May 19, 1936. K. J. E. HESSELMAN 2,040,846

FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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Fig. 1.

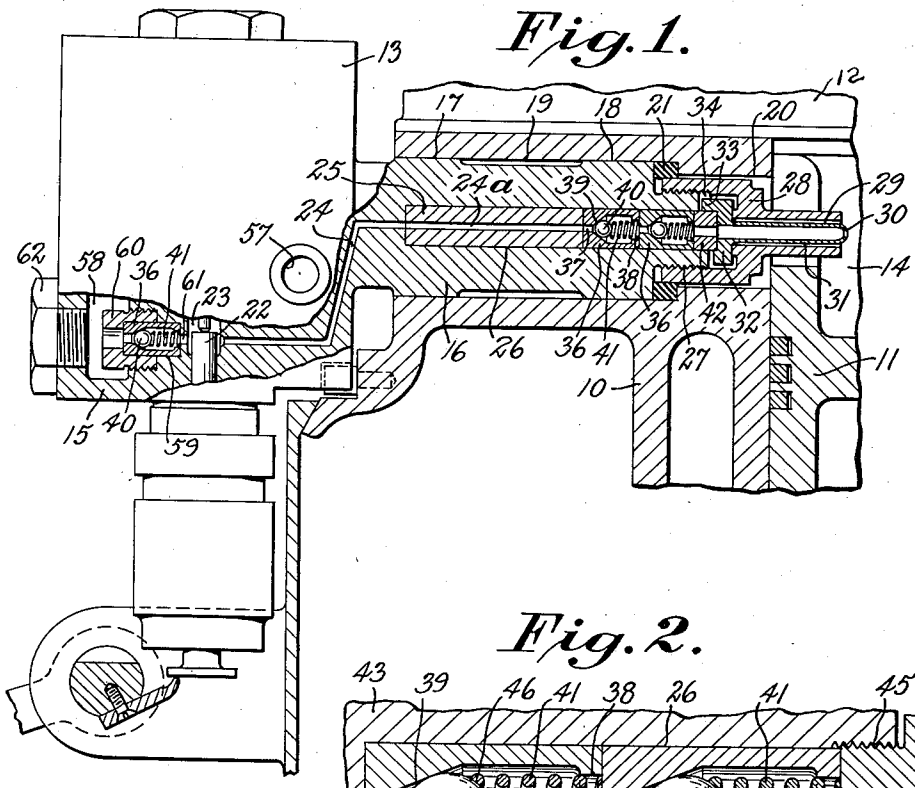
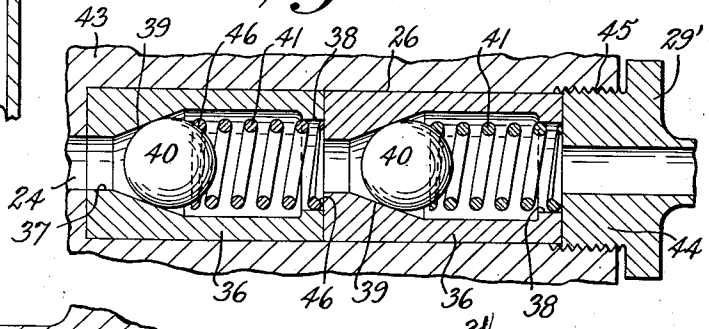


Fig. 2.



