this equipment by the measurement of the times of passage of the train over successive sequences and by their comparison with a fixed time base, resides in the fact that (since these control clock numbers do not vary) a supplementary parameter is made available, constituted by the frequency of the reference signal, which can be adjusted to different values. It then becomes possible to obtain time bases of variable magnitudes, as well as, by consequence, variable desired speeds of travel of the train on headway, these desired speeds being variable by the simple adjustment of the frequency of the reference signal, this time base being now inversely proportional and the desired speed of travel on headway proportional to that frequency. The same piloting cable can thus be adapted to any conditions of desired travelling speed of the train, this desired speed being determined according to the desired time of passage of the train over each sequence.

In particular, when it is desired to pass for example from the operating conditions defined above, which correspond for example to conditions of accelerated travel, to conditions of slow travel, it is sufficient to reduce the frequency of the reference signal, hence to increase the time base corresponding to the time of passage over each sequence of the piloting cable by the train, when the train travels on headway.

The possibility of varying the speed of travel on headway of the train, in particular of permitting conditions of slow travelling, thus also leads to the fact that the train can also approach the slowing-down zones of its path at a slower speed. The braking equipment is actuated progressively as soon as the train passes over the first sequences which begin to become shorter, so that a gentler deceleration is obtained than in the accelerated travel conditions. Since the steady-state speeds of the train are proportional to the frequency of the reference signal, decelerations, in the slowing-down zones mentioned above, vary as the square of the ratio of the frequencies, so that each frequency of the reference signal corresponds to a different decreasing function for the decelerations desired for the train, from the same piloting cable.

Supposing, for example, that it is wished to provide conditions of "normal operation" with a speed $v_n=v_o/1.1$ corresponding to the steady-state speed v_o of the conditions of accelerated operation, it is sufficient to modify the piloting frequency in the same ratio, that is to say to supply the piloting cable with a current of frequency equal to 1,000×1/1.1=910 cycles per second.

The effective time of passage of the train over a sequence, when it travels on headway, will thus vary in the same ratio, since the effective base time corresponding to the operation of the train on headway then becomes equal to 550 msec.

The base times, for three types of different operating conditions having common fixed clock numbers N_F for controlling the steps of traction or of braking or of travel on headway, are shown in FIg. 6, which is presented in the form of a Table; the fixed clock numbers N_F, each provided with the index corresponding to the index of the braking step that it controls, are given in the left-hand column and the effective time bases T_F provided with the corresponding indices, as functions respectively of the three frequencies chosen for the current passing through the piloting cable, namely 1,000 cycles per second, 910 cycles per second, 800 cycles per second, correspond respectively to the clock numbers shown on the same horizontal lines with these time bases T_F.

In particular, each of the braking steps is maintained as long as the measured clock number is comprised between the number N_F having the corresponding index indicated in FIG. 6 and the number N_F corresponding to the actuation of the consecutive more energetic braking step, whatever be the value of the frequency.

This Table also shows the conditions of control of the steps of traction, the first of which T_2 is actuated only when the measured clock number falls below 560 for example (and remains between 560 and 630), the train travelling on headway until this value of the clock number is reached, as indicated by the descending arrow E*a*; the step T_2, once actuated, is nevertheless maintained until the clock number has again reached 500 (which is symbolized by the ascending arrow T_{2a} between the values indicated for N_{T_2} (560) and E (500).

Similarly, T_3 is actuated when the clock number falls below 630 for example, T_3 being advantageously maintained until the clock number has again reached 500 (ascending arrow T_{3a}).

Naturally it is clear that the establishment of three operating conditions of the train which has just been described has only a purely illustrative purpose, since as many operating conditions for the train can be established as frequencies can be chosen for the reference signal. The new feature according to the invention thus permits completely analogical adjustment of the operating conditions of the train.

