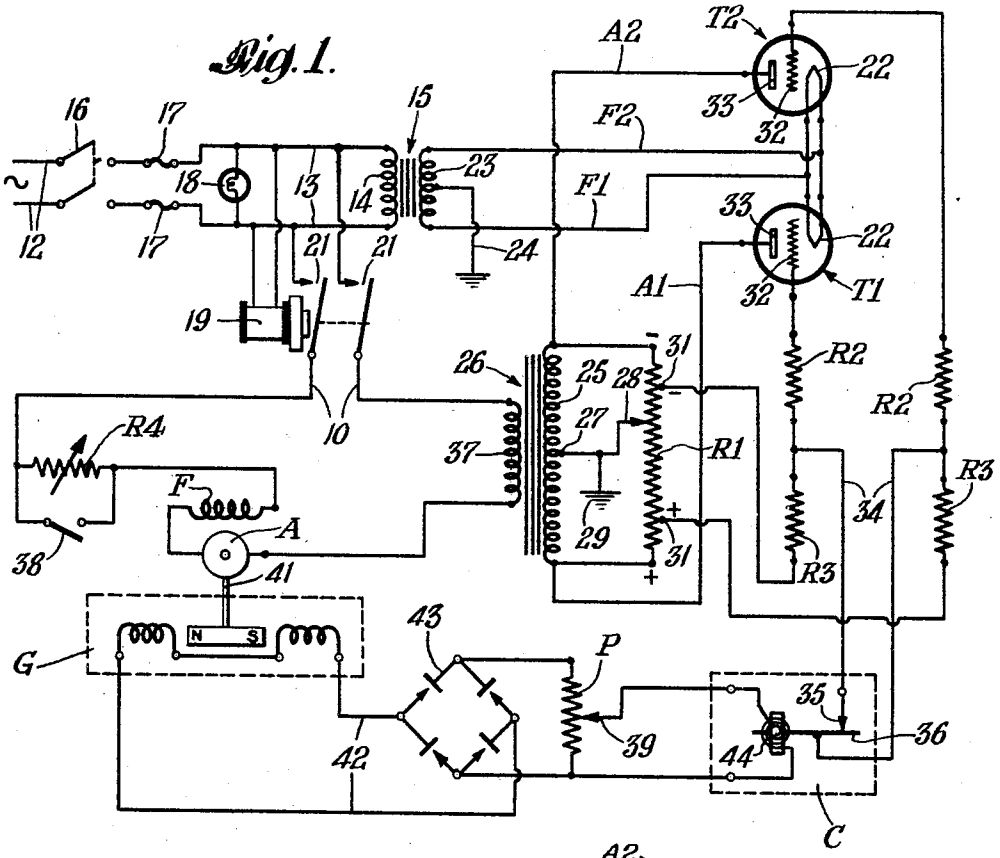
March 9, 1948. R. R. LOBOSCO 2,437,301

SPEED GOVERNOR

Filed Feb. 26, 1944 2 Sheets-Sheet 1

Fig. 1.



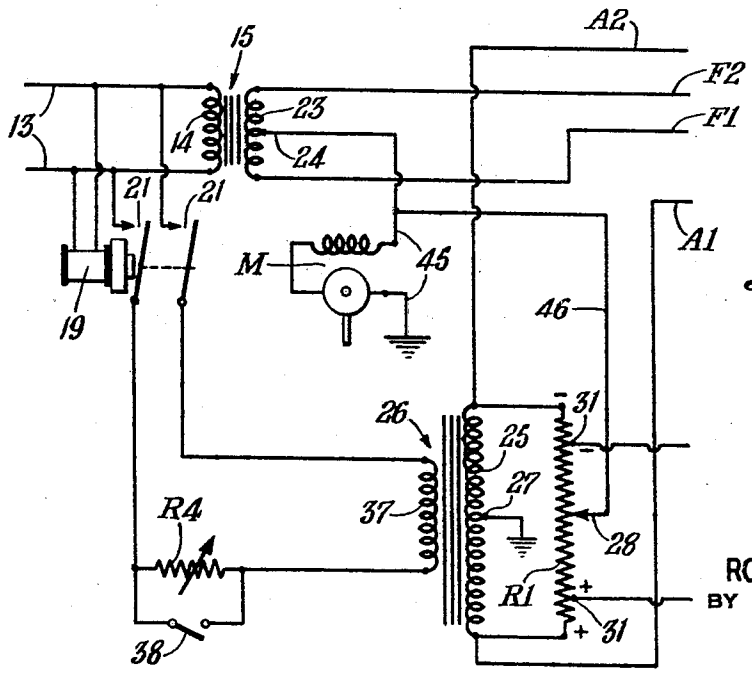


Fig. 2.

