Nov. 26, 1968 E. D. LONG 3,412,718

PRECISION FUEL METERING SYSTEM

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FIG.1

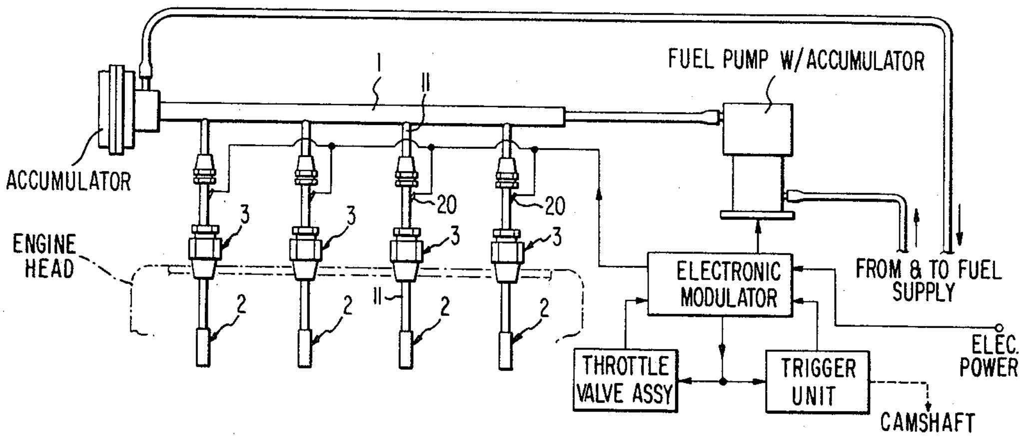


FIG.2

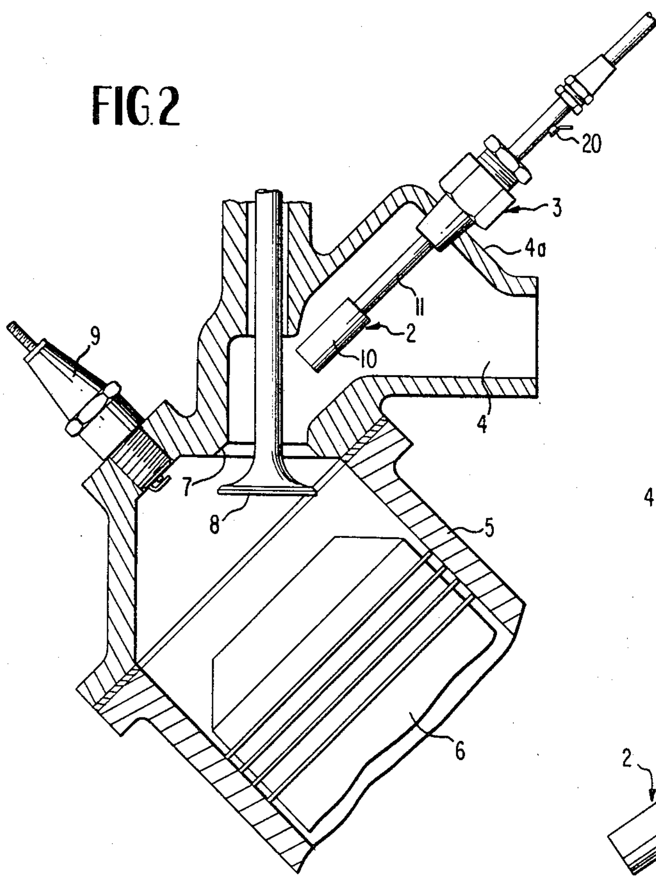
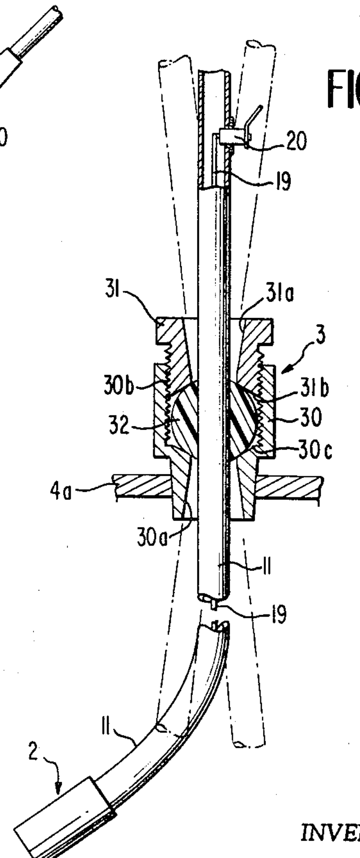


