Feb. 4, 1941. M. ARTZT 2,230,821

SYNCHRONIZING APPARATUS

Filed June 21, 1939 2 Sheets-Sheet 1

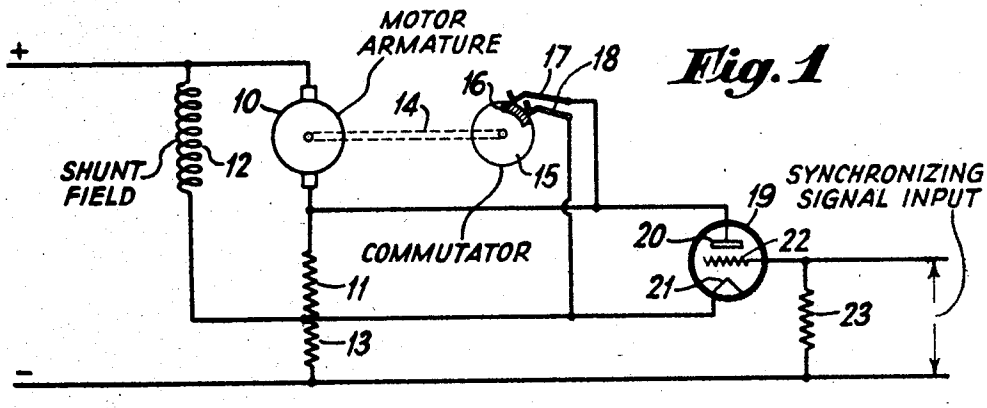


Fig. 1

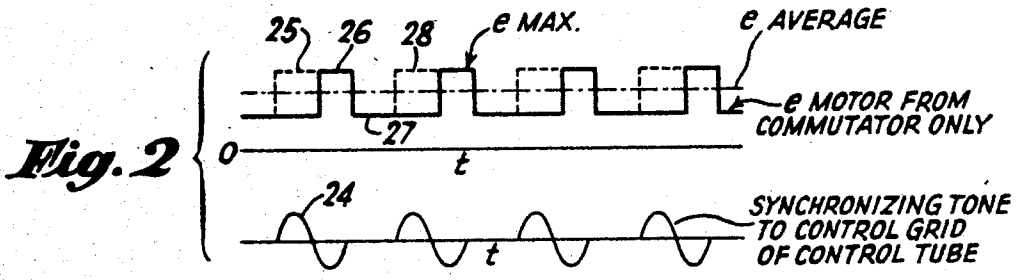


Fig. 2

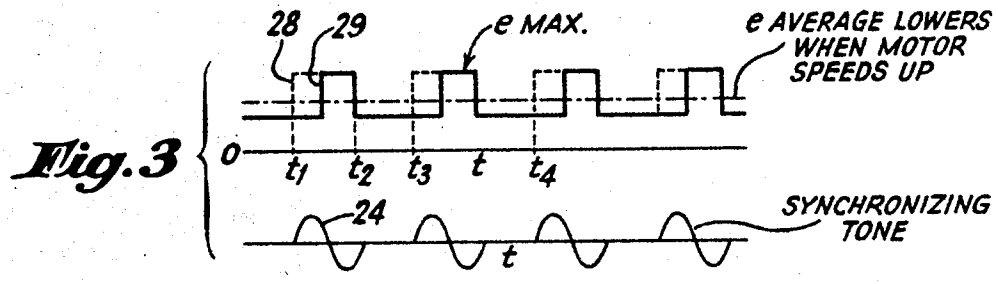


Fig. 3

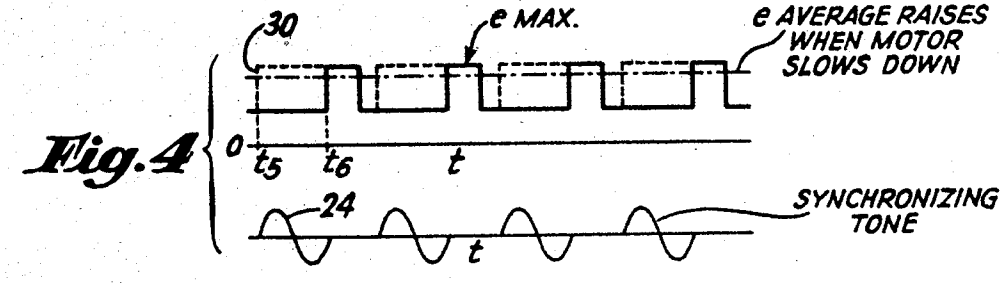


Fig. 4

INVENTOR.
MAURICE ARTZT

BY W. S. Grove.

