Aug. 31, 1926. 1,597,788

J. B. HENDERSON

FOLLOWING MECHANISM AND RELAY

Filed Dec. 28, 1920 2 Sheets-Sheet 1

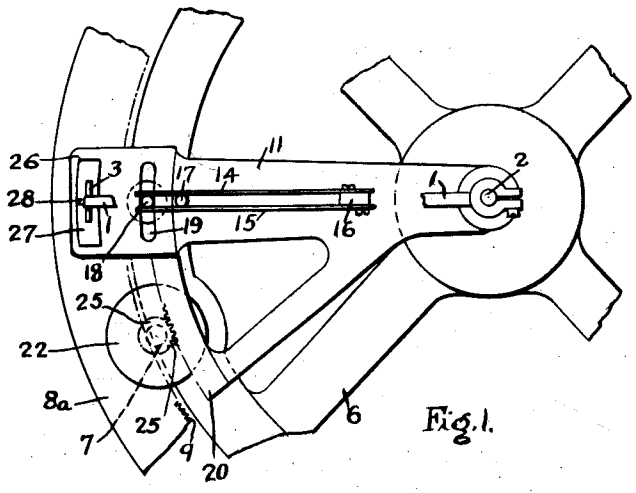


Fig. 1.

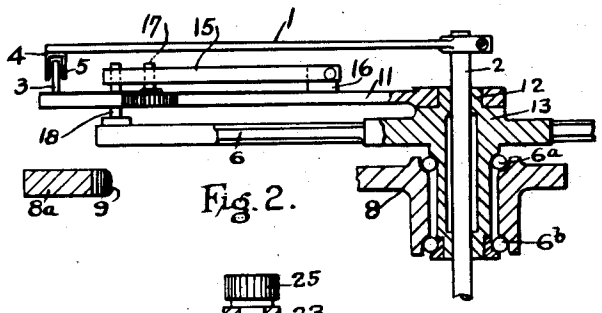


Fig. 2.

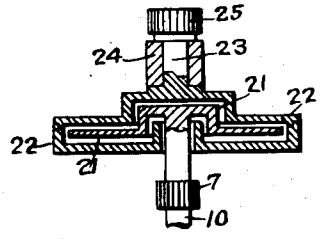


Fig. 3.

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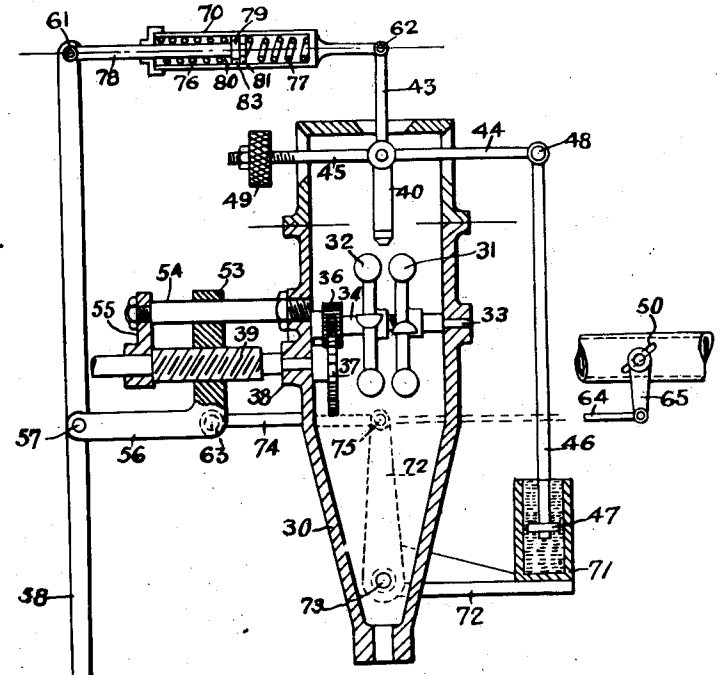
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Fig. 4.



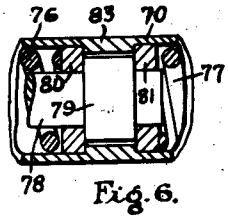


Fig. 6.

Fig. 5.

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UNITED STATES PATENT OFFICE.

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FOLLOWING MECHANISM AND RELAY.

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In following mechanisms two parts have to be kept in phase with each other, these I shall call A and B. For example in gyro-compasses the following element B has to be kept in phase with the sensitive element A which carries the gyroscope. Any motion of A relatively to B calls into play a source of power on B, say an electric motor, the controlling switch of which is actuated by electric contacts between A and B, and this motor turns B until it is in phase with A when the electric circuit is broken. The motor does not stop immediately however but continues to rotate for a short time on account of its own inertia and the inertia of the follower, thus taking B out of phase with A in the opposite direction to the previous deflection. The motor is then energized to rotate in the opposite direction and the motor is reversed, hence when close following is required the following mechanism "hunts" continually.

The object of my invention is to diminish or annul this hunting motion.

