United States Patent

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[54] **INTERNAL COMBUSTION ENGINE WITH AN AIR INLET VALVE AND A FUEL INJECTION VALVE**

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[51] **Int. Cl.**.....**F02b 3/00**

[58] **Field of Search**.....123/32 VN

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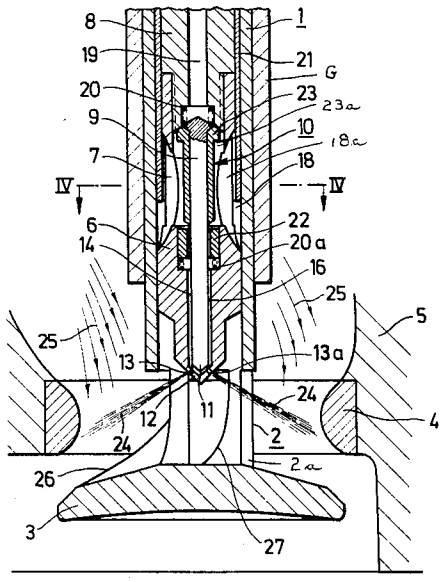
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[57] **ABSTRACT**

An air inlet valve and a fuel injection valve cooperate with a common combustion chamber of an internal combustion engine cylinder to supply a mixture of air and fuel thereinto in properly timed relation. The air inlet valve comprises a valve body covering with a valve seat for controlling inlet of air into the combustion chamber and having a hollow valve stem, the fuel injection valve being disposed for operative movement in said stem to inject fuel into the combustion chamber when the inlet valve is opened.

