July 4, 1944. A. WINTHER 2,353,107

ELECTRICAL GOVERNOR

Filed May 16, 1942 3 Sheets-Sheet 1

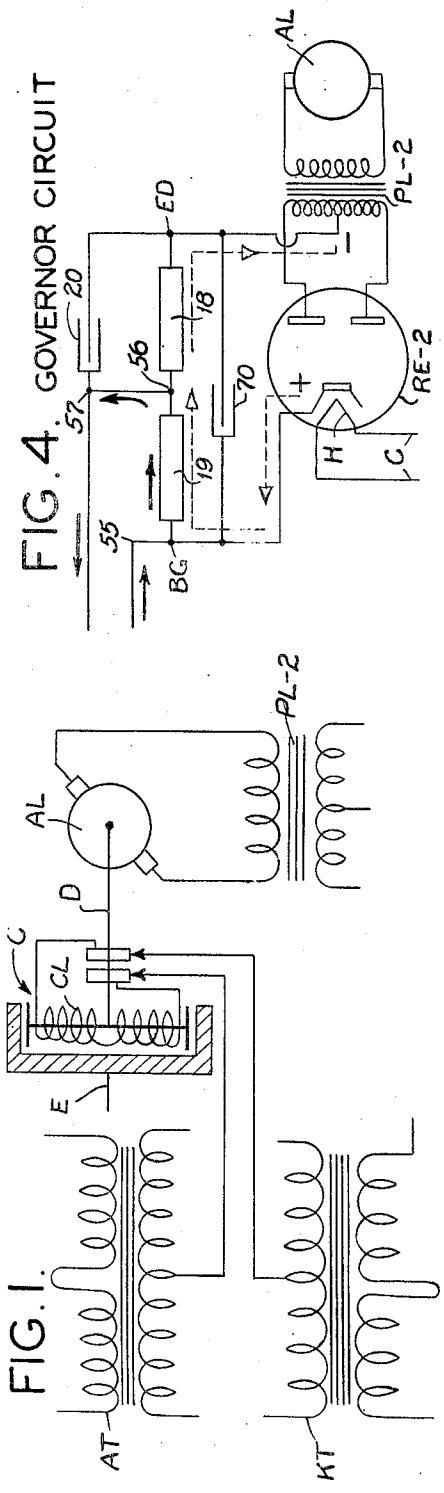


FIG. 1.