Let θ = a displacement of the follower relatively to the primary controlling element;

$\dot{\theta}$ = the angular velocity of the following element, or $d\theta/dt$;

$\ddot{\theta}$ = the acceleration of the following element, or $d\theta^2/dt^2$; and

a, b and c = constants relating to the particular apparatus, easily evaluated by any one familiar with the dynamics of mechanics, then for small displacements θ of the follower relatively to the index pointer of the controlling element, the equation of the above motion of the follower may be represented with a first degree of approximation by $\ddot{\theta} + a\theta = 0$, or the acceleration is simply proportional and of opposite sign to the displacement, which produces simple harmonic motion, hence the continuous hunting.

In my invention I introduce mechanism to damp this oscillation so that the equation of motion may be represented approximately by

$$\ddot{\theta} + b\dot{\theta} + c\theta = 0,$$

or the acceleration is proportional and of opposite sign to the displacement increased by an amount proportional to the velocity of the follower.

Figures 1, 2 and 3 show one method of applying my invention to a relay worked by electric contacts of the common follower type.

Figures 4, 5 and 6 show its application to a servomotor of the Pelton nozzle type described in my British Patent Application No. 2260 of 1916 illustrated in use with a governor for controlling the speed of steam or water turbines or other rotors.

Fig. 1 shows a plan and Fig. 2 a sectional elevation of the relay mechanism in which the primary element A consists of a crank 1 fixed to the spindle 2 and carrying on its outer end the contact roller 3 which turns on pivots 5 in the fork 4 attached to the crank 1. In Fig. 1 only the two ends of the crank 1 are shown the middle portion being cut out to make the diagram clearer.

The following element B consists of a wheel 6 supported on ball bearings 6^a, 6^b on the main frame or support 8 of the mechanism only part of which is shown. The outer ring 8^a of the main frame carries the rack 9 and the wheel 6 is rotated by a small electric motor attached to it driving the pinion 7 which gears with the rack 9. This motor is energized by the current passing from the roller 3 through one or other of two metal segments 26 or 27 of a two part commutator, the direction of rotation of the motor being reversed as the roller 3 passes from one segment to the other in a manner well-known in the art.

In the common arrangement of following mechanism of this type the commutator 26—27 is attached rigidly to the wheel 6 and this wheel hunts continuously if the insulating segment 28 between the metal segment 26—27 is made thin. The object of my invention is to eliminate this hunting and still have close following so that the commutator 26—27 is kept closely in phase with the crank 1.

In modifying the mechanism according to my invention I fix the commutator 26—27 on a crank 11 which is pivoted upon a sleeve 12 forming part of a boss 13 at the centre of the wheel 6. This crank 11 can turn relatively to the wheel 6 and coaxial with it, but is constrained relatively to the wheel 6 by two springs 14, 15 attached to the pillar 16 projecting from the crank 11. These springs press lightly against the pin 17 fixed in the crank 11 and also against the pin 18 fixed in the wheel 6 and projecting from it

through the slot 19 in the crank 11. The crank 11 thus normally turns with the wheel 6 but can be displaced through a small angle relatively to it by the deflection of the spring 14 or 15.

The crank 11 has a toothed segment 20 attached to it on one side and a pinion 25 gears with this toothed segment, this pinion being coaxial with the pinion 7 which drives the wheel 6 and the connection between the two pinions is shown in Fig. 3 on a larger scale. The motor spindle 10 carries the pinion 7 as already described and it also carries a brake disc 21. This disc is surrounded by the brake box 22 which is separated from the disc 21 by a film of viscous fluid. The box 22 is pivoted upon a spindle 23 in a bracket 24 which is attached to the wheel 6 and the spindle 23 carries on its upper end the pinion 25 which gears with the toothed segment 20.

As the motor spindle 10 revolves, the disc 21 revolves with it and the brake box 22 tends to revolve also but is prevented from doing so by the pinion 25 gearing with the toothed segment 20. The torque on the pinion 25 is proportional to the angular velocity of the motor shaft 10 and this torque produces a deflection of the spring 14 or 15 proportional to this angular velocity and the mechanism is so arranged that as the wheel 6 follows the contact roller 3 the commutator 26—27 is advanced by the deflection of the spring 14 or 15 so that it meets the roller in advance of its normal position relatively to the wheel 6. Thus in Fig. 1 suppose the crank 1 is moved clockwise round the circle so that the roller 3 comes on to the segment 26, the motor starts the pinion 7 revolving anti-clockwise so that the wheel 6 revolves clockwise following the crank 1. The brake disc 21 turning anti-clockwise exerts a torque on the brake box 22 and on the pinion 25 tending to turn them also anti-clockwise. The pinion 25 turns anti-clockwise turning the toothed segment 20 and the crank 11 also clockwise until the spring torque due to the deflection of the spring 15 balances the viscous torque on the box 22. The crank 11 is thereby advanced relatively to the wheel 6 through an angle proportional to the rate of turning of the wheel 6.

Instead of a viscous brake 22 I may use an eddy current or air brake or any other suitable type.

Figures 4 and 5 show the application of my invention to a servomotor of the Pelton nozzle type described in my British Patent Application No. 2260 of 1916 which is suitable for governors controlling the speed of steam and water turbines and for many other purposes.

In this servomotor a casing 30 has two Pelton rotors 31 and 32 mounted in it upon spindles 33 and 34 carrying respectively toothed pinions 35 and 36. The pinions both gear with the pinion 37 which is keyed to the shaft 38 projecting through the wall of the casing 30.

The nozzle 40 is pivoted on two small trunnions 41 and 42 (Fig. 5) and fluid under pressure is supplied to it through the flexible pipe 42a. The nozzle carries three cranks 43, 44 and 45 (Fig. 4) 43 serving to oscillate the nozzle on its trunnions and 44 to carry the viscous damper piston 47 upon the link 46 pivoted to 44 by the crank pin 48. The crank 45 carries the balance weight 49.

I will describe my invention in its application to governing the speed of a turbine by way of illustration. The shaft 38 protruding from the casing 30 is required to close say the throttle valve 50 as the governor balls 51 and 52 fly out. The shaft 38 carries a screw 39 on which the nut 53 slides, which is prevented from turning by sliding also on the pin 54 which is one of several supporting the bracket 55 in which the outer bearing of the shaft 38 is carried.

The nut 53 carries the projecting lug 56 on which the rocking lever 58 is pivoted upon the pin 57. The lower end of 58 is connected to the governor bell-crank 66 by the connecting rod 59 and the pin joint 60; the upper end is connected to the jet crank 43 by a link 70 to be described later and the pin joints 61 and 62. A pin 63 on the nut 53 is connected to the crank 65 on the throttle valve 50 by a connecting rod 64, this portion and the governor being shown upon a smaller scale diagrammatically.

If the link 70 is inextensible the mechanism so far described constitutes one of the common types of so-called stable relay mechanisms. If the governor balls 51 and 52 rise, the pin 60 moves to the right and the rocking lever 58 turns upon the pin 57 so that the jet emerging from the nozzle 40 instead of playing between the buckets of the two rotors is moved on to the buckets of rotor 31. The pinion 37 will therefore turn so that the nut 53 moves to the right and centres the nozzle again.

If very close governing were required it would be found that such a mechanism would hunt and my present invention is to stop this hunting. For this purpose I fit between the primary element of the relay, in this case the nozzle 40 and the secondary element or follower, in this case the nut 53, a viscous element consisting of the piston 47 moving in a dash pot 71 attached to a bell-crank 72 pivoted upon a pin 73 attached to the casing 30 and linked to the nut 53 by the connecting rod 74 and the pins 63 and 75. As the nut 53 moves along the screw 39 the dash pot 71 moves up and down. The dash pot 71 contains oil or other viscous fluid

and the piston 47 moves slowly through this fluid.

I also make the connecting link 70 telescopic the central portion being a hollow cylinder containing two light springs 76 and 77 which press two washers 80 and 81 against an annular projection 83 on the cylinder wall (Fig. 6). The piston 79 fits loosely inside this annular projection and is attached to the piston rod 78 which is attached pivotally to the rocking lever 58 by the pin 61. The connecting link 70 is therefore extensible by compressing the spring 76 and compressible by compressing the spring 77.

When the governor balls rise the jet 40 moves to the right, the nut 53 moves to the right and the dash pot 71 moves down dragging the piston 47 with it, by the viscosity of the oil and tending to center the jet 40 by compressing the spring 76. The jet is therefore centered earlier than it would be if the link 70 were rigid the advance being proportional to the rate of motion of the nut 53 or follower.

It will be noticed that in the first mechanism described the viscous element produces no reaction on the primary element of the relay which is the crank 1, but it produces a virtual displacement between the primary and secondary elements by moving the commutator contacts as a whole, and this displacement is proportional to the speed of the relay. In the second case the viscous element produces a reaction on the primary element and produces an actual displacement of the primary element of the relay, the nozzle, and this displacement is proportional to the speed of the relay. In both cases the displacement advances the reversal of the motion of the relay. My invention therefore consists in improvements in relay mechanisms to stop hunting consisting in a connection between the primary and the secondary elements of the relay to produce as the latter approaches the position of reversal of motion, an advance of the time of reversal of the relay by an amount preferably proportional to the speed of the relay mechanism.

I claim:

1. In mechanism of the character described, primary and secondary elements one being adapted to oscillate, and means interrelating said elements operable upon the approach of the position of reversal during oscillations to advance the time of reversal.

2. In mechanism of the character described, primary and secondary elements one being adapted to oscillate, and means including a connection between said elements operable upon the approach of the position of reversal to advance the time of reversal an amount proportional to the speed of operation of said means.

3. In mechanism of the character described, relatively reversible primary and secondary elements, and means including a connection between said elements and embracing a movement-resisting device, said means being operable to advance the time of reversal by an amount proportional to the speed of said movement-resisting means.

4. In mechanism of the character described, primary and secondary elements one of which is oscillatory, and means including a connection between said elements including a braking device, said means being operable to advance the time of oscillatory reversal proportionately to the speed of the mechanism as affected by said braking device.

JAMES BLACKLOCK HENDERSON.