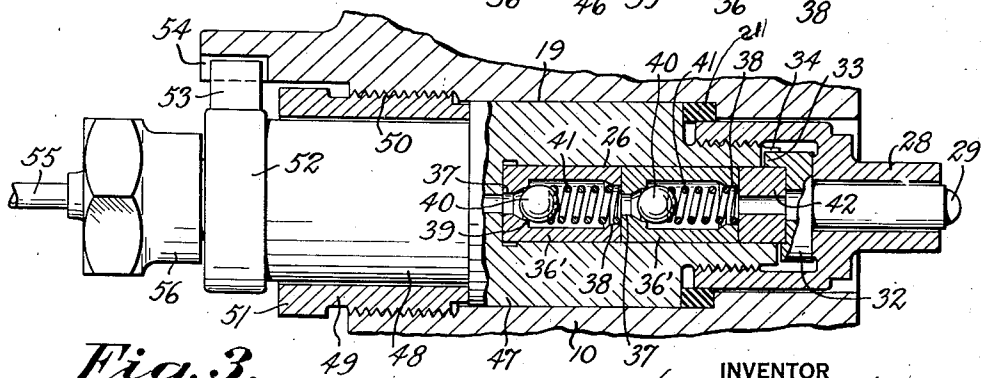


Fig. 3.

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FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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Application September 24, 1932, Serial No. 634,710
In Sweden April 22, 1929

13 Claims. (Cl. 299—107.1)

This application replaces my copending applications Serial Nos. 439,602 and 439,603, filed March 28, 1930, and is a continuing application with respect to my copending application Serial No. 538,756 filed May 20, 1931, and is to be considered as relating back to said applications Serial Nos. 439,602 and 439,603 for all dates and rights incident to filing said applications and applications in foreign countries corresponding thereto, and as relating back, so far as herein continued, for all dates and rights incident to filing said application Serial No. 538,756 and applications in foreign countries corresponding thereto.

The present invention relates primarily to fuel injection systems for internal combustion engines and has particular reference to means for controlling the flow of fuel in injection systems of the solid injection type which inject to each cylinder of an engine a metered quantity of fuel for each working stroke. More specifically the invention relates to valve structure particularly adapted to be associated with the injection nozzles employed in such systems and to fuel injectors consisting of injector nozzle and discharge valve structure in associated relation.

In solid injection fuel supply systems, numerous severe operating conditions are imposed which must be met if the system is to operate successfully and one of the most difficult problems has been to provide valve structure, particularly for the discharge valves of the system, which will operate successfully under the severe conditions imposed thereon. Valves suitable for this service must be of a type which will seat accurately over long periods of time, they must be capable of free and rapid action, they must be of a form such that they can be placed relatively closely adjacent to the injection nozzle, and, if they are to be of practical utility, the structure must be not only of a character eliminating very small orifices which are subject to clogging due to impurities in the fuel but must also be of the simplest possible construction of a character which permits ready disassembly of the parts for purposes of cleaning, repair or replacement. Also, if a satisfactorily practical structure is to be provided, it should be of a character avoiding as far as possible the necessity for joints requiring packing to prevent leakage of fuel.

The general object of the present invention is the provision of improved apparatus including valve structure and injector structure which will satisfactorily meet the numerous and relatively severe operating requirements for structures of this kind. The manner in which the general object of the invention is attained and the more specific nature of the invention, together with the advantages to be derived from its use, will be explained more fully in the ensuing description of the preferred embodiments of the invention illustrated in the accompanying drawing forming a part of this specification.

In the drawing:

Fig. 1 is a view showing part of an engine cylinder having a fuel pump and injection nozzle arrangement embodying the invention;

Fig. 2 is a section on a larger scale showing a discharge valve arrangement similar to the one shown in Fig. 1, and

Fig. 3 is a view showing an injection nozzle assembly incorporating the invention.

Turning now to the arrangement shown in Fig. 1, reference character 10 indicates an engine cylinder in which is located a piston 11 and which is closed at the top by the cylinder head 12 which may or may not be separate from the cylinder 10.

A pump 13, for supplying fuel to combustion chamber 14, comprises a pump body 15 having an integral laterally projecting arm 16 adapted to engage at 17 and 18 the walls of the bore 19 in the wall of cylinder 10. The inner portion 20 of bore 19 is of reduced diameter and provides a shoulder between which and a shoulder on arm 16 there is situated the packing ring 21. Pump 13 may be retained in position by any suitable means, preferably some form of releasable clamp permitting ready removal of the pump such as is disclosed in Patent No. 1,835,490 granted to me December 8, 1931.

