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FUEL INJECTION PINTLE

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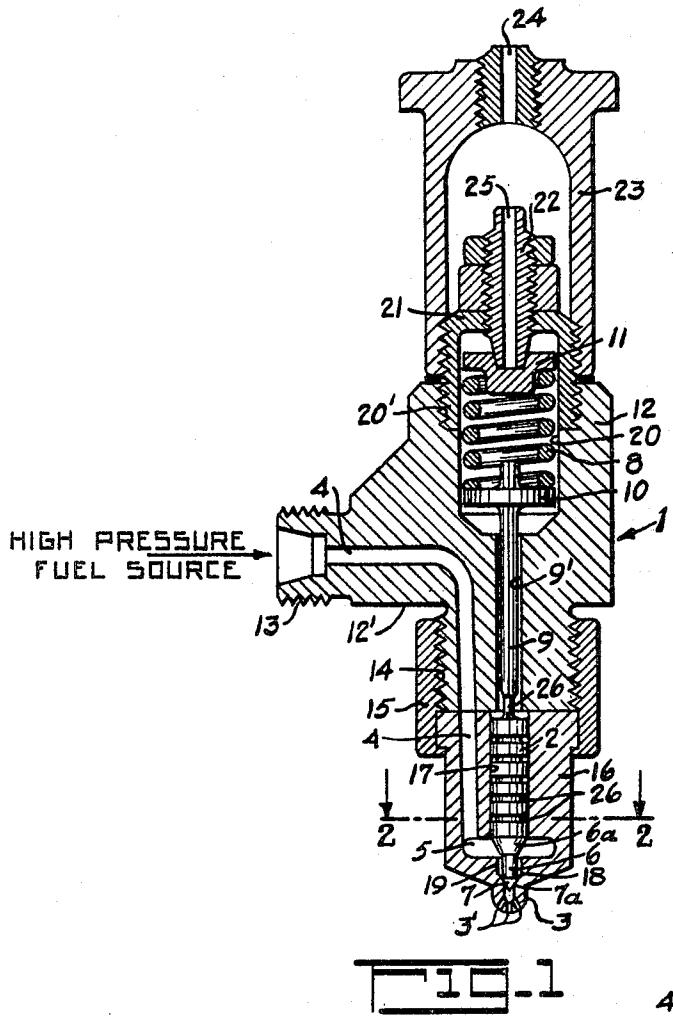


FIG. 1

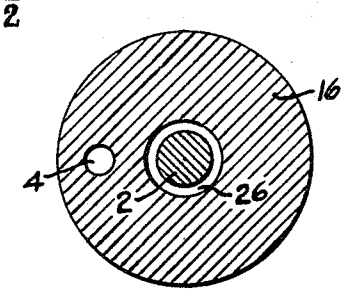


FIG. 2

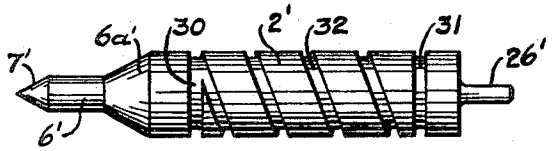


FIG. 3

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FUEL INJECTION PINTLE

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ABSTRACT OF THE DISCLOSURE

A reciprocating fuel injection pintle disposed within a guid bore, the surface of the pintle having recesses therein for entrapping fuel to minimize chattering and prevent seizing.

This invention relates to fuel injection apparatus for high speed internal combustion engines; more specifically, the invention is concerned with fuel injection nozzles and related means for periodically injecting under high pressure a liquid fuel into the engine combustion chamber at a pulsing rate according to engine r.p.m.

In a known form of fuel injection apparatus, liquid fuel under high pulsing pressure is fed to a valve-controlled nozzle for periodic injection into the engine combustion chamber. The nozzle valve, or pintle, is operated in reciprocal manner through an on-off cycle for respective opening and closing of the nozzle exhaust, the "on" stroke being caused by a fuel pressure pulse of high peak value and brief duration, and the "off" stroke by a pretensioned return spring as the pulse pressure falls off. Accordingly, the valve on-off cycle is substantially concurrent with the fuel pressure pulse cycle. The pulsing rate of the source pressure is a function of the engine r.p.m. for proper timing of fuel feed and ignition at the combustion chamber, and the pulse peak pressure is varied according to fuel requirements, i.e., power demand.

