

A fuel injector for an internal combustion engine

The present invention relates to a fuel injector for an internal combustion engine, particularly a two-stroke crosshead engine, having an outer housing with
5 a mounting flange at its back end and an injection nozzle protruding from the housing at its front end, and a fuel passage extending centrally in the injector, the fuel passage passing from the mounting flange through at least one thrust piece, a central fuel tube, a
10 spindle and a spindle guide and ending in the injection nozzle, the spindle guide having a central bore the circularly cylindrical inner surface of which constitutes the guide surface for the spindle, the fuel tube having a front section extending more than halfway down
15 into the central bore of the spindle guide and having a smaller external diameter than a back section and at the transition between the two sections an annular surface facing axially in the direction of the injection nozzle, and a back spring guide for a pre-tensioned
20 closing spring, the spindle having a central bore open to the back in which the front section of the fuel tube is inserted, and a front spindle section with a valve needle which cooperates with a stationary seat surface in the bore of the spindle guide for opening and closing
25 the injector, and a front spring guide for the closing spring, the spring guide being located in a back spindle section protruding from the bore of the spindle guide and the closing spring biasing the spindle forwards in the closing direction, and at the back end of the
30 spindle an annular end surface which is made to abut the annular surface of the fuel tube by the backward opening movement of the spindle, the spindle guide being pressed forwards in the injector housing by at least one thrust bushing abutting an annular surface facing backwards on

the spindle guide and extending backwards past the closing spring, and the thrust piece being pressed forwards by the mounting flange at assembly of the injector with simultaneous compression of the closing
5 spring.

Such a fuel injector is known from DK-B-155757, which describes an injector for injection of readily ignitable pilot oil and gaseous fuel. The thrust bushing here acts as a guide for an external valve slide for
10 opening and closing the gas supply. At its back end the fuel tube acts as a valve housing for a venting valve and thus extends integrally along the main part of the injector length. The spindle for opening and closing of the pilot oil is designed with a relatively large
15 clearance between both the fuel tube on the inside and the bore of the spindle guide on the outside to prevent the spindle from getting caught or being worn unevenly because of alignment inaccuracies between the elongated fuel tube and the bore of the spindle guide.

20 DK-B-167502 (EP-A 0 606 371) teaches a fuel injector in which the closing spring is received in a central cavity in the slide guide, and a central fuel tube is formed integrally with the back section of the slide guide. Also this case requires a relatively large
25 clearance between the bottom section of the spindle and the bore in the slide guide and the front section of the fuel tube, respectively, to compensate for manufacturing tolerances and consequent lack of complete coaxiality between the fuel tube and the bore in the slide guide.

30 A further injector of a somewhat different design is known from DE-A-2030445, in which a hollow spindle with a relatively thin wall thickness slides in the annular space between a fuel tube and a bore in the spindle guide. The back end of the spindle has a very
35 heavily formed front spring guide for the closing

spring. The opening movement of the spindle is here limited by the fact that at its largest diameter the back surface of the spring guide hits a projection in the injector housing. This imparts a bending moment to the thin spindle wall resulting in the wall bending outwards. To avoid the spindle getting caught a relatively large clearance is required between the spindle and the annular surfaces on both sides of it. The fuel tube is bipartite with the joint face located above the back spring guide. At assembly of the injector there is no element to provide an initial positioning of the two tube parts just before the tubes are pressed together, and there is therefore a risk of erroneous positioning of the abutment surfaces of the tubes. Thus, leaks may occur at the joint face, which will result in variations in the fuel volumes injected. It is a further disadvantage of this injector that the pre-tensioning of the compression spring is determined by how far the thrust piece is clamped down into the injector housing. Consequently variations will occur in the opening pressures of a number of identical injectors.