Concerning now more particularly the counting device mentioned above, for counting the number of reference signal pulses received, in the course of the passage of the train over each sequence, it can be established in any appropriate manner. Nevertheless, it is advantageous to use a counting chain controlled by the sequential signals appearing at the terminals S_1–S_2 of the pickups, such as the one that will be described hereafter, this counting chain comprising essentially (FIG. 7) a decade register supplied with the reference signal, comprising advantageously:

three decades D_1, D_2, D_3, mounted in cascade, realizing successively a division by 10, a division by 100 and a division by 1,000 of the reference frequency applied to the input of the first decade;

decoding matrices MD_1, MD_2 . . . for realizing the binary decimal conversion of the binary information given by the decade register, in order to supply clock numbers in decimal form;

a program matrix MP to which are sent the clock numbers obtained at the output of the decoding matrices, capable of switching the clock numbers towards one of the memories, for example, MT_3, MT_2, ME, MF_1, MF_2, MF_3, MF_4, MF_5, each of these memories being adapted to be able to receive only the clock numbers contained in an interval which is proper to it (for example according to the program of Table 1 appearing below) and adapted to be able to register it only in synchronism with the input of the counting device for counting a sequential pickup signal, to control, by the intermediary of power relays (not shown), one of the corresponding steps

T_2, T_3 of traction, of braking F_1, F_2, F_3, F_4, F_5 or E of proceeding on the headway of the train.

Clock number	Memory
100–279	MF_5
280–329	MF_4
330–359	MF_3
360–399	MF_2
400–449	MF_1
450–559	E
560–629	T_2
630–and more	T_3

These memories are such that a single one of them only can control a step; two memories cannot be controlled simultaneously. These memories then define a set of memories comparable to a keyboard where the depression of one key liberates the key already depressed beforehand, without two keys ever being able to be depressed simultaneously, such a feature then permitting to pass from one control to another by the simple excitation of the memory to be brought into play.

The reference signal supplying the counting device is advantageously taken from the output terminals S_3, S_4 (FIG. 5) of the reference coil R of the central pickup C or from the output terminals of the reference coil of the lateral pickup C_1, according as the train passes over a central portion or a laterally offset portion of the piloting cable, the corresponding signals being respectively applied to the inputs **101** or **102** of an "OR" gate P_1 of the counting device, the signal obtained at the output of the gate P_1 being sent, after amplification in an amplifier A, to the input **103** of a Schmidt trigger B, realizing the shaping of the reference signal and supplying at its output **104** a square wave capable of supplying the first decade D, through a triggered gate P.

The sequential pickup signals, advantageously shaped by a device such as the one described with reference to FIG. 5, controlling the above-mentioned device for counting the number of pulses received during the passage of the train over each sequence, are advantageously exploited for:

terminating the counting sequence

controlling the entry into the memory of the clock number then obtained at the output of the decoding matrices

resetting the counting chain to zero

and restarting a new count.

All these operations are realized successively in a very short time, less than the duration, for example of 100 microseconds (μs), of the control pulse, so that the clock number, measured over each sequence, is proportional to the absolute value of the time taken by the train to travel this sequence.

The memory, having registered the preceding clock number, can then control, during the new count, the corresponding step of the equipment for braking, for proceeding on headway, or for traction of the train.

These operations are advantageously controlled by the successive edges of the square control pulse of 100 μsec. and of the signals obtained at the successive outputs of a series of monostable multivibrators M_1, M_2, M_3, connected in cascade. The first monostable multivibrator is triggered by the negative edge of the square control pulse, obtained at the output **106** of an "OR" gate P_2 at the inputs **98**, **99** of which are applied the pickup signals, after their shaping, coming, either from the central pickup C, or from the lateral pickup C_1, according to the disposition of the piloting cable on the track at the region of the sequential signal picked up.

In particular, the square control wave, obtained at the output **106** of the "OR" gate P_2 is applied, in the electronic counting circuit shown schematically in FIG. 7, on the one hand, to the input **107** of the gate P mentioned above, which is then closed by the negative edge of that pulse in order to interrupt the succession of pulses at the input of the first decade D_1, and consequently their counting, and on the other hand, to the input of the monostable multivibrator M_1 adapted to supply at its output a square positive pulse having a duration of 10 μsec., which is applied to the input of the second monostable multivibrator M_2;

The monostable multivibrator M_2 is adapted to be triggered by the negative edge of this latter pulse, thus with a delay of 10 μsec., and is adapted to supply, on the one hand, at its output **108**, a pulse having a duration of 20 μsec. exploited by the one of the memories which is then capable of registering the clock number, and one the other hand, at its output **109**, a concomitant pulse of 20 μsec. whose negative edge triggers, with a supplementary delay of 20 μsec., the third monostable multivibrator M_3; the monostable multivibrator M_3 sends in its turn, via its output **111**, a pulse of 20 μsec. to the zero resetting inputs **112**, **113**, **114** of the decades D_1, D_2, D_3, these decades then being ready to restart a new count of the pulses supplied by the reference signal, as soon as the gate P has again been liberated by the positive front of the 100 μsec. control pulse, for measuring the new clock number corresponding to the travel by the train over the following sequence of the piloting cable, and so on.

