March 19, 1968 H. PAPST 3,373,727

SPRAY NOZZLE

Original Filed Feb. 18, 1964

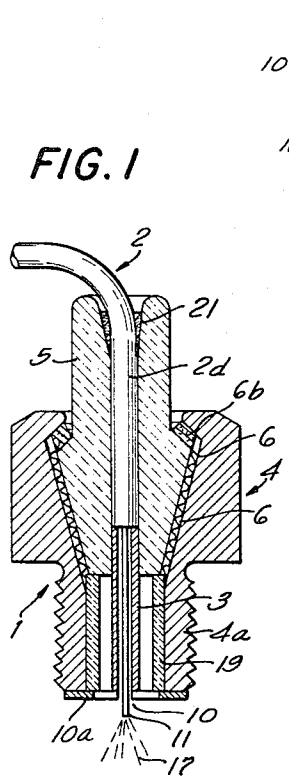


FIG. 1

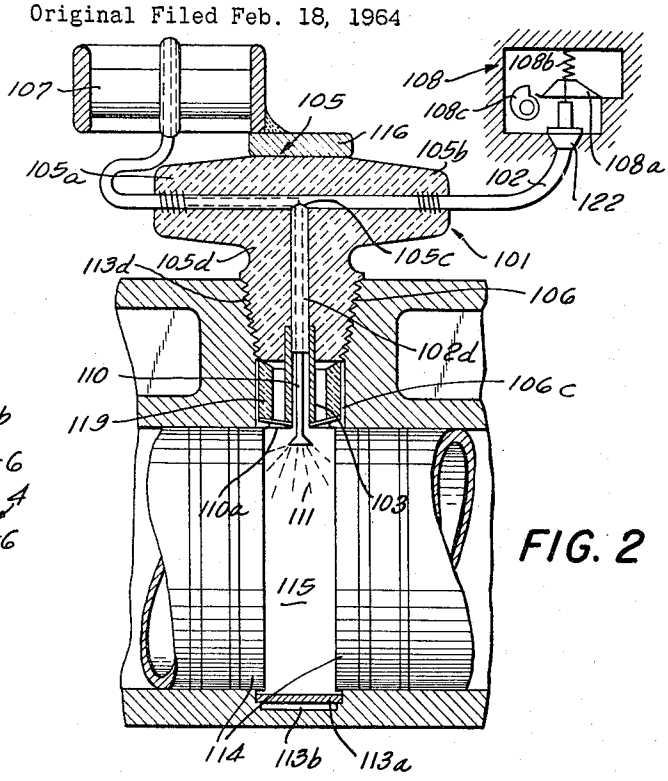


FIG. 2

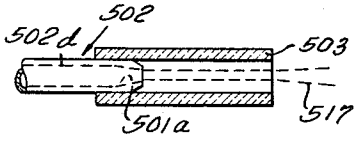


FIG. 3

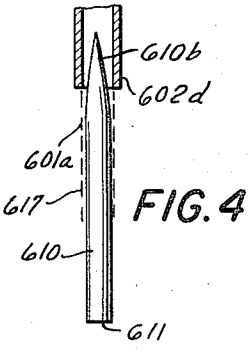


FIG. 4

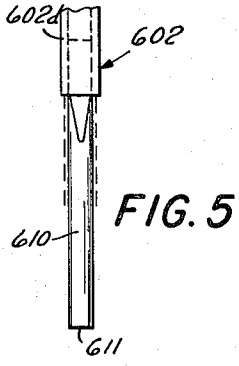


FIG. 5

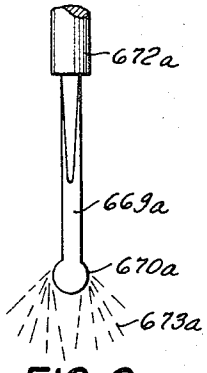


FIG. 6

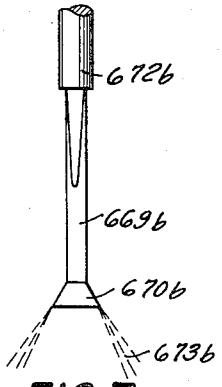


FIG. 7

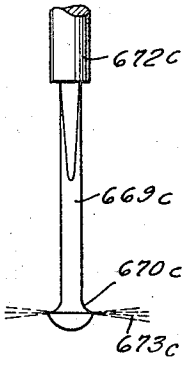


FIG. 8

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SPRAY NOZZLE

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Divided and this application Aug. 23, 1966, Ser. No. 574,421
Claims priority, application Germany, Feb. 18, 1963, P 31,167
12 Claims. (Cl. 123—139)

ABSTRACT OF THE DISCLOSURE

A fuel injection system for an internal combustion engine has an injection pump of the type having a constant rate of discharge in timed relation with the engine, delivers fuel to an open type nozzle forming a tubular discharge pattern within a glow tube.

This is a division of my copending application, Ser. No. 345,725, filed Feb. 18, 1964 now abandoned.

The present invention relates to internal combustion engines, and more particularly to improved spray nozzles which serve to supply atomized fuel to the cylinders of such engines and which are equipped with fuel igniting devices.

It is an important object of my invention to provide a combination spray nozzle and fuel igniting device which is of simple and low-cost construction, which is especially suited for use in internal combustion engines operating with comparatively low compression ratio, and which enables such engines to operate with exceptionally high thermal efficiency.

A further object of the invention is to provide a combination spray nozzle and fuel igniting device which is constructed and assembled in such a way that the ignition of fuel begins immediately when a fuel spray issues from the nozzle.

A concomitant object of the invention is to provide a spray nozzle which embodies a novel fuel igniting device and wherein the fuel igniting device may receive heat from the products of combustion so that it need not be heated externally excepting when the engine is started.