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SPEED GOVERNOR

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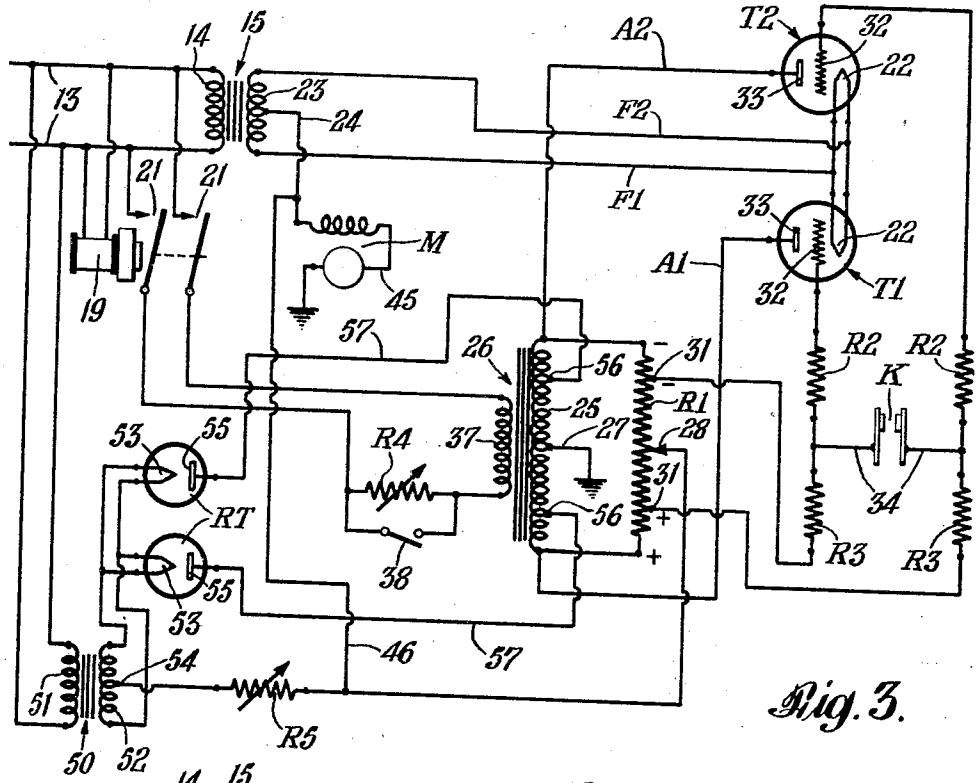


Fig. 3.

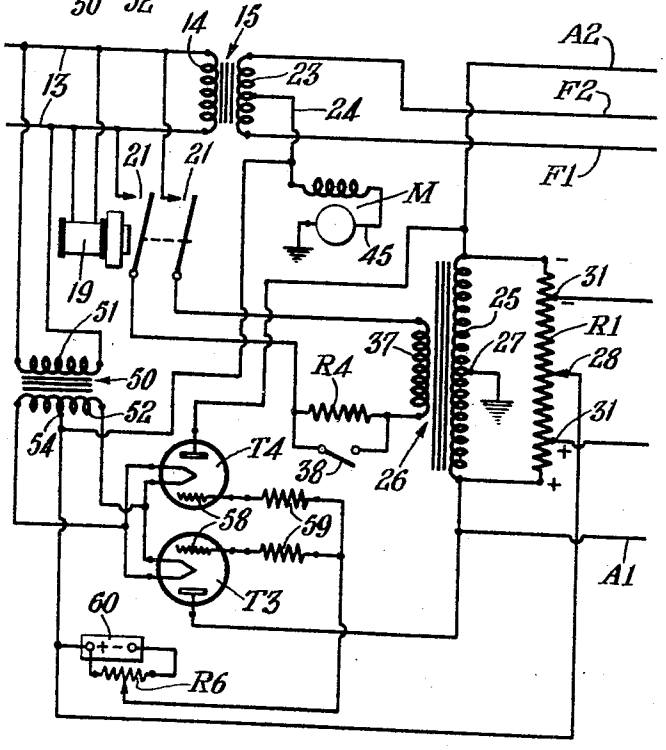


Fig. 4.

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UNITED STATES PATENT OFFICE

2,437,301

SPEED GOVERNOR

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Application February 26, 1944, Serial No. 523,975

19 Claims. (Cl. 318—328)

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This invention relates to governors for maintaining the velocity of a moving member at a substantially constant value, and more particularly to electronic means for governing the speed of an electric motor.

Prior speed controls for electric motors and the like usually employed a centrifugal or eddy-current type of make-and-break governor. A particular application of such governors has been to control the speed of small carriage driving motors in oxy-fuel gas cutting machines which are now used extensively in the metal working art. Such motors are generally of fractional horsepower size, having in themselves a relatively wide speed range, and a relatively light load of the order of 1/50 horsepower, for example, when the motor is of the order of 1/3 horsepower.

The main object of the invention is to provide an improved governor for maintaining the speed of a motor at any desired value, improving the operation of make-and-break contacts, extending the life of such contacts indefinitely, and greatly increasing the time between necessary recalibrations.

Other objects of the invention are to satisfy the following requirements: a relatively wide range of speed adjustment; relatively rapid contact operation; and ability to control the speed of large motors as well as small motors.

Known types of centrifugal make-and-break governors heretofore have not had a wide enough speed adjustment range, so that it has been frequently necessary to resort to mechanical speed changers such as gear shifts in order to obtain a desired speed. Known types of eddy current make-and-break governors generally have a wider speed range than such centrifugal type governors, but there are cases where even wider selective speed ranges could be used.

All known types of make-and-break governors fail to maintain their calibration for more than a relatively short time because of the rapid wear or pitting of the make-and-break contacts. Such governors, therefore, require frequent adjustment or replacement of such contacts.

In order that the driving motor of a gas cutting machine, for example, may deliver a smooth flow of power, the governor contacts should make-and-break at a very rapid rate. Since such contacts in the past handled the entire motor energizing current, rapid wearing of the contacts resulted. Circuits have been used, which to some extent, improve the operating conditions of the contacts, resulting in longer contact life.

