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[11] **3,750,633**

[45] **Aug. 7, 1973**

[54] **ELECTRONIC GOVERNOR FOR FUEL-INJECTION TYPE INTERNAL COMBUSTION ENGINES**

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Mar. 14, 1970 Japan 45/21215

[52] **U.S. Cl.** .... **123/102,** 123/140 MC

[51] **Int. Cl.** **F02d 11/10**

[58] **Field of Search** .... 123/32 EA, 102, 140 MC, 123/139 E

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[57] **ABSTRACT**

An electronic governer for fuel-injection type internal combustion engines in which the speed regulation and "ungleich" effect may be achieved by means of control circuit and "ungleich" setting circuit, and there may be obtained a stable engine output characteristic for the full range of engine speeds from the low- speed to the high- speed by providing anti-overrun circuit and anti-hunting circuit, so that the possibility of hunting under low-speed operating conditions is completely avoided.

4 Claims, 7 Drawing Figures

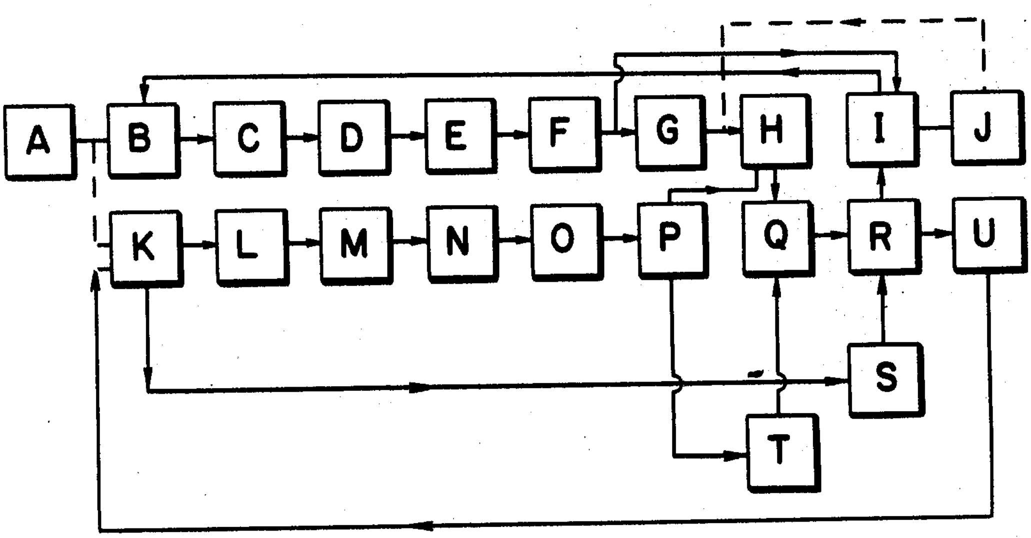

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FIG. I

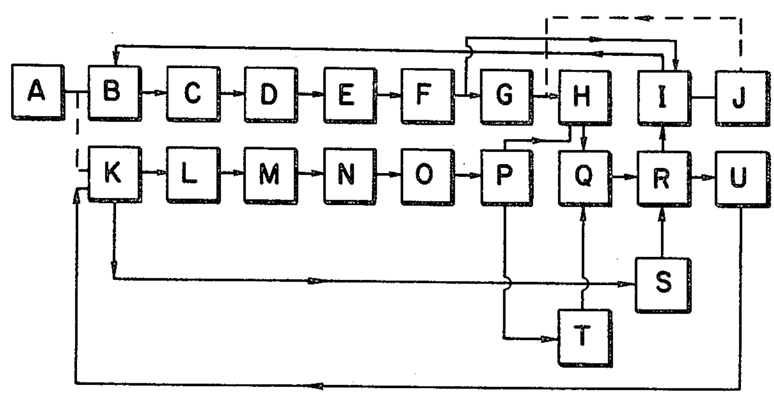


FIG. 3

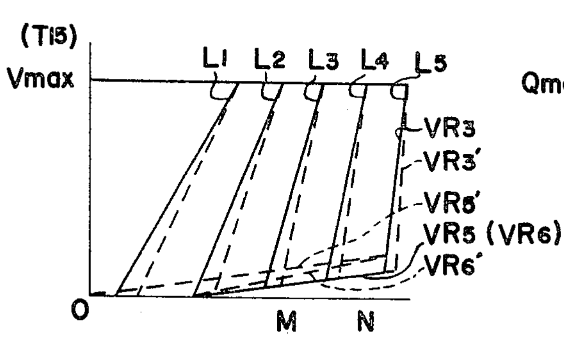


FIG. 4

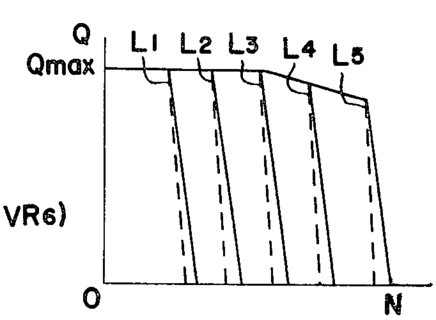


FIG. 2

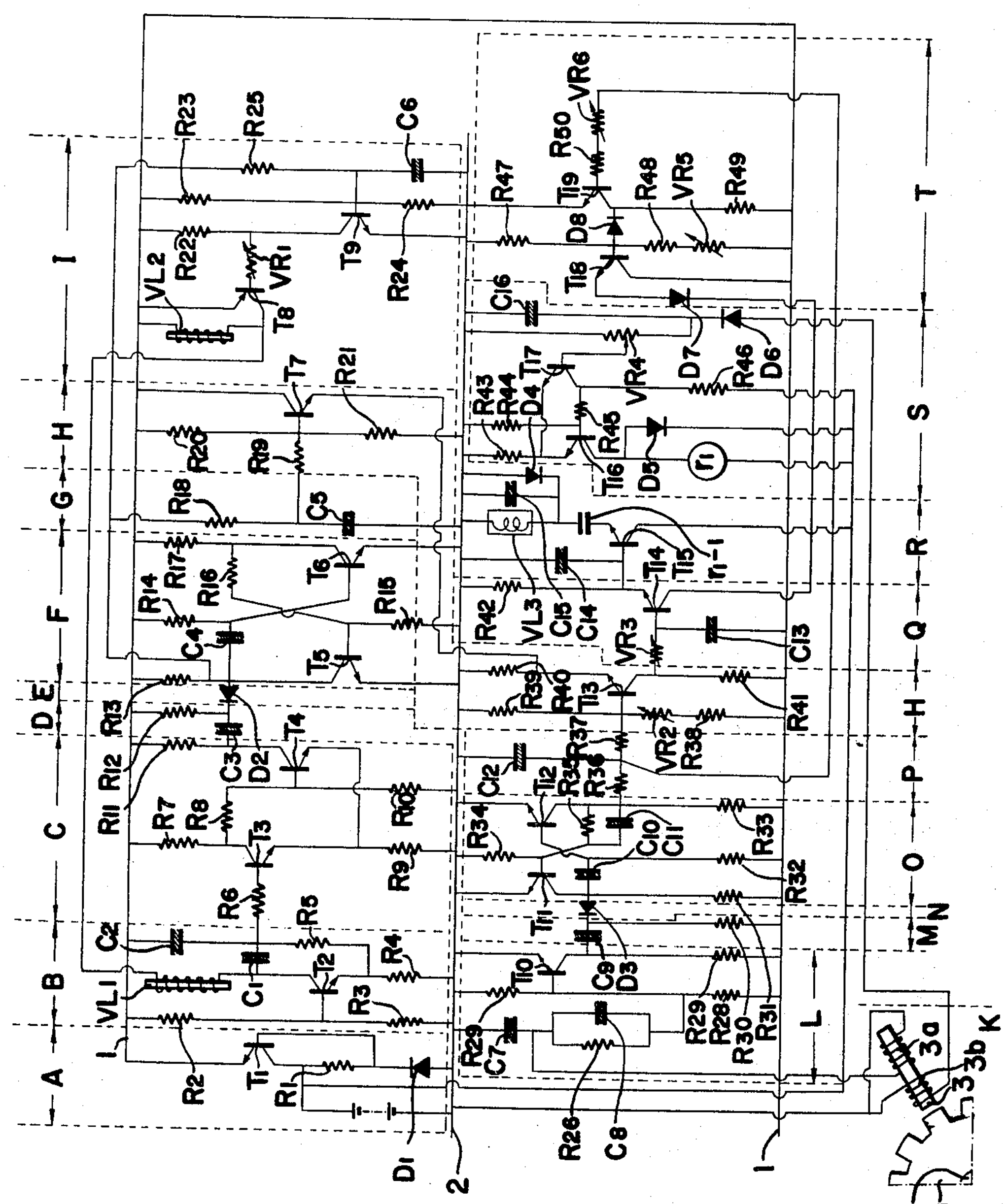


FIG. 5

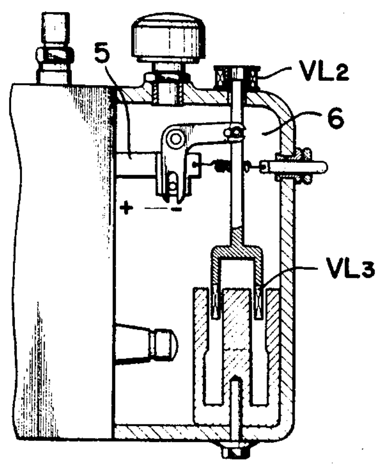


FIG. 6

