Jan. 25, 1949. F. P. VACHA 2,460,246

SPEED RESPONSIVE RHEOSTAT

Filed April 7, 1945 2 Sheets-Sheet 1

Fig. 1

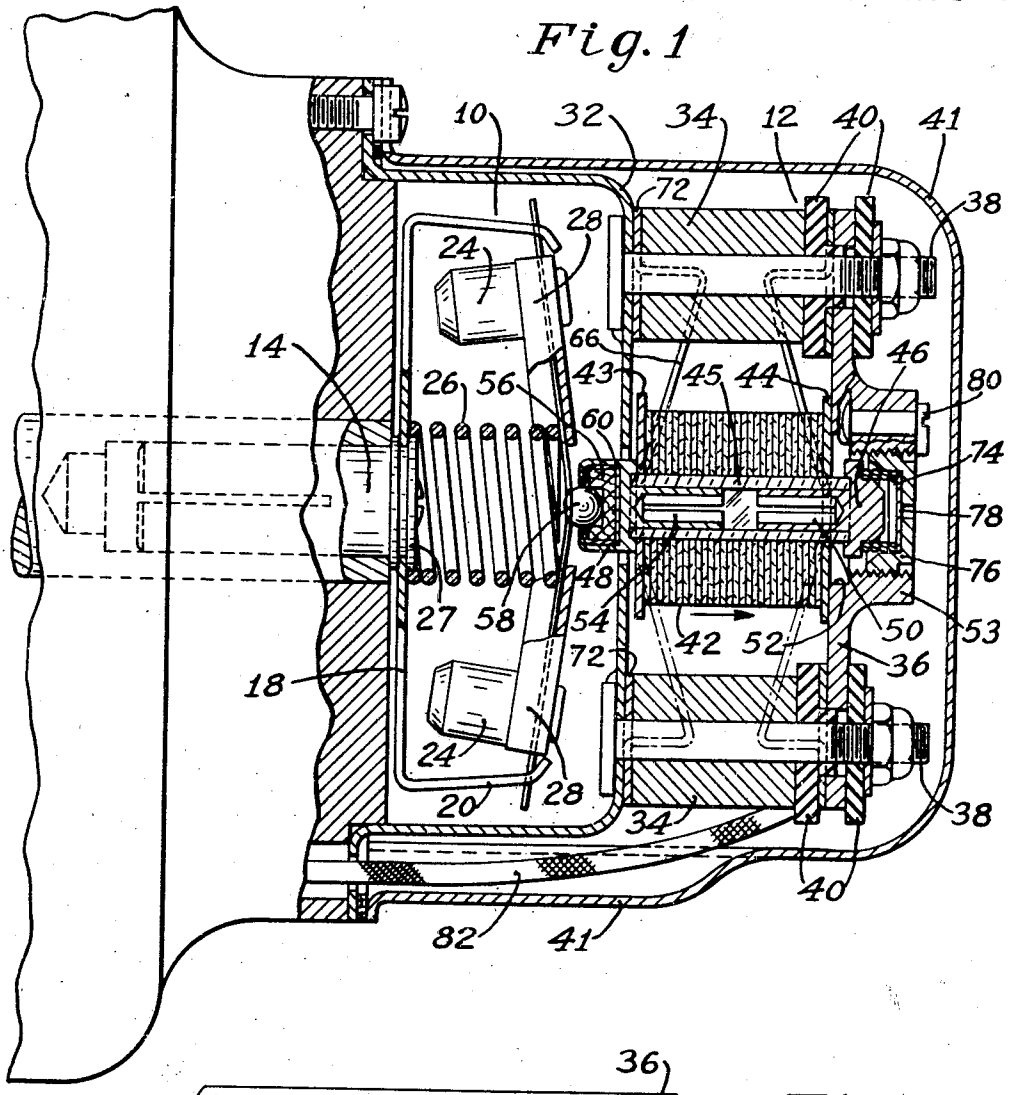
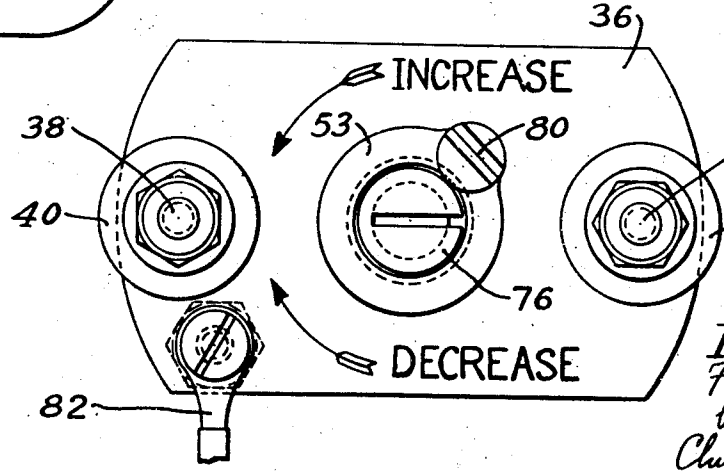