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However, none of such proposals has proven to be entirely satisfactory.

The governor should be capable of controlling the speed of relatively large motors. Because of the severe operating service to which the contacts are subjected it has been seldom possible in the past to use a make-and-break type of governor for controlling the speed of motors which were larger than 1/4 horsepower.

It is, therefore, among the aims of this invention to provide an improved governor circuit which can be used with any governor comprising make-and-break contacts, which greatly reduces or entirely eliminates contact wear, improves speed selectivity, increases the speed adjustment range, and is adapted for controlling the speed of alternating current as well as direct current motors. Another aim of the invention is to provide a governor which more nearly meets all of the requirements of a satisfactory governor than any heretofore known type of governor. Additional aims are to provide an improved make-and-break governor that is simple, comprising readily available standard parts that may be readily assembled at reasonable cost, and which may be attached to any motor with a minimum of machine work.

According to the invention, the actual making and breaking of the motor circuit is performed by electronic devices. Make-and-break contacts are used in the grid control circuits of such devices and serve to render them conductive or nonconductive. When contacts are used in such a circuit, the current and voltage values handled by the contacts is so minute that wear of the contacts is reduced to a negligible factor. The resulting absence of arcing between the contacts increases the speed controlling range of the governor, and causes the motor to run more smoothly. Since the power broken by such contacts remains very small, even when the circuit is controlling large power, the size of the motor whose speed is controlled is limited only by the size of the circuit components. The current across the contacts also alternates in synchronism with the alternating current supply, reducing contact pitting compared to direct current, and assuring long contact life.

The speed adjusting means of the invention includes a potentiometer which is inexpensive and can be located at any desired place, even remotely with respect to the other elements.

Since the electrical load on the make-and-break contacts is extremely small according to the invention, a very slight separation of such

contacts suffices to open the circuit, resulting in as good motor speed regulation at high torques as at low torques. In prior governor circuits, due to an increase in the electrical load on the contacts at high motor torques, the contacts had to be more widely separated than at low torques, adversely affecting the calibration of the governor speed selector for low torques.

Fig. 1 of the drawings is a circuit diagram exemplifying the invention; and

Figs. 2, 3 and 4 are circuit diagrams of modifications of the invention.

Referring to Fig. 1 of the drawings, the invention is diagrammatically illustrated as applied to a system for energizing an alternating current motor circuit 10 containing a series wound A. C.-D. C. universal type motor AF, from an alternating current supply circuit 12, through an input circuit 13 including the primary winding 14 of a cathode heating transformer 15. The circuit 13 is adapted to be connected to the alternating current supply circuit 12 by an on-off switch 16, through protective fuses 17, a pilot lamp 18 being connected across the circuit 13 to indicate when such circuit is energized by the supply circuit 12. A time delay relay 19 is connected across the primary winding 14 of the transformer 15. The time delay relay 19 is provided with contacts 21 which are caused to remain open until cathodes 22 of electronic space discharge devices such as three-electrode gaseous tubes or thyratrons T1 and T2 have been heating for a predetermined length of time by current supplied from secondary winding 23 of the transformer 15. The secondary winding 23 has a grounded center tap 24.

Secondary winding 25 of a transformer 26 is provided with a center tap 27 which is connected to an adjustable center tap 28 of a combination voltage divider and shunting resistor R1. Such center taps are grounded at 29. The center tap 28 is adjusted so that the tubes T1 and T2 are caused to operate or "fire" evenly. This adjustment need only be made when new tubes are installed or when the tubes have been in service for a very long period of time. The resistor R1 is provided with two grid biasing voltage taps 31, having instantaneous polarities as indicated, which reverse each half cycle of the alternating current.

While the tubes T1 and T2 are preferably thyratrons, any other suitable types of space discharge devices may be used. Such tubes include control electrodes such as grids 32 and anodes such as plates 33, respectively, in addition to the cathodes or filaments 22. Current is supplied to the grid control circuits of the tubes through a network including resistors R2 which serve to limit the grid current. The grid control circuits also include resistors R3 of such network which serve to limit the value of current flowing through a governor contact circuit 34 including make-and-break contacts 35 and 36.

A variable resistor or rheostat R4 is connected in series with the motor AF and primary winding 37 of transformer 26, and is adapted to limit the peak motor current in the circuit 10 at low motor speeds. For a small or fractional-horsepower motor the resistor R4 preferably has fixed value of resistance which is adapted to be shorted out at higher motor speeds by a switch 38. If desired, the switch 38 may be actuated by a speed adjusting tap 39 of a potentiometer P. For large motors, the resistance value of the variable resistor R4 is preferably increased as the motor speed is decreased. If desired, the variable resistor R4 may be arranged so that it is adjusted in unison with the speed adjusting tap 39.

A generator G is connected to motor shaft 41 so as to generate a voltage in circuit 42 which is proportional to the speed of the motor armature A. In the example illustrated, an alternating current generator G is used, the generated alternating current being rectified by a full-wave rectifier 43 the D. C. output circuit of which includes the potentiometer P the adjustable tap 39 of which is used as a motor speed selector. The output circuit of the potentiometer P includes a d'Arsonval galvanometer relay or contact meter C comprising the make-and-break contacts 35 and 36 which are normally biased closed, being caused to open only when sufficient current flows through an actuating winding 44 of the instrument C.