16 Claims, 8 Drawing Figures



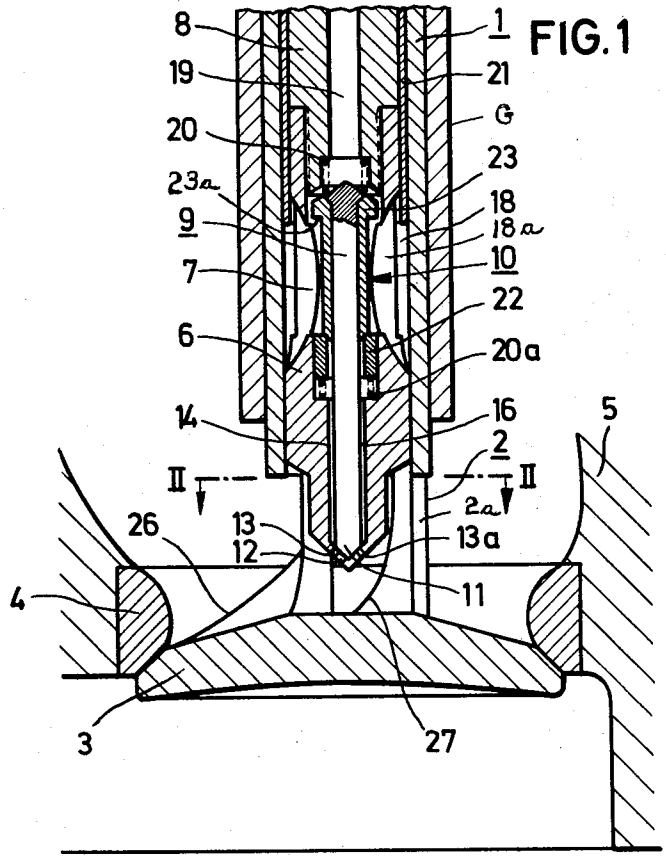


FIG.1

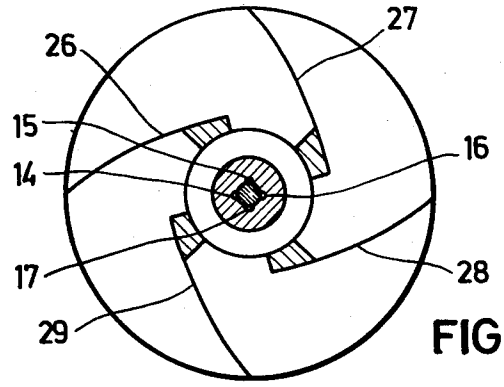


FIG.2

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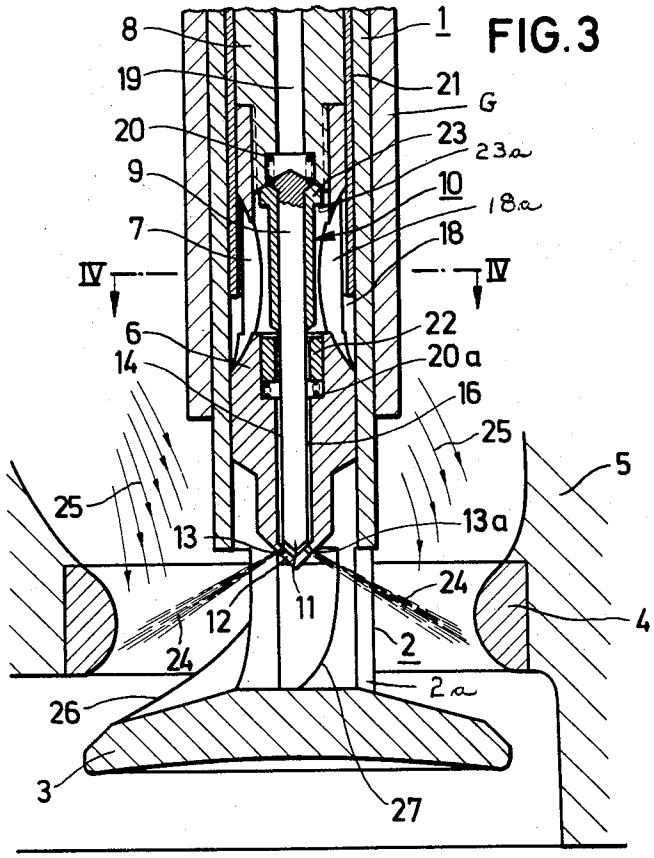


FIG.3

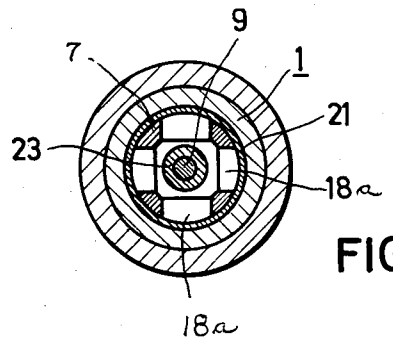


FIG.4

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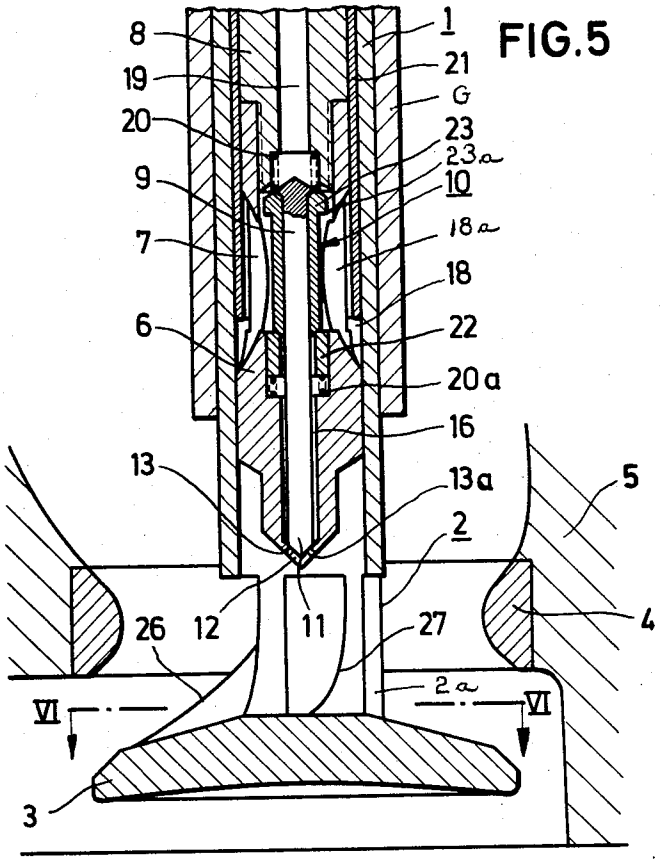