Fig. 2



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Fig. 4

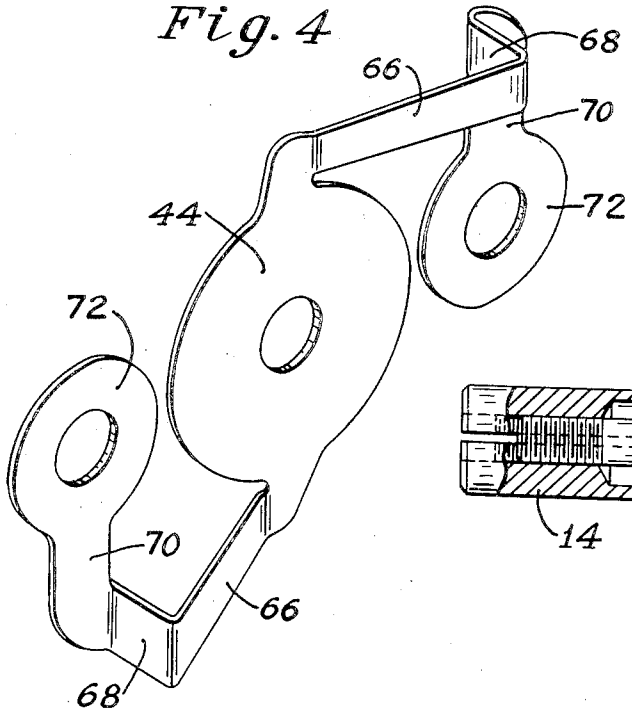


Fig. 3

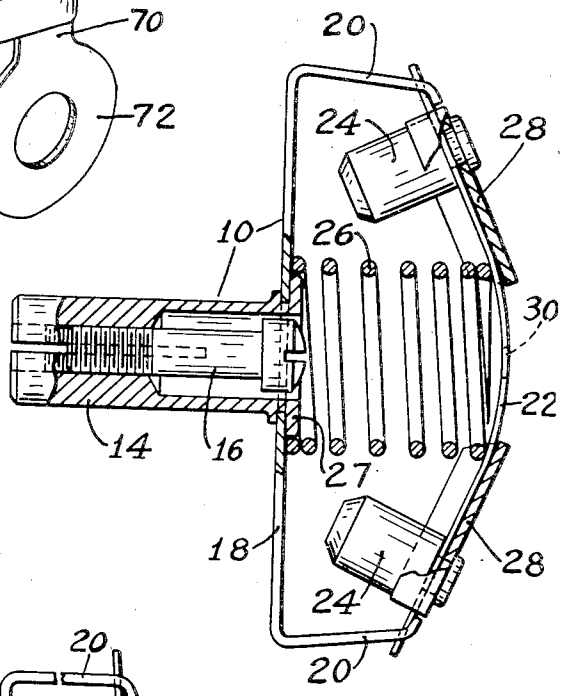


Fig. 6

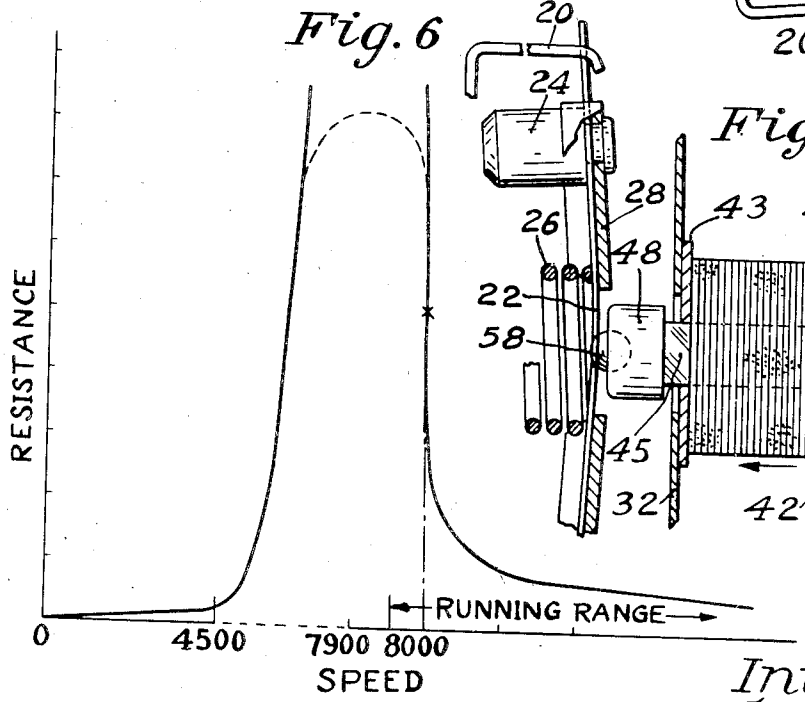


Fig. 5

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2,460,246

UNITED STATES PATENT OFFICE

2,460,246

SPEED-RESPONSIVE RHEOSTAT

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Application April 7, 1945, Serial No. 587,103

16 Claims. (Cl. 201—51)

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The present invention relates to speed controllers, and more particularly to centrifugal governors for electrical machines.

The usual centrifugal governor is of the contact type whereby contacts are opened and closed on slight variations from rated speed, and operating, in the case of direct current motors, to cut resistance into and out of the shunt field. Governors of this type have proved satisfactory for many purposes, but they are open to the objection that the control is not smooth and the motor continually hunts between two speeds above and below regulated speed. Furthermore, when used with inverters for converting D. C. into A. C., the abrupt variations in field current modulate the A. C. output. This modulation of A. C. output is highly objectionable in certain services, as for example, in aircraft use.

The object of the present invention is to provide a speed governor which will provide a smooth, continuous control without abrupt modulation of the output.

With this and other objects in view, as will hereinafter appear, the present invention comprises a centrifugal governor in combination with a pressure-responsive resistance device, preferably a carbon-pile resistor, arranged in such a manner that variations in speed operate to vary the resistance. In connection with D. C. motors and inverters, the resistance device is placed in series with the shunt field. The control of speed is gradual and continuous, so that the machine may be held close to the desired speed and without undesirable modulating effects.

Another feature of the invention comprises means whereby the resistance of the pile is varied in different ways in the starting and operating ranges. For D. C. shunt field control, the resistance is necessarily increased within the operating range as the speed drops. Hence, without a starting control independent of the running control, an unduly high resistance would be included with the shunt field and the machine would have poor starting torque. According to the present invention, the resistance is low at standstill and it is low and variable near rated load, but high for speeds between the starting range and the running range. Thus, control under running conditions is obtained without loss of starting torque.