With the above objects in view, one feature of my invention resides in the provision of a spray nozzle which serves to deliver fuel into the cylinder of an internal combustion engine and which comprises a nozzle holder, a fuel outlet comprising a discharge end received in the nozzle holder and having an orifice arranged to direct streams of fuel into the cylinder, a glow tube preferably detachably secured to the nozzle holder to constitute an extension of the aforesaid discharge end, and a tubular jacket of poor heat conductivity secured to the nozzle holder so as to surround the glow tube. The configuration of the orifice and the internal diameter of the glow tube is selected in such a way that, while flowing through the glow tube, at least the main stream of fuel remains spaced from the glow tube so that the glow tube is not cooled by fuel whereby little heat energy suffices to maintain the glow tube at a temperature which is high enough to insure immediate ignition of fuel.

The engine which embodies one or more mozzles of the above outlined type further comprises a heating device which heats the glow tube to a state of incandescence during starting of the engine, and the thickness and composition of the glow tube may be selected in such a way that heat radiated by the products of combustion which develop on ignition of fuel streams suffice to heat the glow tube to incandescence so that the heating device may be turned off.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved spray nozzle itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawings, in which:

FIG. 1 is an axial section through a spray nozzle which embodies one form of my invention and wherein a cone-shaped spray of fuel is ignited by a solid cylindrical burner tube;

FIG. 2 is a fragmentary axial section through a cylinder of the internal combustion engine which is provided with a slightly modified spray nozzle including a pin with a conical head to form a hollow cone-shaped fuel spray;

FIG. 3 is an axial section through a portion of a different spray nozzle wherein the orifice at the discharge end of the fuel outlet resembles a cone and converges in a direction in which the stream of fuel is discharged into the chamber of an internal combustion engine;

FIG. 4 is a fragmentary axial section through another spray nozzle and illustrates the discharge end of a fuel outlet which receives a wedge-shaped portion of a pin member;

FIG. 5 is a side elevational view of the structure shown in FIG. 4;

FIGS. 6, 7 and 8 illustrate three types of pins which may be utilized in my spray nozzle.