In operation, when the switch 16 is closed, the time delay relay 19 and the filament or cathode heating transformer 15 are energized from the alternating current supply circuit 12. After a predetermined interval of time, during which the cathodes 22 of the tubes T1 and T2 are heated, the time delay contacts 21 automatically close. If the switch 38 is closed, the motor AF is then connected in series circuit relation with the primary winding 37 of the transformer 26. The impedance of such winding limits the power supplied to the motor AF to so low a value that the motor would not run when the secondary winding 25 is open-circuited. However, by connecting a resistor R1 of the proper resistance across the secondary winding of the transformer 26, the impedance of the primary winding 37 can be adjusted to any desired value. In the present case, a value of resistance for resistor R1 is chosen which fixes the impedance of the primary winding 37 to such a value that the power supplied to the motor AF is just below that necessary to rotate the motor AF at a low speed. Thus, the thyratrons T1 and T2 need handle only the control part of the motor energizing power rather than the entire motor energizing power.

With the instantaneous polarities as shown in Fig. 1, and with the governor contacts 35, 36 open, the plate 33 of tube T1 is positive but its grid potential is sufficiently negative to prevent the device from firing. The plate of tube T2 is negative so that it cannot fire. On the next half cycle all of the polarities are reversed and again neither tube will fire. This condition continues as long as the governor contacts 35, 36 remain open.

When the governor contacts 35, 36 close, both tubes have a substantially zero grid bias. Then, with the instantaneous polarities as shown in Fig. 1, the plate of T1 is positive and it will fire but the plate of tube T2 is negative and it will not fire. On the next half cycle all of the polarities will be reversed and the tube T2 will fire but the tube T1 will not fire. As long as the governor contacts remain closed the tubes will continue to fire or operate on alternate half cycles. When the tubes fire, the impedance of the primary winding 37 of the transformer 26 is reduced to a comparatively low value and the motor AF receives practically full line voltage.

From the above description it is evident that insofar as the motor is concerned the combination of this circuit and a conventional make-and-break governor behaves in such manner that the contacts 35, 36, instead of handling the large energizing power required by the motor, handle

only the comparatively insignificant power required to control the tubes T1 and T2.

In the operation of the governor, shown in Fig. 1, when the contacts 35, 36 of the contact meter C are closed, the tubes will fire and the motor AF will receive practically full line voltage and start to rotate. As the motor AF comes up to speed, the generator G generates an alternating voltage proportional to the speed of the motor. The resulting alternating current is rectified by the rectifier 43, the direct current output energizing the potentiometer P. Part of the voltage across the potentiometer P, depending upon the setting of the adjustable tap or contact 39, is applied across the actuating coil or winding 44 of the contact meter C. As soon as the voltage applied to the contact meter winding reaches a value high enough to open the contacts 35 and 36, the tubes T1 and T2 cease firing and the power supplied to the motor AF is reduced. This causes the motor to tend to slow down, decreasing the generated voltage, and reclosing the contacts of the contact meter.

As a result, the motor hunts between the speed necessary to open the contacts and a slightly slower speed which would cause them to close. The average speed at which the motor runs is determined by the setting of the adjustable contact 39 of the potentiometer P. Such setting determines the fraction of total generated voltage applied across the actuating winding 44 of the contact meter. Thus, when the potentiometer tap 39 is adjusted so that the full generated voltage is applied across the actuating coil 44, the generator G develops enough voltage to separate the contacts when the motor is running at a low speed and, therefore, the motor runs at such low speed. However, when the potentiometer tap is set to deliver only a fraction of the generated voltage to the contact actuating coil 44, then the motor AF is caused to operate at a higher speed corresponding to such potentiometer setting in order to open the contacts. The potentiometer is suitably calibrated in motor speed values, or cutting speed values when the motor drives a cutting blowpipe.

The generator type make-and-break governor described above has a greater speed range and stability than prior known types of make-and-break governors, including the eddy-current type governor. The service time between calibrations is extremely long, and the life of contacts is extended indefinitely.

The automatic system described above in connection with Fig. 1 is primarily intended to maintain substantially constant the speed of relatively small series wound universal type A. C.-D. C. motors which are generally employed in oxy-acetylene cutting machines. However, the same basic principles may be used to regulate the speed of larger motors. For example, relatively large series wound A. C. motors may be controlled by using a resistor R1 having a relatively high resistance value so that the impedance of the winding 37 is relatively high when the tubes T1 and T2 are not operating, and shunting the winding 37 with a resistor of such resistance that the motor AF receives a desired non-control current. These changes result in a decrease in the non-control current passing through the transformer windings and thus make possible the use of a smaller transformer 26.

Two-winding induction motors, either single phase or two-phase, may be used with the circuit shown in Fig. 1 or with the modified circuit

for large series wound A. C. motors. For a single-phase motor, one winding should be connected to the alternating current circuit 12 and the other winding in the circuit 10, suitable phase shifting devices being used where necessary. For a two-phase motor, one winding should be connected to the circuit 10, the electronic control circuit receives its power from one phase of a two-phase power supply, and the second winding of the two-phase motor should be connected to the other phase of the two-phase power supply.

The supply current to the motor of the circuit shown in Fig. 1 is alternating. With some motors, such as shunt wound direct current motors, and with some series wound motors, direct current is required. In such case, the alternating current supplied by the circuit 12 should be rectified and, if necessary, filtered in order to supply such direct current.

