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CENTRIFUGAL SPEED GOVERNOR FOR ENGINES

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2 Sheets-Sheet 1

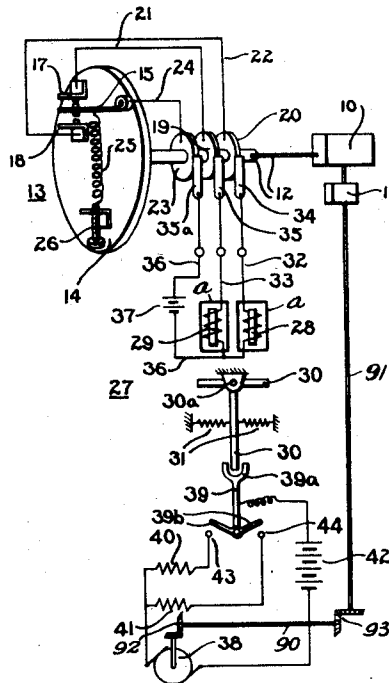


Fig 1

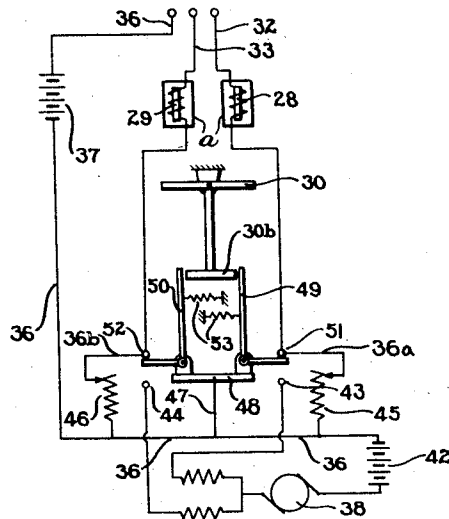


Fig 2

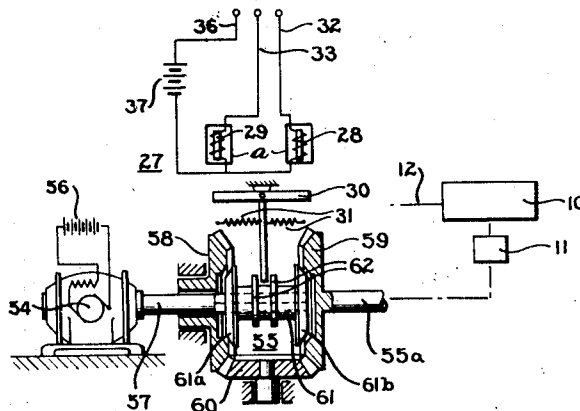
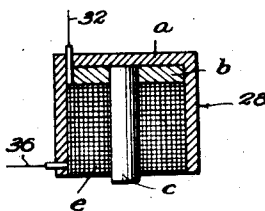


Fig 3

Fig. 6.



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CENTRIFUGAL SPEED GOVERNOR FOR
ENGINES

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This invention relates to engine control means, and more particularly to centrifugal speed governors for engines.

One of the objects of the present invention is to provide novel, highly sensitive centrifugal speed governing means for engines.

Another object is to provide novel speed control means for an engine, which means are light in weight, and inexpensive to manufacture.

A further object is to provide a centrifugal speed governor for an engine having a steady regulating characteristic.

An additional object is to provide a novel governor of the above character having an accurate reversible control over an engine.

A still further object is to provide a novel device of the above character for maintaining an engine at a constant predetermined speed.

The above and further objects and novel features will more fully appear when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for purposes of illustration only and are not intended as a definition of the limits of the invention, reference for this latter purpose being had to the appended claims.

