Sept. 26, 1961 T. M. BALL 3,001,757

MAGNETIC FUEL INJECTION NOZZLE

Filed April 9, 1958

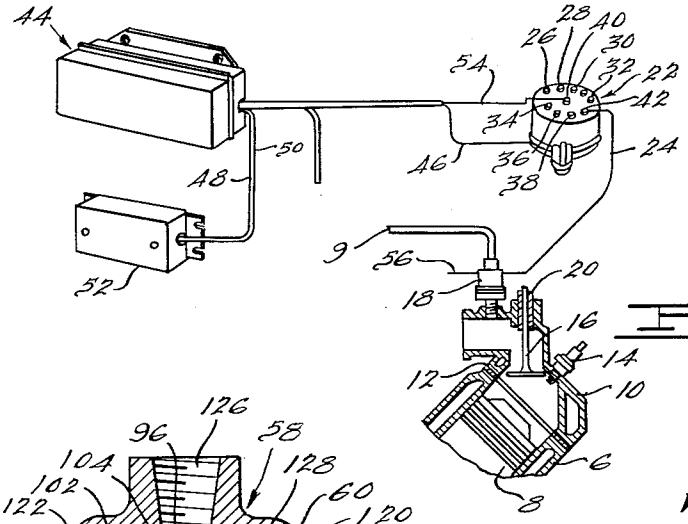


Fig. 1.

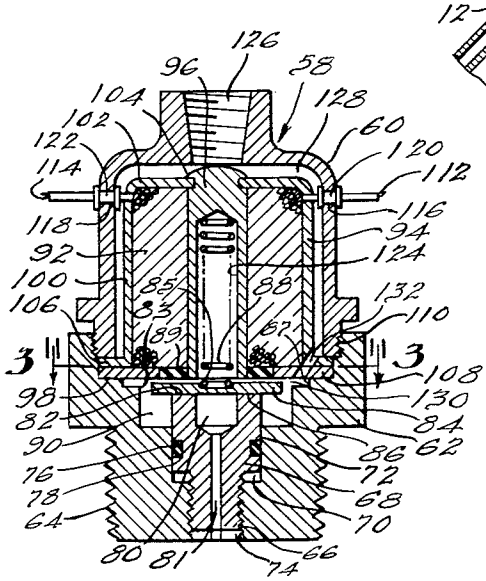


Fig. 2.

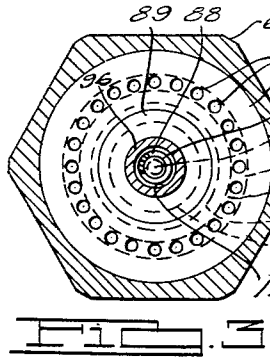


Fig. 3.

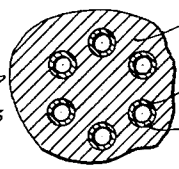


Fig. 5.

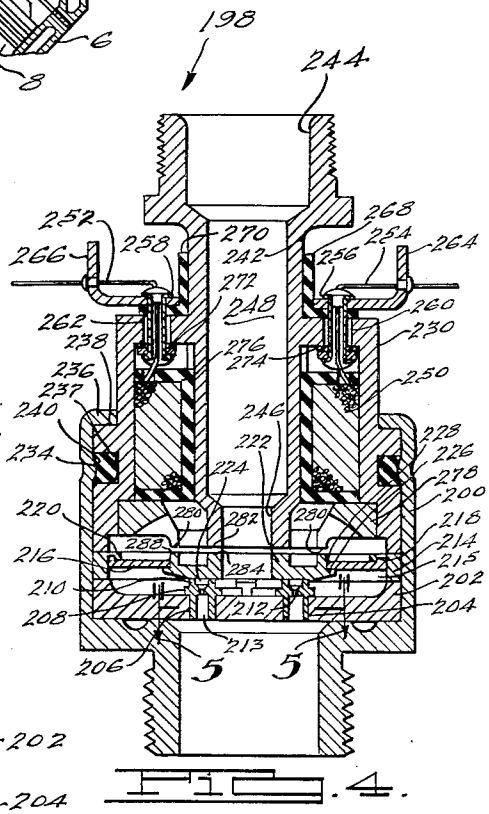


Fig. 4.

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MAGNETIC FUEL INJECTION NOZZLE

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This invention relates to improvements in fuel injection nozzles of the type employed on internal combustion engines.