The known fuel injectors of the type which has a hollow spindle arranged between a central fuel tube and a bore in the spindle guide provide the advantage that the mass of the movable spindle is substantially smaller than is the case with solid spindles, and the relatively small mass of the movable part of the injector promotes rapid valve movements. However, hollow spindles suffer from the disadvantage that they slide between two annular surfaces, which entails a risk of the spindle getting caught if the spindle wall becomes deformed. To counter this and to compensate for said lack of coaxiality, the clearance between the spindle and the adjacent annular surfaces is relatively large, entailing the possibility that the spindle becomes slightly displaced

in the transverse direction into a slightly eccentric position in which the clearances between the spindle and the spindle guide bore and the fuel tube, respectively, are larger on one side than on the other side of the longitudinal axis of the injector. Although the transverse displacements are very small, they result in variations in the volumes of fuel leaking up through the clearances during an injection sequence. When the spindle is arranged completely coaxially, the leakage volumes may be from 50 per cent to 70 per cent smaller than at a transversely displaced position of the spindle, and consequently at different injections of fuel with the same valve and unchanged injection parameters, such as the delivery pressure and volume of the fuel to the injector, variations will occur in the volumes of fuel actually injected. Variations will also occur in the injected fuel volumes from several different injectors, although they have identical settings and are supplied with fuel in the same manner.

20 The object of the present invention is, in a fuel injector of the type mentioned in the introduction, to improve the reproducibility of the injected fuel volumes and to achieve a more exact control of the injection sequence.

25 In view of this the fuel injector according to the invention is characterized in that the external diameter of the back spring guide of the fuel tube is smaller than the internal diameter of the thrust bushing, that the fuel tube is a separate unit exclusively contacting the valve member located behind it through an abutment surface which is arranged on the back surface of the back spring guide and has an annular surface encircling the central fuel passage and being substantially perpendicular to the longitudinal axis of the injector, and that in the front spindle section inserted in the

spindle guide bore, the spindle has an external diameter being at the most 8 μm smaller than the internal diameter of the spindle guide bore, and an internal diameter being at the most 8 μm larger than the external diameter of the front section of the fuel tube.

With this design of the spindle being only slightly larger than the fuel tube and slightly smaller than the slide valve bore, its possibility of transverse displacement between different injection sequences is substantially limited, typically to less than half the displacements that occur in the prior-art injectors of this type. As the fuel leakage is substantially hindered by the fluid friction against the cylindrical surfaces, even a minor restriction of the largest possible clearance between the surfaces provides a noticeable reduction of the variations in the leakage volumes. The more uniform volumes of injected fuel thus obtained promote a more accurate combustion with the desired energy development, reduce the fuel consumption of the engine and increase the possibility of limiting the development of undesired emission products harmful to the environment, such as NO_x , and also the thermal load on the cylinder members and deposition of combustion residues on them can be controlled better. This is especially advantageous in large two-stroke diesel engines that often combust fuel of a very poor quality.

It is a condition for the narrow fits between the spindle and the fuel tube and the spindle guide bore, respectively, that the three valve members are precisely aligned mutually when the injector operates. Contrary to prior-art injectors even small inaccuracies in the alignment between the three valve members or non-uniform load on the spindle of the present tubular thin-walled type will lead to non-uniform wear on the spindle and/or to its becoming caught, for example as a result of small

outward bends in the spindle wall. This has been avoided by the invention by separating the fuel tube from the valve member behind it so that the fuel tube only contains the section of the fuel passage extending from the back spring guide of the closing spring and down inside the spindle. At assembly of the injector parts in the injector housing the spindle can be inserted in the spindle guide, the fuel tube with the closing spring can be mounted on the spindle, the thrust bushing can be pushed down around the back end of the spindle guide, and then the injector housing with these injector parts can be oriented with a vertical centre axis. The fine fits between the spindle, the spindle guide and the fuel tube mean that at the orientation with a vertical centre axis and no load, the parts will mutually adjust coaxially whereupon the other valve members are inserted into the housing and the mounting flange is clamped on. When the other members are mounted, the valve member located behind the fuel tube is inserted into the thrust bushing before the member is moved forwards close to the fuel tube. This provides an initial guiding of the member and prevents transverse displacement thereof at the moment when it is brought into contact with the fuel tube. At the continued clamping of the injector, the valve member is pressed downwards into abutment with the upward annular abutment surface on the fuel tube so that owing to the friction between the abutment surface and the valve member, the position of the fuel tube is fixed correctly with a suitable coaxiality in relation to the spindle guide. It is of importance for the correct position fixation of the fuel tube that the abutment surface is substantially perpendicular to the longitudinal axis of the injector so that transverse guide forces are not applied to the abutment surface at the assembly. For the same reason there has to be a clearance between

the back spring guide and the thrust bushing so that the spring guide is not prevented from adjusting correctly by hitting the thrust bushing.