FIG.3



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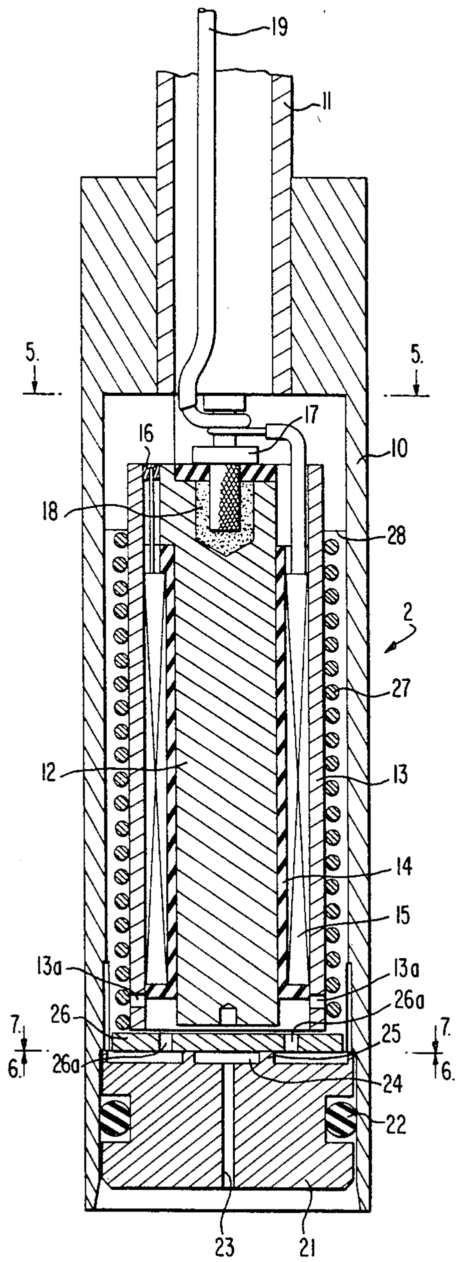

FIG. 4

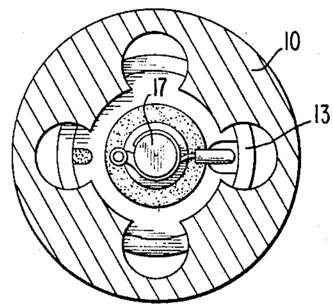

FIG. 5

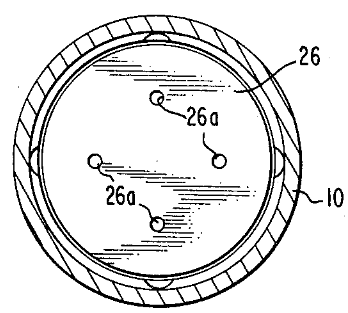

FIG. 6

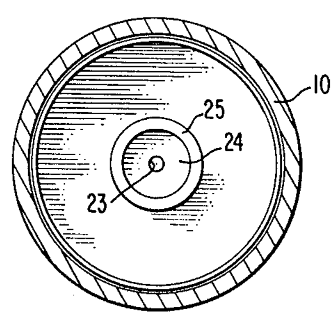

FIG. 7

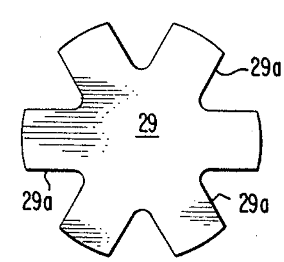

FIG. 8

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PRECISION FUEL METERING SYSTEM