The pump illustrated is of the plunger type and comprises a plunger 22 reciprocably mounted in a suitable bore in the pump body 15 and adapted to draw fuel into pump chamber 23 on the outward stroke of the plunger and to discharge fuel therefrom on the inward stroke. Actuation of the pump plunger may be by any suitable known means (not illustrated). Fuel discharged from chamber 23 passes through the discharge channel 24 which is preferably bored through the pump body and which extends centrally through the pump arm 16. For reasons which will hereinafter be more fully explained, the discharge channel is preferably of relatively small cross-sectional area so as to have minimum volume and in order to facilitate manufacture, the portion 24a of the discharge channel may advantageously be formed by a tubular element 25 seated in the bottom of a bore 26 of

relatively larger diameter which extends inwardly from the end of the arm 16. Insofar as the present invention is concerned, the element 25 may be considered as an integral part of arm 16.

The outer end of arm 16 is threaded as at 27 and threaded over this end of the arm is the annular clamping element 28 serving to releasably hold in position the injection nozzle 29 which has one or more orifices 30 for spraying fuel into the combustion chamber 14. Nozzle 29 comprises a tubular portion 31 and a base portion 32, the latter portion having a lug 33 thereon adapted to enter a suitable notch 34 in the end of the arm 16 to prevent turning of the injection nozzle rotationally from its proper position. The desirability of this arrangement is to prevent displacement from proper position of the orifice or orifices 30 which may be angularly disposed with respect to the longitudinal axis of the nozzle. The clamping element 28 may advantageously be provided with a sleeve portion 35 situated around nozzle 29 for protecting the nozzle against damage when the device is removed from the engine cylinder. The specific details of the internal construction of the nozzle form no part of the present invention and are not illustrated herein. I have found, however, that one very satisfactory type of nozzle to employ is that which is disclosed and claimed in U. S. Patent No. 1,888,082 granted to me November 15, 1932.

The outer portion of the bore 26 contains the valve mechanism and in the embodiment illustrated, the valve mechanism comprises two ball valves arranged serially with respect to flow of fuel to the injection nozzle.

Each of the ball valves comprises a tubular insert 36 located in the bore 26 and having a bore comprising spaced portions 37 and 38 of reduced diameter. The portion 37 of each insert provides a valve seat 39 engaged by a valve ball 40. Valve ball 40 is seated by spring 41, one end of which contacts the valve ball and the other end of which is guided in the portion 38 of the bore. As will be observed from the figure, the guided end of the left hand spring 41 abuts against the end of the adjacent or right hand insert 36 and the guided end of the spring 41 in this latter insert abuts against an annular collar or washer 42 inserted in the end of bore 26 and extending into a suitable recess in the flange portion 32 of nozzle 29. The washer 42 forms a convenient means for centering the nozzle 29 so that it will be in proper alignment with the outlet of the fuel discharge passage.

Turning to Fig. 2, there is illustrated a valve arrangement which is essentially the same as that shown in Fig. 1 but which because of the larger scale of the drawing permits clearer illustration of further details of the invention. In the structure shown in this figure, 43 indicates an outer valve casing which corresponds to the arm 16 in the arrangement shown in Fig. 1. Casing 43 is provided with a bore 26 with which the fuel discharge channel 24 communicates, and valve inserts 36 are situated in bore 26 as in the embodiment shown in Fig. 1. In the present embodiment, the injection nozzle 29' is provided with a base portion 44 threaded to engage suitable threads 45 in the outer end of the bore 26. This arrangement is suitable for an injection nozzle adapted to project fuel axially of the nozzle so that the exact position of the nozzle, rotationally, is immaterial.