FIG. 4. GOVERNOR CIRCUIT

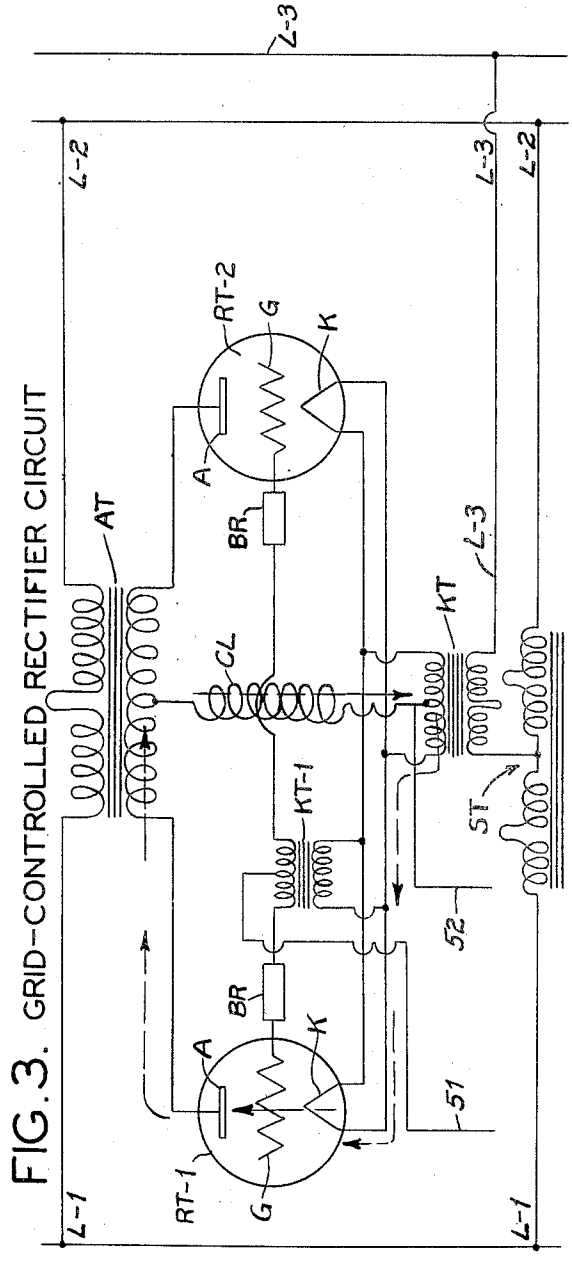


FIG. 3. GRID-CONTROLLED RECTIFIER CIRCUIT

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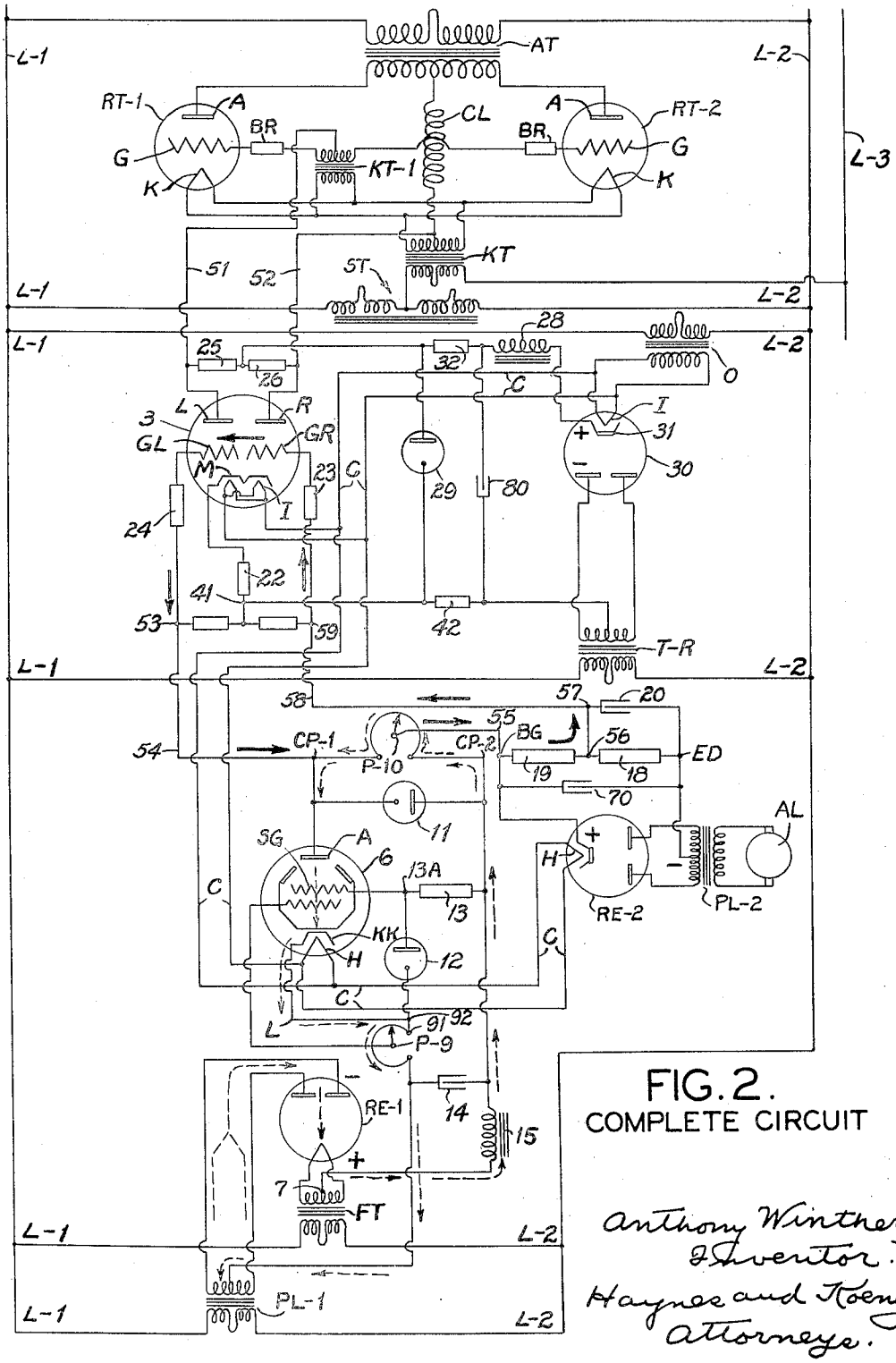