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ABSTRACT OF THE DISCLOSURE

A plurality of fuel metering transducers are employed for simultaneously delivering measured amounts of fuel to the cylinders of an internal combustion engine, once per engine cycle, and in response to an electronic modulator which senses various engine operational and environmental parameters, such as, engine manifold air temperature and vacuum, engine temperature, engine speed, throttle position and barometric pressure. Each of the fuel metering transducers is mounted entirely within the engine air manifold and adjustably positioned adjacent the respective inlet valve for each cylinder, the fuel fed to each transducer being at constant pressure, whereby the measured amount of fuel being admitted to each cylinder depends upon the length of time the transducer is held in open position.

Background of the invention

Heretofore it has been the customary practice to supply the proper fuel-air mixture to the cylinders of spark ignition internal combustion engines through carburetion wherein the liquid fuel is vaporized and mixed with air in the correct proportion. The use of carburetion in these engines has been nearly the universal practice for economy and reliability in general day-to-day performance. While carburetor systems have been satisfactory for their intended purpose, they have been subject to certain disadvantages inherent in their design. For instance, while trying to maintain the proper volume and velocity of air flow to insure an adequate ratio of the fuel-air mixture, the fuel becomes deposited on the wall of the manifold resulting in a reduction of fuel economy. Furthermore, in view of the fact that the heat of the manifold is utilized to facilitate the vaporization of the fuel, hot spots are formed in the manifold which have a tendency to cause backfiring and vapor lock.

In order to overcome the disadvantages experienced with carburetion systems and in an attempt to provide a proper fuel-air mixture for complete combustion in the engine cylinder with a concomitant reduction of exhaust gases, it has been proposed to employ various types of fuel injection systems. However, it has been found that designing a fuel injection system for spark-ignition engines involves much more than merely substituting an injector valve for a carburetor. In both mechanical and electrically controlled injection systems, the proper calibration and control of the fuel-air mixture through the full dynamic range of the engine is most difficult and sometimes impossible to achieve since the bellows, diaphragms and associated control linkage commonly employed in these systems are frequently subject to binding, hysteresis and frequent malfunction.

While the shortcomings of known fuel injection systems have been recognized, the advantages of fuel injection over carburetion in spark ignition engines have equally been recognized by those skilled in the art. For instance, by eliminating the carburetor, the improved engine volumetric efficiency and colder air charges results in an increase of power output at high engine speeds. Furthermore, the fuel-air mixture more closely approaches a stoichiometric composition to thereby reduce the amount of unburned hydrocarbons and carbon monoxide in the exhaust.

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Summary

After considerable research and experimentation, the fuel metering system of the present invention has been devised to overcome the disadvantages experienced in fuel injection systems and comprises, essentially, a plurality of fuel metering transducers mounted entirely within an air chamber such as an engine air manifold. Each of the transducers is adjustably positioned adjacent the respective inlet valve for each cylinder and includes an orifice of fixed area which is opened and closed by an electromagnetically actuated member of fixed travel. The fuel metering transducers communicate with a fuel rail which supplies fuel at constant pressure to the transducers, whereby the quantity of fuel admitted to the cylinders depends upon the length of time the magnetically actuated members are held in open position, the energization of the electro-magnet for each movable member being controlled by an electronic modulator which senses various engine operational and environmental parameters.

Brief description of the drawings

FIGURE 1 is a diagrammatic view of the fuel metering system of the present invention;

FIGURE 2 is a fragmentary sectional view showing the position of a fuel metering transducer relative to the engine cylinder;

FIGURE 3 is a fragmentary sectional view of the connection for adjustably positioning the fuel metering transducer within the engine manifold;

FIGURE 4 is an enlarged longitudinal sectional view of the fuel metering transducer of the present invention;

FIGURE 5 is a view of the transducer taken along line 5—5 of FIGURE 4;

FIGURE 6 is a view taken along line 6—6 of FIGURE 4;

FIGURE 7 is a view taken along line 7—7 of FIGURE 4; and

FIGURE 8 is a plan view of a modified form of a valve element adapted to be employed in the fuel metering transducer of the present invention.