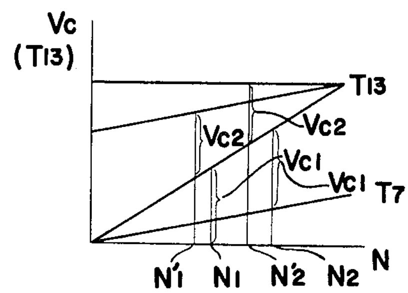
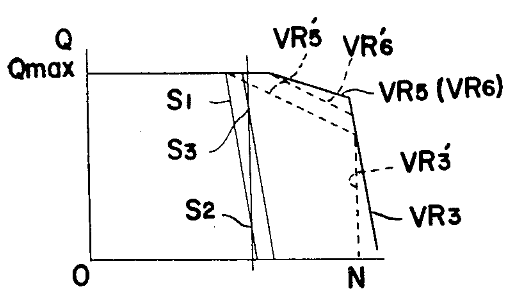


FIG. 7



ELECTRONIC GOVERNOR FOR FUEL-INJECTION TYPE INTERNAL COMBUSTION ENGINES

This invention relates to an electronic governor for fuel-injection type internal combustion engines.

Electronic circuits in governors of this type have heretofore produced an output current for actuating an electromagnetic mechanism to control the fuel regulating rod, according to whose position the fuel injection pump delivers more or less fuel to the engine. Said output current is produced by first applying the output voltage of an oscillating circuit to a monostable multivibrator of a known type. Said oscillator consists of a capacitor and a variable inductance whose inductance value corresponds to the position of the accelerator lever. The output voltage of said multivibrator is then integrated by an integrating circuit and comes out as a DC voltage. On the other hand, a signal is generated by an electromagnetic mechanism coupled to the rotating shaft of the fuel injection pump. This signal, corresponding to the rotational speed of the engine, is applied to a monostable multivibrator of a known type, whose output voltage is then integrated by an integrating circuit and therewith converted into a DC voltage. This DC voltage is compared against the other DC voltage mentioned above to produce the afore-mentioned output current, which is proportional to the difference between said two DC voltages and which is used to actuate the electromagnetic mechanism as stated. In this method, the former DC voltage is proportional to the frequency of the oscillating circuit, whereas the latter DC voltage is proportional to the rotational speed of the engine, so that the resultant control output current as a function of the rotational speed of engine generally takes a constant gradient over the entire range of engine speeds. In other words, the speed regulation of the engine is constant for the entire speed range from low-speed region to high-speed region. Although a small speed regulation is generally desired of the engine, the regulation in the low-speed region needs to be set relatively high with a view to preventing the engine from hunting. Because of this requirement, it has been proposed to feed integrated pulse signals from the input and output of said monostable multivibrator to a differential amplifier circuit in order to change the degree of conduction through a transistor according as the output voltage of said differential amplifier stays below or rises above a certain fixed value, whereby the speed regulation for the low-speed region will differ from that for the high-speed region, but such circuits have failed to satisfy the requirement fully.