In the accompanying drawings, Fig. 1 is a sectional plan view of the preferred governor; Fig. 2 is an end elevation of the stationary unit; Fig. 3 is an elevation of the rotating unit; Fig. 4 is a detail view of one of the floating contacts, Fig. 5 is a detail view illustrating the unit in the running range; and Fig. 6 is a graph illustrating the operation of the governor.

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The invention is herein described as applied to an inverter for converting D. C. to A. C., although it may be used as a speed control in connection with any electrical machine in which the speed may be varied by a variation in resistance.

The preferred form of the invention comprises two units, namely a rotary unit indicated generally at 10 and connected with the inverter shaft, and a stationary unit indicated generally at 12 and mounted in fixed position in the frame of the machine.

The rotating unit, as shown in Fig. 3, comprises a stud 14 to be attached to the machine shaft in any convenient manner. Preferably the stud 14 is an expansible member which is inserted into a hole in the end of the inverter shaft, being held in place by an expanding screw 16. Secured to the stud 14 is a frame 18 with resilient side arms 20 arranged to receive the ends of a bowed flat spring 22 to which are riveted the weights 24. A coil spring 26 bears between the base of the frame and the middle of the spring 22. The spring is maintained in centered position surrounding a cylindrical boss 27 on the base of the frame. Wing members 28 for a purpose to be explained later, are attached to the spring 22, preferably by the same rivets which hold the weights 24. The center of the flat spring is provided with an opening 30.

The stationary unit 12 comprises a cup 32 on which are mounted two metal posts 34 carrying at the outer end a plate 36. As shown in Fig. 1, the posts 34 and plate 36 are held in position by bolts 38, the plate being insulated from the bolts and posts by suitable insulating members indicated at 40. The entire assembly may be enclosed within a cover 41.

A carbon pile 42, consisting of thin annular disks, is mounted between the cup member 32 and the plate 36. At its ends the pile engages floating contacts 43 and 44 to be later described in detail. An insulating supporting tube 45 for the pile, preferably of glass, passes through the holes in the disks and corresponding holes in the floating supports. The tube is held in place by members 46 and 48.

The member 46 comprises a small plug having inwardly extending spring fingers 50 to engage the inner walls of the tube. As indicated in Fig. 1, the plug is grooved at its under side to accommodate the end of the tube. The plug is received

in a central opening 52 in a central boss 53 formed on the plate 36. The peripheral portion of the plug bears against the floating support 44.

The member 48 at the inner end of the tube is similarly provided with spring fingers 54 to engage the inside wall of the glass tube. It will be noted that the fingers 50 and 54 are short enough so that they do not engage one another, and hence the tube forms an insulating support for the carbon pile. Received in the end of the member 48 is a thrust bearing block 56, preferably of Bakelite, in which is received a ball 58, held in place by a suitable retainer 60. The ball 58 is engaged in the opening 30 in the center of the spring 22 of the rotating unit. The member 48 is grooved similarly to the plug 46 to receive the end of the glass tube. The peripheral portion of the member is adapted to engage the floating contact 43 under some circumstances to be presently described, for which purpose the member 48 is free to pass through a central hole in the cup 32.

The construction of the floating contacts 43 and 44 will now be described. These are of special construction, in order to apply true parallel pressure to all portions of the carbon disks. The contact 43 is a disk having arms 66 extending outwardly at diametrically opposite points and connecting with spring arms 68 which in turn are connected with legs 70 joined with feet 72 bolted under the posts 34. The entire member is made from one integral piece of beryllium copper. The contact member 44 is of identical construction, but the feet 72 are engaged in electrical contact with the plate 36 and insulated from the posts 34. The spring arms 68 act to urge the disks 43 and 44 toward the cup 32 and plate 36, respectively.