ATTORNEY.

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SYNCHRONIZING APPARATUS

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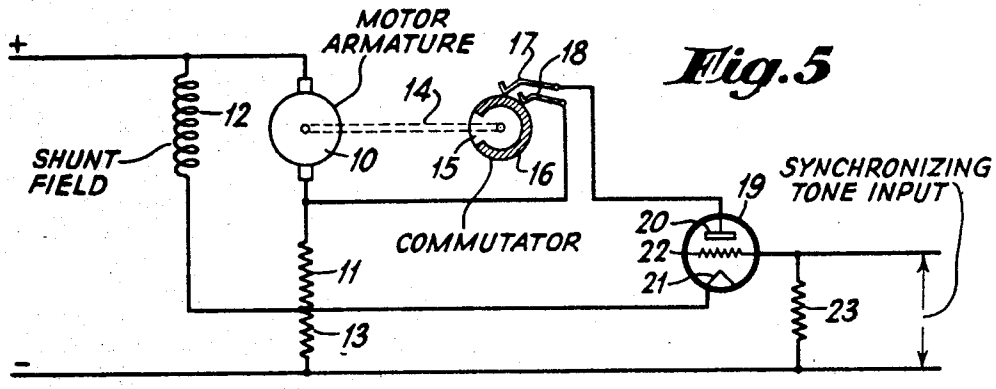