Turning now more particularly to the details of the ball valves, which in the present embodiment are identical with the device shown in Fig. 1, it will be observed that the end of each of springs 41 which is in contact with a valve ball 40 is cut away inwardly so as to provide a surface 46 the contour of which is such as to give at least one line of contact between the surface and the ball which is a true circle normal to and concentric with the axis of the bore and consequently, concentric with respect to the circle representing the line of contact between the valve ball and the valve seat 39. Surfaces 46 are preferably spherically curved and have radii which are the same as the radii of the balls. Also springs 41 are preferably made with end surfaces normal to the axis of the springs and the springs are also preferably cut away inwardly to provide similar surfaces 46 at each end of each spring.

The portion 38 of the bore of each insert 36 is relatively short axially of the insert and preferably has a length approximately equal to the axial length of one turn of a valve spring 41. The external diameter of each spring 41 is substantially the same as the external diameter of the valve ball 40 which it contacts and is also substantially equal to the internal diameter of the portion 38 of the bore in which it is situated, this portion being just large enough to permit the valve ball to pass through it and providing a guide for holding the valve spring and the valve ball against any substantial lateral displacement.

As in the arrangement shown in Fig. 1, axial displacement of the spring in the inner insert is prevented by abutment of one end of this spring against the inner end of the outer insert, and axial displacement of the spring in the outer insert is prevented by abutment of the end of this spring against an adjacent member, which in the present instance is the base portion 44 of the injection nozzle.

The arrangement shown in Fig. 3 illustrates an injection nozzle device adapted to be used in an injection system in which the fuel pump is located at a point remote from the engine cylinder. In the embodiment illustrated, the body 47 of the device, which constitutes an outer valve casing, comprises a cylindrical portion adapted to engage the walls of bore 19 in the wall of cylinder 10 and having a shoulder adapted to engage a packing ring 21 seating against a suitable shoulder in the bore 19. The body or outer casing 47 is provided with a portion 48 of reduced diameter around which there is loosely mounted the externally threaded collar 49 which engages suitable threads 50 at the end of bore 19. Collar 49 is provided with a head 51 adapted to be engaged by a wrench or other suitable tool for screwing the collar into the bore. As will be evident from the figure, the body or casing 47 will be seated in the bore by the abutment of the end of collar 49 against the external shoulder on the casing 47.

A second collar 52 is pinned or otherwise suitably fixed on the portion 48 of the casing, this collar constituting a retaining member for holding the loose collar 49 in its proper position when the device is removed from the cylinder. A lug or other projection 53 on collar 52, adapted to engage a suitable slot 54 in the cylinder, provides convenient means for fixing the casing 47 in a predetermined position of rotation in the bore 19.

The construction of the casing 47 with respect to the bore 26 therein for receiving the valve inserts and also with respect to the manner in which the injection nozzle 29 is clamped to the end of the casing is similar to that previously de-

scribed in connection with Fig. 1 and the description thereof need not be repeated in detail. The inserts 36' are slightly different from the inserts illustrated in Figs. 1 and 2 in that the seats 39 are formed by pressing the balls against relatively sharp corners to provide the desired taper, rather than by making the inserts in the first instance with relatively long tapered portions adjacent the portions 37.

Fuel is supplied to the device through any suitable conduit such as the tubing indicated at 55, which is preferably detachably secured to the casing 47 by means of any suitable known form of connection or union conventionally represented at 56.

The operation of the above described arrangements as discharged valves and also as so-called injection nozzle valves for fuel injection systems will be largely obvious and requires no detailed explanation.

