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J. J. ROOT
ENGINE SPEED REGULATION

2,510,296

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FIG. 3.

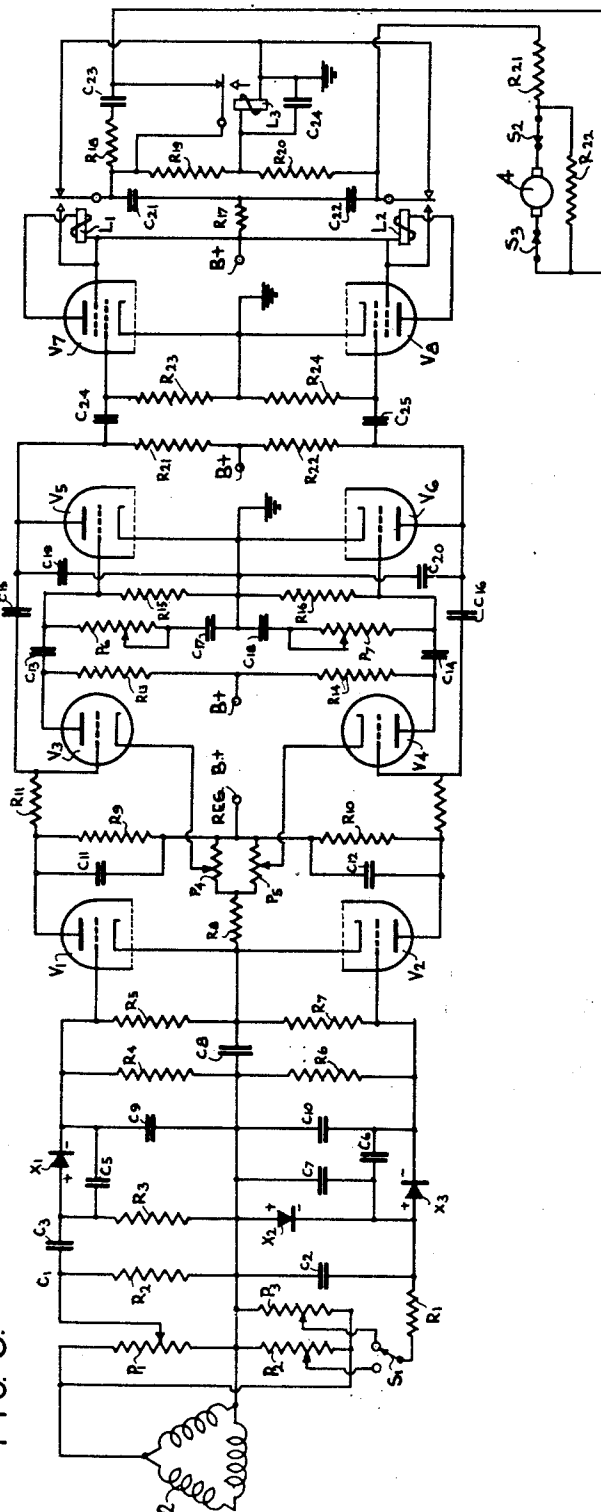


FIG. 1.

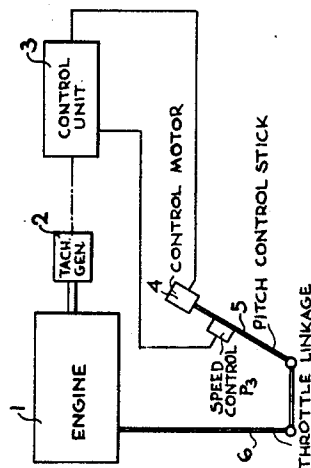


FIG. 2.

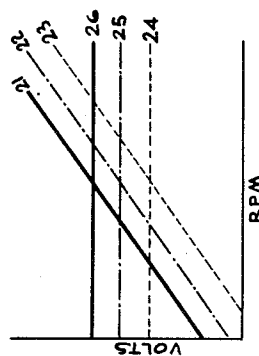
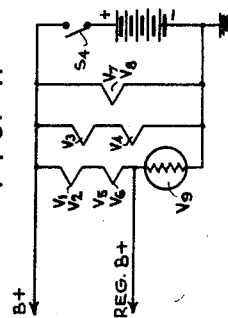


FIG. 4.