Preferably the external diameter of the front spindle section is from 2 to 4 μm smaller than the internal diameter of the spindle guide bore, and the internal diameter of said spindle section is from 2 to 4 μm larger than the external diameter of the front section of the fuel tube. With these narrow fits, variations in the leakage volumes are largely eliminated, and the clearances between the movable spindle and the stationary spindle guide and the fuel tube are just large enough for the spindle to be longitudinally displaced without any problems.

In a further preferred embodiment, there is a substantially larger diameter difference between the inner spindle surface and the outer fuel tube surface from the back end of the spindle and at least until the front spring guide, preferably until the front spindle section located in the spindle guide bore, than in the spindle section positioned in front. For example in the back spindle area there may be a clearance between the spindle and the fuel tube which is 0.1 mm larger than the clearance between the two parts in the front spindle section. The effect of this is that in the longitudinal ring slits on the outer and inner surfaces of the spindle in the area along the front spindle section, approximately the same pressure drop is achieved up through the slits. The result of this is that the spindle wall in the front spindle section does not have to withstand any radially acting pressure difference, and this renders it possible to manufacture the spindle with a very small wall thickness in the front spindle section.

The invention also provides a number of different measures to reduce the spindle mass. It is possible to form the front spring guide of the spindle with a conical front surface and the smallest thickness at its largest diameter. The front spindle section may further have a smaller wall thickness than the front section of the fuel tube. The mass of the front end of the spindle in the area around the valve needle can be reduced by the length of the oblique bores from the bottom of the central spindle bore to the chamber around the valve needle being smaller than 35 per cent of the external diameter of the front spindle section, which reflects the fact that the front spindle end wall has a small wall thickness. A further reduction of the mass in this area can be achieved by the valve needle having a central bore open to the front in its end surface. However, the latter possibility only provides a limited reduction in mass. These various options can be used individually. If several options are used in combination, it is possible to obtain a spindle with an extremely low mass in relation to the size of the injector.

The reduction of the spindle mass provides a further improvement of both the reproducibility of the injected fuel volume and the exact control of the injection sequence. This is because the smaller spindle mass leads to more rapid spindle movements at the opening and closing of the injector and also the spindle and the valve seat become less worn, because the impacts against the valve seat and the limit stop of the opening movement are smaller from the lighter spindle. The rapid valve opening provides an abrupt start to the injection of fuel, which promotes a good and strong atomization of the fuel volume first injected and thus a well-defined and rapid ignition of the fuel. Even more

essential is the rapid injector closing which provides a sudden stop of the combustion and reduces the amount of fuel injected during the closing movement under disadvantageous conditions, viz., at a low pressure and
5 an insufficient injection rate (fuel g/s). This fuel injected at the very last contributes substantially to the formation of emission products, such as NO_x , it constitutes a heavy thermal load on the cylinder elements and soot depositions on them and leads to
10 increased fuel consumption. The lighter spindle reduces the amount of disadvantageously injected fuel and increases the proportion of the total fuel volume per injection that is injected under optimum conditions.

In a preferred embodiment the external diameter of
15 the abutment surface of the fuel tube on the back surface of the back spring guide is smaller than the external diameter of the front section of the fuel tube. Firstly, the small external diameter of the abutment surface has the effect that a small angle between the
20 longitudinal axes of the fuel tube and of the valve member behind it does not result in leakages at the abutment surface, because the manufacturing roughnesses of the two compressed surfaces compensate for any small misalignment in that the roughnesses are compressed in
25 the side at which the surfaces are closest to each other and form a sealing abutment at the diametrically opposite side. Secondly, the small external diameter of the abutment surface results in the fact that the sealing surface pressure between the abutment surfaces
30 always exceeds the current fuel pressure in the fuel passage. When the injector is closed, the surface pressure is created between the abutment surfaces by the backward spring force on the back spring guide and by the backward force on the fuel tube originating from the
35 fuel pressure on the front end surface of the fuel tube.