Fig. 5

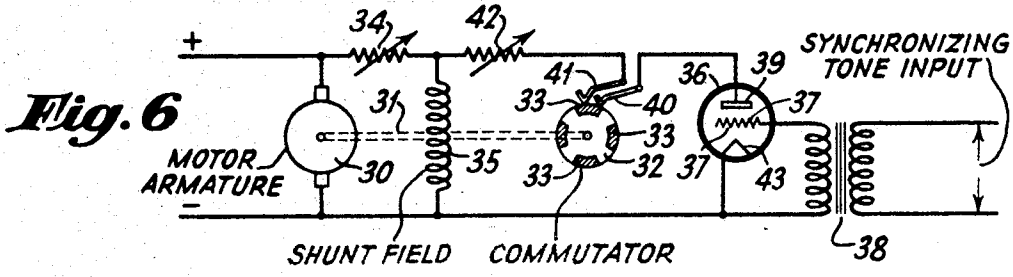


Fig. 6

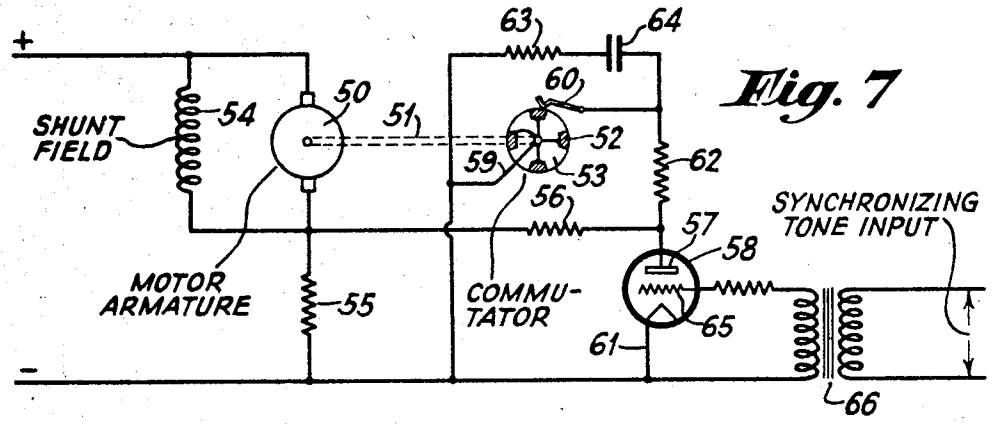


Fig. 7

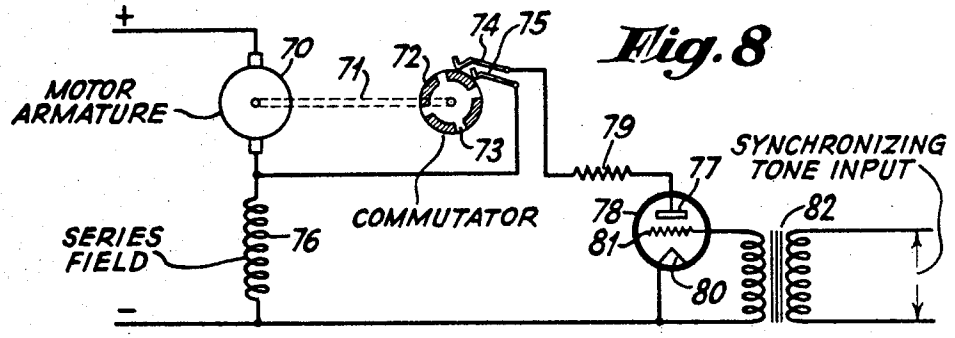


Fig. 8

INVENTOR.
MAURICE ARTZT

BY

ATTORNEY.

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UNITED STATES PATENT OFFICE

2,230,821

SYNCHRONIZING APPARATUS

Maurice Artzt, Haddonfield, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application June 21, 1939, Serial No. 280,303

11 Claims. (Cl. 178—69.5)

My invention relates in general to synchronizing apparatus, and more particularly to a method of, and apparatus for, synchronizing moving mechanical members or systems.

The synchronizing device, which is hereinafter described, has been used in actual practice to synchronize the operation of a facsimile scanner and receiver. It should be borne in mind, however, that this system is equally adaptable to other related problems, and in no way do I consider myself to be limited to its use only with facsimile apparatus.

There are a number of fields of activity in which the operation of prime movers, such as electric motors, in synchronous relationship with each other is desirable. Accordingly, it is one of the objects of my invention to provide a device which will accurately synchronize the movement of such motors.

In the field of facsimile transmission and reception, it is imperative that the receiver move in synchronism with the scanner. The problem of synchronizing a recorder with a scanner can be divided into two parts. The first is the supply at the receiver of a reference frequency. The reference frequency may come from a local circuit such as a tuning fork, or it may be received from the scanner by the channels by which the signal representing the picture to be recorded is received. The second part of the problem is the synchronizing of the driving means with the reference frequency. Accordingly, it is another of the objects of my invention to provide a device which will utilize the reference frequency to control apparatus which will definitely and accurately maintain a facsimile recorder in synchronous operation with a scanner.

One of the objections to some types of presently known systems of synchronizing is the fact that relative complex and sensitive apparatus is necessitated. It is another object of my invention to provide a device which will be relatively simple, accurate, and easy to maintain in adjustment.

Other objects will be apparent to those skilled in the art from a reading of the specification of the apparatus and its operation.

The operation of my apparatus in general is as follows: It has been brought out that this system, as explained hereinafter, has been directed toward the problem of synchronizing the operation of a recorder facsimile transmitter and recorder or receiver. In general, the picture to be transmitted is fastened on a rotating drum, and scanning apparatus linearly measures the light values of the complete picture. Signals representative of the optical values measured are transmitted, and these signals are used to actuate recording means at the receiver to reproduce the image. The recording material is mounted on a picture drum, and it will be readily apparent that for true reproductions, the recorder drum must operate in synchronism with the transmitter drum, that is to say, the two drums must operate not only with equal speeds but in a cophasal relationship. There are also other types of scanning such, for instance, as the so-called "rocker arm" type of scanning, but it will be appreciated that the apparatus disclosed hereinafter will be equally adaptable to these types of scanning and recording since the prime movers which drive the devices must be maintained in synchronous operation.