Fuel injection nozzles of the aforesaid type are conventionally installed on the intake manifold of internal combustion engines. In such installations the nozzle is usually located in close proximity to the intake valve and is intended to deliver pulsations of fuel to the intake manifold adjacent to the intake valve in response to electrical pulses transmitted to the nozzle by a sensory system. The amount of fuel delivered to the manifold by each fuel pulsation is controlled by the nozzle which is in turn controlled by the engine operating conditions as interpreted by said sensory system.

Fuel injection nozzles installed as aforesaid have, prior to my invention, an inherent and most objectionable action in that they do not respond instantaneously to electrical impulses sent by the sensory system and consequently do not deliver the exact amount of fuel required by the engine at any particular time. This gives rise to poor engine performance through the improper fuel-air mixture delivered to the engine, and results in loss of power and fuel economy.

It is an object of my invention to provide an improved fuel injection nozzle adapted for installation as aforesaid but which will overcome the above objections.

Another object is to provide a fuel injection nozzle of simple construction in relation to other nozzles known heretofore which, when installed on an engine intake manifold, will operate efficiently in providing the proper amount of fuel to the manifold as required by the engine at each instant of operation of said engine.

Another object is to provide a fuel injection nozzle with a valve capable of opening and closing many times per second in response to magnetic fields of very short duration created by an electrical coil and a sensory system, which sensory system supplies current impulses to said coil in response to engine fuel requirements.

Another object is to provide a fuel injection nozzle having a solenoid operated valve wherein the valve closing means is a thin disc and has a relatively large surface area disposed in the flux path of said solenoid, so that the disc will be susceptible to the magnetic fields produced by the solenoid coil and will respond practically instantaneously to the magnetic fields to open said valve.

Another object is to provide a fuel injection nozzle having a solenoid operated valve wherein the valve closing means is readily responsive to magnetic fields produced by said solenoid and wherein the responsive nature of said valve closing means to magnetic fields permits the use of relatively weak magnetic fields in opening said valve.

In carrying out my invention I use a magnetically operated valve located within the injection nozzle. This valve comprises a port which is closed and opened by a thin, lightweight disc which responds very rapidly to a magnetic field. The unique shape of this disc allows a

relatively small electrical coil producing a low magnitude magnetic field to be employed in moving said disc to an open position with respect to said port. The use of this small coil avoids the excessive retention of magnetism by the coil and provides a sharply defined magnetic flux cycle. This relatively low magnitude magnetic field also avoids the building up of magnetism in the disc to a point which would retard the return of the disc to the port closing position at the termination of the energization of the coil. As a result of this sharply defined, low magnitude flux cycle the disc is able to respond practically instantaneously to the electrical pulse transmitted to the electrical coil by the sensory system.

Further objects and advantages of my invention will be apparent from the following detailed illustration thereof, reference being had to the accompanying drawings, in which:

FIGURE 1 schematically shows an injection nozzle mounted on an automotive engine and attached to various electrical components of the sensory system;

FIGURE 2 is a cross-sectional detail of the injector of FIGURE 1;

FIGURE 3 is a full section through 3—3 of FIGURE 2;

FIGURE 4 is a cross-sectional detail of a variation of the injector of FIGURE 1; and

FIGURE 5 is a full section through 5—5 of FIGURE 4.

In FIGURE 1 is shown a portion of an automotive cylinder block **6** having reciprocably mounted therein a piston **8**. A cylinder head **10** is mounted on said block and sealed thereto by gasket **12** and bolts (not shown). Mounted in head **10** is a spark plug **14**, an intake valve **16**, and a fuel injection nozzle **18** having a fuel inlet line **9** extending thereto. Valve **16** is reciprocable in bushing **20**. An exhaust valve (not shown) is also reciprocably mounted in head **10**. Fuel injection nozzle **18** is electrically connected to triggering selector **22** by electrical conduit **24**.

Located on the triggering selector **22** are injector lead terminals **26**, **28**, **30**, **32**, **34**, **36**, and **38**, and two output terminals **40** and **42**. The lead terminals are selectively energized within the triggering selector by means of a distributor rotor which selectively distributes the current to brushes within the trigger selector housing which carry the current to the lead terminals. Conduit **24** carries the triggering selector output pulse current to the solenoid of the injection nozzle **18**.

A modulator **44** receives energizing current from the triggering selector **22** through conduit **46**. A rotating lobe cam and two sets of breaker contacts within the triggering selector housing distribute energizing current to the conduit **46**. The modulator **44** carries its own distributing system and distributes energizing current to a resistance box through conduit **48**. This resistance box contains various resistances, the voltages across which are affected by atmospheric and engine conditions. The changes in the voltages across these resistances are carried to the modulator **44** through conduit **50** and are recorded in said modulator. The modulator interprets these voltage changes and evaluates them in terms of the fuel requirements of the engine at the particular instant that the voltage variations are received in the modulator.