Referring to FIG. 1, there is shown a spray nozzle **1** which embodies a device for igniting a cone-shaped spray **17** of diesel oil or another fuel. The nozzle **1** comprises a tubular nozzle holder **4** which is permanently connected to the metallic, normally open, fuel supply conduit or outlet **2** of a fuel injection pump. The discharge end **2***d* of this normally open fuel conduit **2** is a capillary tube and defines a fuel discharging orifice and supports an elongated guide pin member **10** which may be provided with flat faces, grooves or the like to respectively vary the characteristics of the fuel discharging orifice.

A thin glow tube **3** of quartz glass, ceramic or similar insulating heat-resistant material is secured to a tubular high-tension insulator **5** and constitutes an extension of the discharge end **2***d* of the fuel conduit **2**, i.e., fuel discharged from the orifice of the discharge end **2***d* flows around the periphery of the pin member **10** and is surrounded by the glow tube **3** to form a cone-shaped spray **17** at the time it leaves the free end or tip **11** of the pin. The glow tube **3** is spacedly surrounded by a sleeve-like heat insulating jacket **19** which is telescoped into the externally threaded tip **4***a* of the nozzle holder **4**. The inner end portion of the glow tube **3** is telescoped into the insulator **5**, and this insulator has a conical front section which is surrounded by a conical portion **6***a* of a corrugated or grooved metallic shell **6** serving to sealingly engage the surface bounding a complementary conical cavity in the nozzle holder **4**. An annular gasket **6***b* of the shell **6** is adjacent to an annular shoulder of the insulator **5** and is clamped in the nozzle holder **4** to provide a fluid-tight seal between this holder and the insulator **5**. The rear end of the insulator **5** accommodates a body of fusible cement **21** which forms a seal around the conduit **2** and which may consist of a vitreous substance forming a permanent connection for the discharge end **2***d*. It will be noted that the glow tube **3** actually constitutes a tubular extension of the insulator **5**, and the insulating effect of this composite insulator is not affected by deposits of soot because, in actual operation, the glow tube **3** he heated to a very high temperature and glows to ignite the spray without any delay. The spark will jump from the pin **10**

to a disk-shaped electrode 10*a* which is grounded and which is installed at the front end of the jacket 19, i.e., at the front end face of the nozzle tip 4*a*.

It will be noted that the glow tube 3 is disposed between two annular air spaces one of which surrounds the pin member and the other of which is surrounded by the jacket 19. These annular spaces receive pulsating streams of very hot combustion products which rapidly heat the tube 3 to incandescence. The streams of combustion products develop in the combustion chamber (not shown in FIG. 1) which receive the cone-shaped spray 17 when the spray nozzle of FIG. 1 is installed in an internal combustion engine.

Some of the droplets in the marginal zone of the spray 17 will be ignited by contact with hot gases or by contact with the burner tube 3.

The purpose of the jacket 19 is to hinder the cooling of the burner tube 3. The volume of the space in the interior of the jacket 19 depends on the capacity of the cylinder and may range from a few cubic millimeters to several cubic centimeters. Experiments with a 10 HP hingle-cylinder two-stroke engine, wherein the volume of the space in the jacket 19 was 100 mm.^{3}, indicated that the energy consumption of the electric heating of said glow tube was 18 watts and that the ignition was exceptionally regular. The compression ratio was 10:1.