In the drawings, wherein like reference characters refer to like parts throughout the several views—

Fig. 1 is a schematic diagram of one embodiment of the invention;

Fig. 2 is a schematic diagram of a second embodiment of the invention;

Fig. 3 is a schematic diagram of a third embodiment of the invention;

Fig. 4 is a schematic diagram of a fourth embodiment of the invention;

Fig. 5 is a graphical representation of current and moment changes occurring in the governing apparatus; and

Fig. 6 is a sectional detail view of the copper jacket short-circuit winding.

The forms of the invention illustrated in the accompanying drawings, by way of example, comprise centrifugal governing means for an engine, the means being drivably connected to the engine, and including a rotatable member having an arm mounted thereon. The arm is adapted for vibration upon either side of a predetermined central position in a plane perpendicular to the

axis of rotation of said member. Suitable contacts are mounted upon the rotatable member adjacent the vibratable arm, the contacts being connected to suitable means for controlling the performance of the engine in accordance with the duration of the period during which said arm engages each contact.

In the form shown in Fig. 1, an engine 10 having suitable performance control means 11, such as a gas throttle, is drivably connected, for example, by means of a shaft 12, to a centrifugal governor including a vibrator arm mechanism or vibratable contact means 13. The latter is constituted by a rotatable member 14 having a vibratable contact arm 15 mounted thereon and electrically insulated therefrom at a point 16 which is eccentric to the axis of rotation of member 14, said mounting adapting arm 15 for vibration in a plane perpendicular to said axis of rotation. Mounted upon member 14 adjacent either side of the free extremity of arm 15, for a purpose to later appear, are control contacts 17 and 18 which are respectively connected to slip rings 19 and 20 upon shaft 12 by leads 21, 22. Arm 15 is connected to a third slip ring 23 by a lead 24. Suitable means may be employed for resiliently urging the arm 15 towards the center of the rotatable member comprising, for example, a spring 25 attached at the center of gravity of the arm. The tension of spring 25 may be regulated by an axially displaceable bolt 26 having a knurled head, the tension regulation thereby predetermining the speed at which the engine 10 is to move.

Suitable means are provided for controlling a servo-motor which in turn governs said performance control means 11, comprising in the form shown a differential relay 27 having double solenoids 28, 29, each being adjacent an extremity of an armature 30 which is pivotally mounted at 30a and yieldingly held in a central position by opposed springs 31. Means are provided for preventing armature 30 from oscillating in the manner of a pendulum due to rapid alternate energizing of solenoids 28, 29 while the speed of the rotating member remains within given limits, for example ± 30 R. P. M., relative to a predetermined engine speed. Said means may be constituted by a copper jacket short circuit winding surrounding each of said solenoids and compris-

ing a jacket or housing *a*, *b*, a copper short-circuit winding, with *c* the solenoid core, and *e* the solenoid winding as shown in Fig. 6. The design arrangement of the copper short-circuit winding is such that the eddy currents produced in the short-circuit winding *b* will have a dampening effect upon the armature 30. Each of the solenoids 28 and 29 is preferably provided with such structure so as to prevent undesirable oscillation of the armature 30. Solenoids 28, 29 are in connection with contacts 17 and 18 by way of slip rings 20 and 19, said solenoids having communication therewith by leads 32, 33 and brushes 34, 35 respectively. Vibrator arm 15 is in connection with the opposite extremities of said solenoids by said lead 24, slip ring 23, a brush 35a and a lead 36, in which is connected a source of electric energy 37. The leads 32, 33 and 36 comprise an exciter circuit for the differential relay.

20 A servo-motor 38 having an operative connection with the performance control means 11 is controlled by said differential relay, for example by means of a two-way, quick-action switch 39 having a forked extension 39a between the arms 25 of which extends the free extremity of armature 30. Motor 38 is provided with oppositely wound series fields 40, 41, thus adapting the motor for rotation in clockwise and counter-clockwise directions. A source of electric energy 42 is connected to one brush of said motor and to the switch 39. The latter, having arms 39b which may engage contacts 43 or 44 connected to field windings 40 and 41 respectively, is therefore adapted for completing the circuit of said motor in accordance with the pivotal movements of armature 30.