The advantages of the construction and the manner in which it meets the conditions existing in the systems of the type to which the invention relates will be briefly pointed out. It will be observed that the construction enables the valve balls to be placed very close to the point of fuel discharge from the injection nozzle. This results in the trapping of only a very small quantity of fuel between the nozzle outlet and the nearest check valve, which is important for a number of reasons. Fuel oil when subjected to high pressures is compressible to an appreciable extent and if the nearest check valve in the injection system, which may be the pump discharge valve, is remote from the injection nozzle, so that a relatively large quantity of fuel is in the discharge conduit between the nozzle and the valve, the high pressure developed in the engine cylinder on its working stroke may operate to so compress the fuel in the discharge line that combustion gases can enter the bore of the injection nozzle and cause difficulties due to carbonization of fuel within the nozzle. Furthermore, if the arrangement is such that the nearest valve in the discharge line is remote from the nozzle, the metering of the fuel with the degree of exactitude required is rendered difficult if not impossible. In the arrangement shown the possibility of the above difficulties is reduced to a minimum because of the extremely small volume of the discharge channel between the nozzle outlet and the nearest check valve.

The arrangement also provides for comparatively free and unobstructed flow of fuel through the discharge channel from the source of supply to the nozzle, without imposing in the line of flow any small or needle-like orifices which are likely to clog with impurities. It is evident that the ball type of valve provides much less likelihood of difficulty due to clogging than does a needle valve of equal flow capacity.

Although in solid injection systems, fuel is delivered at extremely high pressures, it has been found that with arrangements constructed in accordance with the present invention no packing members are necessary between the several separable elements in order to prevent leakage. The abutting surfaces of the inserts contacting each other and the walls of the outer valve casing form an effective seal preventing leakage of fuel around these parts and the integral outer casing which houses the valve parts obviously prevents external leakage. The only packing employed in the embodiments illustrated is that which is used between the outer valve casing and the wall of the cylinder to prevent leakage of combustion gases and in some forms of construction even this packing may be omitted, although it is generally preferable to employ it.

The particular spring arrangement used also contributes to improved operation of the device since the cutting away of the spring ends in contact with the valve balls, coupled with the guiding of the spring ends in the valve inserts, insures exact centering of the valve balls with respect to their seats. This in turn insures simultaneous engagement of the balls with their seats around the entire circumferences thereof and minimizes the possibility of wear of the seats or of the balls from their true contour. By guiding the springs in the manner illustrated, substantially the full length of each spring is free from frictional contact with any other element so that maximum effectiveness is obtained from a spring of given length and the possibility of sluggish action or sticking of the springs due to a contacting guide surface is eliminated. This is important because of the rapidity with which the valves must function when fuel is supplied therethrough to the cylinder of an engine operating at relatively high speed. The particular arrangement of the valve springs in the inserts also contributes toward minimizing the amount of fuel on the discharge side of the valves. By using cylindrical springs, shorter springs can be used for a given spring load than if conical springs were used and the use of cylindrical springs guided in the manner described permits the use of valve chambers on the discharge side of the balls having minimum volume.

The arrangement according to the present invention is furthermore extremely simple and provides a unitary structure readily removable from an engine cylinder and also capable of quick and convenient disassembly for cleaning or replacement of parts. The construction involves no delicate adjustments and it is practically impossible for the structure to be improperly assembled, particularly when, as is preferable, the ends of the valve springs are made alike so that it is immaterial which ends of the springs contact the valve balls.

The several arrangements described above all relate to discharge or injection valve devices and in these specific devices it is usually desirable on account of the high pressures involved to employ a series of valve balls rather than a single valve ball. In the specific examples described two valve balls have been employed but it will be evident that the number may be increased if desired, or if the pressures involved are relatively low, a single valve ball may be sufficient.

The advantages to be derived from the use of certain of the novel features of the construction are obviously not confined to discharge valve devices but may also be employed in connection with inlet valves. By way of illustration of this latter use, I have shown in Fig. 1 a valve arrangement similar to that previously described as employed for the inlet valve of the pump 13. In this pump fuel is admitted to the body of the pump through a suitable opening 57 and passes to the inlet chamber 58 within the body of the pump. The pump body is recessed at 59 to receive a valve insert 36 of the type already described and containing a valve ball 40 and spring 41. Insert 36 is retained in position by the annular collar or plug 60 threaded into the pump body and the bottom of recess 59 is connected by the inlet passage 61 with the pump chamber 23. For inlet valve purposes, one valve ball is ordinarily suffi-

cient. Removal of the insert 36 is advantageously facilitated by the provision of a suitable opening in the outer portion of the valve body through which the collar 60 and insert 36 may be removed, this opening being normally closed by plug 62.