FIG. 2 illustrates a portion of an internal combustion engine which utilizes a slightly modified spray nozzle 101. A solid thin-walled glow tube 103 of quartz glass or the like is surrounded by a sleeve-like heat insulating jacket 119 which consists of quartz glass or ceramic material and which is received in a cylindrical extension 106*c* of a shell 106. The free end of the extension 106*c* supports a disk-shaped electrode 110*a* which is adjacent to the exposed end face of the jacket 119 and which is provided with radially inwardly extending prongs to support the tip of the glow tube 103. The rear end of the glow tube 103 is received in a substantially T-shaped hollow high-tension insulator 105 having a central conical nipple 105*d* which is surrounded by the shell 106. The clamping means for securing the insulator 105 to the cylinder 113 of the internal combustion engine comprises an arcuate clamping member 116 which overlies and engages a portion of the insulator and which is detachably secured to the cylinder 113 by suitable bolts or similar threaded fasteners. The bolts 112 cooperate with the clamping members 116 to press the conical nipple 105*d* of the insulator 105 against the shell 106 so that the latter bears against the conical surface surrounding a radially extending hole 113*d* in the wall of the cylinder 113.

The insulator 105 is provided with a pair of laterally extending nipples 105*a*, 105*b* each of which is formed with a channel or bore so that the nipple 105*b* may receive a portion of the fuel outlet 102 leading to a source of fuel here shown as a fuel injection pump 108. The central nipple 105*d* of the insulator 105 comprises a channel or bore which extends radially of the cylinder 113 and which accommodates a metallic conduit 102*d* constituting the discharge end of the fuel outlet 102 and serving to convey fuel toward the combustion chamber 115. This discharge end 102*d* is connected to the rear end of a pin member 110. The nipple 105*a* accommodates a metallic conduit 102*a* which communicates with the discharge end 102*d* at a point 105*c* and which leads to a piezoelectric generator 107. The pressure impulses produced by the fuel injection pump 108 are transmitted to the piezoelectric elements of the generator 107. As shown in FIG. 2, the generator 107 may be welded or soldered to the clamping member 116.

The intake end of the fuel conduit 102 is connected with a nipple 122 of the fuel injection pump 108 to make sure that the connection with the pressure side of this pump is absolutely leakproof.

The internal surface of the cylinder 113 is provided

with an annular recess 113*b* which is aligned with the spray nozzle 101 and which receives a heat-resistant annulus 113*a* of sheet metal or the like.

The pin member 110 is provided with a conical head 111 of symmetrical shape which causes the fuel issuing from the discharge end 102*d* to form a cone-shaped spray 117 impinging at an acute angle against the heads of two pistons 114 which are reciprocably mounted in the chamber 115 of the cylinder 113. The fuel evaporates and is combusted without the formation of spot particles. Since the ignition is initiated by the glow tube 103, its timing is independent of the magnitude of compression in the chamber 115.

The fuel injection pump 108 comprises a plunger 108*a* which is biased by a spring 108*b* and this spring is normally compressed by a rotary cam 108*c*. The fuel conduit 102 is normally open so that, when the pump 108 is started and the cam 108*c* releases the plunger 108*a*, the spring 108*b* expands without delay to immediately produce an impulse which sends a stream of fuel down the fuel outlet 102 and through the orifice of the discharge end 102*a*. Thus, plunger 108*a* is periodically, suddenly released to the action of spring 108*b* by the cam 108*c* which has a sharp edge for causing such sudden release. In other words, the pump 108 will deliver a stream of fuel in response to the very first revolution of the cam 108*c*, and such stream is immediately delivered at full speed to make sure that the small space in the interior of the glow tube cannot be filled with fuel. It will be noted that the pump 108 delivers streams of fuel at a delivery speed which is independent of the rotational speed of the cam 108*c* so that the speed of the fuel stream remains substantially unchanged, i.e., only the intervals between consecutive deliveries of fuel streams will change. This insures that the engine is ready to start at all times and in all climates.

The pump 108 need not be machined with utmost precision as long as it is capable of injecting fuel at high speed immediately after starting. Thus, the cost of the engine may be kept low because not only the spray nozzles but also the fuel injection pump may be of very simple and inexpensive construction.

At first, when the engine is started, the electrode 110*a* and the pin 110 (second electrode) will produce sparks therebetween to ignite the fuel. Once the engine is running, the power to the electrodes may be turned off, the incandescent tube 103 being maintained, by the products of combustion, at the temperature necessary for igniting the fuel.