An object of this invention is to provide an improved electronic governor for fuel-injection type internal combustion engines including a circuit means by which the frequency of oscillator circuit is caused to change in accordance with the displacement of fuel regulating rod, thereby expanding the speed regulation for the low-speed range of the engine in order to avoid engine "hunting" when the engine is running in that range of speeds.

Another object of this invention is to provide an improved electronic governor for fuel-injection type internal combustion engines including a circuit means which is connected in parallel with the comparison circuit for comparing the output voltage of the oscillator circuit with another output voltage proportioned to the rotational speed of the engine, and which is arranged

to produce an output signal in proportion to the rotational speed of the engine or the position of accelerator lever, the output voltage of which is superimposed on the output voltage of the comparison circuit thereby obtaining the "ungleich" effect.

A further object of this invention is to provide novel and improved electronic governor for fuel-injection type internal combustion engines in which the speed regulation and "ungleich" effect may be achieved by means of a control circuit and "ungleich" setting circuit, and there may be obtained a stable engine output characteristic for the full range of engine speeds from the low- speed to the high- speed by providing anti-overrun circuit and anti-hunting circuit, so that the possibility of hunting under low-speed operating conditions is completely avoided.

In order that this invention may be more readily understood, a preferred embodiment of this invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a block diagram for an electronic governor according to this invention for fuel-injection type internal combustion engines;

FIG. 2 is a circuit diagram representing a preferred embodiment of this invention;

FIG. 3 is a graph showing the output curves derived from the circuit of FIG. 2;

FIG. 4 is similar to the graph of FIG. 3 but refers to a conventional electronic circuit;

FIG. 5 is a longitudinal cross section showing a control section according to this invention as installed on a fuel injection pump;

FIGS. 6 and 7 both graphs showing output curves available from the electronic circuit arranged to this invention.

Referring to the block diagram of FIG. 1, "A" is a constant-voltage circuit. Output voltage of oscillator circuit "B" is passed onto Schmitt circuit "C," and is then fed through differential circuit "D" and detector circuit "E" to monostable multivibrator circuit "F." Said multivibrator circuit "F" delivers its output voltages to voltage comparison circuit "H," on the one hand, through integrating circuit "G" and to feedback circuit "I" on the other hand. Output voltage of circuit "I" is fed back to said oscillator circuit "B." One of the two output voltages coming out of electromagnetic rotary voltage converter circuit "K" is amplified by amplifier circuit "L" and is led to monostable multivibrator circuit "O" through differential circuit "M" and detector circuit "N." Multivibrator circuit "O" gives its output voltage to said voltage comparison circuit "H" through integrating circuit "P," and output voltage of comparison circuit "H" is fed to fuel regulating rod control circuit "R" through amplifier circuit "Q." The other output voltage developed by integrating circuit "P" is led to said circuit "Q" through "ungleich" setting circuit "T." The other output voltage of electromagnetic rotary voltage converter circuit "K" is led to said fuel regulating rod control circuit "R" through anti-overrun circuit "S." The signal emerging from circuit "R" is fed back to said converter circuit "K" through the engine "U." Thus, a closed loop is formed by these component circuits.

In FIG. 2, T_1 through T_{19} are transistors; D_1 through D_8, diodes; C_1 through C_{16}, capacitors; R_1 through R_{50}, resistors; VR_1 through VR_7, variable resistors; VL_1, a variable inductance associated with the position of accelerating lever of the internal combustion engine; VL_2, a variable inductance associated with the position of fuel regulating rod; VL_3, a movable coil in fuel regulating rod control mechanism for moving the fuel regulating rod of the fuel injection pump in accordance with the output current produced by the electronic circuit network; r_1, a relay; **1**, a positive conductor; and **2**, a negative conductor.