As most modern automotive engines operate at speeds ranging approximately from 500 to 6,000 r.p.m., the injection nozzle, and especially the pintle, required manufacture and assembly with very high degrees of precision for accommodating the very high hydraulic pressures while providing exact fit and small tolerance for avoiding excessive wear, deterioration and "seizing" due to friction, etc. Notwithstanding such precision fabrication and finish, serious failure problems have persisted in practice, as for example, pintle "chattering" resulting in undesirable "secondary injection," seizure of nozzle pintles, pintle galling and bore wear and consequent reduced fuel injection due to bypass leakage at the pintle. Such failures have occurred heretofore in fuel injection nozzles of the highest quality available to the trade.

In accordance with the present invention, the closely fitted surfaces of the pintle and its housing bore, which can in a practical sense be considered as merging into a "cleavage boundary," have a plurality of small pockets or recesses. These recesses are located at points along the length of the pintle and extend generally transversely to and circumferentially of the pintle for entrapping liquid fuel escaping along the aforesaid cleavage boundary.

I have found that this arrangement materially reduces friction and resultant wear, minimizes pintle "chattering," ensures centering of the pintle for preventing "galling" and practically eliminates the hazard of seizing, thereby greatly improving the efficiency, reliability and durability of the injection apparatus.

A principal object of this invention therefore is to provide an improved fuel injection pintle and nozzle combination that efficiently ensures reliable and uniform fuel injection to the engine combustion chamber, and that is durable and wear-resistant for dependable long-life operation.

As used herein, the term "nozzle" is intended to comprehend the essential pintle housing and related structure forming the engine-mounted unit, as well as the conventional apertured fuel exhaust portion.

The invention will be more fully set forth in the following description referring to the accompanying drawing, and the features of novelty will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Referring to the drawing:

FIG. 1 is a sectional view in elevation of the general assembly of fuel injection apparatus embodying the present invention;

FIG. 2 is an enlarged cross-sectional view taken along the line 2—2 of FIG. 1; and

FIG. 3 is an enlarged view of a fuel injection pintle with modified form of boundary surface recessing.

The fuel injection apparatus of FIG. 1 comprises essentially a nozzle housing unit **1** and a fuel-controlling valve or pintle **2** mounted for reciprocal movement within the nozzle. The nozzle unit in practice is specifically adapted for operative attachment to the engine (not shown) so that fuel from the nozzle exhaust **3** can be injected into the combustion chamber.

The fuel supply under a high periodic or pulsing pressure, with peak values ranging, for example, from about 8,000 p.s.i. to 15,000 p.s.i., is directed to the nozzle through a lateral passage **4** that extends downward toward the nozzle exhaust along a path generally parallel to and radially offset with respect to the pintle. This passage terminates near the nozzle exhaust in a chamber **5** that communicates with small-diameter individual nozzle exhaust openings **3'**. The lower portion of the pintle is tapered at *6a* and terminates in a valve portion **6** which extends, together with the taper *6a*, axially through the chamber **5** so as to define an annular space therein.

For closing the nozzle exhaust, the portion **6** has a conical tip **7** for engaging somewhat in the manner of a needle valve a corresponding seat **7'** in the nozzle exhaust **3**. The pintle is normally biased into valve-seating position by a pretensioned spring **8** that is related to the pintle through a force-transmitting stem **9** and attached spring-seat disc **10**. The opposite end of the spring bears on an adjustable seat **11** that is suitably mounted in the nozzle as presently described.

The structure forming the nozzle unit and pintle housing is shown merely by way of example and will be described briefly. A central portion of the housing may comprise a generally cylindrical block **12** having a lateral portion **12'** through which the initial part of the passage **4** extends. A connection can be made at **13** with a fuel line for transmitting the pressure fuel to the nozzle passage **4** and nozzle chamber **5**. The lower end of the block **12** is threaded at **14** for receiving a coupling or collar **15** that unites to the block **12** a generally cylindrical member **16** that constitutes the pintle guide housing and nozzle exhaust portion **3**. The fuel passage **4** extends in alignment downward from the block **12** through the guide housing **16**.