The spray nozzle of my invention is especially useful in internal combustion engines operating at a compression ratio which is less than the compression ratio of conventional engines wherein the air is compressed and is thereby heated to ignition temperature. Owing to the fact that the stream of fuel issuing from the orifice of the discharge end 102*d* remains spaced from the glow tube 103, the latter is not cooled by such fuel or, at worst, the cooling effect of fuel upon the glow tube 103 is rather negligible. Were the bulk of the fuel stream directed against the burner tube 103, this tube could not always be heated to a temperature which would insure immediate ignition of fuel at rapidly following intervals. Products of combustion entering the space within the jacket 119 exhibit a tendency to remain in this space so that the streams of fresh air cannot cause excessive cooling of the glow tube 103. Since the space in the jacket 119 is very small, any pulsation which develop in the chamber 115 in response to admission of fresh air which expels the products of combustion will result in negligible cooling of the glow tube 103 and, moreover, any fresh air entering the jacket 119 is immediately heated to a temperature which is high enough to cause ignition of fuel in the event such ignition is not started by stray droplets of fuel directed toward the burner tube.

FIG. 3 shows in greater detail the construction of the discharge end **502***d* of a fuel outlet **502** which may be utilized with or without a pin. The discharge end **502***d* defines an orifice **501***a* of decreasing diameter which serves to accelerate the fuel stream and to keep it away from the internal surface of a solid burner tube **503**. The fuel stream **517** will spread to form a hollow cone-shaped spray after it passes beyond the free end of the burner tube **503**. For example, this stream may be directed against a baffle provided in the combustion chamber of a cylinder in a manner as described in connection with FIG. 2.

FIGS. 4 and 5 show a portion of a further spray nozzle wherein the discharge end **602***d* of the fuel outlet **602** receives the wedge-shaped inner terminal portion **610***b* of a pin member **610**. This pin member is without a head so that it will cause the fuel stream to form a hollow tubular spray **617** which may impinge against a suitable baffle in the combustion chamber. The orifice **601***a* in the discharge end **602***d* of the fuel outlet **602** may but need not be formed in a manner as described in connection with FIG. 3. Some spray formation will take place at the free end **611** of the pin **610**.

Referring to FIGS. 6, 7, and 8 there are shown three elongated pin members **669***a*, **669***b*, **669***c* each of which comprises a spray-forming head **670***a*, **670***b*, **670***c*. These pin members are respectively secured to discharge ends of fuel outlets **672***a*, **672***b*, **672***c*, and it will be noted that the head **670***a* of the pintle **669***a* is of spherical shape to form a solid cone-shaped spray **673***a*. The head **670***b* is of frusto conical shape and will form a hollow cone-shaped spray **673***b*. The head **670***c* of the pintle **669***c* is of lenticular shape (nail head) and will form a substantially flat annular spray **673***c*. The pintle **669***c* is of particular advantage in internal combustion engines whose cylinders are formed with substantially lenticular combustion chambers.

The exact configuration of the pin member will depend on several factors including the volume of the cylinder member, the configuration of piston heads, the configuration of recesses in the end faces of piston heads, the speed of fuel streams delivered by the fuel outlet, and others.

The spray nozzle of my invention may be utilized in many types of automotive vehicles as well as in certain types of heating furnaces and in combustion chambers of gas turbines or jet propulsion units. If the propagation of ignition in a cylinder chamber is interrupted due to improper atomization of fuel or for another reason, the remainder of the fuel spray is ignited in a fully automatic way, either by heat which is radiated from the burner tube or by products of combustion in the chamber proper.