The evaluated fuel requirements are then converted in the modulator to current pulsations of a length proportional to the engine fuel requirements at that par-

ticular instant. These pulsations are transmitted to the triggering selector **22** by conduit **54**. Suitable means within the triggering selector, which may be a conventional rotor, picks up these pulsations from the modulator and selectively distributes them to the individual injector nozzle solenoids which are energized for a length of time substantially equal to the length of the current pulsation received by the triggering selector from the modulator. Solenoid lead **56** is connected at an appropriate place to the input side of the triggering selector circuit.

In FIGURE 2 is shown a liquid fuel injection nozzle **58** having an upper housing portion **60** threadedly secured to a lower housing portion **62**. Threads **64** on said portion **62** are received in cooperating threads in engine head **10** as shown in FIGURE 1. Secured to housing portion **62** by threads **66** is a valve body designated generally as **68**. Recess **70** in housing portion **62** slidably receives the enlarged head **72** of valve body **68**. A slot **74** is located in the reduced threaded end of valve body **68** to receive a screw driver bit for adjustment of valve body **68** longitudinally of housing portion **62**. A seal ring **76** of suitable fuel corrosion resistant material located in groove **78** of valve body **68** creates a fluid tight seal between said body and housing portion **62**.

An aperature or port **81** centrally located in body **68** provides a fluid passage completely through said body and opens at the top end thereof into a fuel receiving well **80** located in head **72** of said valve body. An accurately machined seat **82** is located on top of head **72** and encircles well **80**. An annular valve disc or wafer **84** of magnetizable material having a face **86** accurately machined to coincide with the machined seat **82** of body **68** is positioned on top of said seat and resiliently retained thereon by spring **88**. This disc may be of "Permalloy" or "hypernik" metal both of which metals have high magnetic permeability and low residual magnetism. A recess **85** in the top of disc **84** receives an end of spring **88** and provides a means for limiting the lateral movement of disc **84** and insures the complete coverage of seat **82** by disc face **86** at all times that said disc face is in contact with said seat. Since the maximum distance of travel of the disc away from the seat **82** is approximately five thousandths of an inch, the tendency of the disc to move laterally is not great. As an additional precaution against too great a lateral movement of the disc, annular shoulder **83** partially defining recess **90** in lower housing portion **62** is provided to abut the outer edge of disc **84** should such lateral movement occur. It is anticipated that as an alternative to the use of spring **88** and recess **85** as a means to prevent the lateral displacement of the disc, the annular shoulder **83** may be used exclusively.

Annular recess **87** provides a fuel entry well in lower housing portion **62**. The fuel under pump pressure is formed through a plurality of apertures **132** (FIGURES 2 and 3) into recess **87**, through the space between the outer periphery of disc **84** and annular shoulder **83**, and into recess **90** which forms a reservoir of fuel under pump pressure. Some fuel is also forced through the space **130** located between the top of the disc and the bottom of the retaining plate **108** into cavity **124** in armature **96** when the disc is in its port closing position. This free passage of fuel completely around the disc prevents the formation of a pressure differential on the opposite surfaces of the disc which would affect its controlled movement. A plastic ring **89** secured to armature **96** provides a fluid tight, non-magnetic seal between retaining plate **108** and armature **96**.

A solenoid **92** comprising a casing generally designated as **94** and armature **96** is positioned within upper housing portion **60** and rests on shoulder **98** of lower housing portion **62**. The solenoid casing **94** comprises a cylindrical side portion **100**, an integral top end portion **102** fitted into groove **104** of armature **96**, a bottom flange **106**, and a bottom retaining plate **108** slidably fitted over the lower end of armature **96**. Upper housing portion **60** is threadedly received in lower housing portion **62** by threads **110** and bears against flange **106** of the solenoid housing **74** to thereby lock the solenoid assembly in position within nozzle **58**. Leads **112** and **114** of solenoid **92** extend through apertures **116** and **118** respectively in casing **94** and are electrically insulated therefrom by bushings **120** and **122** respectively. Armature **96** has a longitudinal spring receiving recess **124** located therein. Fluid inlet aperture **126** is located in the top of upper housing portion **60** and leads into chamber **128** which opens into chamber **130** through several openings located in flange **106** and retaining plate **108**. The electrical current used to actuate the fuel injection system is supplied by the automotive battery or generator.