From the foregoing description it will be evident that the invention is applicable to many different specific applications and that the form and arrangement of the parts in different installations may vary widely without departing from the scope of the invention. The invention also may be employed with any suitable mechaism for providing a properly metered and timed supply of fuel.

What I claim is:

1. In apparatus of the character set forth, a valve comprising an integral casing having a bore therein having a reduced portion providing a valve seat, a cylindrical helical spring in said bore, and a spherical valve ball in said bore between said spring and said valve seat, said spring urging said ball against said seat, said spring having a plurality of turns, said bore adjacent one or a relatively few turns of said spring remote from said seat being of a diameter substantially equal to the external diameter of the spring to guide the same, said bore being of greater diameter adjacent a relatively greater number of turns between the guided portion and the valve member, and said valve ball being of substantially the same diameter as the external diameter of the spring so as to barely pass through the bore at the place of guiding the spring.

2. In apparatus of the character set forth, a valve comprising an integral casing having a bore therein having a reduced portion providing a valve seat, a spherical valve ball adapted to engage said seat and a cylindrical helical spring engaging said ball at the end of the spring for urging said ball against said seat and having said end cut away inwardly to provide a spherically curved surface of contact with the ball, said surface being concentric about the axis of the spring and having the same radius as that of the ball, said bore adjacent the one turn of said spring remote from said seat being of a diameter substantially equal to the external diameter of the spring to guide the same, said bore being of greater diameter adjacent all of the remaining turns of the spring and said ball being of substantially the same diameter as the external diameter of the spring so as to barely pass through the bore at the place of guiding the spring.

3. In apparatus of the character set forth, a valve comprising an integral valve casing having a bore therethrough, said bore having axially spaced portions of reduced diameter and one of said portions providing a valve seat, a spherical valve ball adapted to engage said seat and a cylindrical helical spring for urging said valve toward said seat, said spring having an external diameter substantially equal to the diameter of the reduced portion of the bore remote from the seat, the length of the last mentioned portion of the bore being approximately equal to the axial length of one turn of the spring, the turn of the spring remote from said seat being situated in said last mentioned portion of the bore and guided thereby, the entire bore between said seat and said last mentioned portion being of greater diameter than the spring, and said valve ball being of substantially the same diameter as the external diameter of the spring so as to barely pass through the bore at the place of guiding the spring.

4. In apparatus of the character set forth, a valve insert comprising an inner casing having a smooth cylindrical outer surface and adapted to seat in a cylindrical recess within an outer casing, said inner casing having a bore therethrough coaxial with said cylindrical outer surface, said bore having axially spaced smooth cylindrical portions of reduced diameter, a circular valve seat between one of said portions of reduced diameter and an adjacent portion of the bore, a valve member having a circular portion adapted to engage said seat and a cylindrical helical spring for urging said valve member toward said seat, said spring having an external diameter substantially equal to the diameter of the reduced portion of the bore remote from said seat, the end of said spring engaging said valve member being formed to provide contact surface between the spring and the valve member symmetrical with respect to the common longitudinal axis of the spring and the casing and the end of the spring remote from the valve member being formed with a surface normal to said axis, the length of the portion of the bore of reduced diameter remote from the valve seat being situated in the last-mentioned portion of the bore and guided thereby, said spring being slidably removable from said inner casing through the last-mentioned portion of the bore and the end of the spring remote from the valve member being adapted to be retained in position by a member held within the outer valve casing and abutting against the end of the inner valve casing, the entire bore between said seat and the portion of reduced diameter remote from the valve seat being of greater diameter than the spring and said valve member being of substantially the same diameter as the external diameter of the spring so as to barely pass through the bore at the place guiding the spring.

