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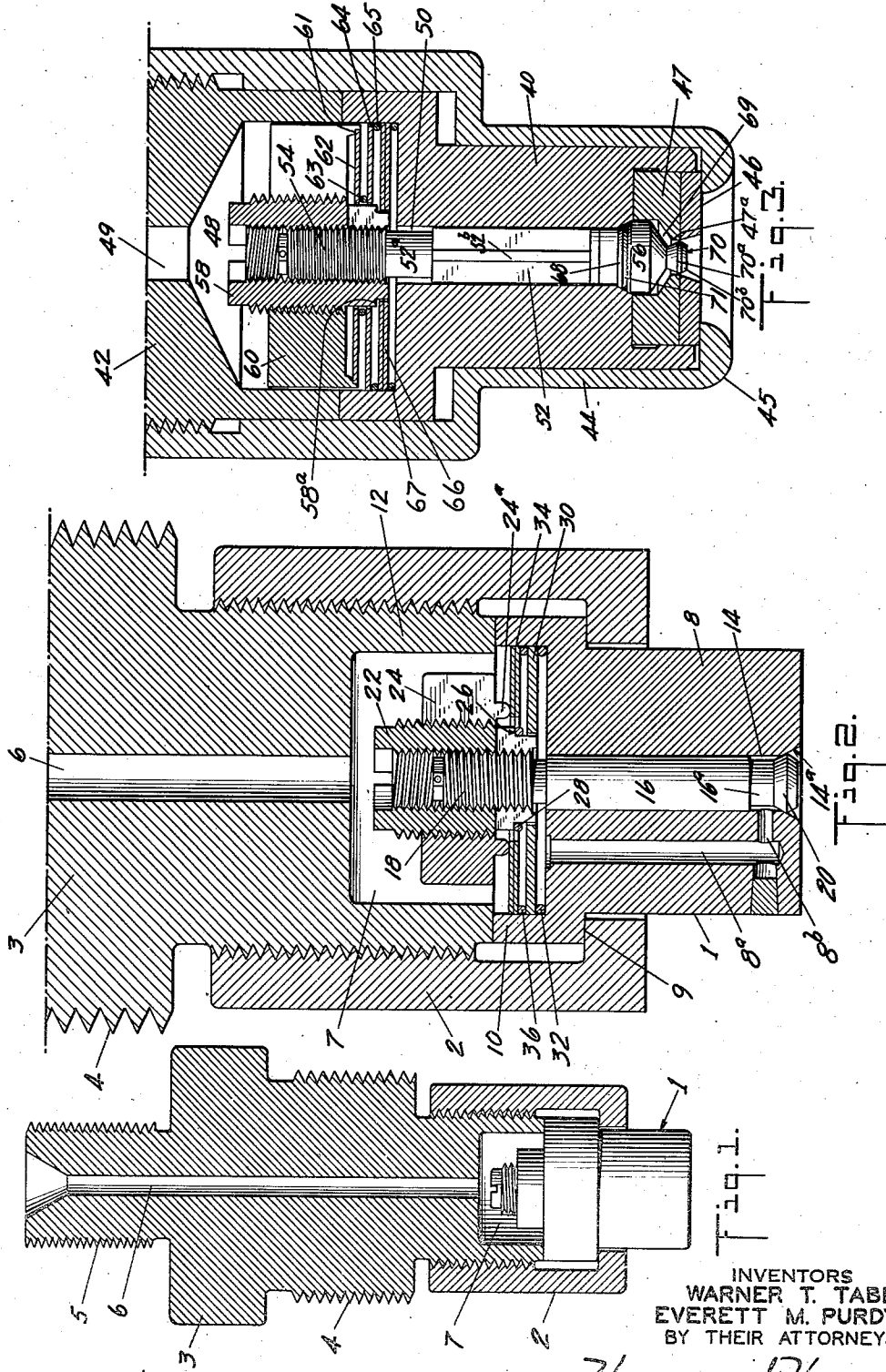
E. M. PURDY ET AL

2,192,803

FUEL INJECTION NOZZLE FOR INTERNAL COMBUSTION ENGINES

Filed July 21, 1937

4 Sheets-Sheet 1



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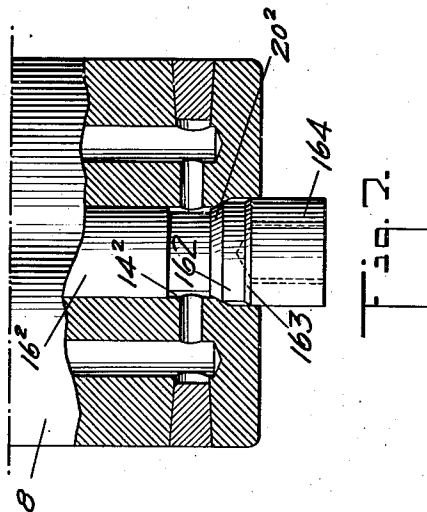
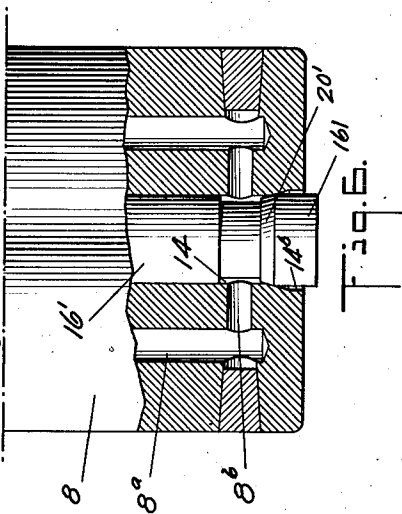
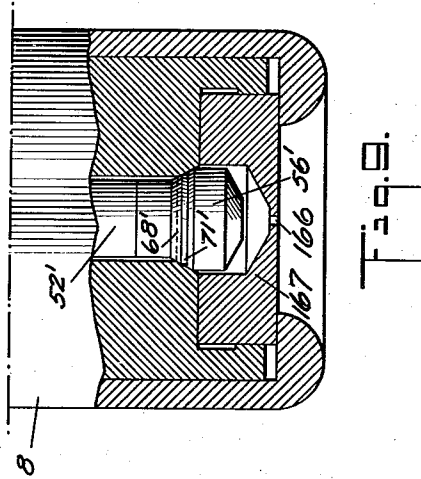
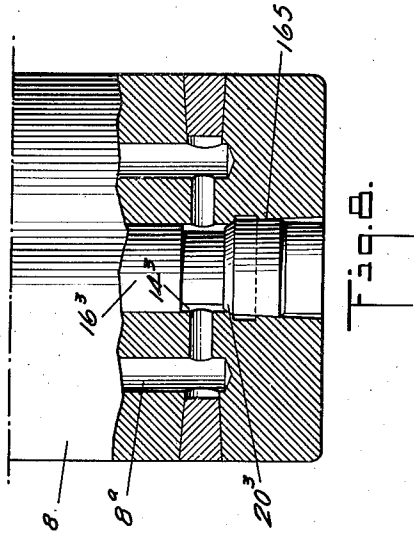
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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

CHARACTERISTICS OF NOZZLE SPRINGS

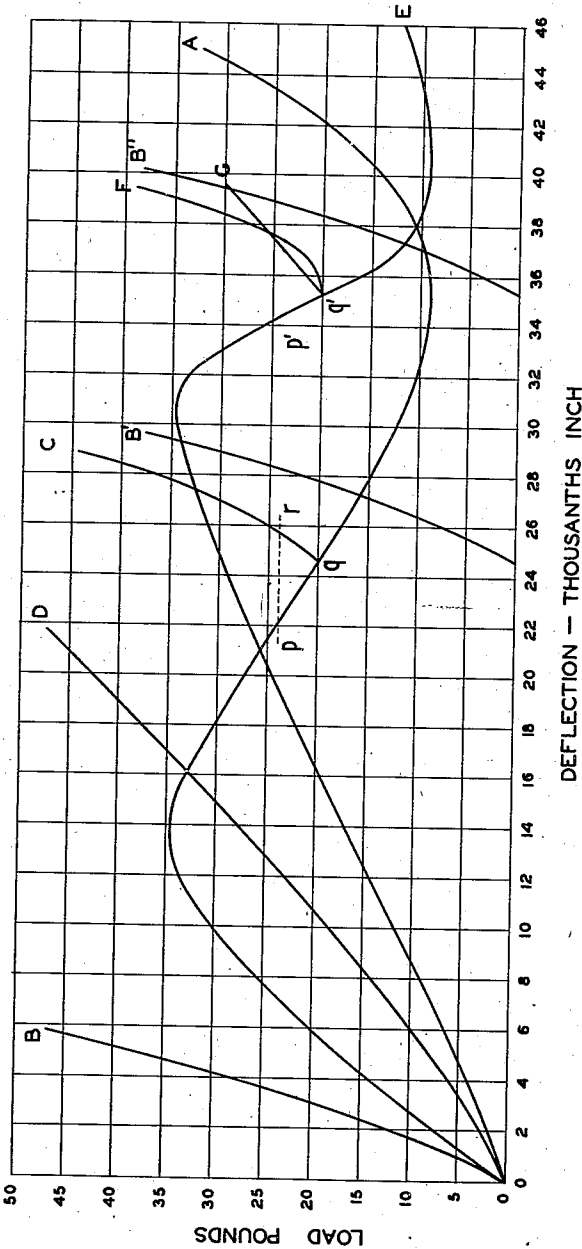


Fig. 10.

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UNITED STATES PATENT OFFICE

2,192,803

FUEL INJECTION NOZZLE FOR INTERNAL COMBUSTION ENGINES

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Application July 21, 1937, Serial No. 154,918

10 Claims. (Cl. 299—107.6)

This invention relates to fuel nozzles and more particularly to fuel nozzles for internal combustion engines and it is an object of this invention to provide an improved fuel nozzle of the type described which will give a quick and positive initial opening movement when the fuel pressure reaches a predetermined value and which shall thereafter give a gradual further opening movement with further increases of the fuel pressure.

It is also an object of this invention to provide a fuel nozzle having the opening movement of the fuel control valve and the member cooperating with the discharge orifice of the nozzle in determining the characteristics of the fuel discharge opposed by a spring means of such characteristics that the desired rates and extent of movement of the valve and member are secured at each fuel discharge operation, the spring means being of such construction that spring means of different characteristics may be readily manufactured for use with fuel nozzles having orifices and members arranged to provide fuel discharges having different characteristics. It is also an object of this invention to provide a fuel nozzle having its initial opening controlled by a spring having a characteristic such that but slight change in the pressure of the fuel is necessary to increase the nozzle opening to the desired extent once the nozzle is opened, and it is a further object of this invention to provide a fuel nozzle of such construction that the characteristic of the controlling springs of the nozzle will change after a predetermined opening of the nozzle. It is a further object of the invention to provide a nozzle having a valve and an orifice controlling stem and controlling springs therefor which give an accelerated initial movement of the valve and stem for a predetermined distance from the position at which the valve is closed and a retardation of the movement thereafter. It is a further object of this invention to provide a fuel nozzle of such construction that various combinations of controlling springs may be made conveniently so as to provide spring characteristics suitable for various nozzle valve and orifice proportions and arrangements and changes may be conveniently made to vary the characteristics of the spray delivered to suit variations of engine requirement.

It is also an object of this invention to provide a fuel nozzle of the type described of such construction that it may be assembled and adjusted at the factory and mounted in the holder so as to be applied to an engine cylinder without neces-

sitating or causing any change in the adjustment of the nozzle.

In the drawings:

Fig. 1 is a view showing the relation of a fuel nozzle in accordance with this invention to its holder and the retainer nut for securing the nozzle to the holder, the nozzle being shown in elevation and the holder and retainer nut being shown in longitudinal section;

Fig. 2 is a vertical sectional view drawn to a larger scale, of a holder, retainer nut and nozzle such as are shown in Fig. 1, part of the holder being broken away;

Figs. 3 and 4 are views similar to Fig. 2 of modified constructions;

Fig. 5 is a view similar to Fig. 2 of a further modification of the controlling spring structure, part of the stem of the fuel controlling valve being shown in section;

Figs. 6, 7, 8 and 9 are fragmentary sectional views showing further modifications of the fuel controlling valve and orifice of the nozzle; and

Fig. 10 is a view showing curves which illustrate, diagrammatically, the operating characteristics of some control springs of the type used in nozzles in accordance with this invention.

In the constructions shown in the drawings the nozzle is arranged to be assembled as a unit and secured by a retainer nut to the holder body member which secures it in position in the engine cylinder wall. In Figs. 1 and 2 of the drawings a nozzle 1 is secured by a retainer nut 2 to a holder body member or holder 3 which is threaded as at 4, for engagement with the engine cylinder wall and, as at 5, for securing to the holder the pipe (not shown) through which the fuel is supplied to the central passage 6 of the holder. The fuel flows through the passage 6 to the chamber 7 formed by recesses in the holder 3 and the nozzle 1 and which is in communication with the nozzle 1.

The nozzle 1 comprises a tip member 8 shouldered, as at 9, for engagement by the retainer nut 2 and having a flange portion 10 forming a recess at its inner end which forms part of the chamber 7. The flange portion 10 of the tip member 8 is held seated against a corresponding flange portion 12 of the holder 3 by the retainer nut 2. The tip 8 is centrally bored, as at 14, and has fitted therein a valve stem 16 which is threaded at its inner end 18 and has a conical valve portion 20 at its outer end which cooperates with a corresponding surface 14a on the tip member 8 in controlling the discharge from the bore 14. Threaded on the end 18 of the

stem 16 is a nut 22 which is externally threaded to receive a nut 24. The nut 22 projects beyond the nut 24 in both directions and is slotted at both ends, at its upper end to receive a suitable tool for adjustment and at its lower end to permit the flow of fuel. At its lower end the nut 22 is also shouldered, as at 26, to form a seat for a spring wire ring 28 which fits about the nut 22 and, in certain positions of the stem 16, bears upon the inner edge of an annular disk spring 30 the outer edge of which rests upon a spring wire ring 32 fitting the recess in the tip 8. The outer nut 24 is also slotted to permit the passage of fuel and on its lower face is provided with an annular rib or projection 24a arranged to bear upon the inner edge of a spring member 34 formed of a plurality of initially cupped annular spring disks and supported at its outer edge upon a spring wire ring 36 which is carried by the outer edge of the spring member 30. The spring member 34 determines the fuel pressure at which the nozzle begins to spray fuel into the engine cylinder and the disks thereof, which are initially cupped towards the nut 24, are placed under an initial pressure by the nut 24, the pressure of the nut being such that the disks are substantially flattened, as shown in Fig. 2, before fuel pressure is applied to the nozzle.

The construction of the nozzle is such that there is an unbalanced area subjected to the fuel pressure acting in a direction to open the valve when fuel under pressure is supplied thereto. When the fuel pressure is sufficient to open the valve, the spring disk member 34 yields, permitting the nuts 22 and 24 and stem 16 to move downwardly until the wire ring 28 on the nut 22 rests upon the spring disk 30 and fuel to flow through passage 6 in the holder 3 to chamber 7, through the slots in the nuts 22 and 24 to the underside of the disk 30 and through passages 8a and 8b in the tip 8 to the bore 14 at the reduced portion 16a of the stem 16 to be discharged as an annular spray between the conical surface 20 on the stem 16 and the cooperating surface 14a at the mouth of the bore 14 in the tip 8.

A spring such as the cupped spring disks of the spring member 34 can have a deflection to spring reaction relation which follows the curve A of Fig. 10. As shown in this curve, the spring reaction for a given deflection, starting with the spring unstressed, increases until a predetermined deflection is attained, whereupon the spring reaction decreases until a further predetermined deflection is attained, after which the spring reaction increases as the spring deflection is increased. In practice, the nut 24 is adjusted so that, with the conical portion 20 of the stem 16 seated on the cooperating surface 14a on the tip 8 the disks of spring member 34 are deflected to such an extent that their reaction is shown by the portion of the curve A adjacent the point p. At this point in its deflection the spring member has a negative characteristic, that is, the spring reaction decreases with an increase in the spring deflection. When a spring having a negative characteristic is overcome by substantially constant or increasing hydraulic pressure and the valve controlled by said spring thus opened, the resistance of the spring decreases as the opening movement of the valve progresses so that the valve opens with a quick and continually accelerated movement. If, for example, the valve starts to open when the fuel pressure is built up to a value corresponding to the vertical ordinate of the point p on curve A and the

fuel pressure is thereafter held constant, as indicated by line pr, the resistance of the spring falls off along the line pq and the excess of the fuel pressure over the spring reaction increases as the opening movement of the valve continues. This increase in the effective opening pressure accelerates the opening movement of the valve as the opening movement continues. In the case of the construction shown in Fig. 2 the accelerated movement of the valve due to the negative characteristic of the spring member 34 is aided by an increase in the unbalanced area of the structure subjected to fuel pressure in a direction to aid the opening movement of the valve immediately upon the start of such opening movement but such increase in the effective area is not necessary for accelerated operation of the valve in view of the action of the spring member 34.

Where the design of the valve and stem is such that there is a large increase in the unbalanced pressure tending to accelerate the opening movement of the valve and stem once the valve is opened, the design of the spring means opposing the opening movement of the valve and stem may be such that instead of having the resistance of the spring means decrease during the initial opening movement of the valve, as described above, the resistance of the spring means may remain substantially constant or increase slightly during the initial opening movement of the valve. Where the resistance of the spring means increases during the initial opening movement the increase during this stage of the deflection of the spring means is less than in the initial and final stages of the deflection of the spring means so that the characteristic curves for the various spring means have the same rapid increase at the initial and final portions as in curve A of Fig. 10 but the intermediate portions of the curves differ in being either downwardly inclined as shown or substantially flat or slightly upwardly inclined where the resistance does not change or increases slightly. Changes in the spring characteristics are brought about preferably by varying the extent to which the disks are cupped in their unstressed condition and by varying the thickness of the disks, or both. A disk of spring stock .010" thick, .543" outside diameter, .259" inside diameter and cupped about .025" from the flat condition gives a spring having a negative resistance portion in its characteristic curve as in curve A. By gradually decreasing the extent of the cupping while at the same time gradually increasing the thickness of the disk the degree of the decline of the center portion of the characteristic curve can be gradually decreased and eventually changed to a slight incline. A spring with a negative resistance characteristic as described is, however, the preferred form of the invention and is used to illustrate various constructions in accordance with the invention but it is to be understood the invention is not limited thereto.

While a quick opening movement of the valve is desirable until the opening is sufficient to give the character of spray desired, the movement of the valve must be checked at or just before such opening is reached and thereafter it is generally desirable that a further enlargement of the spray opening occur only in response to increased pressure on the fuel. In the construction of Fig. 2, the checking of the opening movement of the valve and its further gradual opening in response to increases in the pressure of the fuel is provided for by the spring 30, the point in the

opening movement of the valve at which the spring 30 is engaged being determined by the thickness of the spring wire ring 28 on the nut 22. Varying the thickness of the ring 28 permits of the inner nut 22 being adjusted so that the slotted end thereof may limit the opening movement of the valve by engagement with the inner surface of the tip 3 and also engaging the spring 30 at the desired point in its movement.

The spring 30 shown is initially uncupped and its reaction increases with the deflection. For a disk substantially of the proportions shown in Fig. 2 the curve of this relation does not differ greatly from the straight line characteristic of a typical helical spring but it does have an appreciable curvature, as shown by curve B of Fig. 10. The curve B when displaced so that the curve of the spring 30 begins at a point corresponding to the deflection of the spring 34 at which the spring 30 is contacted by the spring ring 28 is shown at B' and the combined effect of the springs 34 and 30 for a further movement of the stem 10 in response to increased fuel pressure is shown by the curve C extending from the point q on the curve A, point q being the point at which the spring ring 28 contacts with the spring 30.

While it is preferred to have the spring 30 initially flat, it may be cupped in a direction such that an increase of pressure increases the cupping if quicker retardation of the movement of the stem and a more rapid increase in pressure for further movements of the stem are desired. If the spring 30 be cupped so that increases in pressure decrease the cupping at first and then increase it there will be a somewhat greater suddenness of initial retardation and a less gradual further movement of the stem during the first part of such further movement.

In the modification shown in Fig. 3, a nozzle tip 40 is secured to a holder 42 by a retainer nut 44 which is flanged, as at 45, to engage the outer one of the inserts 46 and 47, which are fitted in a recess in the outer end of the tip 40, and secure the inserts in position and the tip 40 in engagement with the holder 42. Both the tip 40 and the holder 42 are recessed to form a chamber 48 which is in communication with a source of fuel supply through the passage 49 in the holder. The tip 40 is centrally bored, as at 50, to receive a slotted valve stem 52 which is threaded, as at 54, on its inner end and is provided with a valve portion 56 at its outer end. Threaded on the valve stem 52 is a nut 58 which is externally threaded to receive a slotted nut 60 having a shoulder 61 forming a seat for the outer edge of a disk spring 62 the inner edge of which bears upon a spring wire ring 63 supported upon the inner edge of a second disk spring 64. The disk spring 64 is supported at its outer edge by a spring wire ring 65 which rests upon the outer edge of a spring member 66 supported at its outer edge upon a spring wire ring 67 fitted in the recess in the tip 40. The inner edge of the spring member 66 is positioned in the path of a shoulder 58a on the nut 58 to be engaged thereby upon a predetermined deflection of the spring disks 62 and 64 and movement of the stem 52. Movement of the stem 52 is limited by engagement of the tip 40 by the nut 58. The spring disk 62 is uncupped and has a characteristic curve such as the curve D of Fig. 10 while the disk 64 is cupped and has a characteristic curve such as curve A of Fig. 10. Combined, their characteristic curve is as curve E of Fig. 10. Spring mem-

ber 66, formed of a plurality of uncupped disks, has a characteristic curve similar to curve B while the combined characteristics of the three springs during the portion of the stem movement after the spring 66 is engaged is indicated by curve F. The characteristics of the combined springs 62 and 64 are such, it will be noted, as to give an extremely rapid opening movement of the valve.

The valve portion 56 has a conical valve surface 68 which cooperates with a correspondingly shaped surface at the lower end of the bore 59 to control the flow of fuel to the discharge opening in the outer insert 46. The inner insert 47 is provided with a recess or opening 69 to receive the valve portion 56, the opening 69 having a cylindrical portion as at 47a of reduced diameter to cooperate with a cylindrical portion 70a of the reduced end portion 70 of the stem 52, while the outer block has a tapered discharge opening in which is the oppositely tapered end 70b of the end portion 70. The cylindrical portion 70a of the portion 70 is of less diameter than the body of the stem 52 and, in cooperation with the tapered opening, determines the nature of the spray discharged by the nozzle. In this case the rapidly accelerated part of the valve movement before the secondary spring 66 becomes effective, preferably is completed while the cylindrical portion 70a of the end of the stem is within or partly within the cooperating small diameter cylindrical surface at 47a of the member 47, but is sufficient to provide an open area past the valve at 68 greater than the cylindrical annular orifice between the end 70 of the stem and the member 47. The restriction to the flow of fuel, therefore, is thereafter that of the cylindrical annular orifice until the inner edge of the cylindrical surface 70a of the end portion 70 of the stem approaches the outer edge of the cooperating cylindrical surface 47a. The effect is thus to provide an orifice of fixed area made quickly effective by the rapidly accelerated initial movement of the stem, and, within a limited further movement of the stem, to provide a varying orifice opening, gradually increasing in area in response to a gradually increasing hydraulic pressure during the final movement of the stem. In this case when the valve 56 cracks sufficiently to leak a small amount of fuel, but insufficiently to build up pressure in the conical annular space adjacent the underside of the part 56 of the stem, the valve seat surface will be added to the stem area previously active to open the valve. The effectiveness of the valve seat surface for this purpose is enhanced by the addition of a groove 71, which insures distribution of pressure thereabout. After the valve seat opens, however, and the effective restriction is at the outer surface of the end 70, there is a considerable back pressure against the valve portion 56 tending to close the valve and the surface acted upon hydraulically to open the valve is much less than before the valve opening movement began. This negative hydraulic differential, however, is compensated for by the use of the spring combination shown, which provides a very steeply declining characteristic curve adjacent p' q' of curve E of Fig. 10. Fuel passes through passage 49 to the chamber 48, through the slots in the nuts 60 and 58 to the bore 50 in the tip 40 adjacent to reduced portion 52a of the stem 52, and upon opening of the valve through the slots 52b in the stem 52 past the valve surface 68, valve portion 56 and the end portion 70 of the stem 52 and through the discharge opening in the outer insert 46. This con-

struction, it will be noted, permits of the annular discharge opening having a large thickness radially irrespective of the size of the stem 52.

In the modification shown in Fig. 4, the tip is divided into an inner portion 75 and an outer portion 76, the outer portion being shouldered to be engaged by a retainer sleeve 77 which is drawn towards the holder 79 by a retainer nut 78 threaded on the holder so as to hold the portions of the tip in engagement with each other and the inner portion 75 in engagement with the holder 79. The holder 79 and the portion 75 are recessed to form a chamber 80 which is in communication through passage 81 in the holder 79 with the fuel supply. The portions of the tip are bored to receive a valve stem 82, the bore being enlarged at the upper end in the outer tip portion 76 to receive a valve 82a arranged to seat on the adjacent face of the inner tip portion 75. The upper portion of the stem 82 is threaded to receive a nut 84 which is shouldered, as at 84a, to engage the inner edge of a cupped disk spring 86 the outer edge of which rests upon the outer edge of an uncupped disk spring 88 bearing at its outer edge portion, only, on the bottom of the recess formed in the inner portion 75 of the tip. The bottom of the recess in the portion 75 is inclined at its outer edge so the disk spring 88 will bear only at its outer edge and there will be sufficient clearance between the remainder of the disk spring and the bottom of the recess to permit of the desired movement of the spring towards the bottom of the recess. The lower portion of the nut 84 is slotted to permit the passage of fuel past the disk springs and the nut is held in adjusted position on the stem 82 by a wire member 90 which has a portion adapted to engage in cooperating slots in the stem 82 and nut 84; a portion fitting a thread in the nut 84 to hold the wire in position and a projecting portion for use in removing the wire. The nut 84 is adjusted to engage the bottom of the recess in the portion 75 of the tip at the limit of movement of the lower disk spring 88 and shims 92 placed between the inner edge of the upper spring disk 86 and the shoulder 84a of the nut give to the disk 86 an initial deflection corresponding to a point on the portion $p-q$ of the curve A of Fig. 10.

In operation, fuel under pressure supplied through passage 81 to the chamber 80 acts upon an unbalanced area of the structure to shift the valve 82a and stem 82 against the action of the disk spring 86 to open the valve 82a and permit fuel to flow through the slots in the nut 84, past valve 82a to the bore for the stem 82, through the grooves 82b in the stem 82 to the bore for the stem at the portion 82c of the stem of reduced diameter to discharge between the conical portion 82d and the outer edge of the bore for the stem 82. As in the other modifications, the disk spring 86 permits of the opening of the valve at a gradually accelerated rate until the disk 86 engages the disk 88 and thereafter the opening of the valve is gradual under gradually increasing fuel pressure until the nut 84 engages the bottom of the recess in the portion 75 and prevents further opening of the valve. In this case, as in the case of Fig. 3, the accelerated movement of the stem 82 preferably opens the valve to a point at which the open area for the passage of fuel past the valve is considerably greater than that of the cylindrical annular discharge orifice at the outer end of the stem. The discharge

orifice area remains substantially constant during the gradual further movement of the stem, until the inner edge of the cylindrical end of the stem reaches the outer edge of the member 76, at which point the discharge orifice area rapidly increases with a further movement of the stem.

In the modification shown in Fig. 5 the tip 8 is secured to a holder 3 by a retainer nut 2, both the holder 3 and tip 8 being recessed to form a chamber 7 which is in communication with a source of fuel supply through the passage 6 in the holder 3 and the tip 8 is bored to receive the valve stem 16.

In this modification the bore in the tip 8 is tapered to form a seat 93 for the valve surface 94 on the stem 16. Below the seat 93 the bore is enlarged slightly for a short distance to permit a free flow of fuel to one or more V-shaped grooves 95 formed in the surface of the stem 16 and gradually reducing in depth a short distance above the lower end of the stem. The lower end of the stem is beveled on its perimeter as at 96 and the bevel may be varied so as to cut off a greater or less portion of each of the grooves 95 and thus provide at each groove an opening of greater or less extent through which the fuel is discharged upon the opening of the valve at the seat 93 until the stem 16 is shifted sufficiently to project the lower end of each groove beyond the lower end of the tip 8. This arrangement provides, as does that of Fig. 4, a substantially constant orifice opening during the initial accelerated movement of the stem, with a rapid enlargement of the orifice opening during the last part of the stem movement. The inner end of the stem 16 is threaded, as at 18, to receive a nut 22 which is exteriorly threaded to receive a nut 24'. The nut 22 is also transversely slotted at both its outer and inner ends; at its outer end to receive a suitable tool for adjusting the nut 22 on the stem 16 and at its inner end to permit the flow of fuel past the spring disks. The outer nut 24' is also slotted to permit the flow of fuel and is shouldered, as at 24b, to form a seat for a spring wire ring 100 arranged to engage the outer edge of a disk spring 102. The disk spring 102 is supported at its inner edge upon a spring wire ring 104 which is supported upon the inner edge of a disk spring 106 and the disk spring 106 is supported at its outer edge upon a spring wire ring which rests upon the bottom of the recess in the tip 8.

In the operation of this modification the spring disks 102 and 106 act in series in resisting the initial opening movement of the valve stem 16 until the shoulder 22b on the nut 22 engages the inner edge of the disk spring 102 whereupon further movement of the valve stem is opposed by the spring disk 106 alone and the spring disk 102 moves with the valve stem without further deflection. In this construction the spring disk 102 is cupped and has a characteristic curve similar to curve A of Fig. 10 while the disk 106 is uncupped and has a characteristic curve similar to the curve D of Fig. 10. The characteristic curve of the combined springs is as shown in curve E of Fig. 10. The shoulder 22b engages the disk spring 106 at some point, as q' , in the curve E and thereafter the spring 106, acting alone, gives a characteristic curve, as G, starting from the point q' .

While nozzles comprising various combinations of springs and control valves have been shown in the modifications just described it is to be

understood that the combinations are not limited to the valve constructions shown in those modifications as the spring arrangements are adaptable for use with valves of other constructions.

5 As illustrative of such other constructions there is shown in Fig. 6 a construction in which the valve stem 16' is cylindrical, as at 161 beyond the conical valve surface 20', and the cylindrical extension 161 cooperates with a slightly enlarged portion, as at 14b, of the bore 14 for the stem 16' in determining the characteristics of the spray formed by the nozzle.

10 In the structure shown in Fig. 7, the stem 16² is provided with a conical valve surface 20² which cooperates with a corresponding valve seat formed in the bore 14² of the nozzle tip 8. Beyond the surface 20² the stem 16² is cylindrical, as at 162, but of less diameter than the bore 14² and the cylindrical portion 162 is joined by a further conical surface 163 to a further cylindrical portion 164 which fits the bore 14². The spring associated with a valve of this construction would enable the stem to accelerate rapidly until the conical surface 20² ceases to restrict the flow of fuel but the flow would be restricted, at this time, by the small opening between the cylindrical portion 164 and the wall of the bore 14². Continued movement of the stem 16² would not increase the discharge opening until the cylindrical portion 164 is moved out of the bore and the flow is then controlled by the common edge of the cylindrical surface 164 and the conical surface 163 cooperating with the lower edge of the bore 14². This construction gives a substantially constant discharge for a considerable portion of the movement of the stem 16² while the cylindrical portion 164 of the stem remains in the bore but upon movement of the cylindrical portion 164 from the bore the discharge opening increases rapidly. The unbalanced area of the stem subjected to fuel pressure and the characteristic pointed out above of the cupped spring give a very rapid acceleration of the stem during its initial movement. Retardation of the movement of the stem by the action of the second spring can be made effective somewhat before the beginning of the control of the discharge by the common edge of the cylindrical surface 164 and the conical surface 163 and thereafter increase in the discharge opening would be gradual upon a gradual increase in fuel pressure, as previously explained.

15 In the construction shown in Fig. 8, the stem 16³ is provided with a conical valve surface 20³ which cooperates with a correspondingly shaped seat in the bore 14³ and beyond the surface 20³ the stem 16³, instead of being cylindrical, gradually increases in diameter for a short distance towards its outer end, as at 165, and cooperates with a correspondingly shaped portion of the bore 14³, the relation of the parts being such, preferably, that the surface 165 closes the discharge passage when the surface 20³ is seated. This construction gives a gradually increasing discharge opening throughout the entire opening movement of the valve stem and is suitable for use with a spring arrangement which gives a rapid initial movement of the valve stem and further gradual movement of the stem upon further increases in the fuel pressure. The rapid and rapidly accelerated movement carries the stem to a point beyond that at which the valve seat appreciably restricts. Thereafter during the period of gradual opening with increase of pressure, restriction is entirely at the discharge orifice surface 165.

In the modification shown in Fig. 9, the stem 52' has an enlarged portion 56' connected to the stem by a conical valve surface 68' which is grooved, as at 71', similar to the construction shown in Fig. 3 but in this modification the discharge orifice is a small opening 166 of fixed diameter in the insert 167. In this modification, the spring arrangement would be such as to permit of a rapid initial movement of the valve stem to provide an opening of the valve of such size as to give maximum discharge through the opening 167 and thereafter further opening movement of the valve stem may be prevented. A spring arrangement such as that of Fig. 3 or Fig. 5 would be most suitable in this case. The springs 62 and 64 in series of Fig. 3 would provide an extremely rapid accelerating effect as at p' q' of curve E of Fig. 10, to compensate for the reduced opening effect of the fuel pressure on the stem after the valve of the stem is unseated. The spring 66 of Fig. 3 may be somewhat stiffer than is properly used with the nozzle structure of Fig. 3, since no gradual opening with increased fuel pressure is required in the case of Fig. 9.

I claim:

1. In a nozzle of the fuel injection type, a casing having a fuel discharge port, a valve controlling said port, a stem on said valve, a cupped disk spring, a second disk spring, means on said valve stem acting upon said springs, said means deflecting said cupped spring to hold said valve closed until subjected to fuel at a predetermined pressure and acting upon said second spring upon a predetermined opening movement of said valve.

2. In a nozzle of the fuel injection type, a casing having a fuel discharge port, a valve controlling said port, a stem on said valve, a cupped disk spring, a second disk spring, means on said valve stem acting upon said springs, said means deflecting said cupped spring to hold said valve closed until subjected to fuel at a predetermined pressure and acting upon said second spring upon a predetermined opening movement of said valve, said springs acting to oppose further opening movement of said valve.

3. In a nozzle of the fuel injection type, a casing having a fuel discharge port, a valve controlling said port, a stem on said valve, a cupped disk spring, a second disk spring, means on said valve stem acting upon said springs, said means deflecting said cupped spring to hold said valve closed until subjected to fuel at a predetermined pressure and acting upon said second spring upon a predetermined opening movement of said valve, said cupped spring being inactive to oppose further opening movement of said valve upon said second spring becoming active.

4. In a nozzle of the fuel injection type, a casing having a fuel discharge port, a valve controlling said port, a stem on said valve, a cupped disk spring, a second disk spring, means on said valve stem acting upon said springs, said means deflecting said cupped spring to hold said valve closed until subjected to fuel at a predetermined pressure and acting upon said second spring upon a predetermined opening movement of said valve, said cupped spring being moved bodily upon said second spring becoming active.

5. In a nozzle of the fuel injection type, a valve for controlling the fuel discharge operable to open position by fuel pressure and a spring opposing operation of the valve by fuel pressure and flexed by the initial portion only of the opening movement of said valve.

6. In a nozzle of the fuel injection type, a valve

for controlling the fuel discharge operable to open position by fuel pressure, and spring means opposing operation of said valve by fuel pressure, said spring means comprising a plurality of springs and having one spring arranged to be flexed by the initial portion only of the opening movement of said valve and held unchanged during the remainder of the opening movement of said valve.

7. In a nozzle of the fuel injection type, a valve for controlling the fuel discharge operable to open position by fuel pressure, and spring means opposing operation of said valve by fuel pressure, said spring means comprising primary and secondary springs and said primary spring being arranged to have its degree of deflection from a free position changed during the initial portion only of the opening movement of said valve and held unchanged during the further portion of said movement.

8. In a nozzle of the fuel injection type, valve means for controlling the fuel discharge operable to open position by fuel pressure and spring means opposing operation of said valve by fuel pressure, said spring means comprising a spring flexed during the initial movement of said valve means providing a restricted discharge opening for said nozzle and a second spring opposing further movement of said valve means providing a larger discharge opening for said nozzle while said first spring is held as flexed during the initial opening movement of said valve.

9. In a nozzle of the fuel injection type, valve means for controlling the fuel discharge operable to open position by fuel pressure and spring means opposing operation of said valve by fuel

pressure, said spring means comprising a spring flexed during an initial movement of said valve providing a uniform discharge from said nozzle and a second spring opposing a further movement of said valve means providing an increasing discharge opening for said nozzle while said first spring is retained in flexed condition as flexed during the initial opening movement of said valve.

10. In a nozzle of the fuel injection type, a casing member having a bore therein, a stem member slidably movable in said bore relative to said casing member, said members having cooperating shoulders forming a valve and valve seat for preventing discharge from said nozzle, said stem member having a slot formed therein at the common sliding surface of said members, said slot extending outwardly from said valve and forming a discharge orifice for said nozzle, the effective cross-sectional area of said orifice being varied by movement of said stem member, said orifice having a substantially constant relatively small cross-sectional area in the closed position of said valve and during initial movement of said stem member from the closed position of said valve and an enlarged cross-sectional area after said initial movement is completed and spring means opposing movement of said stem member from the closed position of said valve, said spring means having a substantially constant effective stiffness during the initial opening movement of said valve stem and a sharply increased effective stiffness upon completion of said initial opening movement.

EVERETT M. PURDY.
WARNER T. TABB.

CERTIFICATE OF CORRECTION.

Patent No. 2,192,803.

March 5, 1940.

EVERETT M. PURDY, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 6, second column, line 7, claim 9, strike out the words "in flexed condition"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of April, A. D. 1940.

(Seal)

Leslie Frazer
Acting Commissioner of Patents.