The solenoid housing portions **94**, **96**, **98**, and **106** are of magnetizable material adapted to carry the magnetic field induced when solenoid **92** is energized. The annular insulator **89** effects a gap in the magnetic circuit, which is bridged by the underlying wafer or valve disc **84**. In this regard, the under surfaces of the members **89** and **108** are flush and parallel to the upper surface of the valve disc **84**. Thus the disc **84** by virtue of its broad area is effective to carry an optimum proportion of the magnetic field and is substantially immediately responsive thereto in controlling fuel flow, as described below.

In FIGURE 4 is shown a variation in the structure of an injection nozzle which is essentially comparable to that of FIGURE 1. This variation **198** comprises a lower housing portion **200** having seated therein a port retaining plate **202** having spaced apertures **204** therethrough as shown in FIGURE 5 which is a sectional view along 5—5 of FIGURE 4. Mounted in apertures **204** are valve bodies **206** having flanges **208** thereon which abut retaining plate **202** and limit the extent of insertion of said valve bodies **206** therein. The fuel intake necks **210** of the bodies **206** are machined across the top to place the tops of all the bodies **206** in substantially a common plane. Restricted apertures **212** extend into enlarged aperture **213** in each valve body.

Mounted adjacent the periphery of retaining plate **202** is a spring retaining ring **214** which interlocks with the valve disc return spring **216** by means of shoulders **218** and **220** located on the spring **216** and retaining ring **214** respectively. Valve disc **222** having a plane face **224** is normally urged into engagement with the tops of bodies **206** to close the latter. Shoulders **226** and **228** on disc **222** abut spring **216** on the bottom and inner edge thereof and prevent said disc from moving substantially in any direction except longitudinally with respect to the injector nozzle **198**.

An upper nozzle housing portion **230** is secured to portion **200** by cooperating groove **232** and indent **234** in the upper housing portion and lower housing portion respectively and by shoulder **238** and flange **236**. A ring **240** positioned in said groove **232** insures a fluid tight seal between housing portions **200** and **230**.

Integral with housing portion **230** is an armature **242** having a threaded fuel inlet connection **244** on one end thereof, a fuel outlet **246** at the other end thereof and a connecting fuel passage **248** therein. Mounted around said armature is a solenoid coil **250** having leads **252** and **254** extending through metal grommets **256** and **258** respectively located in apertures **260** and **262** in the upper nozzle housing **230**. Suitable terminal tabs **264** and **266** are secured to the top of housing portion **240** by said grommets **256** and **258** respectively and are insulated from housing portion **230** by insulation members **268** and **270** respectively. Grommets **258** and **256** are hollow metal rivets which are spaced from the walls of apertures **260** and **262** in housing portion **230**. Insulating washers **274** and **272** insulate the lower portions of grommets **256** and **258** respectively from housing

portion 230. Leads 252 and 254 are soldered to their respective grommets. Insulative spool 276 carries the coil 250. A coil retainer plate 278 frictionally fitted into upper housing portion 230 holds coil 250 in position within the nozzle housing. Spaced segments 280 of plate 278 and rim 282 of armature 242 abut rims 288 and 284 respectively of disc 222 when the disc is magnetically pulled upwards from ports 206.

The operation of the nozzle of FIGURES 1, 2, and 3 is as follows. A supply of liquid fuel under substantially constant pressure is forced into the nozzle inlet 126 through fuel feed line 9. The fuel under pressure fills interstices 128, 132, 87, 30, 124, and 130. Seat 86 of valve disc 84 covers the fuel receiving well 80 in valve head 72 by laying flat against the port seat 82. Spring 88 resiliently urges said disc against seat 82. When an electrical pulse is received by the nozzle solenoid 92 from the triggering selector 22 the magnetic field produced by the solenoid pulls the disc 84 away from seat 82 against the weaker pressure of spring 88 and toward the end of the armature 96. The fuel under pressure consequently flows into well 80 in valve head 72, out through the aperture 81 of the valve body 68 and into the vicinity of the engine intake valve port. When the electrical pulse as determined by the modulator 44 ends, the solenoid 92 is deenergized and the spring 88 forces the disc 84 back against valve seat 82 and stops further flow of the fuel into the port well 80.

The operation of the nozzle of FIGURE 4 is essentially the same. The variation in fuel flow is readily apparent, the flow being through passage 248, underneath disc 222, into the ports 206 and through apertures 212 and 213 to the engine fuel intake system. It is noted that a free passage of fuel under pressure to both sides of the disc 222 is provided in essentially the same manner as in the structure of the nozzle of FIGURE 2.