FIG.5

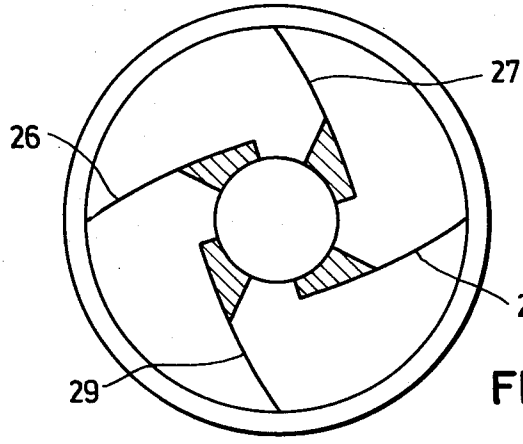


FIG.6

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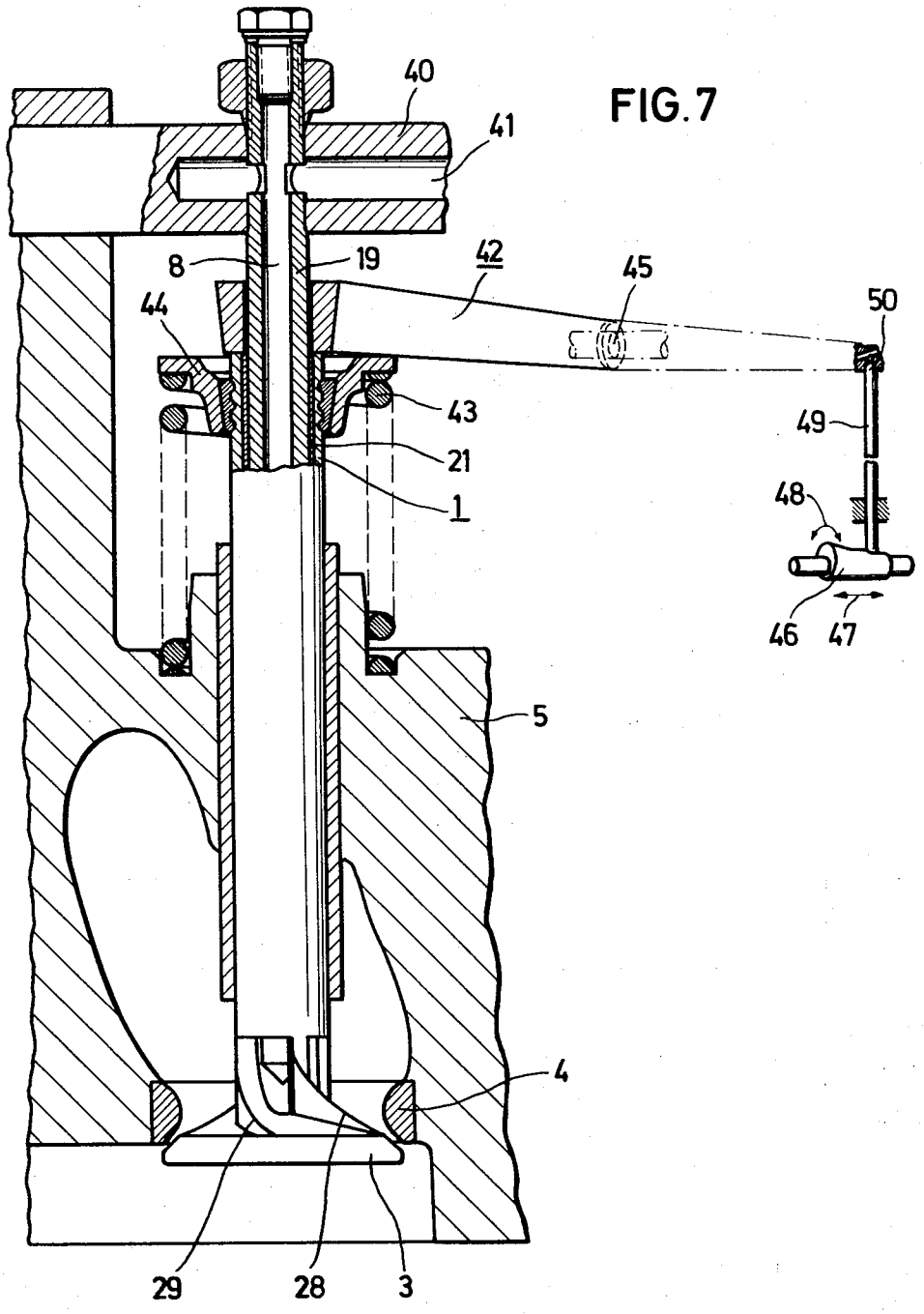
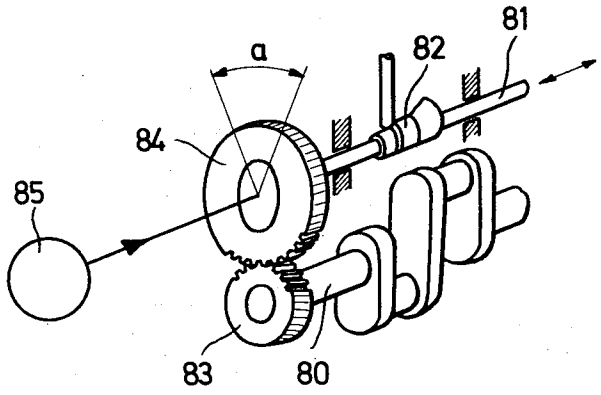


