Briefly, in accordance with the present invention, a toroidal core, having toroidal windings thereon is formed with a central aperture in which a core element is axially movably located, with a small air gap between the core and the movable core element. The movable core element is held in position by pair of flat leaf springs, maintaining the core readily movable in an axial direction, but preventing lateral vibration or shock and presenting substantial stiffness in a radial direction. The movement of the core is controlled by a vacuum chamber, connected to the intake manifold. It is held by a spring against the chamber.

Axial movement of the movable core element, under control of the vacuum chamber, requires little force. The flat leaf spring, however, prevents substantial resistance to lateral, or radial displacement. The air gap between the movable core element and the fixed core, which may be in the order of 0.1 to 0.5 mm, provides for a high reluctance gap which is large with respect to the reluctance of the iron core circuit, so that differences in permeability of materials used in different transducers have but little effect on the final inductance of the element.

A particularly advantageous form of leaf spring is a flat leaf having a pair of outer frame branches and a central connecting leg, with openings formed therein between so that the shape of the spring is similar to a pair of opposed, joint E’s. Such a spring has high stiffness in the plane of the leaf, and little resistance to longitudinal movement transverse to the surface of the leaf.

The structure, organization and operation of the invention will now be described more specifically with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic representation of a fuel injection system in accordance with the present invention, a more full disclosure of which is contained in application Ser. No. 680,668, filed Nov. 2, 1967, and assigned to the assignee of the present invention;

FIG. 2 is a longitudinal section along line II—II of FIG. 3 of a vacuum transducer in accordance with the present invention;

FIG. 3 is a sectional view through the vacuum transducer along line III—III of FIG. 2; and

FIG. 4 is a partial longitudinal sectional view of the transducer along line IV—IV of FIG. 3.

The fuel injection system will be briefly explained with reference to FIG. 1. A 4-cylinder internal combustion engine 10 has intake manifold 12. Electromagnetic fuel injection valves 13 are located at the inlet stubs of the individual cylinders connecting with inlet manifold 12. The injection valves 13 are supplied with fuel by fuel lines 14, connecting to a fuel distributor 15 into which fuel is pumped from a tank 17 by a pump 16, to be supplied under pressure to the injection valves 13. An over-pressure valve, not shown, provides for constant pressure in the distribution chamber 15, so that the time during which any injection valve 13 is open corresponds to a predetermined amount of fuel. Injection valves 13 each include an electric magnet which, upon being supplied with current, opens the valve. An electronic control consisting essentially of a multivibrator 18 and an amplifier 19 controls the time during which current is supplied to the electromagnetic valves, and thus the time during which fuel can be injected. Multivibrator 18 is controlled from an impulse source 22 having a contact 23 operated by a double-rite cam 24 and driven in synchronism with the speed of the engine, for example from the cam shaft thereof, as schematically indicated by the chain-dotted line. Thus, multivibrator 18 will supply two pulses for each revolution of the cam shaft in order to open the injection valves 13.
The time $T$ during which the injection valves are open, that is the time during which a pulse is supplied to valves 13 by the multivibrator 18 is governed by the vacuum in the inlet manifold 12. A transducer 25 is connected to the inlet manifold by means of a connecting line 34. Transducer 25 includes an inductive element which changes inductance in dependence on the vacuum in the inlet manifold. The vacuum within the inlet manifold 12 is controlled by a throttle controller 26. If the vacuum is high, that is when throttle 26 is closed, the impulse period $T$ will be short, thus causing injection of only little fuel. When the throttle 26 is opened, so that the vacuum drops, the impulse periods increase and thus larger amounts of fuel will be injected.

The pressure transducer, see FIGS. 2–4, has a pair of housing parts 30, 31, which are arranged in interlocking relationship and sealed against each other by an O-ring 32, so that the interior 33 of the housing is hermetically closed. Connection line 34 (FIG. 4) connects the interior 33 over a check valve 35 which has a throat opening 36 therein, with the intake manifold 12. The check valve is so arranged that its opens at a pressure differential of over 0.05 kg/cm$^2$.

A cross piece 37, held in position at the junction of the two housing parts 30, 31 secures a core body 38. Core 38 has a cross-sectional aspect of a double U, and preferably is in toroidal form. It has a pair of separate windings forming part of the multivibrator circuit 18. Core 38 is formed with bores 42, 43 at its end faces. An iron core element 44 is located in the bore to be axially movable. Core element 44 is slightly smaller than the bore to provide for a radial air gap and for radial play. The upper end (with respect to FIG. 2) of the core element 44 has screw connection with a leaf spring 45. The lower part of core 44 is provided with a frustoconical portion 41 and connected to a shaft or stub 46 of non-magnetic material, such as brass. A leaf spring 47 is connected, for example by a screw connection, with the stub 46.

Leaf spring 47 is identical with leaf spring 45, and seen best in FIG. 3. The plan view of the spring corresponds to approximately a pair of facing E's. Such a spring provides substantial resistance against radial movement of the core element 44, but on the other hand provides but little stiffness or resistance against axial movement of the core element. This is important because, when used with an automotive type internal combustion engine, vibration and shock forces act on the iron core 44. The arrangement in accordance with the present invention provides for steady and sure guidance of core 44, without the necessity of providing a bearing in the bores 42, 43. Thus, core element 44 can move axially without bearing friction and change its position with respect to coil 39 even at small changes of pressure in the manifold 12. A radial gap of from 0.1 to 0.5 mm, between the core element 44 and iron core 38 decreases the effects of changes in permeability of core 38 and core element 44 on the inductivity of coil 39.

Leaf spring 47, and its matching leaf spring 45, each have a pair of outer or frame legs 49, 50 and a centrally connecting leg 48. As best seen in FIG. 3, both leaf springs 45 and 47, respectively, are connected by means of their central leg 48 with core element 44. The outer frame portions 49, 50 are screwed to cross plates 37, and 55, respectively, with intervening spacers 53, 54 (FIG. 4). Spacers 53, 54 have been omitted from the showing in FIG. 2 for simplicity. Cross plate 45 is, in turn, connected to core 38. The core element 44 is pressed against a pair of evacuated chambers 58, 59, by means of a spring 56, the other end of which bears against an adjustable screw cap 57, screwed into housing part 30. Vacuum chambers 58, 59 themselves are held against the housing part 31 by means of an adjustment screw 62. As best seen in FIG. 2, vacuum chambers 58, 59 are provided with bearing points 63, 64 to be movably connected with respect to adjustment screws 62 and the brass stub 46 carrying core 44, in order to provide a floating self-aligning arrangement which does not place any radial load on leaf springs 45, and additionally greatly simplifying assembly of the entire transducer unit.

Upper housing element 39 has an electrical connector 65 located therein, air-tight and connected to the respective terminals of coil 39.

**Operation**

Core element 40 is pressed against the vacuum chambers 58, 59 by means of spring 56. If the vacuum in the intake manifold 12, and hence in the chamber 33 is high, vacuum chambers 58, 59 expand due to their inherent resiliency, and core element 44 is pressed upwardly (with respect to FIG. 2), thus decreasing inductivity of the coil 39. The amount of fuel injected by the system of FIG. 1 is correspondingly decreased. Upon opening of throttle 26, the vacuum in intake manifold 12, and hence in chamber 33 decreases. If the vacuum drops sharply, the check valve 35 may open. The increased pressure within chamber 33 compresses vacuum chambers 58, 59, and core element 44 is moved downwardly, with respect to FIG. 2, by action of the spring 56. This increases the inductivity of the coil 39 and the injection period of valves 13 likewise increases coil 39.

The functional relationship between vacuum in chamber 33 and inductivity of coil 39 can further be adjusted by forming the core element 44 other than cylindrically, for example by grinding off a portion of its circumference at its lower end, so that the cross-sectional area at one end of the core element 44 will be different from that at the other end thereof, as shown at the frustoconical portion 41. Various structural changes and modifications, as determined by the requirements of particular applications or uses may be made without departing from the inventive concept.

**We claim:**

1. Fuel injection system for internal combustion engines comprising electronic pulse source means synchronized with the rotation of said engine controlling the operation of said valves to inject fuel into said engine; and transducer means connected to the intake manifold of the engine to sense the vacuum thereof and control the operating parameters of said electronic means, said transducer means comprising a fixed core having a central bore; windings linking the magnetic circuit of said fixed core, a movable iron core located in said bore for axial displacement therein and having a radial air gap with respect to said core; a pair of leaf springs retaining said core element in said bore, said leaf springs being mounted to provide substantial stiffness against radial displacement of said core element in said bore and having little stiffness with respect to axial displacement of said core element, at least one of said leaf springs being in the form of a flat leaf having an outer frame and a central connecting leg with openings between said frame and said leg; and vacuum means connected to the intake manifold of said engine to sense the vacuum thereof and in motion transmitting engagement with said movable core element.

2. System as claimed in claim 1, wherein a pair of leaf springs is provided, each leaf spring having an outer frame and a central connecting leg; said outer frames being secured to said fixed core and said central connecting legs being secured to said movable core element.

3. Sensing and controlled transducer assembly for automotive engine fuel injection systems adapted to be con-
3,452,727

5. Assembly as claimed in claim 3, wherein at least one of said leaf springs is in the form of a flat leaf having an outer frame and a central connecting leg with openings between said frame and said leg.

6. Assembly as claimed in claim 3, wherein the cross-sectional area of said core element is different at one end from the cross-sectional area at the other end.

7. Assembly as claimed in claim 6, wherein said core element is provided with a substantially frustoconical portion at its end extending into said axial opening.

8. Assembly as claimed in claim 3, wherein at least one evacuated chamber is supported within said housing, said evacuated chamber having a movable wall bearing against said core element; and resilient means biasing said core element into engagement with the movable wall of said evacuated chamber.

References Cited

UNITED STATES PATENTS
2,918,911 12/1959 Guiot 123—32
3,068,849 12/1962 Thorner 123—103

LAURENCE M. GOODRIDGE, Primary Examiner.

U.S. Cl. X.R.

123—119, 139