5. In fuel injection apparatus, a casing adapted to be removably secured in a suitable bore communicating with the combustion chamber of an engine, said casing having a channel therethrough for flow of liquid fuel, said channel having a portion of enlarged diameter at one end, a plurality of tubular inserts removably secured in said portion, said inserts providing a channel therethrough coaxial with the first-named channel and in communication therewith and including spring-loaded valve means, and an injection nozzle having an open channel therethrough removably secured to the end of said casing adjacent to one of said inserts, said valve means being arranged to check the fuel supply to said nozzle, and means for attaching an oil supply line to said casing for delivery of oil to the first mentioned channel.

6. In fuel injection apparatus, a casing adapted to be removably secured in a suitable bore communicating with the combustion chamber of an engine, said casing having a channel therethrough for flow of liquid fuel, said channel having a portion of enlarged diameter at one end, a plurality of tubular inserts removably secured in said portion, said inserts providing a channel therethrough coaxial with said first-named channel and in communication therewith, spring-loaded valves in said inserts, an injection nozzle having a base portion adapted to be clamped to the end of said casing adjacent to said inserts and a tubular portion adapted to extend coaxially of said channel when the nozzle is in position, means for removably clamping said base portion to the end of said casing, said means

including a tubular extension surrounding the tubular portion of said nozzle to protect the same, and means for attaching an oil supply line to said casing for delivery of oil to the first named channel.

7. In fuel injection apparatus, a casing adapted to be removably secured in a suitable bore in the cylinder structure of an engine and communicating with the combustion chamber of the cylinder, said casing having a passage therethrough for flow of fuel, said passage having a portion of enlarged diameter at one end of the casing, a tubular insert removably mounted in said portion of said passage, said insert having a spring-loaded valve therein and having a passage therethrough in communication with the first-mentioned passage, a fuel injection nozzle adapted to be clamped to said one end of said casing, said nozzle having a discharge orifice angularly disposed with respect to the axis of said casing, means for clamping the nozzle to the casing, means for fixing the nozzle rotationally with respect to the casing, means for fixing the casing rotationally with respect to the engine cylinder structure, and means for attaching an oil supply line to said casing for delivery of oil to the first mentioned passage.

8. In fuel injection apparatus, a casing adapted to be removably seated in a suitable bore in the engine cylinder structure and communicating with the combustion chamber of the cylinder, said casing having a passage therethrough for flow of fuel, said passage having a portion of enlarged diameter at one end of the casing, a tubular valve insert in said portion of enlarged diameter, a spring-loaded valve in said insert, a fuel injection nozzle removably clamped to the end of said casing adjacent said insert and acting to retain said insert in position in the casing, said nozzle having a discharge orifice angularly disposed with respect to the axis of said casing, means for fixing the nozzle rotationally with respect to the casing, means for fixing the casing rotationally with respect to said cylinder structure, means cooperating with said casing and said cylinder structure for removably clamping said casing in said bore and means for attaching an oil supply line to said casing for delivery of oil to said passage.

9. In fuel injection apparatus, a casing having a portion adapted to engage the wall of a suitable bore in an engine cylinder structure communicating with the combustion chamber of the cylinder and portions of reduced diameter at either side of the first-mentioned portion, a channel for flow of fuel through said casing, a valve insert having a spring-loaded valve therein located in said channel, a fuel injection nozzle removably clamped to one of said portions of reduced diameter at the end of the casing adjacent said valve insert, said nozzle being rotationally fixed with respect to said casing and having a discharge orifice angularly disposed with respect to the longitudinal axis of the casing, a collar having external threads thereon, said collar embracing the portion of reduced diameter of said casing at the end thereof opposite the nozzle, said collar being adapted to be threaded into said bore to clamp said casing into position in said cylinder structure, and means for preventing rotation of said casing in said bore.