FIG. 7

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FIG. 8



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INTERNAL COMBUSTION ENGINE WITH AN AIR INLET VALVE AND A FUEL INJECTION VALVE

This invention relates to an internal combustion engine of the type which employs an air inlet valve and a fuel injection valve, both of which are associated with the combustion chamber of a cylinder and in which the air inlet valve contains a valve body cooperating with a valve seat and supported on a movable valve stem. The features of the invention can be used both in reciprocating internal combustion engines as well as in diesel engines. The invention is intended primarily for use with motors for motor vehicles, but can also be used advantageously in other applications, for example, in connection with stationary engines.

Internal combustion engines with air inlet valves and fuel injection valves have heretofore been known, for example, in a form where separate such valves have been provided, whereby the air inlet valve has been disposed directly on the cylinder head, while the fuel injection is accomplished in the area of the intake manifold at a location remote from the air inlet valve. Such relative spacing of the valves has the effect of creating a buffer chamber between the place of injection and the entrance of the intake manifold into the combustion chambers of the respective cylinders and may lead to disturbing uncertainties in regard to the actual time of injection, that is to say, the time at which the fuel actually reaches the respective combustion chambers.

In certain special engines and particularly in diesel engines, it has been known to provide for a direct injection of of fuel into the combustion chamber under pressure. This measure, however, is disadvantageous because of the fact that the film of lubricating oil on the cylinder wall of the engine may be washed away by the injected fuel.

An important object of the present invention is the creation of a universally usable internal combustion engine, which will avoid the disadvantages above enumerated of the prior art and which, moreover, will have further advantages, especially in the field of simplified construction and operation. The internal combustion engine, according to the invention, is characterized in that the valve stem of the air inlet valve is hollow and the fuel injection valve and passages have been disposed in it.

In accordance with the invention, therefore, the air inlet valve and the fuel injection valve are combined into a common constructional unit. This offers the advantage that the place of fuel injection and thus the time of injection are clearly defined. The undesirable washing away of lubricating oils and the repeated local impingement of fuel on certain areas of the cylinder and piston will be avoided, especially when, according to the preferred embodiment of the invention, the valve body is disposed inside the combustion chamber and the injection nozzles of the fuel injection valve are provided in an area of the valve stem adjacent to the valve body. In this embodiment, therefore, the valve body, preferably in the form of a valve head, will be disposed within the combustion chamber for cooperation with a seat in an internal wall of the cylinder or the cylinder head, and the injection nozzles, as viewed from the combustion chamber, lie outwardly of the combustion chamber beyond the valve body. The outwardly

directed surface of the valve body will be formed to assure a turbulent motion and intermixing of the air and fuel flowing into the combustion chamber. This can be achieved in a relatively simple manner, for example by providing generally spirally arranged swirl surfaces or twisted edges on the upper surface of the valve body, radiating from the valve stem.

The hollow valve stem adjacent to the valve body may be formed with radial ports, between which are disposed angularly spaced sectors of the valve stem, hereinafter sometimes referred to as braces, by which the valve stem is fixedly connected to the valve head. With this arrangement, the inflow of the fuel through the nozzle in the fuel injection valve is free and unimpeded.

The injection valve may contain a nozzle head inserted in fluid-tight sliding relation in the hollow valve stem and having injection nozzles and a locking ram, the latter being operatively movable inside said nozzle head, either to close and isolate the injection nozzles from the fuel supply or to place them in communication with the fuel supply.