In operation when the engine 10 is rotating at a desired speed, the centrifugal force acting upon arm 15, the latter revolving at a speed which is either equal to or a function of the engine speed, will overcome the tension of spring 25 and will however, be in equilibrium with said tension. Arm 15, does not float between the control contacts 17, 18 but rather oscillates therebetween constantly when the engine is operating between certain speed limits. When the engine is at the desired speed, the vibrating arm 15 will close contact during equal periods with each of the control contacts. The current impulses fed to solenoids 28, 29 as a result of the oscillation of arm 15 within permissible speed changes, for example ± 30 R. P. M. as above mentioned, creates a fluctuating magnetic field in each solenoid adjacent each extremity of the armature. The effect of the fluctuating fields is smoothed-out by the copper jacket short circuit winding, thus avoiding a pendulum oscillation of the lower arm of armature 30. In this condition the armature remains centralized, the servo-motor is not energized, and consequently no change is made in the adjustment of the engine performance control means 11. However, if the engine speed changes beyond the predetermined limits, for example if the engine rotates at an excessive speed, the centrifugal force acting upon arm 15 will no longer be in equilibrium with the force of spring 25 but will exceed it, and the arm 15 will come to rest upon the control contact 17, thereby energizing coil 29 and tilting armature 30, to cause arm 39b of switch 39 to engage contact 43. Servo-motor 38 will then rotate in a clockwise direction and will adjust the performance control means 11 to retard the engine speed by means of the connecting shafts 90 and 91 operatively connected to the motor 38 by means of bevels 92 and 93.

The motor 38 will rotate in an opposite direction when the speed falls below said predetermined limit, at which time the coil 28 instead of 29 will be energized. The throttle or performance control means for the engine is therefore governed in accordance with the ratio of the period during which arm 15 engages one control contact to the period the arm engages the other contact.

In Fig. 5 there is graphically represented the currents J_1 and J_2 which pass through solenoids 28 and 29 respectively as the engine speed is changed. Shown therewith are the moments M which act upon the armature 30 as the speed is changed.

In connection with the embodiment shown in Fig. 1, when armature 30 is tilted from its central position, the magnetic moment acting thereon rises at a greater rate than the spring moment acting thereon due to the progressive reduction of the air gap between the armature and either solenoid 28 or 29. Consequently, the speed change which must occur before the armature is again returned to the central position by springs 31 is invariably smaller than the speed change which must occur before the armature is tilted away from said central position towards the left or right.

In governing the speed, for example of engines having heavy flywheels, there may be an appreciable phase displacement, or time lag, between the changing of engine speed from a predetermined value and a compensation for said change, the compensation, of course, being accomplished by a servo-motor as above explained. It is desirable that the armature 30 respond promptly and return to the central position at the speed for which the device is adjusted or preferably before this speed is reached. This is also desirable not only to increase the sensitiveness of the device but also because by making the periods of opening and closing of the vibrating arm and the control contacts more brief the contacts can be subjected to heavy loads, thereby enabling the controlling of higher currents and voltages in a single circuit or stage without the use of additional relays.

Novel means are provided for increasing the sensitiveness of the device, for the above reasons, comprising in the form shown in Fig. 2 variable resistances 45 and 46 which are inserted in the exciter circuits of the solenoids 28 and 29 respectively. The embodiment of Fig. 2 is similar to that of Fig. 1 with the exception of the circuit for connecting said resistances, and also the switch means for controlling the servo-motor 38. The engine 10, performance control means 11, and vibrator arm mechanism 13 are not shown in this embodiment but are operatively connected to the device in a manner analogous to that shown in Fig. 1. The lead 36 of the exciter circuit of said solenoids is subdivided into leads 36a, 36b which respectively are in connection from the common lead 36 with solenoids 28, 29. The above-mentioned variable resistances 45, 46 are respectively connected in leads 36a, 36b. Centrally disposed between leads 36a, 36b is a lead 47 which is in communication with a bar 48 which pivotally supports at either extremity thereof L-shaped contact arms 49, 50, the lower leg of each being movable between contacts 51, 43 and 52, 44 respectively. The upper leg of each of the arms 49, 50 is yieldingly urged towards a cross-arm 30b of armature 30 by springs 53. Contacts 51 and 52 are connected in leads 36a, 36b respectively. Power source 42 is connected at one terminal to

motor 38, as in Fig. 1, and the opposite terminal of said source is connected to lead 36.

The operation of this embodiment is similar to that of the first embodiment with the exception of the action of the resistances 45 and 46 which are inserted in the circuit of the differential relay in such a manner that in the "rest" or central position of armature 30, or upon a tilting thereof, they are electrically bridged in the opposite direction by means of the leads 47, the bar 48 and arms 49 or 50. By varying the resistances 45, 46 the switch-off point of said switch, as controlled by the armature 30, may be adjusted.

The embodiment illustrated in Fig. 3 is similar to that shown in Fig. 1 with the exception that a uni-directional servo-motor 54 is employed, thus making it necessary to use a reversible clutch coupling 55, actuated by armature 30, the coupling controlling the direction of rotation of a shaft 55a which is connected to performance control means 11. This arrangement permits the control of a servo-motor in accordance with the constant characteristic as represented in Fig. 5, the characteristic resembling a power delivery curve of a hydraulic valve. The servo-motor, as above explained, is operatively connected to the performance control means 11 of the engine 10. The control means 11 may be a gas throttle for an internal combustion engine, or it may be a pitch adjusting mechanism for an aircraft propeller. The uni-directional motor 54 is continually energized by a source of electric energy 56, thus driving shaft 57, for example, in a clockwise direction. Mounted adjacent shaft 57 is the clutch coupling 55 which, in the form shown, comprises a pair of bevel gears 58, 59 concentric with said shaft, each meshing with a common bevel 60. Interposed between gears 58, 59 and axially shiftable upon and keyed to shaft 57 is a double clutch face element 61 which by faces 61a, 61b is adapted for engaging a suitable clutch face upon the inner surface of either gear 58 or 59 respectively. Double annular lips 62 upon a central sleeve of the element 61 provide means for armature 30 to engage the element and force the same into engagement with one of the bevel gears in accordance with the current impulses predominating in the differential relay 27.

In operation, depending upon the direction of the tilting of armature 30 and the moment producing the tilt, which corresponds to the action of the above-described vibrator contact means, the shaft 55a will rotate either in a clockwise or counter-clockwise direction. The speed of this rotation will be a function of the moment tending to tilt armature 30, and also of the slip of the coupling engaged thereby. The speed of shaft 55a will vary steadily as a function of the instantaneous speed deviation or error of the engine, and hence of the governor or vibrator arm mechanism 13.

The embodiment shown in Fig. 4 illustrates a novel device with a constant or steady regulating characteristic for maintaining constant and uniform a desired speed of an engine. In this embodiment, the shaft 12 rotates the vibrator arm mechanism 13 as above explained, and for a purpose to appear later in addition drives a control dynamo 63 having opposed field windings 64, 65 and an armature 66. Shaft 12 also drives a generator 67 having, for example, a single field winding 68 and an armature 69. Suitable leads 70, 71 from armature 69 are in connection with an armature 72 of a servo-motor 73, the latter having a field winding 74 which is in connection

by leads 75, 76 with a source of electric energy 77. Motor 73 performs a function analogous to that of motor 38 of Figs. 1 and 2, i. e. to adjust suitable performance control means, such as a throttle of an engine (not shown).

In order that the torque of motor 73 may be made a function of the closing period ratio, i. e. the ratio of the period which arm 15 engages contact 17 to the period which the arm engages contact 18, the strength of the field of dynamo 63 is first made a function of said closing period. This is accomplished by connecting field windings 64, 65 to leads 33, 32 respectively, and connecting lead 36 to one terminal of power source 77, the other terminal thereof being connected to the two field windings 65, 64.

The output of dynamo 63 flowing through armature leads 78, 79 might be connected directly to the armature 72 of the servo-motor; however, in order to avoid overloading the contacts 17, 18 and arm 15 with a current which may be necessarily high for the control of motor 73, it is advisable to provide the generator 67 which acts as an amplifier. Consequently, leads 78, 79 are connected to either side of winding 68.

In operation, the arm 15 will rest for a longer or shorter period of time upon either contact 17 or 18 depending upon the deviation of the engine speed from a predetermined value. Since the oppositely wound field coils 64, 65 thereby receive current impulses of different duration, there results a field in the control dynamo 63 which generates a current in the rotating armature 66. This current changes its direction depending on whether the speed of the engine exceeds or drops below the prescribed value. If the prescribed value of the engine speed is reached, the vibrating arm 15 rests for equal periods upon both control contacts 17 and 18. Consequently, the field windings 64, 65 receive current impulses of equal magnitude and duration so that the resulting field of the dynamo equals zero and no current is generated in armature 66. It will be noted that the current transmitted by said armature possesses almost the same characteristic as the current transmitted from the vibrator arm mechanism 13 to the field windings. The current in armature 66 excites the field winding 68 of generator 67 when a change from the prescribed engine speed occurs. The current generated in armature 69 is fed to the servo-motor armature 72 by leads 70, 71. Since the field 74 of the servo-motor is energized by the constant source of electric energy 77, the direction of rotation and the speed of the servo-motor is a function of the direction and strength of the current existing in the armature 72 or 69 and hence the direction and speed of changes in the performance control means or throttle is a similar function.

There is thus provided novel means for governing the speed of an engine. The means are extremely simple in construction, highly sensitive in operation, inexpensive to manufacture, and rugged in construction. The novel apparatus also enables an accurate control to be maintained over auxiliary drives or servo-motors which require high power for the operation thereof.

Although only four embodiments of the present invention have been illustrated and described in detail, it is to be expressly understood that the same is not limited thereto; for example, instead of employing the mechanical reversible coupling as shown in Fig. 3, it is possible to use an electric eddy current coupling which is directly excited by 75

the current from the vibrator arm mechanism 13. It is also possible to drive the control dynamo 63 and the generator 67 independently of the engine which is being regulated, so as to avoid influencing the regulating characteristic of the device in the event of large speed fluctuations. Various changes may be made in the design and arrangement of the parts without departing from the spirit and scope of the invention as the same will now be understood by those skilled in the art. For a definition of the limits of the invention, reference will be had primarily to the appended claims.

What is claimed is:

1. In a centrifugal governor for an engine, a rotatable member, said member being drivably connected to said engine, an arm mounted upon said member, contacts carried by said arm, said arm being adapted for vibration in a plane perpendicular to the axis of rotation of said member upon either side of a predetermined position, the arm being mounted eccentric to the axis of rotation of said member, stationary contacts mounted on said rotatable member, and means for governing the performance of said engine as a function of the ratio of the period during which said arm remains on one side of said position so as to contact one of said stationary contacts to the period said arm remains on the other side of said position and contacts the other of said stationary contacts.

2. In apparatus of the class described, an engine, performance control means for said engine, a servo-motor mechanically connected to said means, a rotatable member, a vibratable arm mounted upon said member, said arm being adapted for movement with said member about the axis of rotation of said member, the latter being drivably connected to said engine, means including a fixed contact on said member disposed on one side of said arm for actuating said motor in one direction of rotation when said arm closes with said contact, and means including a second fixed contact on said member disposed on the other side of said arm for actuating said motor in the opposite direction of rotation when said arm closes with said last-named contact.