This system presupposes there will be made available at the receiver a synchronizing tone which accurately indicates the speed of the scanning system. This can be received by radio as a tone generated by the scanner motor, or if the scanner is held at some fixed speed by tuning fork control, a similar fork can supply this tone at the recorder.

At the receiver is used a motor, which in general practice, although not necessarily, has been a shunt wound direct current motor. Connected to the picture drum is a commutating device which is comprised alternately of conducting and non-conducting segments. This commutator is connected in shunt with the anode-cathode path of a gaseous discharge device, which in general comprises a gas filled thermionic vacuum tube. Accordingly, when a conducting portion of the commutator is engaged, the tube is short circuited from anode to cathode, and thus is extinguished. In addition, a resistance device is connected in the supply circuit of either the armature or the shunt field of the motor or both, and is also connected across the anode-cathode path of the tube. When the tube is conducting, a definite lower potential drop is developed across the member than when the tube is non-conducting, and hence the voltage supplied either to the armature of the driving motor or the shunt field, or both, is increased. Initiation of the discharge of the tube is accomplished by means of the synchronizing signal and, in the case of a gas filled thermionic tube, this is easily accomplished by impressing the signals of proper potential onto the control grid of the tube. Once the discharge is initiated, the control grid loses control of the discharge, and as long as there is a potential

gradient of proper magnitude and polarity between the anode and the cathode of the tube, the discharge will be self-sustaining.

Accordingly, it will be seen that the following action takes place: In synchronous operation, the commutator becomes so phased with respect to the synchronizing tone that it does not short-circuit the anode-cathode path of the gas filled tube until after the receipt of a synchronizing signal. In addition to shorting the anode-cathode path of the tube, the commutator will also short the device across which a potential hereinbefore referred to is developed. The synchronizing signal which is received when the commutator is non-conducting causes the discharge tube to conduct, and effectively shunts or parallels the series device thus increasing the potential supplied to the armature and field. The discharge continues for a period of time until the anode-cathode path of the discharge tube is short-circuited by the commutator and the discharge ceases. However, at the same time the series device in the motor circuit is also short-circuited and, accordingly, a maximum potential is then impressed on the armature and field of the motor. This means then that beginning with the discharge of the tube and continuing until the commutator becomes non-conducting again, the armature and the field of the motor have the potential impressed thereon at a maximum or nearly so, and for a period of time equal to the time from the beginning of the non-conducting section of the commutator until the beginning of the discharge of the gaseous discharge device, the potential impressed will be a minimum determined by the resistance of the series device. Accordingly, the average voltage impressed on the armature and field will depend on the relative length of time the series resistance is short circuited by tube and commutator compared to the length of time it is not shorted by either. In coming up to speed, the commutator will come to some phase position relative to the synchronizing signal at which the correct average potential will be maintained that will give synchronous operation. Now, if the motor should slow down, this phase will change so that the tube will discharge for a longer period of time, and as the short-circuiting of the series device by commutator is for a substantially constant time, the over-all corrective time will be increased. The average potential impressed on the armature and field of the motor will be increased, and hence the motor will tend to speed up. The reverse is true when the motor speeds up and the corrective time is shortened, hence the average voltage impressed on the armature and field of the motor is decreased and the motor slows down.

My invention will best be understood by reference to the drawings in which

Fig. 1 represents one embodiment of my invention,

Figs. 2, 3 and 4 are explanatory curves, and

Figs. 5, 6, 7 and 8 are still further embodiments of my invention.

Referring to Fig. 1, there is shown one embodiment of my invention. There is illustrated a motor having an armature member **10** having resistance **11** illustrated as connected in series therewith, and a shunt field **12** connected in shunt with said motor armature and series resistance **11**. A source of electrical energy supply is illustrated by the positive and negative symbols, and this is connected across the terminal of the connection between the shunt field and the armature, and across the terminal of a resistive member **13** connected serially with the resistance **11** and shunt field **12**. Coupled to the armature is a driving member here illustrated as shaft member **14**, which is adapted to rotate with the armature, and coupled to the shaft member is a commutator member having insulating section **15** and conducting section **16**. Positioned so as to press against the outer periphery of the commutator are two contacters **17** and **18**.

