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DEVICE FOR CONTROLLING THE AMOUNT OF FUEL INJECTED INTO AN INTERNAL COMBUSTION ENGINE AS A FUNCTION OF ENGINE SPEED

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FIG. 2

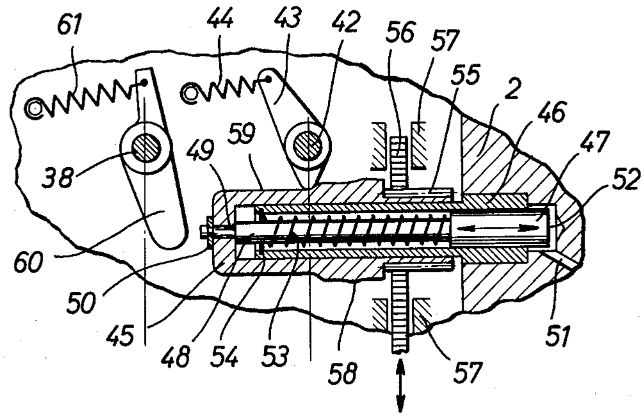
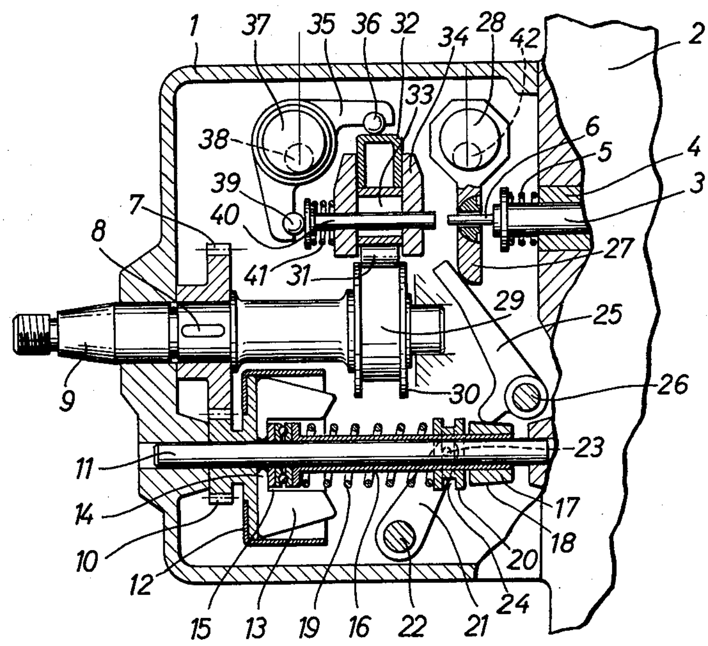


FIG. 1



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DEVICE FOR CONTROLLING THE AMOUNT OF FUEL INJECTED INTO AN INTERNAL COMBUSTION ENGINE AS A FUNCTION OF ENGINE SPEED

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With any fuel injection type internal combustion engine operating on the spontaneous ignition principle, there is associated with every particular engine speed a definite amount of fuel which can be burned completely without any smoke being produced. This amount of fuel may be considered as indicating the limit up to which the engine may be loaded without jeopardizing the economical utilization of the fuel. The fuel requirement of the internal combustion engine can be presented graphically by its fuel consumption characteristic. The fuel-delivery-versus-speed curve of the fuel injection equipment should follow this characteristic as closely as possible. To achieve this objective, and in order to prevent the smoke production limit from being exceeded, it has been customary to provide, besides a governor serving to limit the idling speed as well as the maximum speed of the engine, and also serving to maintain constant the engine speed preselected by the vehicle driver regardless of the load imposed on the engine, an additional governor adapted to limit the motion of the fuel delivery rate adjusting member of the fuel injection pump towards its maximum delivery position in a manner which is dependent on the speed of the engine and furthermore in such a manner that no influence is exerted on the first-named governor.

In a known arrangement, this speed-responsive governor acts upon the fuel delivery rate adjusting member of the fuel injection pump through the medium of a cam which is adapted to cause the fuel-delivery-versus-speed curve of the injection pump to follow the fuel requirement curve of the internal combustion engine. In another known arrangement, the said governor is adapted, as a function of engine speed, to displace an abutment disposed in the path of the fuel delivery rate adjusting member, this abutment preventing the delivery of an amount of fuel exceeding the amount which can be burned in a smokeless manner at the prevailing speed of the engine. In this arrangement, the abutment is constituted by a cam member designed to cause the fuel-delivery-versus-speed curve of the injection pump to follow the fuel requirement characteristic of the internal combustion engine.

In the case of a fuel injection type internal combustion engine it is furthermore necessary, in order to ensure smooth operation and efficient combustion, to advance the moment of fuel injection as the engine speed is increased. This advancement is necessary in order to compensate for the fact that the ignition delay extends over an increasing angle of crankshaft rotation as the speed of the engine is increased. For the purpose of varying the moment of fuel injection as a function of engine speed, it has been known to provide an additional governor adapted to influence the drive system of the injection pump, this governor taking the form of a centrifugal governor or of a control piston. The said control piston is exposed to the fuel transferred to the engine, the pressure of the fuel being dependent on the speed of the engine.

Nevertheless there remains the problem to be solved by the present invention, this problem being to provide a device adapted to cause the rate of fuel delivery characteristic of the fuel injection pump associated with an internal combustion engine to follow the fuel requirement

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curve of the engine, and further adapted to adjust the moment of fuel injection, these two functions being provided by a single speed-responsive governor, the said device being designed to take into account the critical factors affecting the operation of the engine, and the said device being particularly adapted for manufacture by mass production methods due to its simple, dependable and compact construction affording adaptability of the device to a wide variety of types of internal combustion engines. According to the invention, the said problem is solved by the provision of a speed-responsive governor which is coupled to a slidable control cam having formed thereon a control surface and an abutment, the said control surface cooperating with a spring-urged rocker arm adapted to be rotated by an eccentric shaft for the purpose of displacing the fulcrum of the stroke length adjusting member of the injection pump, the said abutment cooperating with a second spring-urged rocker arm adapted to be rotated by a second eccentric shaft for the purpose of displacing the fulcrum of a bell crank lever serving to actuate the pump plunger during its delivery stroke. The incorporation of a correcting member in the form of a control cam in the speed-responsive control loop which is influenced by a single engine speed transducer makes it possible to take into account the important factors affecting the operation of any given type of internal combustion engine, such as the efficiency of the fuel injection pump, the air charge of the engine, the enrichment of the fuel-air mixture during starting, the density of the air, the viscosity and density of the fuel as well as the advancement of fuel injection as the speed of the engine is increased.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawing, illustrating a preferred embodiment of the invention, wherein:

FIG. 1 is a longitudinal sectional view of a control device of the invention; and

FIG. 2 is a longitudinal sectional view of the speed-responsive governor cooperating with the device of FIG. 1, it being understood that the plane of FIG. 2 is parallel to that of FIG. 1.

As shown in FIG. 1, the control device comprises a housing **1** to which is flanged a second housing **2** accommodating the fuel injection pump and the various fuel galleries. Each of the plungers **3** of the fuel injection pump is guided by a barrel **4** fixedly mounted in the housing **2**. Disposed between the outer end face of barrel **4** and a collar formed near the outer end of plunger **3** is a helical spring **5** serving to cause the plunger to perform its suction stroke during which the plunger moves from the right to the left in FIG. 1. During its delivery stroke, the plunger **3** is moved from the left to the right in FIG. 1 by means of a tappet **40** acting on an extension **6** of plunger **3**.

The following part of the specification deals with the parts of the control device by means of which the device is fed signals representing the speed and the torque, respectively, of the internal combustion engine. These parts include a spring-loaded centrifugal governor of conventional construction, the restoring force of the governor spring being variable at will. The centrifugal governor is driven by a gear wheel **7** secured by key and keyway means **8** to the camshaft **9**. The camshaft **9** serving to drive the fuel injection pump and the governor is supported for rotation in the housing **1**. This camshaft **9** is rigidly coupled in the conventional manner (not shown) to the camshaft of the internal combustion engine. The gear wheel **7** meshes with another gear wheel **23** which is rotatably supported by an axle **24** mounted in housing **1**; gear wheel **23** is elastically coupled to the cup-shaped housing 12 of the centrifugal governor for rotation therewith. The centrifugal weights 13 of the governor are pivoted by means not shown within the housing 12, the outward deflection of the centrifugal weights being limited by the cylindrical skirt of housing 12. The centrifugal weights carry internally projecting lugs 14 overlapping a thrust plate 15 which is freely rotatable on axis 11 and which is axially supported from a sleeve 16 by anti-friction bearing means not shown in the drawing. Sleeve 16 surrounds axle 11. Secured to the right-hand end of sleeve 16 is another sleeve 17 formed with a substantially conical peripheral surface 18 serving as a control or cam surface. The restoring force for the centrifugal weights 13 is provided by a helical spring 19 whose left-hand end bears upon a suitable seating surface formed on sleeve 16, the right-hand end of the spring bearing upon an abutment 20 which is axially slidable guided on sleeve 16. To permit abutment 20 to be displaced in an axial direction, there is provided a lever 21 which is rigidly connected to a shaft 22 carried for rotation in housing 1, the lever 21 carrying a pin 23 engaging in an annular groove 24 extending along the periphery of abutment 20. The shaft 22 has one end (not shown) extending to the outside of housing 1, the projecting end of the shaft carrying a lever which is coupled by conventional linkage means to a hand- or foot-operated lever, to be actuated by the operator driving the associated vehicle. For the purpose of transmitting the output force of the centrifugal governor to the rate of fuel delivery adjusting member of the injection pump there is provided a bell crank lever 25 which is pivoted on a stationary pivot 26, one arm of the bell crank lever cooperating with the peripheral cam surface 18 of sleeve 17. The second arm of bell crank lever 25 is abutted by the free end of a single-armed rocker 27 which serves as the rate of fuel delivery adjusting member of the control device in that it constitutes an abutment limiting the length of the suction stroke of pump plunger 3. Rocker 27 is rotatably carried by an eccentric 28 so that the output force of the centrifugal governor can vary the angular position of the rocker, the result being that the rocker is abutted at an earlier or later moment by the returning pump plunger 3.

The camshaft 9 driven by the camshaft of the internal combustion engine carries a cam 29 driving the fuel injection pump. The radially outwardly projecting lateral flanges 30 of cam 29 serve to guide a roller follower 31 supported between cam 29 and a tappet 32 and serving to reduce the sliding friction between the cooperating parts just named. For the purpose of reducing inertia forces, tappet 32 is of hollow construction and is provided with a recess 33 extending transversely of its axis. For the purpose of guiding the tappet in the direction of its axis, there is provided a guide track 34 which is rigid with housing 1. The upper end of tappet 32 is abutted by one arm of a rocker in the form of a bell crank lever 35, the said arm carrying a roller 36 serving to reduce the friction between the arm and the tappet. Rocker 35 is pivotally supported by an eccentric 37 which is fast with an eccentric shaft 38 supported for rotation in housing 1.. The other arm of rocker 35 carries a roller 39 which bears upon the enlarged outer end of a pump tappet 40 which is axially slidably guided in a hole provided in the track projections 34 and extending at right angles to the axis of the first-named tapped 32, the tappet 40 being seen in FIG. 1 to extend through the aforementioned recess 33 of tappet 32. Disposed between the guide track 34 and the enlarged end of tappet 40 is a helical compression spring 41 serving to hold the members 40, 35, 32 and 29 in engagement. In the position shown in FIG. 1, the right-hand end of tappet 40 engages the outer extension 6 of pump plunger 3.

The possibility, provided according to the invention, of introducing into the control device a speed-responsive signal exists in view of the fact the eccentric 28 is attached to the eccentric shaft 42 carried for rotation in housing 1, the result of this arrangement being that rotation of the eccentric shaft causes a variation in the position of the fulcrum of rocker 27. The possibility of varying the position of the fulcrum or axis of rotation of rocker 27 may be utilized to take into account certain controlling factors which are dependent on the speed of the engine, for example the efficiency of the fuel injection pump, the air charge introduced into the engine and, perhaps, for the purpose of enriching the fuel-air mixture during starting.

As shown in FIG. 2, there is provided, for the purpose of rotating the eccentric shaft 42, a two-armed rocker 43 which is rigidly connected to the eccentric shaft; one arm of the rocker 43 is loaded by the force of a restoring spring 44, the other arm of the rocker constituting a tracer finger which cooperates with the peripheral surface of the control cam 45. This cam is of hollow construction and is axially slidably as well as rotatably carried by a sleeve 46 which is fixedly secured to pump housing 2. The sleeve 46 serves to guide a plunger 47 carrying an extension rod 48 to which the control cam 45 is secured for axial movement therewith since the cam is disposed between a shoulder 49 of the plunger extension rod and circular clip 50 engaging in an annular groove provided near the outer end of the extension. The force actuating the plunger 47 is derived from the pressure which is produced by the fuel transfer pump (not shown) disposed within the pump housing 2 and driven by the camshaft of the internal combustion engine. For this purpose, a gallery 51 connects the inner end of the cylinder 52 in which plunger 47 works to the delivery line of the fuel transfer pump. A coil spring 53 provides the necessary restoring force for the plunger 47; the spring 53 surrounds the plunger extension 48, one end of the spring bearing upon the adjacent end face of the plunger, the other end of the spring being retained by a circular clip 54 engaging in an annular groove provided in the adjacent end of sleeve 46. Rigidly connected to the control cam 45 for rotation therewith is a pinion 55 meshing with a gear rack 56 which is slidably guided by track means 57 rigid with the housing 1 enclosing the control device.

Any axial displacement of the control cam 45 in the direction of the double-headed arrow in FIG. 2, i.e. to the left or to the right, will cause the eccentric shaft 42 to be rotated accordingly, this resulting in a displacement of the axis of rotation of rocker 27 corresponding to the three-dimensional shape of control cam 45. The portion 58 of the control surface of cam 45 which is associated with the speed range within which the internal combustion engine is operated under load is designed in such a manner as to take into account the fuel requirement characteristic of the engine and the fuel-delivery-versus-speed curve pertaining to the fuel injection pump. In this connection, the efficiency of the injection pump and the air charge in the engine are variable quantities depending on the fuel requirement characteristic. The portion 59 of the surface of control cam 45 has no influence on the control action of the governor. Located between the portions 58 and 59 of the cam surface is a steeply inclined intermediate portion serving to control the fuel delivery of the injection pump during starting of the engine.

Any rotation of control cam 45 about the axis of plunger 47 will also cause the eccentric shaft 42 to be rotated, this again producing a displacement of the axis of rotation of rocker 27. Such a rotation of cam 45 can be produced by a longitudinal displacement of gear rack 56, the force required to move the gear rack being supplied, for example, by a set of almost completely evacuated barometric capsules. Thus, by giving the peripheral surface of cam 45 a suitable shape, it is possible to take into account the influence of air density on the amount of fuel to be delivered during each stroke of pump plunger 3. However, it is also possible to provide on the periphery of cam **45** a plurality of different longitudinal tracks which are angularly spaced about the axis of the cam, the shape of each track taking into account the viscosity and the density of the fuel. In the latter case it will be convenient to provide for manual adjustment of gear rack **56**, the adjustment being based, for example, on a suitable chart, and at the same time to provide a regulating throttle (not shown) for the purpose of rendering the speed-responsive fuel pressure prevailing in the gallery **51** independent of the viscosity of the fuel.

In view of the time required for the ignition and combustion of the fuel injected into the cylinder of an internal combustion engine, it is necessary to advance the moment of fuel injection as the speed of the engine increases. For this purpose, there is provided on the shaft **38** carrying the eccentric **37** by which rocker **35** is supported a lever **60** which is rigidly connected to shaft **38**, one arm of this lever being loaded by a restoring spring **61**. The second arm of lever **60** extends into the path of cam **45**. Upon cam **45** being displaced to the left in FIG. 2, this being caused by an increase in the speed of the engine and an accompanying increase in the pressure prevailing in the cylinder spade **52**, the cam will act upon the adjacent arm of lever **60** and will cause the eccentric shaft **38** to be rotated, this resulting in a displacement of the axis of rotation of rocker **35**. This, in turn, will cause tappet **40** to be displaced to the right, the result being a reduction of the space which exists, with lever **60** in its position of rest, between the end of tappet **40** and the extension **6** of pump plunger **3**, the result being that the tappet, during its working stroke, will strike the extension **6** of pump plunger **3** at an earlier instant. As a consequence of this, the injection stroke of pump plunger **3** will start at an earlier instant to cause fuel to be injected into the cylinder of the internal combustion engine at a correspondingly earlier time.

The foregoing disclosure and drawings are merely illustrative of the principles of the invention and are not to be interpreted in a limiting sense. The only limitations are to be determined by the scope of the appended claims.

What is claimed is:

1. A control device for fuel injection pumps of an internal combustion engine, said device comprising a housing; a rocker pivotably mounted in said housing and cooperating with the pump plunger so the pivotable movements of said rocker will vary the intake stroke of said plunger; an idling speed and maximum speed governor rotatably coupled with said engine to maintain constant a predetermined speed regardless of load, said governor cooperating with said rocker to pivot same upon variations in engine speed; a regulator carried by said housing and comprising a control cam movable to predetermined positions in response to variation in engine speed, said cam having a surface formed according to the optimum fuel-air ratio for particular engine speeds, and second means engaging said surface and cooperating with said rocker to set the time of the beginning of the pump injection stroke and the stroke length according to the air-fuel ratio of the particular speed; a driving means rotatably coupled with said engine and adapted to engage said pump plunger during its driving stroke to effect the injection stroke thereof; and third means cooperating with said regulator and said driving means to vary the point of said engagement and thus the timing of the beginning and end of the pump injection stroke upon change in engine speed without affecting the quantity of fuel injected.

2. The device of claim **1** wherein said second means include a spring urged member pivotable in response to variation in said cam surface, and means connecting said member to said rocker.

3. The device of claim **1** wherein the surface of control cam is also formed according to the optimum fuel-air ratio for particular air densities and further comprising means to move said cam in response to variations in air densities.

4. The device of claim **1** wherein said driving means comprises a tappet adapted to engage said pump plunger, and a bell crank lever, one arm of which is rotatably coupled with said engine and the other arm of which engages said tappet.

5. The device of claim **4** wherein said third means comprises a second spring urged member disposed in the path of said control cam and adapated to be rotated upon engagement thereby and means connecting said second spring urged member to said bell crank lever to pivot the latter upon engagement of the former by said control cam.

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