FIG. 2.
COMPLETE CIRCUIT

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FIG. 7. AMPLIFIER CIRCUIT

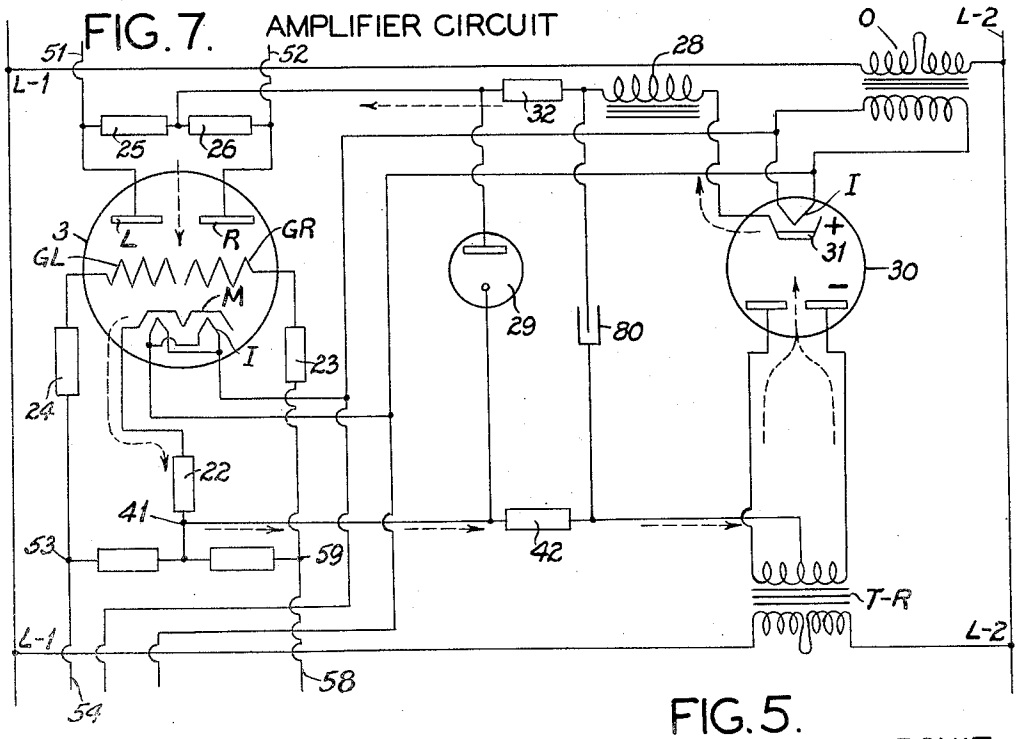


FIG. 5.
REFERENCE VOLTAGE CIRCUIT

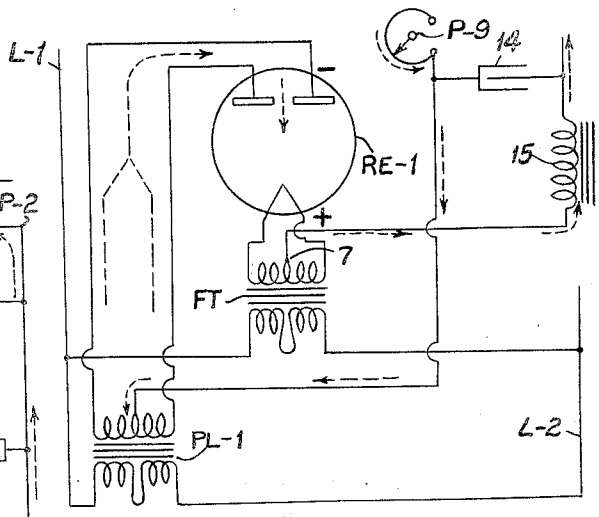
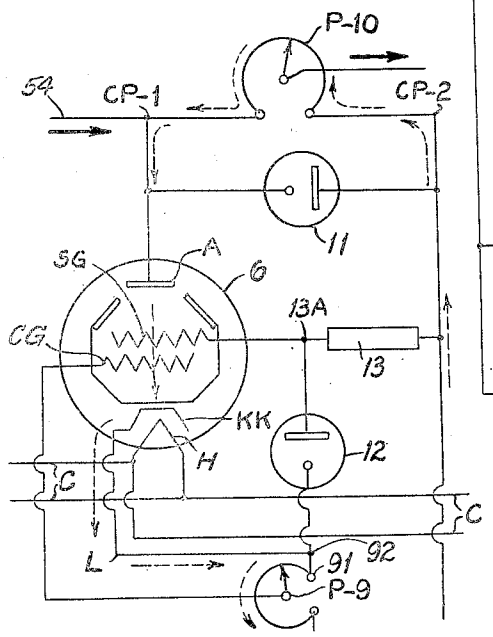


FIG. 6.
REFERENCE VOLTAGE CORRECTING CIRCUIT



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2,353,107

UNITED STATES PATENT OFFICE

2,353,107

ELECTRICAL GOVERNOR

Anthony Winther, Kenosha, Wis., assignor to Martin P. Winther, Waukegan, Ill., as trustee

Application May 16, 1942, Serial No. 443,243

8 Claims. (Cl. 172—284)

This invention relates to electrical governors, and with regard to certain more specific features to governors for controlling eddy-current clutches.

Among the several objects of the invention may be noted the provision of an improvement upon the construction shown in my United States Patent 2,277,284, dated March 24, 1942, which will more accurately hold the speed of an output shaft of an eddy-current clutch substantially constant at any load and speed which may be desired within its range; and in which a controlling reference voltage is maintained substantially constant despite certain supply line voltage changes, whereby constancy of speed may be maintained substantially independently of said line voltage changes. Other objects will be in part obvious and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangement of parts which will be exemplified in the structures hereinafter described, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings, in which is illustrated one of various possible embodiments of the invention,

Fig. 1 is a schematic diagram of certain eddy-current slip clutch parts;

Fig. 2 is a complete wiring diagram;

Fig. 3 is a wiring diagram showing a portion of Fig. 2 constituting a grid-controlled rectifier circuit for supplying the load coil shown in Figs. 1 and 2;

Fig. 4 is a wiring diagram showing a portion of Fig. 2 constituting a governor circuit;

Fig. 5 is a wiring diagram showing a portion of Fig. 2 constituting a reference voltage circuit;

Fig. 6 is a wiring diagram showing a portion of Fig. 2 constituting a reference voltage correcting circuit; and,

Fig. 7 is a wiring diagram showing a portion of Fig. 2 constituting an amplifier circuit for amplifying corrected voltage, maintaining the correctness of said voltage and for applying it to the grid-controlled rectifier circuit of Fig. 3.

Similar reference characters indicate corresponding parts throughout the several views of the drawings.

Since the present construction is an improvement upon that shown in my said Patent 2,277,284, corresponding reference numerals, so far as possible, will be used for parts corresponding herein to parts in said patent, in order that the improvements may more readily be apparent.

In said patent, the field winding of an eddy-current clutch is energized by means of direct current supplied by a pair of three-element, hot-cathode, gas-filled, grid-controlled rectifier tubes of the half-wave type. These tubes are of such a characteristic as require the proper grid potential to cause the grids to fire. In the patent, arrangements are indicated for adjusting and governing the grid potentials for the purpose of controlling the firing of the tubes into the D. C. circuit supplying the clutch winding. The patented construction depends upon a fairly constant supply line voltage for best operation. Thus any change in supply line voltage, such as is sometimes encountered in industrial plants, may cause change in the speed of the eddy-current clutch, which is beyond either manual or automatic control. The present invention avoids the effects of supply line voltage changes, and hence extends the use of the patented structure to conditions of varying line voltages in the supply circuit.

Herein, regulation refers to speed change with load change, and deviation refers to speed change at a given load. Both are reduced by means of the present invention.

Referring to Fig. 1, at CL is shown a winding which provides the flux in an eddy-current slip clutch C. The driving member is shown at E and the driven member at D. At AL is shown a permanent-magnet, A. C. generator, operated by the driven member D. The above parts are substantially as set forth in the patent. Winding CL provides the flux in the clutch, whereby the driving and driven members E and D of the clutch are electrically coupled by what is ordinarily called a slip connection. As indicated in said patent, the driver member of the clutch drives the permanent-magnet, A. C. generator AL, preferably at relatively high frequencies to eliminate pulsations and any tendency to resonate, although this high frequency is not always necessary. If higher frequency alternations are desired, a larger number of poles may be used on the generator, or its rotary speed may be increased by gearing from the driven member of the clutch. In any event, the speed of the generator is proportional to the speed of the driven member of the clutch for which the coil CL furnishes the coupling field.

In relevant figures of the drawings except Fig. 1, only the field winding CL of the clutch C is shown, for simplicity, but it is to be understood

that there is the same slip connection between the driving and driven elements, and that the driven element is mechanically connected with the generator AL, the latter being shown in Figs. 2 and 4, as well as in Fig. 1.

The direct current for the clutch winding CL is immediately supplied over the circuit of Fig. 3 (see also Fig. 2) through a pair of three-element, hot-cathode, gas-filled, grid-controlled, industrial rectifier tubes RT—1 and RT—2 of the half-wave type. These tubes are of such a characteristic as to require the proper grid potential to cause the tubes to fire; otherwise they do not. They are highly sensitive to grid control.

At AT is an anode transformer which supplies power for the D. C. clutch load in the winding CL. This transformer AT is connected on its primary side across line wires L—1 and L—2 of a three-wire A. C. supply circuit (of 110 volts for example). Anodes A of the tubes RT—1 and RT—2 are shown connected to the opposite ends respectively of the secondary of the anode transformer AT. Tube cathodes or heater elements K are energized by means of a transformer KT.

The secondaries of the anode transformer AT and of the cathode transformer KT are connected together at their center taps, as is shown, through the clutch coil CL which provides the D. C. load. Thus the electronic flow through the clutch coil CL may proceed, when permitted, between center tap of the transformer AT, the transformer KT and through the rectifier tubes RT—1 and RT—2, as these tubes are proportionally fired or released by the grids G to pass current unidirectionally. The dotted lines in Fig. 3 indicate electronic flow through tube RT—1 at a given instant. The rectifying action alternates through the two tubes RT—1 and RT—2. It will be understood that if plus conditions were considered, the flow lines would be reversed in Fig. 3.

As indicated at ST, the primary of the transformer KT has a "Scott-tee" quarter-phase lagging connection across the line wires L—1, L—2 and L—3, wherein L—1 and L—2 represent the principal phase, and L—3 represents the phase which lags vectorially by 90°. Grids G of the tubes RT—1 and RT—2 are fed from the secondary of the transformer KT through a transformer KT—1 and series resistors BR respectively. The resistors BR hold the grid current to a low value, being each of the order of 50,000 ohms. Transformer KT—1 superimposes a low voltage A. C. bias wave upon the basic D. C. bias (coming in from another circuit over lines 51, 52 and to be described) thus producing a grid bias of wave form, which wave form of grid bias lags 90° with respect to the anode voltage of the tubes RT—1 and RT—2, so that gradual tube cut-off effect may be had on rectified current by adjusting the overall value of the grid bias voltage wave against the anode voltage wave. This mode of tube control is more stable than that heretofore used in this class of apparatus, and constitutes one of the contributing factors to the improvements obtained, although not the only factor.

The above-described parts (Fig. 3) may be referred to as the principal grid-controlled rectifier circuit in which we have the industrial vacuum tubes RT—1 and RT—2. As above forecast, a characteristic of one of these tubes is that a small change in negative grid voltage (referred to cathode K as a base) will cause a considerable change in the voltage required to fire the tubes and hence also in the proportion of an A. C. sine wave which the tube will fire or pass. For example, at −5.1 volts negative grid bias it may require 200 volts at the anode to cause the tube to fire, while at −5.0 volts negative grid bias, 100 volts would cause the tube to fire. Under such conditions, a change of only .1 volt on the grid is causing considerable change in the current passing through the tube and hence through its load circuit including CL. Since in many applications the supply voltage for grid control may vary between −1 and −6 volts, it can be appreciated that means for providing a stable grid voltage is important in such applications, and thus it is an important purpose of the present invention to supply a stable grid voltage on wires 51 and 52 supplying biasing voltage to the grids G.

The voltage generated by the generator AL is to be used to balance or cancel out the positive grid voltage required to fire or release the tubes RT—1 and RT—2. As long as the tubes fire, the clutch coil CL is energized for effective coupling, which is under a definite grid value at G. Then the voltage generated by the generator AL is to be used to bias or cancel this grid voltage to reduce the strength of the magnetic coupling under excessive speed. Thus, the grid bias is to be made more negative to stop the tubes in response to certain excessive speed conditions of the generator, and thus a further increase in speed on the part of the clutch is to be prevented.

On the other hand, if the voltage of the generator AL falls, as upon incipient speed decrease, the positive values of the grid potentials at G are to be increased, so that the tubes fire and thus increase the excitation and hence tighten the magnetic coupling to increase the speed of the driven member of the clutch. That is to say, as in said patent, the system comprises a means of establishing a relatively fixed grid bias voltage according to a desired speed of the clutch driven member, and a means for changing this voltage in response to change in speed of the output shaft.