The pintle is mounted for high speed reciprocation within its guide bore **17** that extends centrally through the member **16**. A sufficiently precise and close-fitting relation consistent with free relative movement, such as a tolerance of .0002 inch forms in effect a cleavage surface or boundary between the bore wall and pintle. The bore **17** communicates at its upper end with the centrally aligned smaller stem bore **9'**, and at its lower end with the annular chamber **5**. This chamber in turn communicates with a central bore **18** at the exhaust end **3** of the nozzle that has a diameter somewhat larger than that of the cylindrical valve portion **6**. A restricted annular passage **19** is thereby formed through which pressure fuel

from the chamber **5** can flow past the valve seat **7'** and through the jet-like exhaust openings **3'** when the valve is opened, i.e., lifted.

The upper portion of the housing block **12** has a central recess or bore **20** for receiving the spring **8** and its disc-seat **10**. A threaded recess at **20'** receives a bushing **21** within which an adjustment screw **22** is centrally positioned for varying the vertical position of the upper spring seat **11** and thereby the spring tension. The threaded bushing **21** also provides for securing to the block **12** a protective cap **23** that is vented to atmosphere at **24**. The adjusting screw **22** also has a central venting passage at **25** for precluding "air cushion" effect on the pintle spring seat **10**.

The reciprocating action of the pintle **2** for alternatively opening and closing the valve seat opening at **7'** is very rapid as mentioned above and is caused by applied forces of opposite sense having a very steep wave front, i.e., high build-up rate. The fuel pressure pulse when transmitted to the annular chamber **5** acts on the lower part of the pintle **2** as on a differential piston to raise the pintle and valve portion **6** for uncovering the exhaust ports **3'**. As the conical portion **7** is raised from its seat **7'**, the high fuel pressure in chamber **5** causes high velocity flow of fuel through the annular passage **19** and valve seat opening at **7'** to exhaust through the jet-like openings **3'**.

Thus, upon occurrence of an individual pressure pulse, the pintle **2** first is raised sharply against its biasing spring **8**, the nozzle exhaust is opened and high velocity jet-like spray of liquid fuel is ejected from the nozzle. The valve closing is caused by the tensioned spring **8** which acts immediatley with decrease of pulse pressure. The spring stem **9** is in abutting or follow-up engagement with an extension **2'** of the pintle so that any tendency on the part of the stem and spring assembly, due to its inertia to separate from the pintle at **2'** during a sharp opening stroke, results in a return hammer-like impact on the pintle for causing positive seating in the closing stroke. The valve opening stroke of the pintle is limited by the shoulder **12***a*, thereby facilitating fast spring closing action.

For improving the fuel injection operation as outlined above, the main cylindrical portion of the pintle is shown in FIG. 1 as having a plurality of small annular grooves spaced longitudinally along the pintle. These grooves form pockets or recesses at the so-called cleavage boundary between the pintle and its bore wall. These annular recesses entrap small amounts of liquid fuel that inevitably leak along the boundary surfaces at very high pintle speeds, such as from 3,000 to 6,000 strokes per minute, and when so entrapped the fuel in combination with the recessing functions both as a stabilizing damper as presently described and as anti-friction and pintle centering means. Considering here the latter function, the pintle when precisely centered in the guide bore is subject to minimum friction heating and wear, and deterioration due to "galling," etc. This in turn minimizes leakage of fuel past the pintle which could cause significant reduction of fuel injection to the engine.

The recesses formed along the boundary surfaces are conveniently and preferably formed in the pintle; however, it is within the scope of this invention to form the recesses in the bore wall, or in both the bore wall and pintle. The essential arrangement consists of recesses located at points lengthwise of the pintle and extending generally transverse (or tangential) with respect to the longitudinal axis of the pintle and circumferentially thereof. In FIG. 1, the recessing constitutes, for example, five annular grooves approximately equally (or random) spaced along the longitudinal axis of the pintle, the upper and lower grooves being intermediate the cylinder ends of the pintle so as to be within the bore at all times.