It will be noticed that, in the circuit of FIG. 7, it has been proposed to decode only the hundreds and the tens of the clock number and not its units. However by referring to Table 1 given above, it is apparent that the switching between two memories will be realized without considering the units of the clock number, since the switching from one memory to another always implies as well the switching of the tens digit of the particular switching clock numbers chosen.

Needless to say, if it were desired to modify the program of switching of the memories, in particular to cause their switching by clock numbers having nonzero units digits, it would then become necessary to provide a supplementary decoding matrix capable of making the units digit of the clock numbers appear.

As a result, whatever embodiment is adopted, the present invention always provides apparatus for the automatic driving of vehicles, in particular trains, whose operation is sufficiently clear from the foregoing that it is not necessary to give any further explanation in this connection. This apparatus has, with respect to already existent automatic-driving apparatus of the type in question, numerous advantages which have already been mentioned, including the possibility of continuous regulation of the operating conditions of the train.

It also becomes possible, along a path which comprises several sections of piloting cables supplied by distinct sources of current, to envisage the regulation of the intervals of time between the passages of the successive trains in the same station.

Supposing, for example, that one of the trains of the line falls behind schedule (for example by waiting too long in the stations due to a larger number of passengers getting on or off than for the other trains), it can be advantageous to slow down the train which precedes the train already behind schedule, which can be easily accomplished by decreasing in the desired ratio the frequency of the current passing through the section of the piloting cable above which the preceding train is travelling at that time.

Apparatus for the completely automatic driving of a train can also be realized by only bringing into play the variations of frequency of the reference signal, in particular in the case in which, all the other parts of the driving apparatus remaining the same, the path provided for the vehicle is divided into successive intervals of space of lengths equal among themselves, and preferably, equal to the revolution of a wheel of the vehicle, the variations of speed desired from one interval of space to another being then controlled by the modification in the same sense of the frequency of the reference signal.

There again, the counting device described above acts, either on the traction equipment, or on the braking equipment, according as the measured clock numbers are lower than, or higher than a determined base number which is always constant.

The sequential signals exploited by the counting device can, as in the driving apparatus described above, be supplied to it by one or preferably several portions of piloting cable disposed along the track in a manner to divide the track into successive sequences equal among themselves, the periodic currents passing through these portions of cable advantageously constituting, there again, the reference signal exploited by the counting device.

However according to another embodiment of the invention, the division of the track, travelled by the vehicle, into intervals of space preferably equal to the revolution of a wheel of the vehicle and the emission of a sequential signal each time that the vehicle has travelled such an interval of space are obtained by the intermediary of means also carried by the vehicle, in particular by the intermediary of a contact which is closed periodically by one of the wheels each time that this wheel has effected a complete revolution, or more advantageously, by a generator driven by one of the wheels of the vehicle and producing signals having a frequency proportional to the speed of rotation of the wheels, these signals having, at the end of each rotation of the wheel, a determined amplitude exploited to control the stopping of the counting of the pulses of the reference signal when the vehicle has completed the travel of a given interval of space and the beginning of the counting of these pulses on the following interval of space.

FIG. **9** shows diagrammatically a section **300** of track on which rolls the vehicle, a piece of whose body is represented at **301**. Also shown is one wheel **302** of the vehicle. Mounted to be driven by the axle **303** is a rotary generator **304**. This generator, which may be of any appropriate conventional type, delivers the signals of FIG. **8**, which are utilized as previously explained. In particular, it delivers either directly a signal such as that shown at **208**, in the event the generator simply closes a switch each time the wheel to which it is attached makes one revolution, or its output, as shown at S in FIG. **8**, is utilized as explained hereinafter.

The source supplying the reference signal is then, in this embodiment of the invention, constituted by the elements of conductors disposed along the parts of the track considered, these conductor elements carrying periodic currents, preferably alternating, of determined frequencies which are a function of the desired speeds on each of these parts for the vehicle.