10. In fuel injection apparatus, a casing adapted to seat in a suitable opening communicating with the combustion chamber of an engine, said casing having a bore therein, a plurality of tubular inserts slidably mounted in said bore, each of said inserts having a bore therethrough comprising a portion of reduced diameter providing a valve seat, the bores in said inserts being in communication, a plurality of valve members each having a spherically curved surface adapted to engage one of said seats, a plurality of springs each having an end engaging one of said valve members to seat it, means comprising a fuel injection nozzle detachably secured to said casing for retaining said outer insert and its associated spring in position, there being a channel for admitting oil through said casing to the bore of the innermost insert inwardly of the valve seat therein and a channel for conducting oil from the bore of the outermost insert to said injection nozzle, and means for attaching an oil supply line to said casing for delivery of oil to the first mentioned channel.

11. In fuel injection apparatus, a casing adapted to seat in a suitable opening, said casing having a bore communicating with the combustion chamber of an engine therein, a plurality of tubular inserts slidably mounted in said bore, each of said inserts having a bore therethrough comprising spaced portions of reduced diameter, one of said portions providing a valve seat and the other of said portions providing a guide, the bores in said inserts being in communication, a plurality of valve members each having a spherically curved surface adapted to engage one of said seats, a plurality of springs, each of said springs engaging at its one end one of said guides and at its opposite end engaging one of said valve members, the outer insert acting to retain the adjacent insert and its associated spring in position, means comprising a fuel injection nozzle detachably secured to the end of said casing for retaining said outer insert and its associated spring in position, there being a channel for admitting oil through said casing to the bore of the innermost insert inwardly of the valve seat therein and a channel for conducting oil from the bore of the outermost insert to said injection nozzle, and means for attaching an oil supply line to said casing for delivery of oil to the first mentioned channel.

12. In fuel injection apparatus, a casing adapted to seat in a suitable opening communicating with the combustion chamber of an engine, said casing having a bore therein, said bore having a shoulder therein, a plurality of tubular inserts slidably mounted in axially abutting relation in said bore, each of said inserts having a bore therethrough comprising spaced portions of reduced diameter, one of said portions providing a valve seat and the other of said portions providing a guide, the bores in said inserts being in communication and the innermost insert seating against said shoulder, a plurality of valve members each having a spherically curved surface adapted to engage one of said seats, a plurality of springs, each of said springs engaging at its one end one of said guides and at its opposite end engaging one of said valve members, the outer insert acting to retain the adjacent insert and its associated spring in position, a fuel injection nozzle having a recessed base portion, an annular member adapted to engage the end of the bore in said casing and a recess in said base portion for centering the nozzle with respect to the bore, a member for detachably securing the injection nozzle to the end of said casing, said nozzle and said members constituting means for retaining said outer insert and its associated spring in position, there being a channel for admitting oil through

said casing to the bore of the innermost insert inwardly of the valve seat therein and said annular member providing a channel for conducting oil from the bore of the outermost insert to said injection nozzle, and means for attaching an oil supply line to said casing for delivery of oil to the first mentioned channel.

13. In fuel injection apparatus, a casing adapted to seat in a suitable opening communicating with the combustion chamber of an engine, said casing having a cylindrical bore therein at its outer end, said bore having an inlet for liquid fuel at its inner end, a plurality of tubular valve inserts slidably mounted in said bore, each of said inserts containing a spherically curved valve and a spring for seating the valve, the outer insert being closely adjacent to the outer end of said bore and acting to retain the adjacent insert and associated spring in position, means including an injection nozzle detachably secured to the outer end of said casing for retaining said outer insert in position, said nozzle having a discharge orifice angularly disposed with respect to the longitudinal axis of the nozzle and said means including a part for fixing said nozzle rotationally with respect to said casing, means associated with said casing for fixing the casing rotationally with respect to the engine cylinder, and means for attaching an oil supply line to said casing for delivery of oil to said inlet.

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