Tubes RE—1 and RE—2 (Figs. 2, 4 and 5) are of the full-wave rectifier type. RE—1 is used in a reference voltage producing circuit (Fig. 5) for the purpose of supplying a basic-control direct current, its anode current being supplied by a transformer PL—1 operating from the A. C. source lines L—1, L—2. The D. C. circuit of this tube RE—1 passes through point 7 of transformer FT, filtering choke 15, point CP—2 (which is in a correcting circuit to be described; Figs. 2 and 6), and then through the 2500 ohm speed-setting adjustable potentiometer P—10, point CP—1, then through a beam-power tube 6 (across anode A and cathode KK), point L, 75-ohm potentiometer P—9, middle tap of the secondary transformer PL—1, to the plates of the tube RE—1 and back to point 7 via the filament of that tube. The dotted lines in Figs. 2, 5 and 6 show the plus path. An eight-microfarad condenser 14 is used across this circuit for further filtering effects.

The circuit traced in the last paragraph above provides the main reference voltage and is of course subject to voltage variations in the line wires L—1, L—2 introduced by way of the connections through the transformer PL—1. It is the purpose of the reference voltage correcting circuit (indicated in Fig. 6) to smooth out these voltage variations, because said dotted-line circuit mentioned in the last paragraph above is to constitute the feed for input control points 54 and 58 of an amplifier circuit as defined by Fig. 7. This amplifier circuit in turn feeds the critical control grids G of the grid controlled rectifier circuit shown in Fig. 3 via wires 51 and 52.

At this point it may also be mentioned that the amplifier circuit (Fig. 7) also requires some feed from the line circuit L—1 and L—2 (see transformer O) and voltage correcting means is therefore also employed in that circuit, to be described hereinafter.

The potentiometer P—10 serves as a manually variable voltage take-off means by which the above described dotted-line circuit through the tubes 6 and RE—1 impresses voltage upon the grids GR and GL of the amplifier tube 3. This voltage take-off circuit may be traced as follows, as shown by the heavy solid arrows in Fig. 2: Arm of potentiometer P—10, points 55, BG, 100,000 ohm resistance 19, points 56, 57, 58, 59, 250,000 ohm resistance 23, grids GR and GL, 250,000 ohm resistance 24, points 53, 54, CP—1, and back to the potentiometer P—10. In other words, adjustably proportioned voltages are taken off from between the points CP—1 and CP—2 and applied to the amplifier tube 3.

It is next the purpose of the governor circuit shown in Fig. 4 to modify the effect of the adjusted voltage on the grids of tube 3, in accordance with the operation of the generator AL which is driven from the driven member D of the clutch C.

A negative potential is supplied by the action of the tube RE—2 in the governor circuit (Fig. 4) which is supplied by the transformer PL—2 energized from the generator AL. The plus circuit which is shown by dotted arrows in Fig. 4 for this tube is from its anodes to its cathode through point BG, resistances 19 and 18 (10,000 and 40,000 ohms respectively), point ED, and back to the mid tap on the transformer PL—2, a suitable one-microfarad filtering condenser being used across the circuit at 70. The potential generated by the tube RE—2 is directly proportional to the E. M. F. of the generator AL, and this provides the desired regulating control at BG, with auxiliary manual regulation provided for by the potentiometer P—10.

Thus a reference voltage may be selected by adjusting the potentiometer P—10 which determines a speed of the clutch shaft at which the tube firing starts or stops with change in speed. The connection to tubes RT—1 and RT—2 is made through an amplifier circuit to be described in connection with Fig. 7, but the point here to be made is that the basic grid bias thus provided by the reference voltage circuit of Fig. 5 through the tube RE—1 is modified in accordance with the action of the generator AL through the governor circuit of Fig. 4, analogously to the action described in said patent. The difference herein is that the output of the reference voltage circuit of Fig. 5, which is subject to line voltage changes, is corrected by the reference voltage correcting features to be described in connection with Fig. 6, and the auxiliary correcting features used in the amplifier circuit of Fig. 7.

It may be noted at this point that the heaters H of the tubes 6 and RE—2 are energized over a circuit C from the secondary of the transformer O. The primary of this transformer is connected across the lines L—1, L—2. This heater circuit also supplies the heaters I of a rectifier tube 30 and of the resistance bridge amplifier tube 3 in the amplifier circuit (Figs. 2 and 7).

The rectifier tube 30 in the amplifier circuit (Fig. 7) supplies direct current for the amplification. The positive cathode 31 of this tube is the origin of the current which flows through filtering choke 28, 5000 ohm resistance 32, through resistors 25 and 26 of 100,000 ohms each, the latter acting as dividers which supply positive current to the two anodes L and R or the resistance bridge amplifier tube 3. From these anodes L and R the circuit is completed through the cathode M, 2200 ohm resistance 22, point 41, 5000 ohm resistance 42, and the mid point of the secondary of transformer T—R. The forty-microfarad condenser 80 connected across this circuit aids filtering. The primary of T—R is connected across the lines L—1, L—2 as shown. This circuit supplies a potential through tube 3 and hence controls the grids G in the tubes RT—1 and RT—2. This potential is applied to the grids G of tubes RT—1 and RT—2 by lines 51 and 52, including the center tap of transformer KT—1, resistances BR, grids G, heaters K, and center tap of the secondary of transformer KT. Although the potential on the grids G is of the variable D. C. type, the tube 3 will cause that D. C. potential to be of an effective value, according to the firing of the right-hand or left-hand anode L or R of the tube 3. Action in this connection is as follows:

A plus potential is maintained on the right-hand grid GR of tube 3, the parallel circuit for this purpose being traced as follows: CP—2, P—10, points 55 and BG, resistance 19, points 56, 57, 58, 59, 250,000 ohm resistance 23, grids GR and GL, 250,000 ohm resistance 24, points 53, 54 and CP—1. Because the 100,000 ohm resistor 26 is unable to furnish current to the extent required, the wires connected to the right-hand anode GR are exhausted upon firing of tube 3. This produces negative potential all the way to the cathodes K in the tubes RT—1 and RT—2. This in turn leaves the grids G of these tubes relatively plus. Thus, the tubes RT—1 and RT—2 fire to energize coil CL to tighten the clutch coupling.