Thus, the nozzle head is connected to a valve rod within the valve stem, the valve rod and therefore the head being suitably secured against axial movements, as by connection of the valve rod to a distributor shaft on the cylinder head.

The present invention is distinguished by the fact that a pump chamber for the fuel to be injected as well as a check valve have been disposed between the nozzle head with its injection nozzles and the valve rod within the valve stem, the arrangement being such that the check valve connects the pump chamber with the injection nozzles only during the suction cycle of the engine, and during other operational cycles connects it only with the fuel supply. While the injection of a definite quantity of fuel will be assured by the pump chamber, the provision of the check valves serves the purpose of preventing delivery of fuel into the cylinder by interruption of the connection between the fuel supply on the one hand and the nozzle head on the other.

The pump chamber may be formed within the hollow stem by a radially constricted portion of the nozzle head immediately below its connection with the valve rod.

A particularly advantageous feature of the invention is the arrangement of the cam shaft for adjustment both axially in accordance with the position of the gas control lever and also for angular advance or retardation as may be desirable to adapt to changing loads on the engine. The cams of the cam shaft are formed with cam surfaces which are profiled both axially and circumferentially. This feature offers the possibility of varying the time of the fuel injection, both in accordance with the position of the throttle valve and also in accordance with the load on the engine.

Additional features and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 presents a diagrammatic sectional view of a portion of a reciprocating internal combustion engine including a portion of the combustion chamber and the intake and fuel injection valves associated therewith, the intake and injection valves both being closed.

FIG. 2 is a cross-section on the line II—II of FIG. 1.

FIG. 3 is a view similar to FIG. 1, but with the intake and injection valves in their open positions during the suction cycle of the combustion chamber.

FIG. 4 is a cross-section on the line IV—IV of FIG. 3.

FIG. 5 is a view similar to FIGS. 1 and 3, but with the valves in the positions which they occupy immediately after conclusion of the suction cycle.

FIG. 6 is a section on the line VI—VI of FIG. 5.

FIG. 7 is a diagrammatic view, partly in elevation and partly in section, and including the mechanism for operating the valves; and

FIG. 8 is a fragmentary diagrammatic perspective view of the cam shaft of an engine to which the engine is applied and its associated driving and adjusting means.

The structure of the preferred embodiment of the invention given by way of example, will now be explained. The elements of the invention are designated in the various figures by the same reference numerals.

The valve arrangement comprises: The valve stem **1**, having an end portion **2** thereof formed with radially directed ports or openings **2a** adjacent to the valve body **3**, which is in the form of a valve head, and which cooperates with the valve seat **4**, which defines an intake port or opening in the cylinder head **5** of the engine. Valve stem **1** is guided for lengthwise movement through a guide sleeve G, affixed to the cylinder head **5** as in FIG. 7. As is shown in FIGS. **1**, **3**, **5** and **7**, the valve stem **1** is hollow and houses therewithin the fuel injection valve, whose primary components are the nozzle head **6**, the internally threaded upper portion of which is threaded onto and supported by the lower end of the valve rod **8**, the head **6** being formed with a radially constricted or reduced portion or area **7**, spaced inwardly from the wall of the tubular stem **1** to form therewith a pump chamber **18** and having radial ports **18a** opening from the hollow interior of the nozzle head **6** into the pump chamber **18**. It will be noted that the upper end of the hollow nozzle **6** communicates, under the control of the double acting ram or valve body **10**, with the fuel passage **19** through the valve rod **8**. The double acting valve body **10** of the check valve is carried by the locking ram **9** which, in turn, is slidably disposed in the nozzle head **6** for movement in an axial direction.

During operation of the engine, when the injection valve is closed, as in FIG. **1**, the locking ram **9** has its lower conical end **11** in engagement with a mating conically recessed seat **12** of the nozzle head **6**, through which seat the fuel injection nozzles **13** and **13a** have been provided for the injection of fuel. When the conical end **11** of the locking ram thus engages the conically recessed seat **12** of the nozzle head, it covers and closes the injection nozzles **13** and **13a**. There may be a suitable number of such nozzles which are disposed substantially perpendicularly through the downwardly directed face of the conical seat **12**.