An alternate form of recessing is shown by FIG. 3 wherein the recessing constitutes annular terminal grooves **30** and **31** which define the recessing limits; these terminal grooves are interconnected by a helical groove **32** having a pitch such that the recessing extends generally transversely with respect to the pintle longitudinal axis. The pintle recessing shown in FIG. 3 functions to entrap liquid fuel for centering the pintle and minimizing pintle and bore "galling" or wear, and for hydraulic damping in essentially the same manner as in FIG. 1.

The improved and high degree of performance of the fuel injection pintle described above is believed to be due to a combination of several factors, all contributing to more precise valve operation and longer life of the injection apparatus. An important factor in improving valve operation involves hydraulic damping due to the presence of entrapped liquid fuel in the recesses. This damping is caused by shearing action on the liquid at the boundary surfaces and has a stabilizing effect tending to suppress pintle "chattering," which otherwise often occurs as a reuslt of severe hydraulic pressure transients during the pintle opening-and-closing cycle. Such suppression of "chattering" eliminates to a great extent the phenomena of "secondary injection" which, in general, is undesirable in fuel injection systems.

Chattering can be further reduced to a minimum, say within a selected high speed range, by relating the number and spacing of the grooves or recesses to the mass of the pintle so as "tune out," i.e., adjust the natural frequency of the pintle, with respect to a "ringing" or chatter condition.

Another important factor briefly considered above is the material reduction in total friction area due to recessing, in conjunction with a degrading pressure drop controlled by the leakage path across each successive groove (or along an extended helical groove as in FIG. 3). This, together with the liquid shearing action described above tends to keep the pintle concentric, i.e., centered, within its guiding bore, thereby eliminating one-sided or unequal wear, which otherwise would result in eventual "galling" of the pintle, especially where comparatively soft metal is used. In practice, the pintle metal is somewhat softer than the guide bore wall; accordingly, material reduction in friction heating and wear due to the reduced friction area, lubricating action of the fuel and centering of the pintle contribute materially to the life and efficient operation of the pintle.

The recessing further contributes to reduction in wear by entrapping with the recess fuel any foreign or metallic particles that may be present incident to high speed pintle operation, etc. The concentration of such particles is diluted in effect by mixing with the comparatively large volume of entrapped fuel. Thus, any slight scoring due to particles is confined to areas of close clearance, rather than recessed or grooved areas, thereby eliminating wear formed through-channels that would eventually cause excessively high rate of pintle by-pass leakage. Friction wear as mentioned above is further reduced by the fuel-lubricated surfaces that encompass the pintle substantially throughout its length, in conjunction with controlled circulation of the comparatively large volume of entrapped fuel.

It should be understood that this invention is not limited to specific details of construction and arrangement thereof herein illustrated, and that changes and modifications may occur to one skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. Liquid fuel injection apparatus for high speed internal combustion engines comprising:

(a) a nozzle having passage means for admitting fuel under high pulsing pressure to the nozzle exhaust for injection into an engine combustion chamber,

(b) a cylindrical fuel-controlling pintle guided for reciprocal movement within a bore in said nozzle and resiliently biased for closing the nozzle exhaust, the pintle being precision fitted within its guide bore for defining at the relatively movable surfaces thereof an effective cleavage boundary,

(c) the pulsing fuel pressure being directed by said passage means to said pintle at the nozzle exhaust for periodically overcoming the aforesaid bias, thereby opening the nozzle exhaust for periodic fuel ejection,

(d) and one of said boundary surfaces being recessed at points along its guided bore length spaced from the ends of the bore, the recessing extending generally transverse to the longitudinal axis of the pintle and circumferentially thereof for entrapping liquid fuel leaked along said cleavage boundary, said entrapped fuel coacting with said surfaces incident to high speed reciprocating of the pintle and high transient hydraulic pressures at the nozzle exhaust, for damping the pintle against "chattering" and for centering the pintle and minimizing wear and deterioration thereof, said recessing consututing annular grooves at the spaced terminal limits of the recessing and a helical groove interconnecting and terminating at said annular grooves.

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