Description of the preferred embodiment

Referring to the drawings and more particularly to FIGURE 1, the precision fuel metering system in which the fuel metering transducers of the present invention are adapted to be employed, comprises essentially, a fuel rail **1** for supplying fuel to a plurality of fuel metering transducers **2** adjustably mounted on the engine head by swivel joint connections **3**, to be described more fully hereinafter. The fuel supplied to be transducer through the fuel rail is fed thereto at constant pressure by a fuel pump connected to one end of the fuel rail and an accumulator at the opposite end thereof, said accumulator being of the type disclosed in my copending application Ser. No. 645,701, filed June 13, 1967. An electronic modulator of the type described in my copending application Ser. No. 653,484, filed July 14, 1967, is electrically connected to the transducer **2** for actuating the same in response to various engine operational and environmental parameters fed to the modulator by a throttle valve assembly and trigger unit. For example, the engine manifold air temperature and vacuum, barometric pressure and throttle position would be sensed by the throttle valve assembly; and the trigger unit, actuated by the engine cam shaft, would sense the engine speed. When desirable, the trigger unit may be actuated by an electrical signal from the ignition system. The electronic modulator, in turn, feeds the transducers **2** with a square wave pulse, the duration or width of which is a direct function of the integrated valve of the various system sensors.

As will be seen in FIGURE 2, the engine upon which the fuel metering transducer **2** of the present invention is adapted to be mounted is a conventional internal combustion engine including an air intake manifold 4, cylinder 5 and piston 6. Fuel taken into the cylinder through intake port 7, controlled by valve 8, is ignited by spark plug 9.

Referring to FIGURES 4 to 7, the fuel metering transducer 2 of the persent invention comprises a housing 10 connected to the end of a fuel line 11 which is maintained in communication with the fuel rail 1 (FIGURE 1). A solenoid is mounted within the housing and includes an inner pole piece member 12 and an outer pole piece member 13 surrounding and positioned concentrically with respect to the inner pole piece member. A plastic spool 14 having an electrical coil 15 wound thereon is secured to the inner pole piece member, one end of the coil interconnecting the pole piece members as at 16 and the opposite end of the coil being connected to a terminal 17 adhesively secured to the inner pole piece as at 18. A lead 19 is also connected to the terminal 17 and extends upwardly within the fuel line 11 and is connected to a terminal 20 (FIGURE 3) secured to the wall of the fuel line, the terminal 20, in turn, being electrically connected to the electronic modulator (FIGURE 1).

A nozzle 21 is rigidly secured within the lower end of housing 10 and sealed therein by an O-ring 22. A longitudinally extending, centrally disposed orifice 23 is formed in the nozzle and communicates with a recess 24 formed by an annular shoulder or land member 25 disposed on the upper surface of the nozzle and positioned concentrically with respect to the orifice. The annular shoulder 25 forms a seat for a flapper valve 26 which is biased to closed position on the seat by a coil spring 27 having one end engaging the upper surface of the flapper valve and the opposite end engaging a shoulder 28 formed on the opposite end portion of the housing. When the flapper valve is biased to closed position on seat 25, there is a clearance of .004″ between the end of the outer pole piece member 13 and the upper surface of the flapper valve; thus, when the solenoid is actuated, the flapper valve, functioning as an armature, is drawn upwardly a distance of .004″ against the end of the outer pole piece. While in this position, there is a .003″ residual air gap between the end of the inner pole piece member 12 and the upper surface of the flapper valve whereby an adequate magnetic force may be generated in the solenoid. In order to provide a hydrostatic relief to thereby allow the flapper valve 26 to move freely between open and closed positions, apertures 13*a* and 26*a* are formed in the lower end portion of the outer pole piece member and in the flapper valve, respectively.