The driving apparatus thus modified, and more particularly the counting device, can moreover be used, not only for realizing completely automatic driving of the vehicles, but also for realizing semiautomatic driving, or according to one of its particularly advantageous applications, can be adapted as an automatic detection device for detecting overspeeds of travel of the vehicles along certain parts of their paths, for example in the curves, in the zones which precede their passage over the switches, etc.

The counting device is then adapted to control the triggering of the alarm signal mentioned above or the actuation of the braking equipment of the vehicle when the clock number measured over one of the intervals of space exceeds a determined constant threshold.

The construction of such a detector of overspeed can use the same elements as those described in connection with the driving apparatus mentioned above;

The signal supplied by the generator driven by one of the wheels of the train has been represented, by way of example, in FIG. **8** which shows the variations of voltage V of this signal (shown on the ordinate) as a function of the distances l travelled by the train (shown on the abscissa). This signal can be shaped by a circuit of the type described with reference to FIG. **5** in order to supply at each period (at the points **204** of the curve of FIG. **8**) a negative square wave **208**; these square waves **208** then control a counting scale analogous to the one described with reference to FIG. **7**, in which however the program matrix MP and the memories M_{T_3}, M_{T_2}, etc. . . are replaced by a single memory which registers the clock number supplied in decimal form by the decoding matrices M_{D_1}, M_{D_2}, etc. . . in synchronism with the input of a square control signal **208** in the counting scale to control the automatic braking of the train, the actuation of an alarm system, etc. . . if the clock number is lower than a determined base number.

As a result, there are obtained very simple means of detection of overspeeds of a train along certain parts of its path, and the maximum speeds authorized on each of these parts can easily be modified by the corresponding change of the frequency of the reference signal.

Many variations of the invention are possible. For example according to one such variation, the source adapted to supply the variable frequency reference signal can also be established on board the train, its actuation being controlled and the frequency chosen, when the train travels along certain parts of the track, by sequential signals supplied to the train by emitters established at certain regions of the track.

In view of the various modifications and variations which can be made without departing from the spirit or scope of this invention, the invention should not be limited to the particular embodiments described by of example.

What I claim is:

1. Apparatus for driving a vehicle along a predetermined path, comprising:

means for dividing said path into successive intervals of space;

means associated with said intervals for producing sequential signals;

at least one receiver on board said vehicle for detecting these signals at the end of the travel by the vehicle along each of these intervals;

and a speed control device for controlling the effective speeds of the vehicle including means for supplying, on at least certain parts of the path of the vehicle, at least one periodic reference signal whose frequency can be adjusted at the location of each of said intervals of space of these parts, to a value such that the product of this frequency by the length of a given interval is proportional to the average speed desired for the vehicle on this given interval of space, and counting means for counting the periods of the reference signal, said counting means being controlled by said receiver to count the number of periods (clock number) received during the travel by the vehicle along each interval of space, and means to determine for each interval of space if the real speed of the vehicle is equal to, higher than or lower than said desired speed depending upon whether the clock number received for each of these intervals is equal to, lower than or higher than a predetermined base number.

2. Apparatus according to claim **1**, characterized by the fact that said dividing means divide the vehicle path into successive intervals of space that are equal among themselves.

3. Apparatus according to claim **2**, characterized by the fact that said vehicle is wheeled and said dividing means comprise a contact which is closed periodically by one wheel of the vehicle each time that this wheel has effected a complete revolution.

4. Apparatus according to claim **2**, characterized by the fact that said vehicle is wheeled and said dividing means comprise generator means driven by one wheel of the vehicle and producing signals having a predetermined amplitude at the end of each wheel revolution, and means associated with said receiver to detect said predetermined amplitude.

5. Apparatus according to claim **1**, characterized in that the means for supplying said reference signal comprises conductor elements disposed on the vehicle path.

6. Apparatus according to claim **1** further comprising means controlled by said counting means for producing an alarm signal when the clock number received in an interval of space falls below said base number.

7. Apparatus according to claim **1**, further comprising means for giving a braking order to the vehicle when the clock number received in an interval of space falls below said base number.