A thermionic vacuum tube **19** is illustrated and comprises a gas filled discharge device. It will be appreciated that other types of gaseous discharge tubes may be used such, for instance, as mercury vapor tubes, neon tubes, and the like. The tube **19** has its anode **20** connected to the contact member **17** which is adapted to be held in contact with the commutator member. The anode **20** is also connected to the terminal of the armature **10** and resistance **11**. The cathode **21** of the gas filled discharge device is connected to the contact member **18** and to the terminal at which the shunt field of the motor joins the resistor **11**. It will be appreciated therefore that the resistor **11** and the two contact members **17** and **18**, and the space charge path of the gaseous discharge device, are connected in parallel. The tube **19** also has a control grid **22** which is connected to the cathode **21** through a resistor **23** and resistor **13**. The synchronizing signal input is represented as being directly across the resistance **23**.

Referring to Fig. 2, there are shown explanatory curves to explain the operation of the device shown in Fig. 1. In this figure, there is shown plotted against time as one co-ordinate, two sections, one of which represents the potential impressed on the armature of the motor and the other which represents the synchronizing tone. The operation is as follows: The synchronizing tone is illustrated as a sine wave although a flat topped or peaked wave would be just as readily usable. The synchronizing tone is impressed across the resistor **23** of the gas filled discharge device **19** and causes this device to conduct, the control grid at this time having control of the tube. When the positive half **24** of the synchronizing signal causes the tube to conduct, the resistance **11** is effectively short-circuited by the anode to cathode circuit of the tube **19**, and the armature potential is raised very nearly to maximum value. This is illustrated by the dotted section **25** of Fig. 2, and it further is assumed that the commutator is so positioned that at least one of the contacts **17**, **18** is in contact with an insulating section of the commutator. Even though the synchronizing tone signal goes negative, the control grid **22** of the tube having lost control of the discharge in the tube, the discharge will continue until the plate potential of the tube is either interrupted or rendered negative. As the motor rotates, the contacts **17** and **18** both will come into contact with the conducting segment **16** and will short-circuit the resistor **11**. Thus the tube **19** is robbed of plate potential and the tube ceases to conduct. However, while this is true, the resistor **11** also is short-circuited by the commutator so that the potential drop therein from the power supply is eliminated and the motor armature has a potential value impressed thereon which is represented by the black solid section **26** of the curve of Fig. 2. It is at this time that the motor armature receives the

maximum potential, of course assuming a steady source of voltage supply. The length of time that the resistor 11 is short-circuited depends upon the speed of the motor armature, and when one of the contacters 17 or 18 leaves the conducting section 16 and impinges onto the insulating section 15 of the commutator, the voltage impressed on the motor armature will drop due to the fact that no plate current can now flow in the anode circuit of the tube 19, and will not again flow in the tube until the receipt of another positive synchronizing signal. This is illustrated by the lower solid section 27 of the curve of Fig. 2. This lower solid section is continued on to the next position of the commutator with respect to time in a solid line for the purpose of showing the effect purely of the commutator conductor 16, although as a matter of fact the voltage impressed on the motor armature again will increase at the point 28 of the curve of Fig. 2 when the tube 19 again becomes conducting. Thus, it will be seen that the average voltage impressed on the armature of the motor lies somewhere between the peak voltage represented at 26 and the line 27, and is clearly indicated as *e* average.

Referring to Fig. 3, there is shown graphically what occurs when the motor armature 10 speeds up. Upon receipt of the positive half of the synchronizing signal 24 illustrated in Fig. 3, the tube 19 will conduct and the resistance 11 will be effectively short-circuited by the anode-cathode path of the tube, and the voltage across the armature will rise as indicated at the face 28 of the curve. However, if the motor has speeded up, this means that with respect to time the conducting section 16 of the commutator will close the contacts 17 and 18 at an earlier time relatively to the beginning of discharge as illustrated by the forward face 29 of the voltage curve shown as due to the commutator action only. This means that the two sections of the voltage rise, one of which is illustrated as a dotted section and the other of which is illustrated as a solid section will be brought closer together so-to-speak, or the overall time between the interval t_1 and t_2 is shortened. Since the tube 19 will not conduct until the receipt of the next synchronizing signal, this means that the space between t_2, or the time at which the conducting segments leave one of the contacts 17 or 18, and the time t_3 which is the time when the tube 19 begins to conduct, will be lengthened. This means that the average voltage impressed on the armature is decreased, and hence the motor will be slowed down.