When the locking ram **9** is raised from its seated position shown in FIG. **1**, to the position shown, for example, in FIG. **3**, it uncovers nozzles **13** and **13a** to place these nozzles in communication with the fuel channels **14**, **15**, **16** and **17**, best shown in FIGS. **1** and **2**. The result of this is that, as is shown in FIG. **3**, the double acting valve body **10** of the check valve will move upwards to close the lower end of the fuel passage **19** and thus disrupt or discontinue the communication between the pump chamber **18** and the fuel line **19**. For this purpose, the double acting valve body **10** is acted upon by two relatively opposed compression springs **20** and **20a**, the upper spring **20** of which is stronger than the lower spring **20a**. Thus, the pressure of the fuel in the line **19**, together with over-powering pressure of the spring **20** will normally tend to maintain the double acting valve body **10** and the locking ram **9** in the position shown in FIG. **1** to close the injection nozzles **13** and **13a**. However, as soon as the cylindrical pump piston **21**, shown in FIG. **1**, is moved downwardly with the surrounding valve stem **1** for a sufficient distance, it increases the pressure of fuel within the pump chamber **18** to an amount sufficient to move the valve body **10** upwardly by pressure on the downwardly directed shoulder of its radial flange or projection **23a**. The resulting upward movement of valve body **10** carries with it the locking ram **9** to unseat the end **11** of the locking ram from the conical valve seat **12**, and to uncover nozzles **13** and **13a**. In addition to its main portion **10**, the double acting valve body has associated therewith an annular member or portion **22** having a larger external diameter than the adjacent portion of the valve body **10**, so that the cylindrical piston **21** which moves with the valve stem **1**, controls the operation of the check valve and thus of the injection valve in the preferred embodiment here illustrated. Piston **21** is fixed to the valve stem **1** for axial movement therewith relative to the injection valve **6**, which is supported from the fixed valve rod **8** by means of the radially ported and radially constricted upper end portion **7** of the nozzle head **6**. The movement of the valve stem **1** and piston **21** is coupled with the operation of the air inlet valve **3**.

As indicated in FIG. **3**, after uncovering the nozzles **13** and **13a**, the fuel flows freely through such nozzles in the form of jets **24** which are directed diagonally downwardly through the ports **2a** of the valve stem and through the intake port of the cylinder defined by the valve seat **4** for entrainment in the inflowing air indicated by the arrows **25** in FIG. **3**.

The radially constricted and ported section **7** of the nozzle head **6** is shown in cross-section in FIG. **4**, wherein the ports **18a** open radially outwardly through said section **7** into the pump chamber **18**.

The mode of operation of the invention is as follows:

When the intake valve **3** is closed, as in FIG. **1**, the nozzles **13** and **13a** are covered by the locking ram **9** which is in its lowered and seated position so that no fuel can flow through these nozzles. Correspondingly, the double acting ram **10** is also in its lowest position and seated against the member **22** to prevent any backflow of fuel from the fuel channels **14** to **17** as the result of suction or under-pressure occurring in the pumping chamber **18**.

When the suction cycle of the cylinder is initiated by the downward movement of the valve stem **1**, together with the valve head **3** and cylindrical piston **21**, as shown in FIG. **3**, then, in consequence of the relatively high pressure occurring in the pumping chamber **18**, the enlarged piston like head or flange **23** of the double acting ram **10** is moved upwardly by such pressure counter to the action of the spring **20** and unseated from member **22** to permit flow of fuel from the pump

chamber **18** to the fuel channels **14** through **17**, and the pressure reliefdmember or valve **22** is moved downwardly by the fuel pressure against the action of spring **20***a*. The precisely defined quantity of fuel contained in the pumping chamber **18** is delivered through channels **14** through **17** to the nozzles and is sprayed outwardly through the nozzles **13** and **13***a* as jets **24**, as in FIG. **3**, both by the compressive action of the cylindrical piston **21** and by the suction within the engine cylinder, the jets of fuel **24** being mixed with the inflowing air **25** by the spirally arranged swirl surfaces **26** to **29**, respectively, on the upper or outer face of the intake valve **3**.

As soon as the pressure in the pumping chamber **18** is reduced at the completion of the suction cycle and the pump chamber **18** has been emptied, the double acting valve body **10** of the check valve will return to its starting position as shown in FIG. **5**, even prior to the closing of the air inlet valve, or, in other words, before the valve head **3** seats against the valve seat **4**. Again, therefore, the pumping chamber **18** is connected only with the fuel supply line **19**, while its connection with the fuel channels **14** to **17**, inclusive, leading to the nozzles **13** and **13***a*, is interrupted by seating of the valve body **10** on the upper end of the pressure relief valve **22**. Thus, the pumping chamber **18** will be filled again with fuel from the fuel passage **19** in readiness for the next suction cycle.