If the driven member D of the clutch accelerates, thus building up the speed of the generator AL, the voltage is increased across 40,000 ohm resistance 18, current being drawn from point ED, the effect being applied instantaneously to reverse the potential of grids GR and GL through the two-microfarad condenser 20. The reversal circuit is plus out of the cathode of RE—2, to BG, 55, P—10, CP—1, 54, 53, 24, GL, GR, 58, 57, 18, ED, to minus at the center tap of the PL—2 secondary. This potential reversal in the grids GL and GR reverses the action of tube 3 on tubes RT—1 and RT—2 and shuts off these tubes RT—1 and RT—2 as follows:

In the tube 3, the left-hand grid GL now becomes plus and the anode L, due to resistance 25, exhausts electrons from the wire system connected to itself, including the grids G of the tubes RT—1 and RT—2. Thus these grids G become negative. This definitely shuts off the tubes RT—1 and RT—2, until the speed of the driven member of the now more loosely coupled clutch member D decreases enough to drop the voltage of the governor AL, after which the cycle is repeated with a small speed deviation to effect control.

When the positive effect occurs either on the grid GR or the grid GL, this is augmented by the fact that the other grid GL or GR respectively becomes negative. Thus when plate R is positive, plate L is negative and vice-versa, and these plates act in conjunction in controlling the grids G. This may be seen from their respective connections with grids G and the heaters K.

Thus it will be seen that the tube 3 is continuously caused to fire and to stop firing the tubes RT—1 and RT—2 in response to the governing voltage produced by the generator AL.

Referring to the circuit of the governor AL for further details of the governing action (Fig. 4), it may be said that the principal part of this circuit is that indicated as RE—2, BG, 19, 56, 18, ED, and the center tap of PL—2. There is however a parallel circuit to this main circuit originating at BG and passing through 55, potentiometer P—10, points CP—1, 54, 53, resistance 24, grids GL and GR, resistance 23, points 59, 58, 57, condenser 20 or resistor 18, and ultimately back to point ED which is the negative end of both parallel circuits.

In opposition to the last-mentioned parallel circuit may be traced another one originating positive at CP—2 from tube RE—1, flowing through the potentiometer P—10, through points 55, BG, resistor 19, points 56, 57, 58, 59, resistance 23, and grid GR. The circuit continues through the tube 3, through resistance 24, points 53, 54, CP—1, which closes the circuit through tube 3 to tube RE—1 as already described. It will thus be seen that if the circuit through the tube 6 is causing the tube 3 to fire, this firing effect can be overcome by the counter-action of the circuit associated with the generator AL. That is to say, the potentials of the grids GL and GR are reversed when the speed of the generator AL rises high enough. Thus the circuit associated with the tube 6 causes the tubes to fire continuously while this circuit is controlling, and the circuit from the generator AL causes the tubes to stop firing when that circuit is controlling. In addition, the effect which takes place in tube 3 is amplified so as to cause increase in voltage (in step with the performance of the tube) to be placed on the grids of the principal tubes RT—1 and RT—2. That is, rectifier tube 30 delivers a much higher voltage to the tube 3 than could be generated and delivered directly from the generator AL. Therefore a small change in voltage delivered by the generator AL will cause a much larger change in voltage from tube 3, which larger change is delivered to the principal grids of the tubes RT—1 and RT—2. Therefore, it may be seen that the tube 3 and its rectifier supply tube 30 are in effect, along with their wiring, an amplifying circuit, and hence there is increase in the sensitivity with which this governor will react to incipient speed change. The result is better regulation and less speed deviation.

Across the circuit between tubes 30 and 3 (shown by dotted arrows in Fig. 7) is a cold cathode tube 29, known as a VR—105. This cold cathode tube constitutes an automatic resistance leak, and due to its characteristics has the function of causing a relatively short circuit across certain potentials to which it may be connected. Hence if the voltage across the circuit of the tube 29 rises unduly above the rating of the tube 29 (due for example to line fluctuations), the tube becomes more conductive and bleeds its connected circuit (see dotted lines in Fig. 7) of enough current to hold the connected circuit voltage steady at rating.

A similar cold cathode tube 11 (of type VR—105 is used across the output circuit from tube RE—1 (which circuit is also the plate circuit of tube 6). This circuit for convenience is indicated by dotted lines in Figs. 2, 5 and 6, this circuit being the one that supplies points CP—1 and CP—2 across the adjustable potentiometer P—10. Thus the cold cathode tube 11 also constitutes an automatic resistance leak or bleeder to reduce fluctuations which may occur from the line.

The screen grid SG of the tube 6 is supplied with voltage through the 12,000 ohm resistance 13. It can be appreciated that any increase in voltage on the positive side of the basic grid source shown in Fig. 5 would ordinarily cause the voltage of this screen grid SG to rise. This would result in an incipient rise in the anode current of the tube 6. Therefore, control of this screen grid voltage is desired. Also, with increased anode current, increased voltage is applied to the point 13A (Fig. 6) which should be corrected.