In both structures the actual distance that the disc 84 or 222 must travel away from the ports in order to open the same and allow the necessary fuel therethrough is very small and is measured in thousandths of an inch. The length of time that the disc remains away from the ports is measured in milliseconds and is determined by the modulator current pulse transmitted to the injector solenoid by the triggering selector. Since the injector solenoid must become energized many times a second when the engine is running at high speeds, the disc which the solenoid must pull away from the valve ports must be of such a weight and shape as to take best advantage of the short duration of the magnetic field produced by the solenoid. The disc must respond instantaneously to the field produced by the solenoid and must thereafter respond instantaneously to the tension of the return spring 88 or 216 with a minimum susceptibility to residual magnetic forces when the solenoid is deenergized.

I have determined that the best shape of the disc is substantially flat, one-half to three-quarters of an inch in diameter, and thirty to forty thousandths of an inch in thickness. When so shaped the disc is very light and is immediately susceptible to the magnetic field of the solenoid particularly since the relatively large surface area of the disc is transverse to the plane of the greatest field force produced by the solenoid. It is noted that any time lag in the response of the disc to the induced field of the coil is detrimental to the timing of the fuel injection system and the resulting performance of the engine. This time lag is an important error factor since the total time that the disc is normally in its port opening position during one flux cycle is in the vicinity of 0.5 millisecond.

While the preferred embodiments of the invention has been described and shown, it is understood that alterations and modifications may be made thereto, provided the said alterations and modifications fall within the scope of the appended claims.

What I claim is:

1. A post acting low inertia solenoid valve for controlling the flow of fluids in relatively small quantities comprising a housing, a flow control port therein, a freely shiftable valve disc having one side engageable with said port to close the same, the edges of said disc being spaced from said housing to enable limited and comparatively frictionless movement of said disc toward and away from said port, the other side of said disc being substantially flat and continuous, the space between said disc and housing comprising conduit means for passage of fuel therethrough upon movement of said disc from said port, means yieldingly urging said disc toward said valve port, said disc being of a magnetic material susceptible of being shifted from said port by a magnetic field, a plate of magnetic material having its peripheral portion secured to the inside of said housing and spaced from said disc, apertures in said plate forming part of said conduit means, and an electrical coil in said housing having an armature extending through said plate and spaced from said disc, said coil being spaced from the inside of said housing to form part of said conduit means.

2. In a liquid fuel control system for an internal combustion engine, fluid conduit means adapted for connecting an engine with a source of liquid fuel, a hollow valve housing comprising a part of said conduit means and having a valve port, a freely shiftable valve disc having one side engageable with said port to close the same, the edges of said disc being spaced from said housing to enable limited and comparatively frictionless movement of said disc toward and away from said port, the other side of said disc being substantially flat and continuous, the space between said disc edges and housing comprising part of said conduit means for passage of fuel therethrough upon movement of said disc from said port, means yieldingly urging said disc toward said valve port, said disc being of a magnetic material susceptible of being shifted from said port by a magnetic field, a plate of magnetic material having its peripheral portion secured to the inside of said housing and spaced from said disc, apertures in said plate forming part of said conduit means, and an electrical coil in said housing having an armature extending through said plate and spaced from said disc, said coil being spaced from the inside of said housing to form part of said conduit means.

3. In a liquid fuel control system for an internal combustion engine, fluid conduit means adapted for connecting an engine with a source of liquid fuel, a hollow valve housing comprising a part of said conduit means and having a valve port, a freely shiftable valve disc having one side engageable with said port to close the same upon movement of said disc, the edges of said disc being spaced from said housing to enable limited and comparatively frictionless movement of said disc toward and away from said port, the other side of said disc being substantially flat and continuous, the space between said disc edges and housing comprising part of said conduit means for passage of fuel therethrough upon movement of said disc from said port, means yieldingly urging said disc toward said valve port, said disc being of a magnetic material susceptible of being shifted from said port by a magnetic field, a plate of magnetic material having its peripheral portion secured to the inside of said housing and spaced from said disc, apertures in said plate forming part of said conduit means, an electrical coil in said housing having an armature extending through said plate and spaced from said disc, said coil being spaced from the inside of said housing to form part of said conduit means, and electrical insulating means interposed between said metal plate and said armature for preventing shunting of magnetic flux away from said disc.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,001,757 September 26, 1961

Thomas M. Ball

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 54, before "through" insert -- 52 --; column 3, line 56, for "formed" read -- forced --; column 4, line 68, for "240" read -- 230 --; column 5, line 15, for "laying" read -- lying --; column 6, line 13, before "and" insert -- edges --.

Signed and sealed this 6th day of March 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents