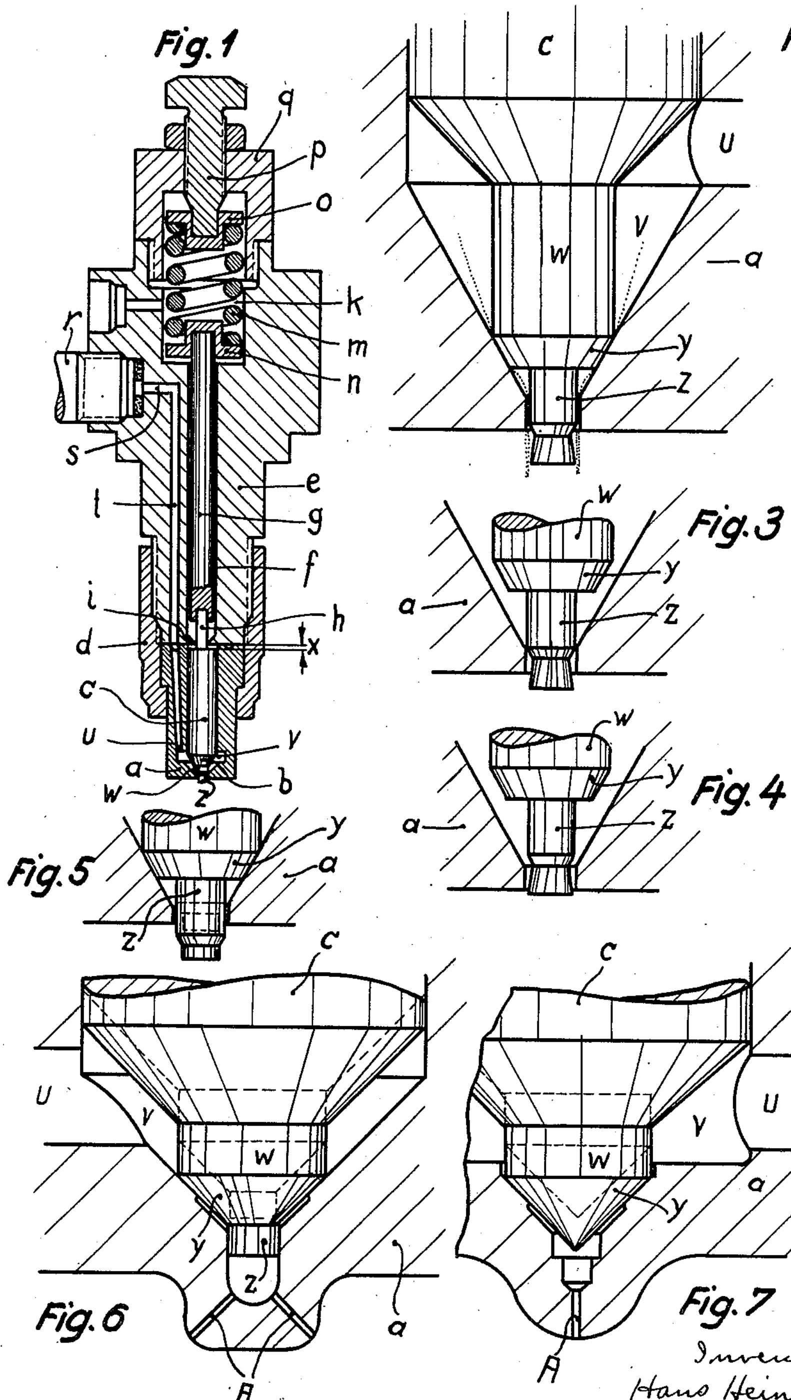
Oct. 8, 1935. H. HEINRICH ET AL 2,017,028

INJECTION NOZZLE FOR SELF IGNITING INTERNAL COMBUSTION ENGINES

Filed Feb. 26, 1934 2 Sheets-Sheet 1



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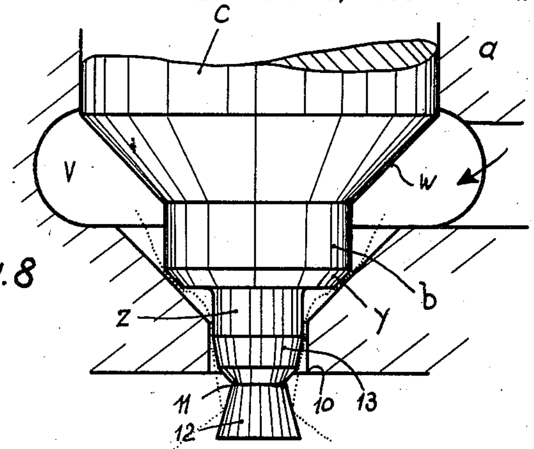

Fig. 8

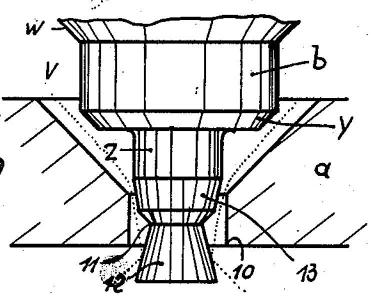

Fig. 9

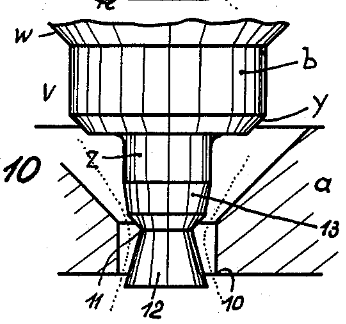

Fig. 10

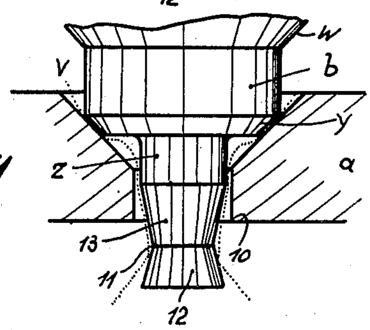

Fig. 11

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Patented Oct. 8, 1935

2,017,028

UNITED STATES PATENT OFFICE

2,017,028

INJECTION NOZZLE FOR SELF-IGNITING INTERNAL COMBUSTION ENGINES

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Application February 26, 1934, Serial No. 713,072
In Germany March 13, 1933

8 Claims. (Cl. 299—107.5)

The present invention relates to injection nozzles for self-igniting internal combustion engines in which the needle-valve is raised from its seat against the force of a closing spring by the pressure of the fuel impinging on it, and in doing so, forms, in conjunction with the nozzle body, a throttling opening or gap during the first part of its opening lift of smaller cross-section than the valve opening during the remainder of the lift, which gap represents the narrowest cross-section in the fuel discharge path.

This type of nozzle is often known by the name of "liquid-controlled pin nozzle". The pin extension of the needle valve, which is usually arranged forwardly of the seating shoulder of the needle valve at the needle end, and guided with more or less play in the nozzle body over the whole or only over a part of the lift of the needle, has already been provided in such nozzles for various reasons.

In cases where the guiding gap of the pin forms at the same time the cross-section of the nozzle outlet, the form of the pin determines the guidance and breaking up of the fuel and thus the shape of the jet.

It has also been already proposed to make a fairly short cylindrical pin extension on the needle and mount it with the closest possible sliding fit in its guide, which is also cylindrical. In this case, the pin, which emerges from its guide after only a small part of the opening lift of the needle, simply acts as an additional packing member.

Furthermore, a pin has often been arranged at the forward end of the needle valve, because by its movements it prevents the nozzle mouth becoming incrusted.

According to a further known proposal the gap which determines the narrowest nozzle cross-section between the pin and the guide is so formed that the free cross-section of the nozzle only gradually enlarges on the opening lift of the valve. In this way the quantity of fuel injected at the beginning of the opening movement of the valve was to be kept as small as possible. This known proposal was based on the recognition of the fact that most nozzles, even at the very beginning of the opening of their valve, quite suddenly allow much too great a share of the quantity of fuel to be introduced into the combustion chamber at one injection operation, so that this large quantity produces explosive rises in pressure on its self-ignition, which causes heavy running of the engine.

Although the originator of this known proposal recognized quite rightly that the frequent very heavy running, especially at low speeds (e. g. when running idle), could be avoided by the amount of fuel reaching the combustion chamber being kept as small as possible during the first part of the injection period, he did not succeed in finding a solution to meet his requirements. It may perhaps be due to this, that his proposal has been disregarded in practice.

The reason why the known proposal is not successful is probably to be found in the circumstance that the time in which the proposed injection operation is performed during a part of the opening stroke is much too short with the nozzle then employed, as well as in other known pin nozzles, to produce an appreciable improvement in the defect to be removed.

The very short duration of the operation is, as has now been established, to be ascribed to the fact that the nozzle needle, as soon as it begins to lift, flies into its open position at much too great a speed, so that to a certain extent a large spraying section is suddenly opened, and accordingly a large quantity of fuel emerges from the nozzle, contrary to what is intended directly after the beginning of the injection. The pin itself contributes much to this sudden opening operation. As soon, in fact, as the needle begins to rise from its seat, the highly compressed fuel, which owing to the throttling gap existing between the pin and its guide, is not at first substantially relieved from pressure, passes below the surface between the pin and the edge of the valve-seat and acts on this additional surface in the opening direction. It is this force which so excessively accelerates the opening of the needle in the known pin nozzles, that the desired injection characteristic beginning with a flat rise was hitherto thus not attained.

It is the recognition of this last-mentioned factor in accelerating the opening movement of the needle valve, together with the consideration that it would quite substantially assist in the avoidance of severe ignition explosions if the relatively flat curve of the rise in injection which is characteristic at the beginning is extended until the end of the ignition delay, that has led to the present invention. It is thus a question of only allowing so much fuel to escape from the pin nozzle during the period of the ignition delay, or for a large part of this delay as can be burnt on ignition without severe explosions. This can be attained by the acceleration of the nozzle needle being substantially diminished, at least during the initial part of its opening lift, where its pin throttles the fuel outlet considerably more than on the remaining part of the lift. If the acceleration of the opening movement is reduced to such an extent that, during the first part of the lift a time elapses which corresponds substantially to the duration of the ignition delay, the desired object is attained.

According to the invention, this is effected by the stiffness of the closing spring being proportioned in such a way that its increase in force during the initial part of the stroke which the needle performs until the throttle gap between pin and guide is substantially enlarged is greater than that force which tends to accelerate the needle during the opening.

Suitable valves in practice for the stiffness of the spring are a load of about 22–40 kg. to 1 mm. of spring compression. Within these limits helical springs of steel wire can be made in acceptable sizes, the needle lift kept within the usual limits, and also the surfaces provided on the needle for the fuel pressure to act upon suitably stepped relative to one another.

Six examples of construction of the invention are shown in the accompanying drawings, in which:—

Figure 1 is a longitudinal section of a pin nozzle together with holder, in full size.

Figure 2 is a longitudinal section through the lower part of the nozzle according to the first construction enlarged about ten times, in the closed position of the needle.

Figure 3 shows on the same enlarged scale a portion of Figure 2, but with the needle partly raised, whilst in

Figure 4 the needle is shown fully raised.

Figure 5 shows the second example of construction, drawn in the same way as in Figures 3 and 4, but in this case the needle is resting on its seat.

Figure 6 is a longitudinal section enlarged about ten-fold, of the third example.

Figure 7 shows the fourth construction in the same manner.

Figures 8, 9 and 10 show the fifth construction also in longitudinal section and enlarged about ten-fold in three different positions of the needle.

Figure 11 shows the sixth example in the same mode of illustration. The needle is here shown in its position at the beginning of the injection.

Referring now more particularly to the first example of construction shown in Figs. 1 to 4 inclusive, *a* is the nozzle body, *b* the nozzle needle, which with its stem *c* is closely guided in a bore in the nozzle body. The upper end of the nozzle body is pressed by a cap-nut *d* firmly and tightly against the lower end of the stem of a nozzle-holder *e*. The holder stem is bored longitudinally. Through this longitudinal bore *f* passes a pressure rod *g*, the lower end of which is seated on the upper extension *h* of the needle which is supported relative to the guide stem and projects a little distance into the longitudinal bore *f*. The bore *f* has at the lower end a contracted part, whose diameter is smaller than the diameter of the guide bore of the nozzle body, so that an annular shoulder *i* is situated above the guide bore of the nozzle body, which limits the opening stroke of the needle to the extent *x*, which amounts to about 0.6–0.8 mm.

An enlarged recess *k* in the head of the nozzle holder receives a very stiff closing spring *m*, which is supported below on a spring plate *n* on the upper end of the pressure rod *g* and at top bears against a spring plate *o*. The upper spring plate engages around the end of an adjusting screw *p*, which is screwed into the top of a cap *q* that closes the spring chamber *k*.

The supply of fuel to the nozzle takes place through the connection piece *r*, the bores *s*, *t*, in the nozzle-holder *e*, and a passage *u* in the nozzle body *a*.

From the passage *u* the fuel passes into an annular space *v* in the nozzle body formed by reducing the needle relative to its stem. The reduced needle extension *w* carries the seating surface *y* for the needle.

In this first example of construction, as shown more clearly in Figs. 2–4, the extension *w* is again stepped down below the seating surface *y*. The pin *z* so formed fits with quite small clearance into the throat of the nozzle which is made cylindrical over its end portion. The lower part of the pin is made obtusely conical for guiding the jet of fuel, and in such a way that the obtuse cone with its larger diameter forms the lower end of the needle.

The fuel conveyed to the annular space *v* acts on the annular shoulder between the needle guide *c* and the extension *w*, and after it has sufficient pressure lifts the needle against the pressure of its closing spring *m*. During the first part of the needle lift, from its position shown in Fig. 2 to its position shown in Fig. 3, the outlet gap for the fuel is formed by the very narrow annular space existing between the cylindrical part of the pin *z* and the nozzle throat. This annular space permits only a little fuel to be sprayed. In order that this first part of the opening stroke of the needle may not take place too quickly a very stiff closing spring is provided, and furthermore, the annular shoulder between the stem *c* of the needle and the extension *w* is made very large in comparison with the annular shoulder *y* between the extension *w* and pin *z*, much greater than this was hitherto usual in pin nozzles. The additional action of the annular shoulder surface *y* between extension *w* and pin *z*, on which the fuel pressure acts in the direction of opening as soon as the needle is raised from its seat and thereby tends to accelerate the needle stroke, is mitigated by this arrangement of the annular shoulder surfaces. The effect of the supplementary acceleration forces is still further reduced by the stiff spring *m*, so that the above-mentioned first part of the lifting or opening movement of the needle extends over a longer part of the injection period than it otherwise would. This first part of the needle lift, for example, from the position of the needles shown in Fig. 2 to its position shown in Fig. 3, in which the cylindrical surface of the pin *z* strongly throttles the fuel discharge, is preferably so proportioned that this part of the stroke is adapted to the ignition delay period; that is, the arrangement is such that the time interval of execution of this first part of the needle lift corresponds substantially to the duration of the ignition delay and especially so at low speeds of the engine. The result is that in this first part of the injection operation little fuel reaches the combustion chamber.

As soon as the cylindrical part of the pin *z* emerges from its guide in the bottom of the nozzle body, a substantially larger spraying cross-section is opened. The quantity of fuel sprayed in the unit of time then correspondingly rises.

Very useful conditions are given by making the ratio of the two above-mentioned annular shoulder surfaces of the needle about 5.5:1, and fixing the total needle lift at about 0.7 mm. and the above mentioned first part of that lift at about 0.4 mm., and the stiffness of the spring at about 30 kg. per millimetre of spring movement. A spiral spring of 4 mm. round steel wire of 16 mm. external diameter and having about 4.5 convolutions approximately produces this stiffness.

The second example of construction according to Fig. 5 differs from the first only by an unessential alteration of the needle pin *z*, whose lower reduced end is here made cylindrical. This nozzle produces a narrow straight jet, whilst the nozzle in Fig. 1 produces a more conical jet.

The third example of construction, Fig. 6, shows a so-called orifice nozzle having two spraying orifices A. The length of the pin *z* is here suited to the magnitude of the first part of the needle lift. The throttling produced by the annular gap between the pin *z* and its guide should of course be made greater than the throttling by the spraying holes A.

The same also applies to the nozzles shown in Fig. 7, where the lower end of the needle extension *w* forms the pin which effects the throttling during the first part of the needle lift.