When the injector is open, the fuel pressure acts on the fuel tube with a larger backward force, because the fuel pressure acts on the whole front end of the spindle, and from the spindle this backward force is transmitted to the fuel tube via the axially facing annular surface on the fuel tube. Preferably, the external and internal diameters of the backward abutment surface of the fuel tube have substantially the same dimensions as the external and internal diameters, respectively, of the front spindle section, such dimensions providing a completely directly axial flow of forces in the spindle wall.

In a design which is particularly simple to manufacture and assemble, the fuel injector is intended for injection of preheated fuel, such as heavy fuel oil, the valve element located behind the fuel tube is a valve housing for a fuel circulation valve, and the annular back end of the thrust bushing abuts a forward abutment surface at the back end of an annular recess in the front part of the outer valve housing surface when the injector is assembled, whereby the length of the thrust bushing determines the pre-tensioning of the closing spring. With this design, the thrust bushing in the mounted valve is located between two annular abutment surfaces on the spindle guide and the valve housing, respectively, and creates a well-defined and predetermined distance between the valve seat in the spindle guide and the front surface of the valve housing abutting the abutment surface on the fuel tube. As the valve spindle carries the front spring guide and the fuel tube carries the back spring guide of the closing spring, the latter is pre-tensioned in an unambiguous manner when the injector is assembled, and at the same time the spindle has a well-defined and predetermined travel or lifting height between the closed and the open

positions. The pre-tensioning and the spindle lifting height may, for example, be finely adjusted for use of the injector in a specific engine by a change of the length of the thrust bushing, a shorter length, all
5 other things being equal, resulting in a higher pre-tension and smaller lifting height. It provides a considerable simplification at the assembly of the injector that the injector parts just have to be clamped as much together as possible to obtain the correct
10 spring pre-tensioning and thus correct opening and closing pressures for the injector. This precludes the considerable variation of the spring pre-tensioning and thus the opening pressure from one valve to another, which may occur in valves where the spring pre-tension-
15 ing has to be set by screwing the mounting flange more or less down on to the injector housing.

A further assembly simplification can be obtained by the spindle guide, the spindle, the closing spring, the fuel tube, the thrust bushing and the valve housing
20 of the circulation valve being assembled into a pre-assembled unit in which the valve housing and the spindle guide are locked to each other via the thrust bushing. This renders it possible to supply a complete and pre-assembled replacement unit for an injector so
25 that replacement of the essential parts can be effected very rapidly. The locking may, for example, be carried out by shrinking the thrust bushing on to the spindle guide and the valve housing or, after pressing the thrust bushing on to the two injector parts, by carrying
30 out a position fixing of the thrust bushing in relation to each of the two other parts by means of a pin inserted in transverse, associated bores in the thrust bushing and the part in question.

Suitably, a through-going cavity may be provided
35 in the longitudinal direction of the injector between

the inner surface of the injector housing and the outer surfaces of the valve housing, the thrust bushing and the spindle guide. The cavity provides the advantage that the stationary injector parts inside the injector housing are fixed between two points, viz., a forward surface on the inner surface of the mounting flange and a backward surface on the injection nozzle, which promotes a rotationally symmetrical loading condition in the parts of the injector. A further advantage is that the cavity acts as a draining passage for any leaked fuel.

An example of an embodiment of the invention will now be described below in further detail with reference to the drawing, which shows a longitudinal, sectional view through a fuel injector according to the invention.

The fuel injector generally designated 1 has a mounting flange 2 with an inlet stub 3 to which a high-pressure pipe from a fuel source, not shown, can be connected. The fuel source may be, for example, a piston fuel pump, such as of the Bosch type, which is periodically actuated by a cam on a camshaft, or a high-pressure reservoir connected periodically via control valves to the inlet stub 3. The fuel may be liquid or gaseous or may be slurries of solid fuels or emulsions containing at least one of these states, and the valve may also be used for injection of liquid or gaseous additive media to the combustion, either alone or in mixtures.