Since the locking ram **9** will also have returned to its seated position, it will be impossible for any fuel retained in the channels **14** to **17** to be discharged through the nozzles **13** and **13**a, prior to the next cycle of operation.

FIG. **7** shows diagrammatically a preferred form of actuating means for the valve assembly above described. As mentioned above, valve rod **8**, defining therewithin the fuel supply channel **19** extends upwardly through the upper end of the valve stem **1** and is secured to the cylinder head distributor shaft **40**, which, in turn, contains a channel **41** through which fuel is delivered under pressure into the supply passage **19** in a manner to avoid the formation of bubbles in the fuel.

For driving the valve stem **1** and the cylinder pump piston **21**, there is provided a rocker arm **42** in combination with the valve spring **43** which is compressed between the retainer attachment **44** fixed on the valve stem **1** and the cylinder head **5**. The valve spring **43**, therefore, resiliently urges the valve stem **1** and the cylindrical pump piston **21** upwardly.

The rocker arm **42**, which is suitably fulcrumed at **45**, is oscillated angularly about its fulcrum by a cam **46** on rotating cam shaft **81**. According to the invention, the cam **46** is movable in two directions, i. e. it is movable in the direction of its axis of rotation, as indicated by the double arrow **47**, as determined by the position of the gas lever or throttle, and may be advanced or retarded angularly in its rotation about its axis, as indicated by the double arrow **48**, in accordance with the load on the engine. The surface of the cam **46**, therefore, is profiled both axially, in the direction of arrows **47** and circumferentially in the direction of arrow **48**, (see FIG. **7**) and is operatively engaged by the cam follower **49** which, in turn, is connected to the rocker arm **42** at **50** to angularly position the rocker arm in response to the angular and axial movements of the cam **46**.

The operation of cam **46** may be achieved in simple manner through helical gears **83** and **84** employed for transmission of rotation from the crankshaft **80** of the engine to the camshaft **81**, as shown diagrammatically in FIG. **8**, wherein the camshaft **81** is supported for rotation and for axial shifting movement together with the gear **84** affixed to it. As a result, the required rotary retardation or advancement of the cam **81**, in accordance with the load imposed on the engine, may be assured through the use of a servo motor **85** which is responsive to such loading to shift the camshaft **81** accordingly.

More specifically, and as is illustrated in FIG. **8**, the crankshaft **80** and the camshaft **81** are interconnected by the two helical gears **83** and **84**. The camshaft **81** is slidable axially in relation to the crankshaft **80** as by means of the servo motor **85**, which is controlled in response to loading of the engine, as a result of which, because of the helically arranged intermeshing teeth of the gears **83** and **84**, there is produced a relative angular movement between the said gears which serves to relatively advance or retard the rotary movement of the camshaft **81**.

Having thus described our invention, we claim:

1. For use in an internal combustion engine, valve mechanism including an air intake valve comprising a valve head and an elongated, hollow, cylindrical, axially shiftable valve stem connected to the head for shifting the latter between open and closed position in response to axial movement of the stem, and a fuel injection valve disposed within said hollow stem, said fuel injection valve comprising:

a nozzle head structure mounted in said stem for axial movement relative thereto, said structure being disposed in spaced relationship relative to said valve head in a direction axially of the stem to present a hollow space in the stem between the valve head and the structure, there being at least one fuel injection port in said air intake valve intercommunicating said hollow space and the area surrounding the air intake valve,

said nozzle head structure comprising a nozzle head element disposed adjacent said space, a fuel inlet element disposed in axially spaced relationship relative to said head element and means rigidly interconnecting said elements to present a fuel metering chamber having generally fixed dimensions in said stem therebetween,

there being at least one injection nozzle passageway extending through said nozzle head element for normally intercommunicating the space and the chamber and a fuel inlet passageway extending from the fuel inlet element and into the chamber;

rod means connected to said nozzle head structure for holding the same motionless relative to the stem when the latter is shifted axially;

piston means carried by the valve stem and extending into said chamber for reducing the volume of the latter when the valve stem is moved axially relative to the nozzle head structure in a direction to open the air intake valve; and

metering valve mechanism including a double acting valve body mounted in said chamber for move-

ment between an injection nozzle passageway closing position and a fuel inlet passageway closing position, there being pressure responsive means on the valve body for moving the latter toward its fuel inlet passageway closing position in response to an increased pressure in said chamber resulting from a reduction of the volume thereof by virtue of the axial movement of the stem in said direction to open the air intake valve, whereby a metered quantity of fuel is discharged through the injection nozzle and said port when the air intake valve is opened.