3. In apparatus of the class described, an engine, a throttle for said engine, a trembler contact mechanism comprising a vibratable arm and stationary contacts relative to said vibratable arm, the contacts being mounted adjacent to and on either side of the arm, a servo-motor, the latter being mechanically connected to said throttle, and means for controlling said servo-motor as a function of the periods during which said vibratable arm closes with said contacts.

4. The combination with an engine having a drive shaft and performance control means of a shaft operatively connected to said drive shaft, a vibratable arm, the latter being adapted for rotation with said shaft and having an axis of vibration parallel and eccentric to the axis of the shaft, control contacts mounted adjacent opposite sides of said vibratable arm, a servo-motor operatively connected to said performance control means, and means for controlling said servo-motor as a function of the ratio of the periods during which said vibratable arm closes with one stationary contact to the periods during which said vibratable arm closes with the other stationary contact.

5. The combination with an engine having

speed control means therefor, of a servo-motor operatively connected to said control means, a vibrator contact mechanism including a vibratable arm and stationary contacts arranged on both sides of said arm, said mechanism being drivably connected to said engine, and means for governing said servo-motor in accordance with the relation of the closing periods of said vibratable arm with each of said contacts.

6. In apparatus of the class described, a rotatable shaft, a vibratable contact arm, said arm being mounted eccentric to said shaft and adapted for rotation therewith, control contacts mounted adjacent said arm, a differential relay operatively connected to said arm and contacts, said relay having an exciter circuit, two or more variable resistances, and means for placing the latter in bridged connection in said exciter circuit when said differential relay is in a centralized position.

7. In apparatus of the class described, an engine, a throttle for said engine, a servo-motor, the latter being mechanically connected to said throttle, vibrator contact means, the latter being drivably connected to said engine, a differential relay having an armature, means for operatively connecting said relay to said contact means, and means for controlling said servo-motor in response to movements of said relay armature.

8. In apparatus of the class described, an engine, speed control means therefor, vibrator arm means, the latter being drivably connected to the engine, a uni-directional servo-motor, the latter being in operative connection with said speed control means, a reversible clutch included in said operative connection, and means for controlling said clutch in accordance with movements of said vibrator arm means.

9. In apparatus of the class described, an engine, performance control means for said engine, an electric servo-motor, vibrator arm means, the latter being drivably connected to said engine, an electric generator electrically connected to said vibrator arm means, and an amplifier electrically connected to said generator, said amplifier being electrically connected to said servo-motor, the torque of the latter being governed by the current from said amplifier, said servo-motor being operatively connected to said performance control means.

10. In a centrifugal governor for an engine having speed control means therefor, a rotatable member drivably connected to said engine, an arm mounted upon said member, said arm being adapted for vibration in a plane perpendicular to the axis of rotation of said member upon either side of a predetermined position, the arm being mounted eccentric to the axis of rotation of said member, control contacts mounted upon said member on either side of said predetermined position, an electric generator having oppositely connected exciter windings, each of the latter being connected to a control contact, and a servo-motor, the latter being actuable by a current from said generator, said control means being operatively connected to said servo-motor.

11. In an apparatus of the class described, an engine, performance control means for said engine, control means operatively connected to said performance control means, a vibratable arm drivably connected to and operated by said engine, a generator having its output controlled by the movement of said arm, and an amplifier connected to the generator output and to said

control means for governing the torque of said control means.

12. In apparatus of the class described, a rotatable member, a vibratable contact mechanism mounted upon said member comprising a vibratable arm and stationary contacts, said contacts being mounted adjacent to and on either side of said arm, the arm being mounted eccentric to the axis of rotation of said member and the plane of vibration of said arm being

perpendicular to said axis of rotation, means for rotating said member, performance control means for said last-named means, and means mechanically connecting said control means for governing said control means as a function of the ratio of the period during which said arm closes with one of said contacts to the period said arm closes with the other of said contacts.

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