The circuits named above will be functionally described by referring to the same FIG. **2**. Circuit "A" is a known constant-voltage circuit using a Zener diode and utilizing the Zener characteristic. Circuit "B" is an oscillator including transistor T_2, resistors R_2 through R_5, variable inductance VL_1 and capacitors C_1, C_2. The oscillating frequency is varied by varying the inductance of VL_1, whose coil has a core. This variation is accomplished by coupling said core to the accelerator lever. The sinusoidal output voltage of oscillator "B" is led to Schmitt circuit "C" comprising transistors T_3, T_4 and resistors R_6 through R_{11}, and is changed thereby to a square-wave pulse signal. Differenctial circuit "D," formed by resistor R_{12} and capacitor C_3, forms, out of the square-wave signal coming from circuit "C," a trigger pulse signal, which enters detector circuit "E" to be changed thereby to a negative trigger pulse signal. This negative trigger pulse signal is transformed into a constant-width square-wave pulse signal by monostable multivibrator circuit "F" comprising transistors T_5, T_6; load resistors R_{13}, R_{17}; bias resistor R_{15}; base resistor R_{16}; time-constant setting resistor R_{14}; and capacitor C_4. The output signal of multivibrator "F" undergoes integration in integrating circuit "G" comprising resistor R_{18} and capacitor C_5, and comes out of circuit "G" as a DC voltage proportional to the pulse density representing the position of the accelerator lever. This DC voltage is fed into one of the inputs of comparison circuit "H."

Electromagnetic rotary voltage converter circuit "K" comprises an assembly of permanent magnet 3 and detector coils *3a*, *3b*, which is located close to a toothed-wheel magnetic body *4a* coupled to injection-pump camshaft **4**. Rotation of body *4a* induces voltage in detector coils *3a*, *3b* wound on permanent magnet 3 as the teeth or peripheral protrusions of body 4a move in succession past the permanent magnet. Voltage induced in this manner in coil *3a* is applied for amplification to amplifier circuit "L" comprising transistor T_{10}, capacitors C_7, C_8 and resistors R_{26} through R_{29}. The amplified voltage signal undergoes differentiation in differentiation circuit "M" comprising capacitor C_9 and resistor R_{30}, and emerges as a trigger pulse signal, which is then detected by detector circuit "N" having diode D_3. Detector "N" eliminates positive pulses from this signal, so that a negative trigger pulse signal appears from its output and applies to monostable multivibrator circuit "O," wherein it is transformed into a constant-width square-wave pulse signal. Circuit "O" is constituted by transistors T_{11}, T_{12}; load resistors R_{31}, R_{33}; bias resistor R_{34}; base resistor R_{35}; capacitor C_{11}; time-constant setting resistor R_{32}; and capacitor C_{10}. The output signal of multivibrator "O" is finally converted into a DC voltage proportional to the rotational speed of the engine by integrating circuit "P" having resistor R_{36} and capacitor C_{12}. This DC voltage is the other input signal of said voltage comparison circuit "H."

Comparison circuit "H" is constituted by transistors T_7, T_{13}, resistors R_{19} through R_{21} and R_{37} through R_{41}, and variable resistor VR_2. Emitters of transistors T_7 and T_{13} are both connected to negative conductor **2** through resistor R_{40}. Transistor T_7 has its collector connected to positive conductor **1**. Transistor T_{13} has its collector connected to positive conductor **1** through resistor R_{41}. Resistors R_{38}, R_{39} and variable resistor VR_2 serve as a bias resistance for use in setting the operating point of transistor T_{13}: changing ohmic value of VR_2 for adjustment changes the operating point to change the rotational speed of the engine in idling condition. In comparison circuit "H," the output signal of said oscillator circuit "B," varying with variable inductance in this circuit, applies to the base of transistor T_7 to switch on this transistor, thereby admitting current into resistor R_{40}. Consequently, the potential of the emitter of transistor T_{13} rises in proportion to the voltage change representing a displacement of said accelerator lever, thereby making transistor T_{13} less conductive than before. In other words, the case of conduction through transistor T_{13} varies with the output voltage of integrating circuit "P," which is proportional to said rotational speed of the engine, but the difficulty of conduction varies with the output voltage of oscillator circuit "B" which is proportional to the position of accelerator lever, represented by L_1 through L_5 in FIG. **3**. The output voltage of circuit "H," being therefore representative of the difference between the two voltage signals, is next amplified by circuit "Q" having variable resistor VR_3 for setting speed regulation. It is by this resistor that the input voltage of transistor T_{14} is controlled to vary the rate of change (or gradient of the curve) in output voltage for changes in the rotational speed of engine as indicated by dotted lines L_1 through L_5 in FIG. **3**. Since the output voltage of transistor T_{14} applies to movable coil VL_3 of the fuel regulating rod control mechanism, said rate of change determines the speed regulation of the engine. Resistor VR_3 is to be so set as to provide the smallest possible regulation not entailing the possibility of engine hunting, for a small regulation is generally desirable in applications. Once so set, resistor VR_3 is very unlikely to require a change of its setting later. The DC output voltage of integrating circuit "P," proportional to the rotational speed of the engine, is led through a branched path to the collector of transistor T_{14} in amplifier circuit "Q," through "ungleich" setting circuit "T" comprising variable resistors VR_5, VR_6, transistors T_{18}, T_{19}, resistors R_{48} through R_{50} and diodes D_7, D_8. It follows that a rise in the rotational speed of engine raises the base potential of transistor T_{19} to switch on this transistor and, while it is conducting, the base potential of transistor T_{18} is down, so that the collector current of this transistor is low. This decreased collector current in turn decreases the collector current of transistor T_{14} in amplifier circuit "Q." Therefore, the output current of power amplifier circuit "R" decreases, as represented by line VR_5 in FIG. **3**, to effect so-called "ungleich" action on fuel supply.