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ENGINE SPEED REGULATION

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2 Claims. (Cl. 318-464)

1 This invention relates to electronic apparatus for adjusting the speed of an engine to any desired value and automatically maintaining the engine speed at the selected value.

The apparatus of my invention provides a light weight compact control unit which enables the speed of the engine to be set by a manual operation the same as it was prior to the installation of my apparatus. When applied to a helicopter engine its speed can be set by turning a potentiometer which may be mechanically connected to the throttle twist grip on the helicopter pitch control stick. The throttle is turned by a motor which is energized so as to have a large torque even at the lowest speeds of the motor. The electronic control unit forming a part of my invention varies the speed of the engine rapidly for large deviations from the desired speed and varies the speed of the engine more and more slowly as it approaches its proper value. Thus my apparatus achieves rapid, accurate and flexible control of the engine speed.

It is the object of my invention to provide electronic control apparatus which shall be light in weight, compact, simple to operate and shall rapidly, accurately and safely maintain an engine at the speed to which it is adjusted to operate.

The invention will be fully understood from the following description and drawings in which:

Fig. 1 is a block diagram of the major components of my invention,

Fig. 2 is a diagram showing the effect of certain controls utilized in my apparatus, and

Fig. 3 shows a detailed circuit diagram of the control unit.

Fig. 4 is a circuit diagram of the power supply arrangement of the control unit.

Referring to Fig. 1 there is shown an engine 1 whose speed is to be adjusted and governed. The engine may be that of a helicopter although it will be evident that my control apparatus can be applied to any type of engine or apparatus the speed of which is to be governed. The tachometer generator 2 is connected to the engine and rotates therewith so that the speed of the engine is indicated exactly by the alternating voltage signal supplied by the tachometer. The tachometer is hence an intelligence unit which transmits engine speed information to the electronic control unit 3. The output of the control unit energizes the motor 4 which changes the throttle adjustment of the helicopter engine 1 to correct for deviations from the desired engine speed. The speed of the engine may be adjusted by a speed control potentiometer P3. Both the po-

2 tentiometer P3 and the control motor 4 may be mounted in the helicopter pitch control stick 5. The motor 4 may be connected to the throttle linkage 6 by a shaft extending through the pitch control stick 5. The throttle linkage 6 and the shaft-connected thereto are now used in mechanical throttle controls.

Referring now to Fig. 3 the tachometer 2 is shown connected across potentiometers P1, P2, and P3. The potentiometers P2 and P3 are connected to the tachometer 2 alternatively by the switch S1. The potentiometers P2 and P3 serve similar functions but potentiometer P2 provides a local control for servicing and test operation while potentiometer P3 provides a remote operating control for the engine speed. The potentiometer P1 is connected to a high pass filter C1, C3, R2. The output of this high pass filter is rectified by a crystal or other type rectifier X1. A voltage tapped off potentiometer P2 or P3 is applied through a low pass filter R1, C2 to a voltage doubling rectifier. The voltage doubling rectifier includes a condenser C4 and rectifiers X2 and X3. The rectifiers X1, X2 and X3 are shunted by small protective condensers C5, C7 and C6 respectively. Because of the high pass filter the voltage developed across the resistor R4 increases with frequency as indicated by the line 2i in Fig. 2. The voltage developed across the resistor R5 is a reference voltage and remains substantially constant with engine speed because as the tachometer speed increases its voltage increases so as to approximately compensate for the increasing attenuation of the low pass filter due to increasing frequency. The voltage across the resistor R6 is represented by the lines 24, 25, or 26, of Fig. 2. Lowering the tap on potentiometer P1 reduces the voltage across the resistor R4 so that it is represented by the lines 22 or 23 instead of the line 21. Adjustment of the potentiometer P1 varies the range of engine speeds which may be obtained by adjustment of the potentiometers P2 or P3. The potentiometer P1 is therefore used to set the range of engine speeds, and particularly the maximum speed desired, while potentiometer P3 is used to control the engine speed in operation.