The arms 66 and 68 are of spring material, and they may be adjusted with relation to their corresponding contact disks 43, 44 to urge the disks in one direction or the other. For the inner disk 43, the arrangement of the arms is such that the disk is urged into contact with the cup 32. For the outer disk 44, the same setting may be used, in which case the arms tend to force the disk into engagement with the plate 36. Under these conditions the floating members themselves would apply no compression to the pile. Or, as will be explained later, the outer disk 44 may be set with relation to the arms 66, 68 so that the spring pressure of the arms forces the disk away from the plate 36; in other words, if no other forces were acting, the disk 44 would be spaced inwardly from the plate 36 to a slight extent. With such a setting the disk 44 is itself capable of applying some compressive force to the pile. The operation of the apparatus under both conditions will be described later.

The plug member 46 is urged to the left, as viewed in Fig. 5, by a coil spring 74, the compression of which is adjusted by a screw plug 76 threaded into the boss 27. A washer 78 is received within the plug to bear against the spring. The speed for which the unit is to govern may be adjusted by varying the compression of the spring. A retaining member 80 may be used to prevent accidental removal of the plug.

An electrical lead 82 connects with the plate 36 which forms one terminal of the pile. This lead is connected with the shunt field of the inverter in the usual manner. The other end of the pile is grounded to the frame by reason of the connection of member 43.

When the device is assembled, as shown in Fig. 1, the springs 22 and 26 of the rotating member are considerably compressed, thereby pressing against the ball 58. At standstill, the force due to these springs overcomes the force of the spring 74, so that the entire carbon pile unit is forced to the right, as shown in Fig. 1. The ball-thrust member 48 bears against the floating member 43, and the member 44 is pressed against the plate 36. The carbon disks are under high compression so that the resistance is a minimum. Consequently, a high field current is available at starting.

As the machine is started, the forces due to rotation of the weights act in a manner to straighten the spring member 22, thus diminishing the spring pressure against the ball 58. The member 48 moves toward the left. At some speed below the running range, the floating contact member 43 bottoms against the cup 32 and the member 48 leaves engagement therewith. At this time, the spring forces due to the rotating member and the spring 74 act only on the tube 45 and are ineffective to apply any compression to the pile. The pile may or may not be then under compression, depending on the setting of the floating contact disk 44 in relation to its arms 66, 68. It has been previously stated that the arms may be adjusted in a manner to urge the disk 44 either toward or away from the plate 36. If the disk is urged toward the plate 36, then at this time the pile will be under no compression and the resistance will be very high, practically infinite. The diminution of field current caused by the presence of this high resistance in the field circuit accelerates the speed-up of the machine. It will be noted that the space taken by the pile and floating members is slightly less than the space between the cup 32 and the plate 36, which constitute the end supports for the pile, whereby a small "lost motion" is provided. The setting of the disk 44 to provide a substantially infinite resistance is satisfactory in machines having a light series field, thus assuring rapid acceleration in the intermediate range.

For larger units, it may be necessary to maintain some shunt field current in order that the torque will not be too greatly reduced. To this end the disk 44 is set to be urged by its spring arms 66, 68 away from the plate 36, that is, toward the pile, so that it applies some compression to the pile even when the other springs apply no compression thereto. The compression thus applied to the pile by the disk 44, in this intermediate range is less than that applied by the other springs of the unit in the starting or running range. The amount of compression, and hence the maximum resistance in the intermediate range, may obviously be adjusted by the pressure applied by the floating contact disk 44.

In any case, as the speed further increases the force due to the rotating member further diminishes. Under the action of spring 76 the plug 46 then engages the floating disk 44, as shown in Fig. 5, and the pile is again subjected to strong compression between the floating member 44 and the now stationary member 43. The control is now in the running range, wherein the disks are variably compressed in dependence on speed. If the speed increases above the regulated value, the disks are compressed further to increase the field current, and if speed is reduced, the compression is relaxed to decrease the field current, whereby the inverter speed is quickly restored to the desired value.