Referring to Fig. 4, there is illustrated the operation of the device when the motor tends to slow down. Upon receipt of a positive half 24 of the synchronizing signal, the tube 19 will conduct as shown by the leading face 30 of the dotted section of curve. The motor having slowed down, a longer period of time will elapse before the conducting section 16 closes the contacts 17 and 18 than in the case of synchronous operation, as illustrated in Fig. 2. This means that the time interval t_5 and t_6 will be much greater than when the motor is running synchronously. The effect is such as to separate the two sections of the curve illustrated by the dotted portion and the solid portion so that the time interval between the time when the resistor 11 ceases to be short-circuited by the conducting segment 16 and the time when plate current from the tube 19 flows through the resistance will be greatly shortened. This means then that the average voltage impressed on the motor armature will increase, and hence the motor will speed up. Thus, changes in loading, line voltage, or other factors tending to affect speed of operation will cause corresponding phase shifts of the commutator with respect to the synchronizing signals, and such phase shifts will automatically increase or decrease the average armature potential in such a direction as to correct this phase shift and maintain synchronous operation since, for synchronous operation, the average voltage is predeterminable.

Referring to Fig. 5, there is shown an alternative arrangement wherein instead of short-circuiting the gaseous discharge device during a portion of the time, the gaseous discharge device is rendered non-conducting during this portion of the time of a cycle of operation by opening its anode circuit. The conducting segment 16 thereof extends around the greater portion of the periphery of the commutator and the insulating section 15 is comparatively small wtih respect thereto. The arrangement is the same as in Fig. 1 with the exception of the comparative sizes of the insulating section 15 and the conducting section 16 of the commutator, and that the commutator is connected in series with the tube 19 rather than in shunt.

It should be noted in this figure that the contacters 17 and 18 are connected serially with the anode-cathode output of tube 19 and this series circuit then connected in shunt with the resistor 11. This means then that the anode 20 of the tube 19 is robbed of anode potential when one of the contacters 17 or 18 engages an insulating section 15 of the commutator. The circuit of Fig. 1, however, has the advantage over the arrangement disclosed in Fig. 5 of being comparatively sparkless in operation, whereas the disclosure of Fig. 5 is not entirely so.

Referring to Fig. 6, there is shown another embodiment of my invention. In this figure, the motor armature 30 through appropriate driving means 31 is operatively associated so as to rotate the commutator, the latter having insulating sections 32 and conducting sections 33. A variable resistor 34 is interposed between one terminal of the shunt field 35 and one terminal of the motor 30. The gaseous discharge tube 36 has a control grid 37 onto which is impressed the synchronizing pulses through the transformer 38. The anode 39 of the tube is connected to one of the contactors 40. The other of the contactors 41 is connected serially with a resistor 42 and this is joined to the terminal of the shunt field, the latter being connected to the resistor 34. The other terminal of the armature and shunt field are connected together and to the cathode 43 of the tube 36. This means that the tube is conducting only as long as the contactors 40 and 41 both engage one of the conducting segments 33 of the commutator, since the contactors 40 and 41 are arranged to operate serially with the anode 39 of the tube 36.

In actual practice, the number of segments of the commutator is determined by the speed of the motor and the control frequency. If the motor is to run at 1800 R. P. M., and the synchronizing tone is 480 cycles for instance, the number of conducting segments preferably used has been sixteen. The length of the segments is so proportioned to the insulation between them that the anode circuit of the gaseous discharge tube is opened long enough to de-ionize the tube and allow the grid to regain control of the anode current over each insulating space.