It is possible to make a setting at any point, as desired, between the lines VR_5 and VR'_5 in FIG. **3** by means of variable resistor VR_5 in circuit "T." Similarly, the gradient of the "ungleich" curve can be varied at will between the lines VR_6 and VR'_6, as shown in FIG. **3**, by means of variable resistor VR_6. A word on the meaning of "ungleich" here may be in order: this term refers to the fact that, in an internal combustion engine, the amount of air the engine draws for each intake stroke of the piston decreases as the rotational speed of engine rises, and means the automatic action calculated to decrease or lower the maximum fuel supply to the engine cylinders progressively from low to high over the range of engine speeds.

The feedback circuit "I" according to this invention will now be described. Detector coil VL_2 for sensing the position of fuel regulating rod is electrically connected in series to coil VL_1 of oscillator circuit "B," and the core of this coil is mechanically connected with fuel regulating rod **5** as shown in FIG. **5**. A change in inductance of detector coil VL_2 therefore affects the oscilating frequency of circuit "B." Thus, when "hunting" occurs, the fuel regulating rod will rock to and fro; in this rocking motion, suppose the fuel regulating rod displaces itself in the direction for increasing fuel supply. The oscillator frequency will then rise in circuit "B" to increase the current flowing in movable coil VL_3 in the injection-pump fuel regulating rod control mechanism, so that the fuel regulating rod **5** displaces subsequently in the direction for increasing supply.

If the fuel regulating rod **5** in rocking motion moves in the direction for decreasing fuel supply, a chain of events opposite in sense to those mentioned above takes place. This is because, as will be noted in the block diagram of FIG. **1**, the signal in fuel regulating rod control circuit "R" is fed back through the circuits "U," "K," "L," "M," "N," "O," "P," "H" and "Q," and also through the other loop formed by "I," "B," "C," "D," "E," "F," "G," "H" and "Q," not including circuit "U" (engine), which minimizes the time delay in the flow of signal to stabilize the engine speedily.

By this feedback signal, the speed regulation in low-speed region can be made wider to minimize the possibility of hunting, as will be later seen. The output current of power transistor T_{15} used in said control circuit "R" is derived from the difference in output voltage between transistors T_7 and T_{13} in comparison circuit "H." Therefore, assuming a given position of accelerator lever, a rise in rotational speed of engine due to a fall in engine load will move fuel regulating rod **5** in the direction for decreasing fuel supply, causing the core to be pushed into said coil VL_2 and thereby increasing its inductance. Hence the oscillating frequency of circuit "B" will fall to raise the output voltage of transistor **7** in comparison circuit "H." For this reason, the difference between said two output voltages diminishes to raise the rotational speed of engine, whereby the control output current is increased until the engine output power balnces with engine load. In FIG. **6**, this relation is illustrated by curves plotted in a graph with the output voltage of transistor T_{13} (collector voltage V_c) taken on the vertical axis and the rotational speed of engine "N" taken on the horizontal axis, the parameters being the emitter voltages of transistors T_7 and T_{13}.