When the engine is running at its proper speed the voltages across resistors R4 and R6 will be equal and opposite and in this case no voltage will be impressed across the resistors R5 and R7. If the engine speed increases above the desired value the upper end of resistor R5 becomes positive with respect to the lower end of resistor R7. The control grid of the D. C. amplifier tube V1 then

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becomes positive with respect to ground and the control grid of tube V2 becomes negative. The plate current of tube V1 then increases while that of tube V2 decreases. The increased current through resistor R9 lowers the grid potential of tube V3, while the decreased current through resistor R10 raises the potential on the grid of tube V4. Conversely, a decrease of engine speed below the desired value will increase the potential on the grid of tube V3 and decrease the potential on the grid of tube V4.

Tubes V3 and V5 form a multivibrator producing substantially square wave pulses to accelerate the engine while V4 and V6 form a multivibrator producing similar pulses to decelerate the engine. When the engine speed is greater than the desired value the negative potential on the grid of tube V3 blocks the acceleration multivibrator and the positive potential on the grid tends to start the deceleration multivibrator. The voltages from the D. C. amplifiers V1 and V2 required to start the multivibrators are determined by the setting of potentiometers P4 and P5. These potentiometers set the biases on the cathodes of tubes V3 and V4.

When the voltage impressed on the grids of tubes V3 and V4 are only slightly greater than the starting voltage the condensers C17 and C18 are charged slowly by the plate currents of the tubes V3 and V4. For higher positive grid voltage on one of these tubes the plate current is greater and the condenser C17 or C18 is charged more rapidly. Potentiometers P6 and P7 control the rate of acceleration and deceleration, respectively, of the engine speed for a given deviation thereof from its proper value. It is the charging rate of these condensers through the potentiometers P6 and P7 which largely determines the repetition rate of the multivibrators. It can be seen that a large deviation from the desired engine speed will produce a higher repetition rate and correspondingly less pulse width than a small deviation. The effect of making the repetition rate approximately proportional to the deviation is to increase the rapidity with which deviations are corrected, and to reduce the rate of correction as the engine speed approaches its proper value to thereby avoid over-run and hunting. Hunting is also decreased by setting the potentiometers P4 and P5 so as to permit certain minimum deviations from the selected engine speed without operating the multivibrators. Thus the potentiometers P4 and P5 set certain tolerances within which no corrections of the engine speed are made. These tolerances can be made immaterially small so far as the performance of the airplane is concerned, and yet be quite effective in avoiding hunting.

The pulse output of the multivibrators is fed through the coupling condensers C24 and C25 to the grids of tubes V7 and V8. In the plate circuits of these tubes relays L1 and L2 are connected. In the unenergized position these relays ground the wires leading to the control motor 4. Upon the occurrence of a pulse, say through the condenser C24, the relay L1 is energized and the moving contact thereof is connected to B+ connecting one side of the motor 4 to B+ while leaving the other side grounded and feeding a pulse to the motor to turn it in the desired direction. Operation of the relay L2 similarly feeds a pulse to the motor 4 in the opposite direction. In this manner each pulse received from the multivibrator feeds a current pulse of fixed amplitude to the motor 4. The rate of rotation of the motor will

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therefore be determined by the repetition rate of the multivibrators.

A filter C21, C22, R19 and R20 are connected across the movable contacts of the relays L1 and L2 to prevent sparking.

Another relay L3 is connected between resistors R19 and R20 and directly to ground. Operation of relay L3 removes the short circuit across resistor R18 and condenser C23. The impedance of these last two elements is sufficient to practically disconnect the motor. The resistors R19 and R20 may have such a value that the closing of either relay L1 or L2 for too long a time will be sufficient to operate relay L3 and interrupt the rotation of motor 4. Relay L3 thus affords protection against faulty operation, particularly against excessive rotation of the motor 4 in one direction.