In operation, with the gaseous discharge tube drawing no current, the resistance 34 is so set

that the motor runs slightly slower than 1800 R. P. M. and the value of resistance 42 is adjusted so that with the gaseous discharge tube drawing anode currents at all times, the motor runs faster than 1800 R. P. M. Operation at 1800 R. P. M. then demands that the tube draw anode current only part of the time. It will be seen from the figure that when the tube is conducting, the shunt field current is partially by-passed through the tube. If the motor runs slow, the time interval elapsing during the receipt of a synchronizing tone and the interval during which contactors 40 and 41 are on a conducting segment is increased, and as a consequence, a portion of the field current is by-passed through the gaseous discharge tube for a longer interval of time than is usual during synchronous operation. As a result the average field current is less than when the motor is operated synchronously, and this drop in field current tends to speed up the motor. The reverse is true if the motor tends to run fast. Less of the conducting portion of the commutator will close the contactors 40 and 41 after the grid of the tube 39 initiates discharge due to the shifting forward of the phase between the commutator and the synchronizing tone, and as a result the average field current will be increased and, accordingly, the effect is to slow down the motor. It may be seen that with proper choice of commutator spacings and proper choice of resistors 34 and 42, a condition may be obtained in which wide line voltages or load changes may be compensated for automatically and the motor held in synchronism with the control tone.

Referring to Fig. 7, there is shown still a further embodiment of my invention. In this figure, the motor armature 50 is operatively connected to the drive member 51 which is adapted to rotate a commutator having conducting sections 52 and insulating sections 53. The shunt field 54 is connected directly across the armature circuit, and connected serially between the motor and the supply line is a resistor 55. One terminal of this resistor is connected to the negative side of the supply line and the other terminal which joins the motor circuit is connected through a resistor 56 to the anode 57 of the gaseous discharge tube 58. The commutator has a common brush 59 connected to all of the conducting segments and a contactor 60 is adapted to press against the periphery of the commutator and ultimately come into engagement with the conducting segments 52. In this case, the common brush 59 is connected to the cathode 61 of the tube 58, and the other brush 60 is connected through an anode resistor 62 to the anode of the tube. Accordingly, both the armature and the shunt field are affected by the anode current of the tube 58. This results in less of a tendency on the part of the driving motor to hunt. A resistor 63 and a condenser 64 are shunted across the commutator in order to act as a spark suppressor. The synchronizing tone is impressed onto the grid 65 of the gaseous discharge tube 58 through the transformer 66.

Referring to Fig. 8, there is shown an embodiment of my invention for use with a series wound type of motor. In this case, the motor armature 70 is connected operatively to a drive member 71 which in turn is connected so as to rotate a commutator having conducting sections 72 and insulating sections 73. Two brush members 74 and 75 are positioned so as to contact the commutator, and the brush 75 is connected to the terminal at which the armature 70 is connected to the series field 76 of the motor. A brush 74 is then connected to the anode 77 of the gaseous discharge tube 78 through a resistor 79. The terminal of the series field 76 remote from the terminal which is connected to the armature is connected to the negative side of the supply line and to the cathode 80 of the gaseous discharge tube 78. The control grid 81 of the tube is connected to the cathode through the secondary of a transformer 82, the primary of which is adapted to have the synchronizing tone impressed thereon.

In this arrangement, the operation is such that if the motor slows down, the average field current is lowered and the average armature current is increased so that the effect is to speed up the motor. On the other hand, if the motor speeds up the phase relation between the input tone and the conducting sections of the commutator are changed so that the average field current is increased and the average armature current is decreased so that the effect is to decrease the speed of the motor. Reference may be had to the explanation regarding Fig. 6 as to how this is accomplished. If the arrangement as disclosed in Fig. 8 is used on an alternating current series motor, the tube 78 could control only during the positive half of the supply cycle so that the armature would receive a maximum of one-half the time through the tube and the field, and the other half of the time through the field only.

It will be appreciated that there may be departures from the exact description contained in this specification which will be within the spirit and scope of my invention, for example, such as the fact that the normal commutator of a D. C. motor may be used as a substitute for the auxiliary commutator which has been described in this specification.