In the operation of the fuel metering transducer, fuel, being fed under constant pressure through fuel line 11, flows into the annular chamber defined by the outer peripheral wall of the outer pole piece member 13 and the inner peripheral wall of the housing 10. When a signal is received from the electronic modulator for actuating the solenoid, the flapper valve 26 is pulled upwardly from seat 25 thereby compressing spring 27 and allowing the fuel to flow into recess 24 and through orifice 23 into the engine cylinder. When the solenoid is de-energized, the spring 27 expands forcing the flapper valve downwardly onto the seat 25.

Since the fuel metering transducers are to be actuated once per engine cycle, the relatively small mass of the magnetically actuated flapper valve 26, moving through the fixed distance of .004″ to open and close the orifice 23 of fixed area, readily adapts the flapper valve for operating speeds in the order of 1000 cycles per second, and since the fuel is being fed to the transducer at constant pressure, the quantity of fuel admitted into the engine cylinder depends upon the length of time the flapper valve is held in open position.

While the flapper valve shown in FIGURES 4 and 6 consists of a disc having axially extending hydrostatic relief apertures formed in the body of the disc, another embodiment of the flapper valve is illustrated in FIGURE 8 wherein the disc 29 is formed with a plurality of circumferentially spaced hydorstatic relief notches 29*a* formed in the periphery thereof.

While the admission of the proper quantity of fuel to the engine cylinder in response to the engine speed and the absolute weight of the air charge is an important feature of the present invention, another equally important feature of the invention is the location of the fuel metering transducer within the engine manifold to provide port injection of the fuel to thereby prevent deposition of the fuel on the walls of the manifold while at the same time allowing proper vaporization of the fuel. In order to properly position each fuel transducer within the manifold, the swivel joint connection 3, as illustrated in FIGURE 3, is provided, comprising a socket 30 mounted within the wall 4*a* of the engine air intake manifold; the socket being provided with a tapered bore 30*a* forming a divergent throat portion on one end thereof. The opposite end of the socket has a threaded portion 30*b* for receiving a socket nut 31. The socket nut is also provided with a tapered bore 31*a*, similar to bore 30*a* formed in the socket, but diverging in an opposite direction therefrom; the construction and arrangement of the divergent bores facilitating the lateral adjustment of the fuel line, to be described more fully hereinafter. Seat portions 30*c* and 31*b* are formed on the socket and nut, respectively, for accommodating a spherical member 32 through which the fuel line 11 is slidably mounted.

When mounting the fuel metering transducers on an engine, a plurality of apertures are formed in the wall 4*a* of the manifold; and a fuel line 11, having a fuel metering transducer 2 secured to the end thereof, is inserted through each of the apertures, after which the socket 30 is slipped on the fuel line and swaged into the aperture. The spherical member 32 and socket nut 31 are similarly slipped on the fuel line and assume the position shown in FIGURE 3; however, before the nut 31 is tightened, the fuel metering transducer is properly positioned relative to its respective injection port by manually pushing the fuel line through the sphere 32 until the fuel metering transducer 2 touches the stem of valve 8. The fuel line and associated transducer is then backed off slightly from the valve stem and adjusted laterally as shown in dotted lines in FIGURE 3. When the proper position of the transducer has been obtained, the nut 31 is tightened to thereby bind the sphere 32 on the seats 30*c* and 31*b*. The spherical member 32 is formed from a suitable plastic, such as Teflon, which is characterized by its relatively low coefficient of friction and sealant properties. Accordingly, by forming the spherical member 32 from Teflon, the lateral and longitudinal adjustment of the fuel line and associated fuel metering transducer is not only enhanced but also when the nut 31 is tightened, the Teflon sphere provides an excellent seal within the swivel joint connection.

The construction and arrangement of the fuel line 11, fuel metering transducer 2 and swivel joint connection 3 readily adapts the assembly for mounting on various types of conventional engines. While it has been found that the swivel joint connection, as described hereinabove, will generally accommodate adjustment of the fuel metering transducer, in some instances, it may be necessary to bend the end of the fuel line as shown in FIGURE 3.

From the above description, it will be appreciated by those skilled in the art that the precision fuel metering system of the present invention provides a system having good cold starting and warm-up characteristics, good part throttle economy and good wide open throttle power; and since very few moving parts are employed, the system is not likely to get out of order even after long and continued use.