A small resistor R21 may be placed in series with the motor to hold the current therethrough to a safe value in case of jamming of the throttle mechanism or other misoperation. Switches S2 and S3, which in practice may be one double pole switch mounted on the pitch control stick 5, can be used for disconnecting the motor. Another resistor R22 is connected across the motor 4 and the switches S2 and S3.

The power supply for the control unit may be a 24 to 28 volt battery. The tubes V1 and V2 may be the two halves of a type 6J6 tube. Tubes V3 and V4 may each be a type 12AT6 tube. Tubes V5 and V6 may also be 2 sections of a 6J6 tube. Tubes V7 and V8 may be the two sections of a type 28D7 tube. The battery supplies the necessary heater currents and a B+ voltage of about 24 volts. By means of a regulator tube V9, which may be an Amperite 4H11 tube, a regulated B+ voltage of about 12 volts is obtained and applied to the potentiometers P4 and P5.

In normal operation of my apparatus only the potentiometer P3 is varied to vary the engine speed. The range of engine speeds available is determined by the setting of potentiometer P1. Since this range is fairly wide the main effect of varying potentiometer P1 is to limit the maximum engine speed. When the engine is running at its proper speed the voltages derived from the rectifiers balance each other. If the proper speed is exceeded the voltage across the high pass filter increases and a voltage is impressed across resistors R5 and R7. If the engine speed should decrease below the proper value the voltage across the resistors R5 and R7 will change its polarity. The magnitude of this voltage will be determined by the magnitude of the deviation from the proper speed. This voltage causes the acceleration or deceleration multivibrator to oscillate, and thereby determines the direction of rotation of the motor 4, which in turn determines whether the engine will be accelerated or decelerated. The multivibrators oscillate as long as a sufficient positive voltage is applied to the grid of the first tube, V3 or V4. The rate of oscillation, or the repetition rate, depends on the magnitude of this grid voltage. Consequently the rate of correction depends on the magnitude of the speed deviation. The deviation required to initiate a correction is adjusted by the tolerance control potentiometers P4 and P5.

For the purpose of explaining the invention a specific embodiment thereof has been described in detail, but it will be apparent to those skilled in the art that many changes other than those mentioned can be made without departing from the invention, and the latter is, therefore, to be

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limited only to the extent set forth in the appended claims.

I claim:

1. Apparatus for controlling the speed of an engine comprising a winding operated through rotation of the engine to produce an alternating voltage signal, means for converting a first portion of said signal into an intelligence signal which varies in accordance with the speed of said engine, means for converting a second portion of said signal into a reference signal which, compared to the intelligence signal, is relatively invariant with the speed of the engine, a pair of multivibrators respectively responsive to said intelligence and reference signals for generating pulses having a repetition rate corresponding to the magnitude, respectively, of the said intelligence and reference signals, a reversible motor controlled by said multivibrators and a high pass filter in the circuit of said intelligence signal, said filter having a voltage output of increased magnitude with the increase of speed of said engine, and a low pass filter in the reference signal circuit for maintaining said reference signal of a substantially constant magnitude.

2. Apparatus for controlling the speed of an engine comprising a winding operated through rotation of the engine to produce an alternating voltage signal of a frequency corresponding to the speed of the engine, means for converting a first portion of said alternating voltage signal to a direct current intelligence voltage varying in magnitude in accordance with the frequency

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thereof, means for converting a second portion of said alternating voltage signal into a reference voltage of a magnitude which is substantially invariant with respect to the speed of the engine, means for combining said intelligence and reference voltages to obtain a third voltage whose polarity and magnitude correspond to the sense and magnitude, respectively, of the output of the winding, first and second multivibrators for producing pulses of varying widths and repetition rates, said third voltage being operative to alternately trigger each of said multivibrators when the speed of the engine deviates from a predetermined speed and so as to determine the pulse width and repetition rate of each multivibrator, and a servo motor connected to said multivibrators so as to receive direct current pulses of one polarity from one of said multivibrators and of the other polarity from the other of said multivibrators.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,264,985	Kovalsky	Dec. 2, 1941
2,382,847	Baumann	Aug. 14, 1945
2,408,451	Sorensen	Oct. 1, 1946
2,460,064	Curtis	Jan. 25, 1949