It should be understood that by the term "synchronizing" I mean to include not only the movement of two mechanical members at equal speeds, but also in a definitely maintained phase relationship.

What I claim is:

1. Apparatus for synchronizing the movement of the rotating element of two electrically driven motors comprising means operating under the control of one of said motors for developing a recurring signal indicative of the position of the moving element of one of said motors, a source of energy supply for the other of said motors, resistive means connected to one of the electrical elements of the latter motor and to the source of energy supply for said motor whereby at least a portion of the energy supplied to said latter motor traverses the resistance, and means responsive to the recurring signal and associated with said resistive means for intermittently altering the energy traversing said resistive means in accordance with the speed of the motor to be synchronized.

2. Apparatus in accordance with claim 1 wherein the means responsive to the recurring signal includes a gaseous discharge device.

3. Apparatus in accordance with claim 1 wherein the means responsive to the recurring signal includes a gas filled thermionic discharge tube.

4. Apparatus for synchronizing the moving elements of a first and a second electric motor and wherein means associated with the first of said motors develops a recurring signal indicative of

the position of the rotationg member comprising a source of power supply for the second of said motors, a resistor connected serially with the moving element of said second motor, and moving element of said motor and said resistor being connected in shunt across the power supply, a commutator having at least one conducting and one insulating segment, said commutator being driven by the moving element of said second motor, a gaseous discharge device having at least two of its electrodes connected in shunt with at least a portion of the resistance, switch means connected in shunt to the discharge path of said gaseous discharge device, said switch means being so positioned as to be alternately opened and closed by contact with the conducting and non-conducting sections of the commutating member, and means responsive to said recurring signal for initiating current through the said gaseous discharge device.

5. Apparatus in accordance with claim 4 wherein said gaseous discharge device comprises a gas filled thermionic tube.

6. Apparatus in accordance with claim 4 wherein said second motor is a shunt member, said shunt field being connected at one extremity thereof to the armature of the motor and connected at the other extremity thereof to the resistance member to a point on said resistance without the portion thereof which is connected in parallel with the thermionic discharge device.

7. Apparatus for synchronizing the movement of a first and second electric motor and wherein said second motor is a shunt wound motor comprising a source of energy supply for said second motor, a resistive means connected serially with said motor armature and also said energy supply means, a commutating member having at least one conducting and one insulating segment, said commutating member being driven by said second motor armature whereby the position of the commutator is indicative of the position of the armature of the motor, a gaseous discharge device having at least two electrodes thereof connected in parallel with said resistive means, a plurality of contactors each electrically connected to an electrode of said gaseous discharge devices and connected in the anode-cathode circuit thereof, said contactors being so positioned as to be rendered alternately conductive and non-conductive by contact with a conducting or an insulating section of said commutator, and means for initiating discharge in said gaseous discharge device by means of the recurring signal.

8. Apparatus in accordance with claim 7 wherein said discharge device comprises a gaseous thermionic tube.

9. Apparatus in accordance with claim 7 comprising in addition, a time constant circuit connected in shunt across the contactors.

10. Apparatus for synchronizing the movement of a first and second electric motor wherein said second electric motor is a series wound motor comprising means associated with said first motor for developing a recurring signal indicative of the phase of the rotating element, a source of energy supply for said second motor having one terminal thereof connected to the armature and the other terminal thereof connected to the field of said second motor, a commutating member having at least one conducting and one insulating segment operatively associated with said second motor armature and adapted to be driven thereby, whereby the position of the elements comprising said commutator is indicative of the position of said second motor armature, a gaseous discharge device having at least two electrodes, one of said electrodes being connected to one terminal of the source of energy supply, a pair of contactors adapted to engage with the commutator and adapted to be alternately rendered conducting and non-conducting thereby, one of said contactors being connected serially to the terminal of said motor where the series field and armature join, and the other of said contactors being connected serially with the other of said electrodes of said gaseous discharge device, and means for initiating discharge in said gaseous discharge device by means of said recurring signals.

11. Apparatus in accordance with claim 10 wherein said gaseous discharge device comprises a gas filled thermionic tube.

MAURICE ARTZT.