Cold cathode tube 12 (of the VR—105 type) is connected from point 13A to points 92 and 91, the former being in conductive relation to the cathode KK and the latter being on the potentiometer P—9 which is in conductive relation with the control grid CG. Thus, some of the current in the line 13, 13A, SG is bypassed by way of the cold cathode tube 12 and is applied to the cathode KK and the point 91 on the potentiometer P—9. Thus the potential of the cathode KK is raised because positive potential from point 13A has been conducted to KK as well as to point 91. This means that the voltage of P—9 and control grid CG will drop relative to KK. Thus the control grid CG is made more negative by making the cathode KK relatively more positive.

On the other hand, the voltage of screen grid SG has been slightly raised, even though it has been somewhat regulated by the regulation of current through the tube 12. Therefore, a position is to be found for P—9 so that the change in voltage on screen grid SG upwards will exactly be accompanied by change in voltage downward on control grid CG. Thus by offsetting a rise of voltage on the screen grid SG by a fall in voltage on the control grid CG, a more constant current is assured across points CP—1 and CP—2 despite changes in voltage from the reference voltage circuit L—1, L—2.

In making adjustments, artificially stimulated voltage changes may be brought about in the reference voltage circuit over the range of voltage change to be expected in practice. A milliammeter (not shown) if placed in series with tube 11 will show any change in current through this tube as a result of the artificially induced voltage change. Then potentiometer P—9 is adjusted until change in current disappears, during artificially induced voltage changes in the circuit. Such disappearance means that an increase in voltage on screen grid SG is causing a balancing decrease in voltage on the control grid CG. The degree of voltage change that can be accommodated successfully has been as high as 30% up or 30% down without a visible change in a milliammeter recording current flow through tube 11.

Thus tube 11 constitutes a leak circuit controlling anode voltage and tube 12 constitutes a grid leak circuit controlling grid voltages.

Assuming 105 volts to be normal, and assuming that it rises to 106 across one of these type VR-105 tubes, the current will change from .0075 ampere to .025 ampere. Since in a circuit such as is associated with the tube 6, the total current flowing is only .080 ampere, it will be seen that there is hardly any tendency for any voltage rise in such a circuit. Any incipient

rise is prevented by the heavy current by-pass action of the VR–105 type of tube. Thus the effect of these tubes **11**, **12** and **29** is to maintain constant voltage conditions in the feed to supply wires **51** and **52** of the grids in the grid controlled rectifier circuit.

Since the present invention provides a substantially constant screen grid voltage in tube **6**, moderate changes in voltage on the plate make very little difference in the current through this tube **6**. Ordinarily a rising plate voltage also means a rising screen grid voltage, but in the present invention, the tube **12** constitutes a voltage regulator for the screen grid voltage of tube **6**. Thus, for the present purpose, this tube is substantially a current regulator. And, if the current flowing through the potentiometer P—**10** is constant, then the desired voltage drop across P—**10** will remain constant, which means that the basic grid voltage will be constant, as ultimately applied to the grids of tubes RT—**1** and RT—**2**, regardless of voltage variations across L—**1**, L—**2**, L—**3**. It will, however, be understood that adjustments at potentiometer P—**10** determine voltages for the rectifying circuit against which the governer circuit functions proportionally.

It should also be borne in mind that the total consumption of current in the grid circuit of the tube **3** is so small, being of the order of 2 to 5 microamperes, that the output of the voltage regulation system is not materially changed by its load.

Commercial designations for tubes that are useful in the various locations are as follows:

RT—**1** and RT—**2**	EL C6J
3	6N7
5 and **30**	6X5GT
6	1622
7	5U4G
11, **12** and **29**	VR–105

It should be understood that an ordinary screen grid tube can be used in place of the beam-power tube **6**, but the latter is preferable.

Some advantages of the invention are as follows:

It is readily possible to obtain speed reduction of the large values of 60-to-1 and a speed regulation in response to load change, of 3% under such conditions. In more moderate speed reduction ranges, say 10-to-1, speed regulation may be held to within 1 or 2% with load change.

In regard to speed deviation at some reduced speed at constant load at a desired constant R. P. M., the electronic circuit herein can be used to obtain speed deviation of less than .10%.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As many changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, comprising an A. C. supply circuit, at least one power rectifier tube energized from the A. C. supply circuit to supply direct power current to said coil, a control grid in the tube, a second rectifier supplied from said A. C. circuit, a circuit for said second rectifier, an amplifier circuit including an amplifier tube having a grid control, said circuit of the second rectifier being connected to apply a controlling potential to the amplifier grid, means connecting the output of the amplifier tube for controlling the grid of the power rectifier tube, a generator connected with said driven member for proportional angular velocity in relation thereto, and a circuit supplied by the generator adapted to apply a modifying potential to the circuit connected to the grid of the amplifying tube in accordance with the angular velocity of the generator.

2. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, comprising an A. C. supply circuit, at least one power rectifier tube energized from the A. C. supply circuit to supply direct power current to said coil, a control grid in the tube, a second rectifier supplied from said A. C. circuit, a circuit for said second rectifier including an adjustable potentiometer, an amplifier circuit including an amplifier tube having a grid for control, said circuit of the second rectifier being connected to apply a controlling potential through said potentiometer to said grid of the amplifier tube, means connecting the output of the amplifier tube to the grid of the power tube for controlling the latter, a generator connected with said driven member for proportional angular velocity in relation thereto, and a circuit supplied by the generator adapted to apply a modifying potential to the circuit connected to the grid of the amplifying tube, in accordance with the angular velocity of the generator to modify control on said grid of the amplifier tube.

3. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, comprising an A. C. supply circuit, at least one power rectifier tube energized from the A. C. supply circuit to supply direct power current to said coil, a control grid in the tube, a second rectifier supplied from said A. C. circuit, a circuit for said second rectifier including an adjustable potentiometer, an amplifier circuit including an amplifier tube having a grid for control, said circuit of the second rectifier being connected to apply a controlling potential through said potentiometer to said grid of the amplifier tube, means connecting the output of the amplifier tube to the grid of the power tube for controlling the latter, a generator connected with said driven member for proportional angular velocity in relation therto, and a circuit supplied by the generator adapted to apply a modifying potential to the circuit connected to the grid of the amplifying tube, in accordance with the angular velocity of the generator to modify control on said grid of the amplifier tube, and means in said circuit of the second rectifier for maintaining a substantially constant voltage supply through the potentiometer independent of substantial voltage fluctuations in said A. C. circuit.

4. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, comprising an A. C. supply circuit, at least one power rectifier tube energized from the A. C. supply circuit to supply direct power current to said coil, a control grid in the tube, a second rectifier supplied from said A. C. circuit, a circuit for said second rectifier including an adjustable potentiometer, a D. C. amplifier circuit including a rectifier sup-

plied by said A. C. supply circuit and including an amplifier tube having a grid for control, said circuit of the second rectifier being connected to apply a controlling potential through said potentiometer to said grid of the amplifier tube, means connecting the output of the amplifier tube to the grid of the power tube for controlling the latter, a generator connected with said driven member for proportional angular velocity in relation thereto, and a circuit supplied by the generator adapted to apply a modifying potential to the circuit connected to the grid of the amplifying tube, in accordance with the angular velocity of the generator to modify control on said grid of the amplifier tube, means in said circuit of the second rectifier for maintaining a substantially contsant voltage supply through the potentiometer independent of substantial voltage fluctuations in said A. C. circuit, means energizing said amplifier circuit from the A. C. line, and means in the amplifier circuit for maintaining a controlled voltage on the amplifier tube which is substantially independent of A. C. line voltage fluctuations.

5. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, a D. C. circuit including said field coil, at least one rectifier tube in said D. C. circuit supplying said D. C. circuit to energize said field coil, said tube having an A. C. supply circuit, an amplifier circuit energized from said A. C. circuit including an amplifier tube having a plate circuit connected to the control grid of said rectifier tube, means for making the voltage of said plate circuit substantially independent of voltage fluctuations in said A. C. circuit, a reference voltage circuit energized from said A. C. circuit and supplying control means for the amplifier tube through a variable potentiometer, a governor circuit, a generator responsive to movement of the driven member of said clutch for energizing said governor circuit, the governor circuit and the reference voltage circuit being connected so that the former exerts a controlling action on the latter in accordance with speed of the clutch-driven member, means associated with said reference voltage circuit for correcting fluctuations in voltage from said A. C. supply circuit, said last-named voltage correcting means comprising a vacuum tube through which flows current of the reference voltage circuit, and leak circuits connected across the reference voltage circuit and across the internal elements of said vacuum tube.

6. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, a D. C. circuit including said field coil, at least one rectifier tube in said D. C. circuit and supplying said D. C. circuit with direct current to energize said field coil, an A. C. circuit energizing said D. C. circuit, a control grid in the tube, a second rectifying circuit energized from the A. C. circuit and including means for applying a biasing potential to said control grid causing current normally to flow in said field coil circuit, an amplifying circuit between said second rectifying circuit and said rectifier tube and means for making the current through said second rectifying and amplifier circuits substantially constant in response to substantial variation in voltage in the A. C. circuit.

7. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, a D. C. circuit including said field coil, at least one rectifier tube in said D. C. circuit and supplying said D. C. circuit with direct current to energize said field coil, an A. C. circuit energizing said D. C. circuit, a control grid in the tube, a second circuit including means for applying a predetermined biasing potential to said control grid causing current normally to flow in said field coil circuit, an amplifying circuit between said second circuit and said rectifier tube, said second circuit including a screen grid tube having a plate and a screen grid and a control grid, and means for making the current through said screen grid tube substantially constant in response to wide variation in voltage, comprising spill-over means connected in its plate circuit, spill-over means between its control grids, a generator connected with said driven member for proportional angular velocity in relation thereto, a third circuit supplied from the generator and including means connected with the amplifier circuit to apply potential in opposition to the biasing potential from the second circuit to modify the bias on the amplifier circuit in accordance with angular velocity of the generator.

8. Control apparatus for an eddy-current clutch having a driving member and a driven member and a D. C. field coil, comprising a three-phase A. C. supply circuit, at least one rectifier tube energized from the A. C. supply circuit to supply direct current to said coil, an anode and a control grid in the tube, means for providing a substantially constant grid bias voltage, a transformer having a secondary connected to the anode and a primary connected across one phase of said circuit, a second transformer supplying the grid from a secondary and having a Scott-tee connection between its primary and said circuit to provide upon the grid a bias rider voltage wave in addition to said constant bias voltage and which lags the anode voltage, said means for providing a substantially constant grid bias voltage comprising an amplifier circuit including a rectifier energized from said A. C. circuit and controlling the grid of said rectifier tube, means for making the voltage of said amplifier circuit substantially independent of voltage fluctuations in said A. C. circuit, said means for providing a substantially constant grid bias voltage also including a reference voltage circuit energized from said A. C. circuit and supplying the control for the amplifier tube, a governor circuit, a generator responsive to movement of the driven member of said clutch for energizing said governor circuit, the governor circuit and the reference voltage circuit being connected so that the former exerts the controlling action on the latter in accordance with the speed of the clutch-driven member, and means associated with said reference voltage circuit for substantially correcting fluctuations in voltage caused by voltage fluctuations from said A. C. supply circuit.

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