2. Valve mechanism as set forth in claim 1 wherein is included pressure relief means disposed in said chamber and operable for increasing the volume of the latter in response to the development of an excessive pressure therein.

3. Valve mechanism as set forth in claim 1 wherein said port extends through the wall of the valve stem adjacent said valve head.

4. Valve mechanism as set forth in claim 3 wherein the surface of the valve head adjacent said port is characterized by a surface formation in the form of twisted edges shaped to cause thorough mixing of air and fuel.

5. Valve mechanism as set forth in claim 1 wherein said piston means includes a cylindrical piston disposed in surrounding relationship to said fuel inlet element and having an end portion extending into said chamber.

6. Valve mechanism as set forth in claim 5 wherein said injection nozzle passageway and said fuel inlet passageway are generally axially aligned and said double acting valve body is axially elongated and shiftable in an axial direction.

7. Valve mechanism as set forth in claim 6 wherein said nozzle head element includes means presenting a central, axially extending recess extending toward and terminating in communication with said injection nozzle passageway, said double acting valve body including an elongated extension received in said recess, said body and said recess being configured to present at least one axially extending fuel channel therebetween normally intercommunicating said injection nozzle passageway and said chamber.

8. Valve mechanism as set forth in claim 7 wherein is included a plurality of said injection nozzle passageways, the portion of said recess adjacent said passageways being defined by wall means having a conical configuration, said nozzle passageways extending from said adjacent portion of the recess and generally perpendicularly through said wall means.

9. Valve mechanism as set forth in claim 8 wherein the elongated extension of the double acting valve body is provided with a conically configured terminus which is complemental in shape to said portion of the recess adjacent said nozzle passageways whereby the latter are closed when said conical terminus is forced against the wall means defining the conical portion of the recess.

10. Valve mechanism as set forth in claim 7 wherein said double acting valve body includes a portion at the opposite axial end thereof from said extension which is larger in diameter than the latter, said portion including an end element complementally configured to mate with the end of said fuel passageway which opens into the chamber to prevent fuel from entering the chamber.

11. Valve mechanism as set forth in claim 10 wherein is included means for yieldably biasing said double acting valve body in an axial direction toward the injection nozzle passageway and away from the end of the fuel inlet passageway, said double acting valve body including an annular abutment adjacent said end element thereof, said abutment being disposed generally in a plane perpendicular to the axis of the stem and facing into said chamber to present said pressure responsive means for forcing said valve body toward the end of the fuel passageway against the bias of the yieldable biasing means when the pressure in the chamber is increased beyond a predetermined level.

12. Valve mechanism as set forth in claim 11 wherein is provided means presenting an enlarged annular space surrounding said recess and communicating with said chamber, there being an annular pressure relief valve element disposed in said annular space in surrounding relationship to said elongated extension and spring means urging said element toward said chamber and into sealed contact with said portion of the valve body, said relief valve element being larger in diameter than said portion and operable to be shifted into the annular space to increase the volume of the chamber when the pressure in the latter exceeds a predetermined level.

13. Valve means as set forth in claim 1 wherein said engine includes a camshaft mounted for both axial and angular movement and a cam lobe on the camshaft configured to transmit axial movement to a valve stem in operable connection therewith in response to either axial or angular movement of the camshaft, said valve stem being in operable connection with said lobe.

14. Valve means as set forth in claim 1 wherein said engine includes a distributor shaft, said rod means being connected to the distributor shaft and being held thereby to prevent axial movement of the nozzle head structure with the valve stem.

15. Valve mechanism as set forth in claim 1 wherein said rod means and said fuel inlet element are interconnected, said rod means having an axial bore therethrough presenting said inlet fuel passageway.

16. Valve mechanism as set forth in claim 4 wherein said surface comprises helically inclined surface portions.

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