In the absence of a feedback signal arising from detector coil VL_2, control output voltage V_{c1} is obtained at engine speed N_1 with parameter T_{13}, as will be noted in FIG. **6**, but, when a feedback signal occurs, it will be seen that output voltage of transistor T_7 comes into play to produce control output voltage V_{c1} at engine speed N_2. This relation means a widening of speed regulation. Similarly, for falling engine speed, V_{c2} will not be avilable unless the engine speed goes down from N'_2 to N_1. The feedback signal need to be eliminated if the speed regulation has to be small in the normal load and speed ranges. To meet this requirement, such an arrangement is included in the circuit network according to this invention as will remove the signal when the running engine is accelerated by means of the accelerator lever. In this arrangement to be explained hereunder, the output voltage of monostable multivibrator circuit "F" is integrated by means of resistor R_{25} and capacitor C_6, and the integrated voltage signal is applied to the input of transistor T_9. This input voltage varies with the position of the accelerator lever, so that, as the lever is moved in the direction (+) for increasing fuel supply, the base potential of transistor T_9 rises to switch on this transistor. According as transistor T_9 is more or less conductive, transistor T_8 similarly conducts more or less to decrease the current flowing in coil VL_2, thus eliminating the feedback signal. Thus, moving the accelerator lever in the direction (−) for decreasing fuel supply,the base potential of transistor T_9 falls to switch off this transistor and also transistor T_8, so that a current flows in coil VL_2 to introduce a feedback signal.

Anti-overrun circuit "S" will next be considered. This circuit is a known Schmitt circuit, whose input receives voltage from coil 3b of electromagnetic rotary detector circuit "K." With the power-source voltage applying between positive conductor **1** and negative conductor **2**, transistor T_{16} becomes conductive on account of dividers R_{44} and R_{46} to energize the coil of relay r_1 connected to the collector of transistor T_{16}. This energization closes, in relay r_1, contact r_{1-1}, which is connected to the input side of movable coil VL_3 in the fuel regulating rod control mechanism. As engine speed rises to and over the maximum level, the base potential of transistor T_{17} rises to switch this transistor on, so that, in turn, the base potential of transistor T_{16} falls to switch this transistor off, thereby interrupting, in relay r_1, the excitation current flowing in the relay coil, which is connected to the collector of transistor T_{16}. This interruption opens said contact r_{1-1} in relay r_1, to shut off the current flowing in said movable coil VL_3 to allow the fuel regulating rod **5** to shift, under the urging force of spring **6**, in the direction (−) for decreasing fuel supply, thereby preventing any abnormal rise of engine speed. Fuel regulating rod **5** is constantly urged by spring **6** in said direction (−) so that, even when the control circuit network fouls up for one reason or another to become inoperative, no overrunning condition of the engine can occur; the engine is prevented from overrunning and will stop running by itself.

The governor actions described thus far will be viewed again but in relation to the control of the engine.

Turning on the starter switch initiates the flow of current in movable coil VL_3 to shift fuel regulating rod **5** to the position Q_{max} of fuel supply, FIG. **7**. With the rod in this position, the engine fires up more easily. Upon starting up, suppose the engine is carrying a steady partial load represented by point S_1, FIG. **7**: if the load decreases under this condition, the engine speed rises as limited by the speed regulation there. Consequently, the pulse density in the output pulse signal of detector circuit "K" applying to monostable multivibrator circuit "O" increases to raise the output voltage of integrating circuit "P." This raised output voltage decreases the output current of power amplifier circuit "Q," whereby the excitation current in movable coil VL_3 decreases to allow the fuel regulating rod to be pulled back in the direction (−) for decreasing fuel supply until engine output power balances with the load at point S_2, FIG. 7. Conversely, an increase of load in the above-mentioned condition of the engine results in a chain of similar events opposite in sense to what has just been described, thereby moving the fuel regulating rod in the direction (+) until the system resumes another balanced state.