In Figs. 5–7 the highest position of the needle is shown in broken lines.

The jet indicated in dotted lines in Fig. 2 shows that during the first part of the lift of the needle, that is, at the beginning of the injection, the fuel does not strike on the upper surface of the conical end of the pin. Only after a considerable lift of the needle does the jet strike and then recoil or rebound from the conical wall of the end of the pin. The action of this recoil surface, which is very conducive to the breaking up of the fuel, is thus absent in this case during the first part of the opening lift of the needle, so that the atomization of the part of the charge of fuel first sprayed which initiates the ignition is not as good as in the constructions shown in Figs. 8–11 later to be referred to. This less thorough atomization of the fuel becomes noticeable more especially at a slow speed in engines in which the speed of delivery of the injection pump is directly dependent on the engine speed. The insufficient atomization at the beginning of the injection may then cause irregular beginning of ignition and incomplete combustion.

The spraying of the jet past the conical rebound surface provided at the end of the pin is mainly to be ascribed to the fact that in the nozzle according to Fig. 2 the very narrow outlet opening at the beginning of the needle lift is cylindrical for a comparatively narrow length, so that the jet sprayed at the beginning of the needle lift is carried past the conical end of the pin without striking the same and rebounding therefrom.

In order to conduct the jet of fuel from the very beginning of the injection against the surface of the conical end of the pin, and thereby to thoroughly break it up from the very beginning, the gap which determines the guidance of the jet on the first part of the opening lift is suitably formed in accordance with the constructions shown in Figs. 8–11, which is best done by making the part in question of the pin tapered towards the constriction.

In the construction shown in Figs. 8–10, the upper part of the pin *z* is cylindrical, and penetrates, when the needle is closed (Fig. 8), with very slight play a little way into the nozzle throat, which is also cylindrical. The pin then tapers slightly up to the immediate proximity of the edge 10 of the mouth on the nozzle body. It is then sharply constricted at 11. From the point of greatest constriction up to its free end, the diameter of the pin conically increases to a diameter which is not quite so large as the diameter of the cylindrical part of the pin. The surface of the obtuse or inverted cone 12 formed at the free end of the pin serves as a contact and recoil surface during the whole lift of the needle for the jet of fuel sprayed from the nozzle gap. The length of the pin is so proportioned that its free end still projects somewhat beyond the nozzle throat when the needle has completed its full opening stroke. This position of the needle is shown in Fig. 10.

In the first part of the needle lift, from the position of the needle shown in Fig. 8 to its position shown in Fig. 9, the cylindrical part and then the slightly tapered part 13 of the pin first strongly throttle the passage of the fuel. When in the further course of the opening lift, from the position of the needle shown in Fig. 9 to its position shown in Fig. 10, the constriction 11 has been drawn so far into the mouth hole that the width of the outlet gap has become considerably larger and the fuel can discharge in greater quantity per unit of time.

The course of the jet shown in dotted lines clearly shows that the fuel is conducted in all positions of the needle, owing to the slight taper of the part 13 of the pin, against the surface of the conical part 12 of the pin, and is well broken up by rebounding from this surface.

The construction shown in Fig. 11 differs from that shown in Figs. 8–10 only in that, in this case, the tapered part 13 of the pin merges directly into the constriction 11. The throttling produced by the pin in the first part of the needle lift of course decreases more quickly here than in the construction according to Figs. 8–10.

We declare that what we claim is:

1. A fuel injection device for internal combustion engines comprising a nozzle body supplied with liquid fuel under pressure and having a discharge nozzle, a needle valve for said nozzle seating therein in the closed position of the valve and having a rearward abutment surface within said nozzle body engaged by the liquid fuel to effect the opening stroke of said valve, said nozzle and valve being cooperatively formed and arranged to provide a fuel discharge opening increasing in cross-sectional area for the discharge of fuel therethrough as said valve increases its opening movement, said needle valve having another abutment surface in the region of the valve seating exposed to the opening pressure of said liquid fuel only when said valve is moved from its seat whereby pressure of said fuel on said other abutment surfaces tends to accelerate the opening stroke of said valve after its initial movement from its seat but with said other abutment surface having less area for pressure contact of the fuel therewith in a direction tending to lift said valve than that of said rearward abutment surface, and spring means opposing the opening movement of said valve with a force sufficient to substantially prevent said acceleration of said opening stroke of said valve.