It will be seen that in the starting range the pile is compressed toward the right and in the

running range it is compressed toward the left, while the lost motion provides an intermediate condition of zero (or minimum) compression to accelerate the speeding up of the machine. Between starting and running conditions, the pile is shifted bodily from one position (Fig. 1) to the other (Fig. 5).

A graph illustrating typical operation is given in Fig. 6. This is for an inverter having a rated speed of 8000 R. P. M. At standstill the resistance of the pile is 0.20 ohm. At 4500 R. P. M. the resistance has increased to 0.50 ohm. Above 4500 R. P. M. the resistance increases rapidly. If zero compression is applied in the intermediate range, the resistance rises toward infinity, as indicated by the solid line. If some compression is maintained in the intermediate range, the intermediate range is as illustrated generally by the dotted portion of the curve. The running range is indicated as beginning at about 7980. At the desired speed of 8000, the risistance may be about 20 ohms; the curve is there very steep, so that a sensitive control of speed is readily obtained.

The regulated speed may be adjusted by varying the compression of the spring **74**, which is easily accomplished by adjusting the screw **76**.

The construction of the rotating unit is of importance. The spring forces of the rotary unit are made up of the forces due to the resilient arms **20** of the frame, the flexure of the flat spring **22** and the force due to the coil spring **26**. The coil spring is desirable because the large force required for compression of the pile could not be provided by a flat spring of convenient size. The wing members **28** are used to flex the flat spring **22** and compress the coil spring **26**; they prevent any tendency of the flat spring to buckle.

The rotary unit is preferably so adjusted that at the regulated speed, the spring **22** is nearly straight but slightly bowed outwardly as shown in Fig. 5. In this position the forces due to the arms **20** and the flat spring **22** are relatively weak as compared with the corresponding forces under the starting condition (Fig. 1) when the spring **22** is bowed outwardly to a greater extent. Thus in the running range, a "soft" and sensitive spring action is provided.

For claims to sub-combinations of the complete apparatus disclosed herein, reference is to be made to my co-pending applications as follows: Serial #47,657, filed September 3, 1948, containing claims to the resistance mechanism per se, and Serial #47,658, filed September 3, 1948, containing claims to the centrifugal mechanism per se.

Having thus described the invention, I claim;

1. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device, a stationary spring acting on the resistance device, the rotary unit having spring means variably opposing said stationary spring in the running range, and means independent of the running range control for applying pressure to the resistance under starting conditions.

2. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a carbon pile resistor, a stationary spring acting on the pile, the rotary unit having spring means variably opposing said stationary spring under running conditions, and means for compressing the pile by the rotary spring means independently of the running control to provide reduced resistance under starting conditions.

3. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a carbon pile resistor, a stationary spring acting on the resistor, the rotary unit having spring means, means for applying a compressive force to the pile from the rotary spring means under standstill and low-speed conditions, said means becoming ineffective at a speed below the running range, and means whereby the rotary spring means variably opposes the stationary spring in the running range.

4. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a carbon pile resistor, supports for the resistor separated by distance slightly greater than the length of the resistor, a stationary spring acting on the resistor, the rotary unit having spring means opposing the stationary spring, and a member movable by the rotary spring means to compress the resistor in one direction, the stationary spring acting to compress the resistor in the other direction, said member being disengaged from direct compressive action on the resistor at a speed below the running range.

5. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive pile resistor, supports for the pile separated by distance slightly greater than the length of the pile, floating contact members engaging the ends of the pile, a stationary spring to act on the floating contact at one end, a speed-responsive spring means for the rotary unit opposing the stationary spring and acting in a direction to compress the pile against the opposite support, and means engaging one of the floating contact members under starting conditions to compress the pile under the action of the rotary spring means, said means being disengaged from the direct compressive action on the resistor at a speed below the running range.

6. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device, a stationary spring acting on the resistance device, the rotary unit having spring means variably opposing the stationary spring in the starting and running ranges to apply variable pressure to the resistance device in accordance with the speed, and means for diminishing the pressure on the resistance device in an intermediate speed range.

7. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device, a stationary spring acting on the resistance device, the rotary unit having spring means variably opposing the stationary spring in the starting and running ranges to apply variable pressure to the resistance device in accordance with the speed, and means for rendering said springs ineffective to apply pressure to the resistance device in an intermediate speed range.

8. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device, a stationary spring acting on the resistance device, the rotary unit having spring means variably opposing the stationary spring in the starting and running ranges to apply variable pressure to the resistance device in accordance with the speed, and means for rendering said springs ineffective to apply pressure to the resistance device in an intermediate speed range, and additional spring means to apply a small pressure to the resistance device in said intermediate range.

9. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pres-

sure-responsive resistance device, a stationary spring acting on the resistance device, the rotary unit having spring means variably opposing the stationary spring in the starting and running ranges to apply variable pressure to the resistance device in accordance with the speed, and means for bodily shifting the resistance device in an intermediate speed range and rendering said springs ineffective to apply pressure thereto.

10. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device, a stationary spring acting on the resistance device, the rotary unit having spring means variably opposing the stationary spring in the starting and running ranges to apply variable pressure to the resistance device in accordance with the speed, and means for bodily shifting the resistance device in an intermediate speed range and rendering said springs ineffective to apply pressure thereto and additional spring means to apply a small pressure to the resistance in said intermediate range.

11. A centrifugal governor comprising a rotary unit having a centrifugal weight and spring means, a pressure-responsive pile resistor, end supports for the pile, a stationary spring, the rotary spring means and the stationary spring acting to compress the pile toward one support at standstill and toward the other support under running conditions, and means to effect a bodily shift of the pile in an intermediate speed range and to reduce the compression below that for either the standstill or running conditions.

12. A centrifugal governor comprising a rotary unit having a centrifugal weight and spring means, a pressure-responsive pile resistor, end supports for the pile, a stationary spring, an axial supporting member for the pile, the stationary spring and the rotary spring means being connected to opposite ends of said axial member, the pile being supported for bodily shifting between the end supports, means to apply pressure directly to the pile between the rotary unit and one end support at low speed, and means to apply pressure directly to the pile between the stationary spring and the other end support under running conditions, said springs being ineffective to act on the pile in an intermediate speed range during which the pile is bodily shifted between the supports.

13. A centrifugal governor comprising a rotary unit having a centrifugal weight and spring means, a pressure-responsive pile resistor, end supports for the pile, a stationary spring, an axial supporting member for the pile, the stationary spring and the rotary spring means being

connected to opposite ends of said axial member, the pile being supported for bodily shifting between the end supports, means to apply pressure directly to the pile between the rotary unit and one end support at low speed, and means to apply pressure directly to the pile between the stationary spring and the other end support under running conditions, said springs being ineffective to act on the pile in an intermediate speed range during which the pile is bodily shifted between the supports and additional means for applying to the pile a small pressure in said intermediate range.

14. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device, running range control means to control the pressure on the resistance device by the rotary unit, said means acting to increase the pressure on the resistance device upon an increase in speed and to reduce the pressure on a decrease in speed, and means independent of the running range control means for applying pressure to the resistance under starting conditions.

15. A centrifugal governor comprising a rotary unit provided with a centrifugal weight, a pressure-responsive resistance device including a carbon pile resistor, control means to control the pressure on the resistance device by the rotary unit, said means acting to increase the pressure on the resistance device upon an increase in speed and to reduce the pressure on a decrease in speed, and means independent of the running range control means for applying pressure to the resistance under starting conditions.

16. A speed-responsive rheostat comprising a rotary unit, a pressure-responsive resistance device, running range control means to control the pressure on the resistance device by the rotary unit, said means acting to increase the pressure on the resistance device upon an increase in speed and to reduce the pressure on a decrease in speed, and means independent of the running range control means for applying pressure to the resistance under starting conditions.

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