By means of a union nut 5, an external housing 4 for the injector is clamped to the mounting flange which in its turn can be clamped to the engine cylinder by means of bolts inserted in holes 6 in the flange. A fuel passage 34 extends from a supply opening 7 in the inlet stub centrally through the injector to an injection nozzle 8, from which fuel can be injected via nozzle

holes, not shown, into the working chamber of the internal combustion engine.

A spindle guide 9 is pressed downwards against the inner surface of the injection nozzle by means of a thrust bushing 10, a valve housing 11 and a thrust piece 12 abutting a forward inner surface of the mounting flange. The thrust bushing has approximately the same external diameter as the valve housing 11 and the back section of the spindle guide 9 and is inserted in an annular recess in each of these parts so that the axially facing annular end surfaces of the thrust bushing 10 abut axially facing abutment surfaces 13, 14 on the spindle guide and the valve housing.

A valve body 15 is inserted in bores in the valve housing 11 and is biased by a relatively weak compression spring 16 to the position shown. A protruding forward abutment surface 17 on the front end of the valve housing abuts a corresponding backward annular abutment surface 18 on a protruding section on the back end of a central fuel tube 19, and the joint face between the two substantially parallel and plane abutment surfaces is located in a plane which is substantially perpendicular to the longitudinal axis of the injector.

Immediately below the abutment surface 18, the fuel tube has a protruding collar 20 constituting a back spring guide for a closing spring 21, which is a mechanical compression spring of a conventional type. At the front of the spring guide, the fuel tube continues in a circularly cylindrical back section 22, the external diameter of which is slightly smaller than the internal diameter of the spring. The back section ends at the front in an annular surface 23 located in a plane perpendicular to the longitudinal axis of the injector. The surface 23 forms a transition between the back

section of the fuel tube and a front section 24, which has a smaller diameter and extends down into a bore 25 open towards the back in a spindle 26 and to the front end of the fuel tube, located a short distance from the bottom of the bore 25. The short distance is larger than the lifting height of the spindle.

The spindle guide 9 has a central bore having in one section a circularly cylindrical inner surface 27 constituting a guide surface for the spindle. In front of this section, the spindle guide has a pressure chamber 28 having a conical stationary valve seat that cooperates with a corresponding conical movable valve seat at the front end of a valve needle 29 on the front end of the spindle. At the front side of the valve seat, the bore of the spindle guide continues to the central bore in the injection nozzle 8.

The spindle 26 has a front spring guide 30 in the form of a protruding collar, the back of which is perpendicular to the longitudinal axis of the injector, and the front surface 31 of which is conical. The closing spring is located between the two spring guides 20 and 30 and inside the thrust bushing 10. At assembly of the injector parts, the closing spring is compressed to a pre-tensioned state. The forward closing force produced by the spring on the front spring guide 30 of the spindle is of a very accurate magnitude because the compression of the spring at assembly is determined by the length of the thrust bushing 10 and the length of the unloaded closing spring.

The diameter of the inner surface of the spindle is from 2 to 4 μm larger than the external diameter of the front section 24 of the fuel tube, and the external diameter of the front spindle section 32 inserted in the spindle guide bore is from 2 to 4 μm smaller than the internal diameter of the bore 27. The wall thickness of

the front spindle section is approximately 30 per cent smaller than the wall thickness of the front fuel tube section 24. The front end wall of the spindle at the bottom of the bore 25 has a relatively small wall thickness, the annular end surface encircling the valve needle 29 being almost perpendicular to the longitudinal axis of the injector. The oblique bores 33 connecting the bore 25 with the compression chamber 28 have a length smaller than 35 per cent of the external diameter of the section 32 owing to the small wall thickness.

The central fuel passage 34 extends from the supply opening 7 down through the thrust piece 12 to a central bore 35 in the valve body 15, where the passage branches off into several oblique bores 36 opening out into a pressure chamber 38 located about a valve needle 37. At the front of the stationary valve seat cooperating with the valve needle 37 the fuel passage continues centrally through the front of the valve housing 11, past the abutment surfaces 17 and 18 and further forwards through the fuel tube 19 opening out at the bottom of the bore 25 in the spindle, from where the fuel passage continues through oblique bores 33, the pressure chamber 28 and to the nozzle holes, not shown, in the injection nozzle 8.