Fig. 2 shows how the circuit shown in Fig. 1 may be altered so to deliver a pulsating direct current to a motor M the speed of which is kept constant according to the invention. The inductance of the motor windings tends to smooth such pulsations but additional filtration may be used if necessary or desirable.

In Fig. 2, the primary winding 14 of transformer 15 is connected to the alternating current supplying circuit by a switch, as shown in Fig. 1. A series wound D. C. motor M is connected between the center tap 24 of the secondary winding 23 of transformer 15 and ground by a motor load circuit 45. The transformer 26 has its primary winding 37 connected to the supply circuit by contacts 21 of the time delay relay 19. Connected in series circuit relation with the winding 37 is a variable resistor R4. Such variable resistor is provided with a short circuiting switch 38 for the purpose pointed out above in connection with Fig. 1. The secondary winding 25 of the transformer 26 is provided with a center tap 27 which is grounded. The anodes 33 of the electric discharge devices T1 and T2, as shown in Fig. 1, are connected to terminals of the secondary winding 25 by conductors A1 and A2. The voltage divider R1 is connected across the secondary winding 25 and has an adjustable center tap 28 connected by a conductor 46 to the center tap 24 of the secondary winding 23 of the transformer 15. The filaments 22 of the devices T1 and T2, Fig. 1, are connected to the terminals of the secondary winding 23 by conductors F1 and F2. The control grids 32 of the devices T1 and T2 are connected to the voltage divider taps 31 by the network of resistors R2 and R3. As shown in Fig. 1, make-and-break contacts 35, 36 are connected between the resistors of the network for controlling the operation of the electric discharge devices T1 and T2, such contacts being operated by means responsive to the speed of the motor M so that the motor is caused to run at a constant predetermined speed.

In Fig. 2 the circuit arrangement is such that all of the direct current to the terminals of the motor load circuit 45, which energizes the motor M is rectified by the tubes T1 and T2, the load circuit 45 being connected between the center tap 24—adjustable tap 28 circuit 46 connection and ground.

The armature of a shunt wound motor may be connected to the load circuit 45 of Fig. 2 in place of the series wound motor M, the field winding being connected to receive its power from any suitable D. C. source of supply. In or-

der to use a field controlled shunt wound D. C. motor with the circuit shown in Fig. 2, the usual contact arrangement of the make-and-break governor is reversed because the speed of such a motor is increased by decreasing the field excitation. Therefore, the governor contacts are arranged so that they are open when the motor is below the desired speed and closed when the motor reaches or is above such desired speed. With such arrangement the motor field winding is connected to the load circuit 45 and the armature to a suitable D. C. source of supply.

Since a shunt wound D. C. motor with differential field windings has two field windings: a main field winding and a bucking field winding which opposes the main field winding; the bucking field winding may be connected to the load circuit 45, the main field winding and armature being connected to a suitable direct current source of supply.

Since it is desirable to have the tubes T1 and T2 rectify only the control part of the motor energizing current supplied to the motor load circuit 45, Fig. 3 shows a circuit arrangement for using a pair of rectifier tubes RT.

In Fig. 3 the input circuit 13 is connected to an alternating current supply circuit by a switch, as shown in Fig. 1, and contains the primary winding 14 of transformer 15, the secondary winding 23 having a center tap 24. The series wound motor M is connected between the center tap 24 and ground by a load circuit 45. The center tap 27 of the secondary winding 25 of transformer 26 is also connected to ground. The primary winding 37 of transformer 26 is connected to the circuit 13 through a variable resistor R4 which is provided with a short circuiting switch 38. The circuit containing winding 37 is adapted to be connected to the input circuit 13 by contacts 21 of the time delay relay 19. The space discharge devices T1 and T2 each has an anode 33 connected to one terminal of the secondary winding 25 of the transformer 26 by conductors A1 and A2. The voltage divider R1, which is connected across the secondary winding 25 of the transformer 26, has an adjustable center tap 28 connected to the center tap 24 of the secondary winding 23 of the transformer 15 by a conductor 46. The filaments 22 are connected to the terminals of the secondary winding 23 of the transformer 15 by conductors F1 and F2.

In the circuit arrangement of Fig. 3 a third transformer 50 is provided having a primary winding 51 connected to the input circuit 13, and a secondary winding 52 connected to the filaments 53 of the rectifier tubes RT. The secondary winding 52 has a center tap 54 connected to the adjustable center tap 28 of the voltage divider R1 through variable resistor R5. The anodes 55 of the rectifier tubes RT are connected to the secondary winding 25 of the transformer 26 by conductors 57 which in turn are connected to the taps 56 of the secondary winding 25. The electric discharge devices T1 and T2 have control grids 32 which are connected to the taps 31 of the voltage divider R1 by a network of resistors R2 and R3 between which there is connected a make-and-break circuit 34 containing make-and-break contacts K. Such contacts are operated by any suitable means responsive to the speed of the motor M so that the motor is caused to run according to the invention at a substantially constant speed. The plates 55 of the tubes RT are connected to properly chosen taps 56 of the winding 25 so that it is not necessary to waste too much power in the variable resistor R5 which is used to adjust the non-control part of the motor energizing current to a desired value.