When it is desired to increase the engine output power during normal operation, the usual practice is to move the accelerator. When the accelerator lever of oscillator circuit "B" is moved to change the inductance of VL_1, the excitation current flowing in movable coil VL_3 increases, so that the fuel regulating rod 5 will move in the direction (+) until point S_3 (FIG. 7) is reached. There may be cases in which a smaller speed regulation is desirable. In such a case, the setting of variable resistor VR_3 is to be brought down to a lower value to obtain a modified characteristic curve represented by the dotted line VR'_3. If a greater "ungleich" effect is desired, the line VR_6 is to be repositioned to shift the gradient of the curve to the dotted line VR'_6, and the line VR_5 is to be repositioned to bring the operating point to the dotted line VR'_5.

From the foregoing description, the excellence of the governor according to this invention will be noted to lie in that the governor permits both the speed regulation and the "ungleich" effect to be adjusted, includes a new and anti-overrun circuit and an anti-hunting circuit and therefore assues a stable engine output characteristic for the full range of engine speeds from the low-speed to the high-speed region, and that the governor in given an added function of completely eliminating the possibility of "hunting" under low-speed operating conditions.

While this invention has been described in detail with respect to its preferred embodiment it will be understood by those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of this invention and it is intended, therefore, to cover all such changes and modifications in the appended claims.

What is claimed is:

1. An electronic governor for a fuel-injection type internal combustion engine, comprising variable frequency oscillator means for producing a first, reference signal, means for generating a second, d.c. voltage signal related to the rotational speed of the engine, comparison circuit means for comparing the signal produced by said oscillator means and said d.c. voltage signal produced by said generating means, and for producing a control signal in accordance therewith, fuel regulating rod control means for controlling the displacement of the fuel regulating rod, means, including a power amplifier circuit, for connecting the control signal output of said comparison circuit means to said fuel regulating rod control means, and feedback circuit means responsive to the position of the fuel regulating rod for controlling the frequency of said variable frequency oscillator circuit means in accordance with the displacement of the fuel regulating rod, said power amplifier circuit including means for setting the speed regulation provided by the governor and said governor further comprising means responsive to a signal related to said d.c. voltage signal for decreasing the current output of said power amplifier circuit in response to an increase in the rotational speed of the engine so as to automatically decrease the fuel supply to the engine progressively from low to high over the engine speed range.

2. An electronic governor as claimed in claim 1 further comprising override means for overriding said feedback circuit means in accordance with the position of the accelerator operating lever.

3. An electronic governor as claimed in claim 1 wherein said fuel regulating rod control means includes an electromagnetic control coil, said governor further comprising anti-overrun circuit means for providing a stable engine output characteristic over the full engine speed range and comprising relay means responsive to said d.c. voltage signal for terminating the current flow to said electromagnetic control coil when the engine speed reaches a predetermined value so that the fuel regulating rod moves in a direction to decrease the fuel supply to the engine.

4. An electronic governor for a fuel-injection type internal combustion engine, comprising variable frequency oscillator means for producing a first, reference signal, means for sensing engine rotational speed and for generating a second, d.c. voltage signal the magnitude of which is related to the rotational speed of the engine, comparison circuit means for comparing said first signal produced by said oscillator means and said d.c. voltage signal produced by said generating means and for producing a control signal in accordance therewith, electromagnetic fuel regulating rod control means for controlling the displacement of the fuel regulating rod, means for connecting the control signal output of said comparison circuit means to said electromagnetic fuel regulating rod control means, circuit means responsive to the position of the fuel regulating rod for controlling the frequency of said variable frequency oscillator circuit means in accordance with the displacement of said fuel regulating rod, and anti-overrun circuit means for providing a stable engine output characteristic over the full engine speed range and comprising relay means responsive to said d.c. voltage signal for terminating the current flow to said electromagnetic control means when the engine speed reaches a predetermined value so that the fuel regulating rod moves in a direction to decrease the fuel supply to the engine, said connecting means including power amplifier circuit means including means for setting the speed regulation provided by the governor, and said governor further comprising means responsive to a signal related to said d.c. voltage signal for decreasing the current output of said power amplifier circuit means in response to an increase in the rotational speed of the engine so as to automatically decrease the fuel supply to the engine progressively from low to high over the engine speed range.

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