Drain holes 39 render it possible for leaked fuel to be drained away from the cavity around the closing spring 21 to a through-going cavity extending in the longitudinal direction of the injector at the inner surface of the injector housing 4.

Between the injection periods there is a certain supply of preheated fuel at low pressure to the supply opening 7. This fuel flows out into the cavity around the compression spring 16 via a side-facing leakage channel 40 in the front part of the thrust piece 12. Drain openings 41 in the valve housing 11 pass the

circulating fuel to a chamber 42, from where a return pipe, not shown, carries the fuel away from the injector. The fuel circulation in the closing periods of the injector ensures that the fuel system is kept
5 preheated at a suitably high temperature.

As soon as the fuel pressure starts rising at the beginning of an injection period, the pressure in the pressure chamber 38 rises, and the valve body is influenced by a backward force that overcomes the force
10 from the compression spring 16, whereupon the valve body is displaced backwards and cuts off the leakage channel 40. Then the fuel pressure spreads through the fuel passage down into the pressure chamber 28. When the fuel pressure here reaches the opening pressure of the
15 injector, the spindle 26 is actuated by a backward force larger than the force of the closing spring 21, which makes the spindle become displaced backwards until the annular end surface of the spindle hits the annular surface 23 on the fuel tube. The surface 23 thus acts
20 as a limit stop for the spindle movement and determines the lifting height of the spindle. The spindle displacement opens for fuel access to the injection nozzle, which starts the injection. When the delivery pressure of the fuel drops again at the end of the injection, the
25 pressure in the chamber 28 drops suitably so that the closing spring overcomes the backward pressure of the fuel on the spindle, whereupon the spindle is returned to the closed starting position where the valve needle 29 abuts the associated seat and cuts off access to the
30 injection nozzle.

For a spindle of the thin-walled design shown, it is important, to avoid deformations of the cylindrical spindle wall, that the backward end surface of the spindle is in axial extension of the cylindrical spindle
35 wall, because this ensures that the impact of the

spindle against the surface 23 only imparts axially directed forces to the spindle.

If there is no need for circulation of preheated fuel during the closing periods of the injector, the
5 injector can be simplified by omission of the circulation valve. In that case the thrust piece 12 and the valve housing 11 may be formed as an entire thrust-piece-like unit with a central through bore constituting the section of the fuel passage 34 that connects the
10 supply opening 7 with the central passage in the fuel tube.

It is also possible to expand the injector for use in connection with injection of several different fluids, for example by applying the injector elements
15 described above in connection with an injector of the type described in the above Danish patent No. 155757. Such an injector may, for example, be used for injection of gas and pilot oil, or for injection of a fuel and another fluid modifying the combustion process, such as
20 water, contributing to reduction of the formation of undesired emission products.



P A T E N T C L A I M S

1. A fuel injector (1) for an internal combustion engine, particularly a two-stroke crosshead engine, having an outer housing (4) with a mounting flange (2) at its back end and an injection nozzle (8) protruding from the housing at its front end, and a fuel passage (34) extending centrally in the injector, the fuel passage passing from the mounting flange through at least one thrust piece (12), a central fuel tube (19), a spindle (26) and a spindle guide (9) and ending in the injection nozzle,

the spindle guide having a central bore (27) the circularly cylindrical inner surface of which constitutes the guide surface for the spindle,

the fuel tube having a front section (24) extending more than halfway down into the central bore of the spindle guide and having a smaller external diameter than a back section (22) and at the transition between the two sections an annular surface (23) facing axially in the direction of the injection nozzle, and a back spring guide (20) for a pre-tensioned closing spring (21),

the spindle having a central bore (25) open to the back in which the front section of the fuel tube is inserted, and a front spindle section (32) with a valve needle (29) which cooperates with a stationary seat surface in the bore of the spindle guide for opening and closing of the injector, and a front spring guide (30) for the closing spring, the spring guide being located in a back spindle section protruding from the bore of the spindle guide and the closing spring biasing the spindle forwards in the closing direction, and at the back end of the spindle an annular end surface which is made to abut the annular surface (23) of the fuel tube by the backward opening movement of the spindle,