Fig. 4 shows a circuit arrangement for using another pair of thyratrons T3 and T4 to supply the non-controlled part of the motor energizing current. Such part of the motor energizing current is adjusted by means of a voltage divider adjustable resistor R6 which is used to change the grid bias to tubes T3 and T4. While such circuit shows amplitude control of the tubes T3 and T4, phase shift control of such tubes may be used if desired. In Fig. 4 the circuit is somewhat like that shown in Fig. 3 except that thyratrons T3 and T4 are employed having control grids 58 the biasing circuits of which contain fixed resistors 59 and a C-battery 60 provided with the voltage divider or adjustable resistor R6, the positive terminal of the C-battery 60 being connected to the center tap 54 of transformer 50.

One of the principal features of this invention is the resistor network which supplies voltage bias to the control electrodes of the electronic tubes. Such network makes it unnecessary to use a grid biasing battery which must be replaced at intervals for proper operation of the apparatus. Furthermore, according to the invention, an alternating voltage is handled by the make-and-break contacts, and the grid voltage is proportional to the plate voltage so that such contacts handle no more voltage than is necessary to control the tubes. Such factors contribute to stable operation and substantially unlimited contact life.

The resistor network by-passes part of the motor current so that the tubes are required to handle only the control part of such current. The resistance in series with the motor energizing circuit for use at low values of motor speed materially improves the performance of the motor at low speed values and increases the tube life by limiting the current peaks which are caused by the low counter electromotive force values of the motor at low speeds. At higher motor speed values such series resistor is short circuited by closure of the shunt switch which may be mechanically connected to the adjustable contact of the speed setting potentiometer in the supply circuit of the contact meter.

What is claimed is:

1. In combination, an alternating current supply circuit a transformer having primary and secondary windings; a switch for connecting said primary winding to said circuit; a pair of electric discharge devices each having an anode, a control grid and a cathode; circuit means connecting such anodes to opposite terminals of said secondary winding; a voltage divider connected across said secondary winding; a grid biasing circuit for each of said devices comprising a pair of resistors connected to said voltage divider and the control grid of each device; means including a center tap on said secondary winding, adjustable contacts connecting the grid biasing circuits to said voltage divider, and equal values of resistance in the corresponding resistors of such circuits, for balancing the operation of said devices; a make-and-break contact circuit connected across said grid biasing circuits between said pairs of resistors for causing the devices to operate when the make-and-break contacts close; a motor the speed of which is increased by the operation of said devices; and means comprising a generator driven by said motor, a potentiometer energized by said generator, and a contact meter connected to said

potentiometer for opening the make-and-break contacts when the motor speed reaches a predetermined value as determined by the adjustment of said potentiometer.

2. In combination, a transformer having primary and secondary windings; a pair of electric discharge devices each having an anode, a control grid and a cathode; circuit means connecting such anodes to opposite terminals of said secondary winding; a voltage divider connected across said secondary winding; a grid biasing circuit for each of said devices comprising a pair of resistors connected to said voltage divider and the control grid of each device; means including a center tap on said secondary winding, adjustable contacts connecting the grid biasing circuits to said voltage divider, and equal values of resistance in the corresponding resistors of such circuits, for balancing the operation of said devices; a make-and-break contact circuit connected across said grid biasing circuits between said pairs of resistors for causing the devices to operate; a motor the speed of which is responsive to the operation of said devices; and means comprising a generator driven by said motor, a potentiometer energized by said generator, and voltage responsive means connected to said potentiometer for operating the make-and-break contacts when the motor speed reaches a predetermined value as determined by the adjustment of said potentiometer.

3. In combination, an alternating current supply circuit; a transformer having primary and secondary windings; a switch for connecting said primary winding to said circuit; a pair of electric discharge devices each having an anode, a control grid and a cathode; means connecting such anodes to opposite terminals of said secondary winding; a voltage divider connected across said secondary winding; a grid biasing circuit for each of said devices comprising a pair of resistors connected to said voltage divider and the control grid of each device; means including a center tap on said secondary winding, adjustable contacts connecting the grid biasing circuits to said voltage divider, and equal values of resistance in the corresponding resistors of such circuits, for balancing the operation of said devices; a make-and-break contact circuit connected across said grid biasing circuits between said pairs of resistors for causing the devices to operate when the make-and-break contacts close; a motor the speed of which is increased by the operation of said devices; and adjustable means for opening the make-and-break contacts when the motor speed reaches a predetermined value as determined by the adjustment of said means.

4. In combination, a transformer having primary and secondary windings; a pair of electric discharge devices each having an anode, a control grid and a cathode; means connecting such anodes to opposite terminals of said secondary winding; a voltage divider connected across said secondary winding; a grid biasing circuit for each of said devices comprising a pair of resistors connected to said voltage divider and the control grid of each device; means including a center tap on said secondary winding, adjustable contacts connecting the grid biasing circuits to said voltage divider, and equal values of resistance in the corresponding resistors of such circuits, for balancing the operation of said devices; and a make-and-break contact circuit connected across said grid biasing circuits between said pairs of resistors for causing the devices to operate.

5. In combination, an alternating current supply circuit; a switch connected to said circuit; a first transformer having a primary winding connected to said switch, and a secondary winding having a grounded center tap; a second transformer having a primary winding connected to said switch, and a secondary winding; a pair of electric discharge devices each having an anode connected to one terminal of said last-named secondary winding; a voltage divider connected across such secondary winding and having an adjustable center tap connected to a grounded center tap of such winding; said devices having filaments connected to the terminals of the secondary winding of said first transformer; said devices also having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; a series wound motor and a variable resistor connected in series circuit relation with the primary winding of said second transformer; and means responsive to the speed of said motor for operating said contacts.