8. Apparatus according to claim **1**, characterized in that said dividing means comprise a piloting cable and means for passing an electric current through said cable, said piloting cable being disposed along the vehicle path in such a manner that this current creates a sequential signal adapted to be received by said receiver, each time that the vehicle has travelled an interval of space of length proportional to the average speed desired for the vehicle at the corresponding region of said path.

9. Apparatus according to claim 8, characterized in that said counting means produces a traction or a braking order for the vehicle depending upon whether the clock number received in each interval of space is higher than or lower than said base number.

10. Apparatus according to claim 8, characterized in that said counting means produces successive braking orders when the received clock number falls below determined values of decreasing order all of which are lower than said base number, and produces successive traction orders when the clock number exceeds determined values of increasing order all of which are higher than said base number.

11. Apparatus according to claim 8, characterized in that said reference signal is also formed by the current passing through the piloting cable.

12. Apparatus according to claim 8, characterized by the fact that the means for supplying the reference signal comprises a device mounted on board the vehicle, adapted to be controlled by control signals supplied via the piloting cable to produce reference signals of different frequencies.

13. Apparatus for driving a vehicle along a predetermined path, comprising:

a piloting cable;

a receiver on board said vehicle;

means for passing an electric current through said cable, said piloting cable being disposed along the vehicle path in such a manner that this current can create a signal adapted to be received by said receiver each time that this vehicle has travelled an interval of space of its path having a length proportional to the speed desired for the vehicle at this region of its path, this piloting cable being a single cable comprising a plurality of cable segments disposed along the vehicle path as prolongations of each other, these cable segments being connected in twos by groups, similar to each other, and made to describe, at the location of each said groups, a figure of discontinuity having the form of an inclined Z whose upper and lower bars, connected to the adjacent ends of two successive segments, form an angle with the segments, the other ends of these bars being connected to each other by an element transverse with respect to the direction of said segments, these groups extending respectively along relatively short distances of the path, each segment and one of said associated groups having a length each equal to one interval of space, said receiver comprising pickup means exposed permanently to the field produced by the current passing through the piloting cable, thereby to receive signals from said current; and

means for utilizing the signals so received to achieve automatic driving of the vehicle.

14. Apparatus according to claim 1, characterized by the fact that the lower and upper bars of the figure of discontinuity in the form of an inclined Z form an angle of 45° and the transverse element an angle of 90° with said segments of the piloting cable.

15. Apparatus according to claim 14, characterized by the fact that said pickup means comprises two coils, situated at a distance one from the other smaller than the dimension of the groups in the direction of travel of the vehicle, these coils both normally moving along the piloting cable segments vertically in line with these segments, one of the ends of one of the coils being connected to one of the ends of the other coil, so that the voltages induced in each of these coils are in phase when said pickup moves above these segments.

16. Apparatus for driving a vehicle along a predetermined path, comprising: means for dividing said path into successive intervals of space; means associated with said intervals for producing sequential signals; at least one receiver on board said vehicle adapted to detect these signals at the end of the travel of by the vehicle along each of these intervals; and a speed control device for controlling the effective speeds of the vehicle including means for supplying, on at least certain parts of the path of the vehicle, at least one periodic reference signal whose frequency can be adjusted at the location of each of the said intervals of space of these parts to a value such that the product of this frequency by the length of a given interval is proportional to the average speed desired for the vehicle on this given interval of space, and counting means for counting the periods of the reference signal; said counting means being controlled by said receiver to count the number of periods (clock number) received during the travel by the vehicle along each interval of space, thereby to determine for each interval of space of the real speed of the vehicle is equal to, higher than or lower than said desired speed depending upon whether the clock number received for each of these intervals is equal to, lower than or higher than a predetermined base number, said counting means comprising a decade register controlled by said receiver and supplied with the reference signal, said register comprising several decades mounted in cascade for realizing successive divisions by 10 of the frequency applied to the input of the first of said decades, decoding matrix for realizing the binary decimal conversion of the binary information given by the decade register, in order to supply clock numbers in decimal form, a program matrix onto which are sent the clock numbers obtained at the output of the decoding matrices, and memories to which said clock numbers are switched by said program matrix, each of these memories being adapted to receive only the clock numbers contained in an interval which is proper to it and to register only in synchronism with the input into the counting means of a sequential signal, thereby to control one of the corresponding steps of traction, of braking or of travel on the headway of the vehicle.

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