the spindle guide being pressed forwards in the injector housing by at least one thrust bushing (10) abutting an annular surface (13) facing backwards on the spindle guide and extending backwards past the closing
5 spring, and the thrust piece (12) being pressed forwards by the mounting flange at assembly of the injector with simultaneous compression of the closing spring, c h a r a c t e r i z e d in that the external diameter of the back spring guide (20) of the fuel tube
10 is smaller than the internal diameter of the thrust bushing (10), that the fuel tube (19) is a separate unit exclusively contacting the valve member located behind it through an abutment surface (18), which is arranged on the back surface of the back spring guide and has an
15 annular surface encircling the central fuel passage (34) and being substantially perpendicular to the longitudinal axis of the injector, and that in the front spindle section (32) inserted in the spindle guide bore (27) the spindle (26) has an external diameter being at the most
20 $8\text{ }\mu\text{m}$ smaller than the internal diameter of the spindle guide bore, and an internal diameter being at the most $8\text{ }\mu\text{m}$ larger than the external diameter of the front section (24) of the fuel tube.

2. A fuel injector according to claim 1, c h a r -
25 a c t e r i z e d in that the external diameter of the front spindle section is from 2 to $4\text{ }\mu\text{m}$ smaller than the internal diameter of the spindle guide bore, and that the internal diameter of said spindle section is from 2 to $4\text{ }\mu\text{m}$ larger than the external diameter of the front
30 section of the fuel tube.

3. A fuel injector according to claim 1 or 2, c h a r a c t e r i z e d in that from the back end of the spindle and at least until the front spring guide, preferably until the front spindle section
35 located in the spindle guide bore, there is a substan-



tially larger diameter difference between the inner spindle surface and the outer fuel tube surface than in the front spindle section.

4. A fuel injector according to any one of claims 5 1-3, characterized in that the front spring guide (30) of the spindle has a conical front surface (31) and the smallest thickness at its largest diameter.

5. A fuel injector according to any one of claims 10 1-4, characterized in that the front spindle section (32) has a smaller wall thickness than the front section (24) of the fuel tube.

6. A fuel injector according to any one of claims 1-5, characterized in that the length of 15 the oblique bores (33) from the bottom of the central spindle bore (25) to the chamber around the valve needle (29) is smaller than 35 per cent of the external diameter of the front spindle section.

7. A fuel injector according to claim 6, characterized 20 in that the valve needle (29) has a central bore open to the front in its end surface.

8. A fuel injector according to any one of the preceding claims, characterized in that the external diameter of the abutment surface (18) of 25 the fuel tube on the back surface of the back spring guide (20) is smaller than the external diameter of the front section (24) of the fuel tube.

9. A fuel injector according to any one of the preceding claims, characterized in that 30 the external diameter and the internal diameter of the backward abutment surface (18) of the fuel tube have substantially the same dimensions as the external diameter and the internal diameter, respectively, of the front spindle section (32).



10. A fuel injector according to any one of the preceding claims, characterized in that the fuel injector is intended for injection of preheated fuel, such as heavy fuel oil, that the valve element
5 located behind the fuel tube is a valve housing (11) for a fuel circulation valve, and that the annular back end of the thrust bushing (10) abuts a forward abutment surface (14) at the back end of an annular recess in the front part of the outer valve housing surface when the
10 injector is assembled, whereby the length of the thrust bushing determines the pre-tensioning of the closing spring (21).

11. A fuel injector according to claim 10, characterized in that the spindle guide,
15 the spindle, the closing spring, the fuel tube, the thrust bushing and the valve housing of the circulation valve are assembled into a pre-assembled unit in which the valve housing and the spindle guide are locked to each other via the thrust bushing.

20 12. A fuel injector according to any one of the preceding claims, characterized in that a through-going cavity is provided in the longitudinal direction of the injector between the inner surface of the injector housing (4) and the outer surfaces of the
25 valve housing, the thrust bushing and the spindle guide.