Actual experiments with my improved spray nozzles prove that the engine utilizing such nozzles operates very satisfactorily with common types of fuel without a high octane or cetane number, that the consumption of fuel is comparatively low and that such fuel cannot produce knocking or similar noises even though it may be used without antiknock ingredients. The ignition systems of engines utilizing my improved spray nozzles will operate without high-frequency disturbances and a cold engine will be started without any delay. Also, the ignition system is comparatively simple and more reliable than conventional ignition systems. The compression ratio of the engine may be higher than in an Otto engine, and the volume of cylinder chambers may be smaller so that the engine may be provided with a large number of cylinders to insure that the transmission of torque to the output shaft of the engine is more uniform.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A spray nozzle for delivering fuel to the cylinder of an internal combustion engine, comprising a fuel conduit having an orifice opening in a given direction; an elongated glow tube surrounding said orifice and extending from said orifice in said given direction, said glow tube having along its entire length an internal diameter which is greater than the diameter of said orifice; and an elongated pin member extending in said given direction from within said orifice coaxially with the same and through said glow tube and coaxially thereof, said pin member having within the confines of said orifice and of said glow tube a diameter which does not exceed the diameter of said orifice, said pin member and said glow tube defining between themselves an elongated annular passage for delivering fuel to the engine cylinder.

2. A spray nozzle according to claim **1**, wherein said elongated pin member extends through and beyond said glow tube.

3. A spray nozzle according to claim **2**, wherein said elongated pin member has a free end located beyond said glow tube, said free end comprising an enlarged portion.

4. A spray nozzle according to claim **1** wherein the portion of said pin member located within said glow tube has a constant diameter along its entire length.

5. A spray nozzle according to claim **1**, further comprising a tubular jacket of poor heat conductivity spacedly surrounding said glow tube so as to define an annular space therewith.

6. In an internal combustion engine, in combination, a cylinder defining a combustion chamber; a source of fuel; fuel pump means communicating with said fuel source for receiving fuel therefrom and having outlet means for delivering fuel pumped by said pump means, said pump means comprising energy storage and release means for storing energy and for suddenly and periodically releasing the same to periodically deliver streams of fuel to said outlet means; and a spray nozzle comprising a fuel conduit communicating with said outlet means of said pump means and having an orifice opening in a given direction and communicating with said combustion chamber for conducting streams of fuel from said outlet means to said chamber at high speed, an elongated glow tube surrounding said orifice and extending from said orifice in said given direction, said glow tube having along its entire length an internal diameter which is greater than the diameter of said orifice and the configuration of said orifice being such that at least the main stream of fuel issuing therefrom has a diameter, while passing through said tube, which is smaller than the internal diameter of said tube so that at least the main stream of fuel issuing from said orifice remains spaced from said tube while passing therethrough said nozzle further comprising an elongated pin member extending in said given direction from within said orifice coaxially with the same, and through said glow tube and coaxially thereof, said pin member and said glow tube defining between themselves an elongated annular passage for delivering said main stream of fuel to the engine cylinder.

7. In an internal combustion engine according to claim **6**, wherein said fuel pump means comprises a pump having a housing defining a fuel receiving chamber communicating with said source and with said outlet means, plunger means reciprocable within said chamber, biasing means operatively connected to said plunger for biasing the latter in a first direction said plunger including a cam follower portion, and cam means adapted to be driven by the internal combustion engine and cooperating with said cam follower portion for intermittently urging the latter and thereby said plunger against the action of said biasing means in a direction opposite to said first direction, said cam means intermittently releasing said plunger to the

action of said biasing means so that said plunger intermittently delivers streams of fuel through said outlet means to said spray nozzle.

8. In an internal combustion engine according to claim 7, wherein said cam means includes a cam surface having a drop edge, said follower portion of said plunger being urged by said biasing means to follow said cam surface in order to produce a brief pulse-like injection of fuel when said follower portion drops over said drop edge of said cam surface.

9. In an internal combustion engine according to claim 7, wherein said cam means includes a rotary cam member having a transverse cam edge.

10. A spray nozzle according to claim 1, further comprising heating means for heating said glow tube.

11. In an internal combustion engine according to

claim 6, further comprising heating means for heating said glow tube.

12. A spray nozzle according to claim 1, further comprising heating means for heating said elongated glow tube.

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