6. In combination, an alternating current supply circuit; a switch connected to said circuit; a first transformer having a primary winding connected to said switch, and a secondary winding having a grounded center tap; a second transformer having a primary winding connected to said switch, and a secondary winding; a pair of electric discharge devices each having an anode connected to one terminal of said last-named secondary winding; a voltage divider connected across such secondary winding and having an adjustable center tap connected to a grounded center tap of such winding; said devices having filaments connected to the terminals of the secondary winding of said first transformer; said devices also having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; a variable resistor connected in circuit relation with the primary winding of said second transformer; and means responsive to the speed of said motor for operating said contacts.

7. In combination, a first transformer having a primary winding, and a secondary winding provided with a grounded center tap; a second transformer having a primary winding and a secondary winding; a pair of electric discharge devices each having an anode connected to one terminal of said last-named secondary winding; a voltage divider connected across such secondary winding and having an adjustable center tap connected to a grounded center tap of such winding; said devices having filaments connected to the terminals of the secondary winding of said first transformer; said devices also having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; a series wound motor and a variable resistor connected in circuit relation with the primary winding of said second transformer; and a means responsive to the speed of said motor for operating said contacts.

8. In combination, a first transformer having a primary winding, and a secondary winding pro-

vided with a grounded center tap; a second transformer having a primary winding and a secondary winding; a pair of electric discharge devices each having an anode connected to one terminal of said last-named secondary winding; a voltage divider connected across such secondary winding and having an adjustable center tap connected to a grounded center tap of such winding; said devices having filaments connected to the terminals of the secondary winding of said first transformer; said devices also having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; a motor the speed of which is responsive to the operation of said devices; and a means responsive to the speed of said motor for operating said contacts.

9. In combination, an alternating current supply circuit; a motor adapted to be energized from said circuit; an alternating current generator driven by said motor; a rectifier connected to the output circuit of said generator; a potentiometer connected to said rectifier; a contact meter having a winding connected to said potentiometer, and an armature adapted to rapidly operate make-and-break contacts continuously in response to the speed of said motor; and space discharge amplifier means responsive to the continuous operation of such make-and-break contacts for controlling the speed of said motor so that the motor runs at a substantially constant speed the value of which is determined by the adjustment of said potentiometer.

10. In combination, a motor; a generator driven by said motor; a potentiometer connected to said generator; a contact meter connected to said potentiometer and adapted to continuously operate make-and-break contacts rapidly in response to the speed of said motor; and space discharge amplifier means responsive to the rapid operation of such make-and-break contacts controlling the speed of said motor so that the motor runs at a substantially constant speed the value of which is determined by the adjustment of said potentiometer.

11. In combination, an alternating current supply circuit; a switch connected to said circuit; a first transformer having a primary winding connected to said switch; and a secondary winding having a center tap; a series wound motor connected between said center tap and ground; a second transformer having a primary winding connected to said switch; a variable resistor connected in series circuit relation with said last-named winding; said second transformer having a secondary winding provided with a center tap connected to ground; a pair of electric discharge devices each having an anode connected to one terminal of said last-named secondary winding; a voltage divider connected across said secondary winding, said voltage divider having an adjustable center tap connected to the center tap of the secondary winding of said first transformer; said devices having filaments connected to the terminals of the secondary winding of said first transformer; said devices also having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; and means responsive to the speed of said motor for operating said contacts so that the motor is caused to run at a constant predetermined speed.

12. In combination, an alternating current supply circuit; a first transformer having a primary winding connected to said circuit, and a secondary winding having a center tap; a motor connected between said center tap and ground; a second transformer having a primary winding connected to said circuit, and a secondary winding having a center tap connected to ground; a pair of electric discharge devices having anodes connected to opposite terminals of said last-named secondary winding, a voltage divider energized by said last-named secondary winding, said voltage divider having an adjustable center tap connected to the center tap of the secondary winding of said first transformer; said devices having filaments connected to the secondary winding of said first transformer; said devices also having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said device; and means responsive to the speed of said motor for operating said contacts so that the motor is caused to run at a substantially constant speed.

13. In combination, an alternating current supply circuit; a first transformer having a primary winding adapted to be connected to said circuit and a secondary winding having a center tap; a series wound motor connnected between said center tap and ground; a second transformer having a primary winding adapted to be connected to said circuit through a variable resistor, and a secondary winding having a center tap connected to ground; a pair of space discharge devices each having an anode connected to one terminal of the secondary winding of said second transformer; a voltage divider connected across the secondary winding of said second transformer, said voltage divider having an adjustable center tap connected to the center tap of the secondary winding of said first transformer; said devices having filaments adapted to be heated by current from the secondary winding of said first transformer; a third transformer having a primary winding connected to said switch and a secondary winding having a center tap connected to the adjustable center tap of said voltage divider through a variable resistor; a pair of rectifier tubes having anodes connected to the secondary winding of said second transformer, and filaments connected to the terminals of the secondary winding of said third transformer; said devices having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; and means responsive to the speed of said motor for operating said contacts so that the motor is caused to run at a substantially constant predetermined speed.

14. In combination, an alternating current supply circuit; a first transformer having a primary winding connected to said circuit and a secondary winding having a center tap; a motor connected between said center tap and ground; a second transformer having a primary winding connected to said circuit, and a secondary winding having a center tap connected to ground; a pair of space discharge devices each having anodes connected to opposite terminals of the secondary winding of said second transformer; a

voltage divider connected across the secondary winding of said second transformer, said voltage divider having an adjustable center tap connected to the center tap of the secondary winding of said first transformer; said devices having filaments connected to the secondary winding of said first transformer; a third transformer having a primary winding connected to said circuit, and a secondary winding having a center tap connected through a variable resistor to the adjustable center tap of said voltage divider and to the center tap of the secondary winding of said second transformer; a pair of rectifier tubes having anodes connected to the secondary winding of said second transformer, and filaments connected to the secondary winding of said third transformer; said devices having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; and means responsive to the speed of said motor for operating said contacts so that the motor is caused to run at a substantially constant predetermined speed.

15. In combination, an alternating current supply circuit, a switch connected to said circuit, a first transformer having a primary winding connected to said switch and a secondary winding having a center tap; a series wound motor connected between said center tap and ground; a second transformer having a primary winding connected through a rheostat to said switch, and a secondary winding having a center tap connected to ground; a pair of spaced discharge devices having anodes connected to the terminals of the secondary winding of said second transformer; a voltage divider connected across the secondary winding of said second transformer, said voltage divider having an adjustable center tap connected to the center tap of the secondary winding of the first transformer; said devices having filaments connected to the terminals of the secondary winding of said first transformer; a third transformer having a primary winding connected to said switch, and a secondary winding having a center tap; a pair of thyratron tubes having plates connected to the terminals of the secondary winding of said second transformer, filaments connected to opposite terminals of the secondary winding of said third transformer, and control grids connected through fixed grid biasing resistors and an adjustable grid biasing resistor to the center tap of the secondary winding of said third transformer, the last-named tap being connected to the adjustable tap of said voltage divider; means connecting the center tap of the secondary winding of said third transformer to the center tap of the secondary winding of said first transformer; said devices having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; and means responsive to the speed of said motor for operating said contacts so that the motor is caused to run at a substantially constant predetermined speed.

16. In combination, an alternating current supply circuit, a first transformer having a primary winding connected to said circuit, and a secondary winding having a center tap; a motor connected between said center tap and ground; and a second transformer having a primary winding connected to said circuit and a secondary

winding having a center tap connected to ground; a pair of space discharge devices having anodes connected to opposite terminals of the secondary winding of said second transformer; a voltage divider connected across the secondary winding of said second transformer, said voltage divider having an adjustable center tap connected to the center tap of the secondary winding of the first transformer; said devices having filaments connected to the secondary winding of said first transformer; a third transformer having a primary winding connected to said circuit, and a secondary winding having a center tap; a pair of thyratron tubes having plates connected to the secondary winding of said second transformer, filaments connected to the secondary winding of said third transformer, and control grids connected through a grid bias adjusting resistor to the center tap of the secondary winding of said third transformer, the last-named tap being connected to the adjustable tap of said voltage divider and to the connection between the center taps of the secondary windings of the first and third transformers; said devices having control grids; a network of resistors connecting said control grids to said voltage divider; make-and-break contacts connected between the resistors of said network for controlling the operation of said devices; and means responsive to the speed of said motor for operating said contacts so that the motor is caused to run at a substantially constant predetermined speed.

17. In combination, a motor, a pilot generator driven by said motor, an electric circuit energized by said generator having a component the value of which is responsive to the speed of said motor, a pair of electronic discharge devices connected in balanced push-pull relation, said devices having a grid control circuit comprising make-and-break contact means responsive to such component, a balanced resistor network associated with the grid control circuit of said devices, a transformer the dual secondary of which energizes the anode-cathode circuits of said devices, a voltage divider energized by said secondary and in turn energizing the control grid circuits of said devices so that the operation of said devices is responsive to a preselected value of such component, an electric power supply circuit adapted to energize said motor and the primary of said transformer, the circuit arrangement being such that the power supplied to said motor is regulated by the operation of said electronic discharge devices through said make-and-break contact means to maintain substantially constant the speed of said motor, and an adjustable speed selector impedance coupled to said electric circuit for adjusting the effective value of said component.

18. In combination, a motor having an energizing circuit, motor speed control contacts, means responsive to the speed of said motor for continuously operating said contacts, and a space discharge amplifier relay circuit having a control circuit coupled to said contacts and an output circuit coupled to said motor energizing circuit, the circuit arrangement being such that the power across said contacts is extremely small, reducing arcing to a negligible factor and indefinitely increasing the effective life of said contacts, said amplifier relay circuit operating in response to the continuous rapid operation of said contacts to control the energy supplied to said motor so that the motor speed is maintained thereby at a substantially constant preselected

value, said motor energizing circuit containing a resistor in series with said motor for use at relatively low motor speed values, and means for switching a conductor across said resistor to shunt out said resistor at motor speed values above said relatively low speed values.

19. In combination, a motor having an energizing circuit, motor speed control contacts, means responsive to the speed of said motor for continuously operating said contacts, and a space discharge amplifier relay circuit having a control circuit coupled to said contacts and an output circuit coupled to said motor energizing circuit, the circuit arrangement being such that the power across said contacts is extremely small, reducing arcing to a negligible factor and indefinitely increasing the effective life of said contacts, said amplifier relay circuit operating in response to the continuous rapid operation

of said contacts to control the energy supplied to said motor so that the motor speed is maintained thereby at a substantially constant preselected value.

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