I claim:

1. In a fuel metering system for an internal combus-

tion engine wherein an electronic modulator is employed for actuating a fuel metering transducer in response to various engine operational and environmental parameters, the improvement comprising, fuel metering transducer means adjustably positioned within the injection port of the engine cylinder, and swivel joint means mounted on the wall of the engine air manifold and connected to said fuel metering transducer means; said swivel joint means comprising, a socket mounted within the wall of the engine air intake manifold, a tapered bore formed in one end of said socket forming a divergent throat portion, a nut threadably mounted in the opposite end of said socket, a tapered bore formed in said nut forming a divergent throat portion extending in a direction opposite to the throat portion formed in the socket, seat portions formed on the interior wall of said socket and on the end portion of the nut extending within the socket, and a spherical member mounted between said seat portions, said fuel transducer means including a fuel line slidably mounted within said spherical member and extending through said divergent throat portions, whereby the position of the fuel metering transducer means may be adjusted relative to the injection port of the engine cylinder by manually sliding the fuel line through the spherical member and swivelling the fuel line and associated spherical member to a predetermined position, said transducer means being held at the predetermined position by tightening said nut to thereby bind the spherical members on said seat portions.

2. In a fuel metering system according to claim 1, wherein the fuel metering transducer means comprises, a housing, a fuel line connected to one end of said housing, solenoid means mounted within said housing, a nozzle rigidly connected to the opposite end of the housing and spaced from said solenoid means, said nozzle including a longitudinally extending orifice formed therein, an annular land disposed on the inlet end of the nozzle and positioned concentrically with respect to the orifice, a flapper valve positioned within said housing between the solenoid and said land, and a coil spring surrounding said solenoid means and extending between the end of the housing and the flapper valve for biasing the flapper valve against said land to close said nozzle orifice, said flapper valve being spaced from said solenoid means when biased to closed position, whereby when the solenoid is energized the flapper valve is drawn against said solenoid means to open said nozzle orifice.

3. In a fuel metering system according to claim 2, wherein the flapper valve comprises a disc having hydrostatic relief apertures formed therein whereby the flapper valve may move freely between open and closed positions.

4. In a fuel metering system according to claim 2, wherein the flapper valve comprises a disc having a plurality of circumferentially spaced hydrostatic relief notches formed in the periphery thereof, whereby the flapper valve may move freely between open and closed positions.

5. A fuel metering transducer comprising, a housing, a fuel line connected to one end of said housing, means operatively connected to the fuel line for supplying fuel at constant pressure to said housing, solenoid means having a core mounted within said housing, a nozzle rigidly connected to the opposite end of the housing and spaced from said solenoid means, said nozzle including a centrally disposed, longitudinally extending orifice formed therein, an annular land disposed on the inlet end of the nozzle and positioned concentrically with respect to the orifice, a flapper valve positioned within said housing between the solenoid and said land, and a coil spring surrounding said solenoid means and extending between the end of the housing and the flapper valve for biasing the flapper valve against said land to close said nozzle orifice, said flapper valve being spaced from the core of said solenoid means when open and when biased to closed position, whereby when the solenoid is energized the flapper valve is drawn a fixed distance against said solenoid means to open the nozzle orifice of fixed area, thereby allowing the fuel to flow through said nozzle orifice, the quantity of fuel discharged through the nozzle orifice depending upon the length of time the flapper valve is held in open position.

6. A fuel metering transducer according to claim 5, wherein the flapper valve comprises a disc having hydrostatic relief apertures formed therein whereby the flapper valve may move freely between open and closed positions.

7. A fuel metering transducer according to claim 5, wherein the flapper valve comprises a disc having a plurality of circumferentially spaced hydrostatic relief notches formed in the periphery thereof, whereby the flapper valve may move freely between open and closed positions.

8. A fuel metering transducer according to claim 5 wherein said flapper valve is spaced from the solenoid means a distance of the order of .004" when in closed position.

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