2. A fuel injection device as defined in claim 1 and further characterized by said spring means being formed to oppose the opening stroke of said valve with a total force for the entire opening stroke of said needle valve greater than the force exerted by the liquid fuel on said other abutment surface of said needle valve.

3. A fuel injection device for internal combustion engines comprising a nozzle body supplied with liquid fuel under pressure and having a discharge nozzle, a needle valve seating in said nozzle and having a rearward abutment surface engaged by the liquid fuel to effect the opening stroke of said valve by the pressure of the liquid fuel, said nozzle and valve being formed and cooperatively arranged to provide a restricted or throttled fuel discharge opening during an initial part of the opening stroke of said valve and a substantially increased fuel discharge opening through the remainder of its opening stroke, said valve having another abutment surface in the region of the valve seating so exposed to the pressure of the fuel when the valve is moved from its seat as to tend to accelerate said initial part of the opening movement of said valve but with said other abutment surface having less area for pressure contact of the fuel therewith in a direction tending to lift said valve than that of said rearward abutment surface and spring means opposing the opening movement of said valve with a force sufficient to substantially prevent said acceleration of said opening stroke.

4. A fuel injection device as defined in claim 3 and further characterized by said needle valve having an opening stroke of approximately 0.7 mm. and of which said initial part is approximately 0.4 mm., said rear abutment surface and said other abutment surface on said needle valve having areas for pressure contact of the fuel therewith lying between the ratios of 3.5 to 1 and 7 to 1, and said spring means comprising a coil spring of a strength at least equal to 22 kg. per millimeter of spring compression.

5. A fuel injection device for an internal combustion engine comprising a nozzle body supplied with liquid fuel under pressure and having a cylindrical discharge bore, a needle valve of circular cross section throughout and having a main body portion seating within said nozzle body and an end portion of reduced diameter projecting through said bore and reciprocating therein in the opening and closing movements of said valve, said end portion of said needle valve being of less diameter than said bore to provide an annular fuel passage between them, said end portion of said needle valve being itself of reduced diameter intermediate its length and having its annular surface to the rear of said reduced diameter forwardly and inwardly converging to said reduced diameter and its forward annular surface outwardly flaring to the free end of said valve whereby said bore and said end portion of said needle valve cooperate to provide an annular fuel discharge opening of cross-sectional area for the passage of fuel increasing from a minimum as the valve progresses in its opening movement and of a form so directing the fuel in its discharge through said opening as to cause the same to contact with and rebound from the flared terminal end portion of said valve and become atomized thereby.

6. A fuel injection device for internal combustion engines comprising a chambered nozzle body supplied with liquid fuel under pressure and having a nozzle discharge orifice, a needle valve comprising a body portion mounted in said nozzle body for reciprocatory movement and having a rearward annular abutment surface engaged by the liquid fuel to effect the opening stroke of said valve by pressure of the liquid fuel and a forward annular abutment surface of substantially less surface area than said rearward abutment surface engaging against said nozzle body inwardly adjacent said nozzle orifice in the closed position of the valve and a reduced needle portion projecting forwardly from said forward abutment surface within said nozzle orifice to substantially restrict the cross-sectional area thereof effective for discharge of fuel during an initial portion of the opening stroke of said valve and providing an increased cross-sectional area for the discharge of fuel during the remaining portion of the opening stroke of the valve, and means resiliently opposing the opening movement of said valve, said means comprising a spring having a factor of stiffness effective to prevent substantial acceleration of the opening movement of said valve incident to fuel pressure on said forward abutment surface during said restriction of said nozzle orifice by said needle portion of said valve.

7. A fuel injection device for internal combustion engines as defined in claim 6 and further characterized by said needle portion of said valve being formed to effect said restriction of the cross-sectional area of said nozzle orifice during a major portion of the length of the opening stroke of the valve.

8. A fuel injection device as defined in claim 6 and further characterized by said forward abutment surface on said needle valve having an area for pressure contact of the liquid fuel therewith in a direction tending to lift said valve less than half that of said rearward abutment surface.

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