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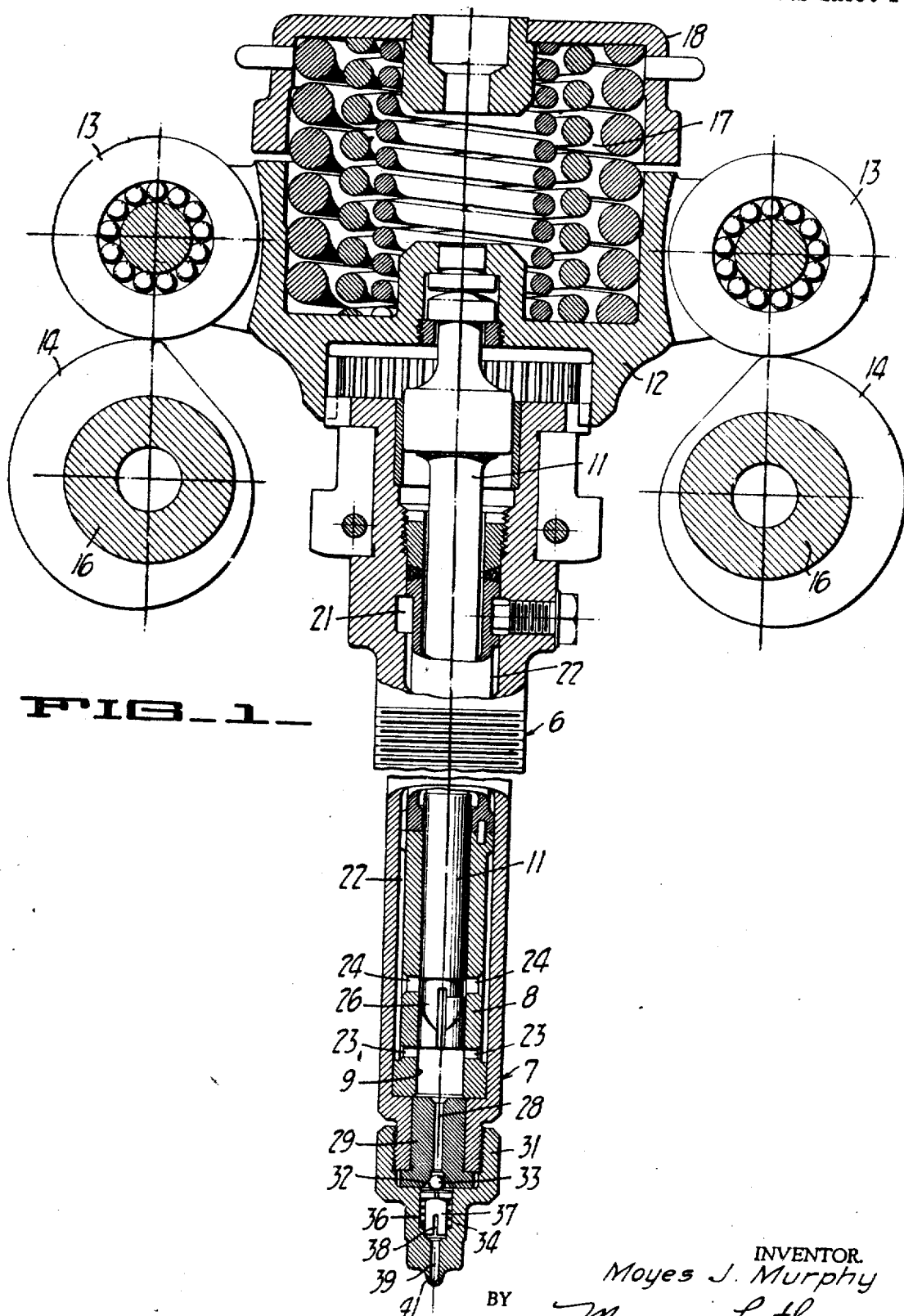
M. J. MURPHY

2,272,094

FUEL INJECTOR

Filed May 10, 1937

2 Sheets-Sheet 1



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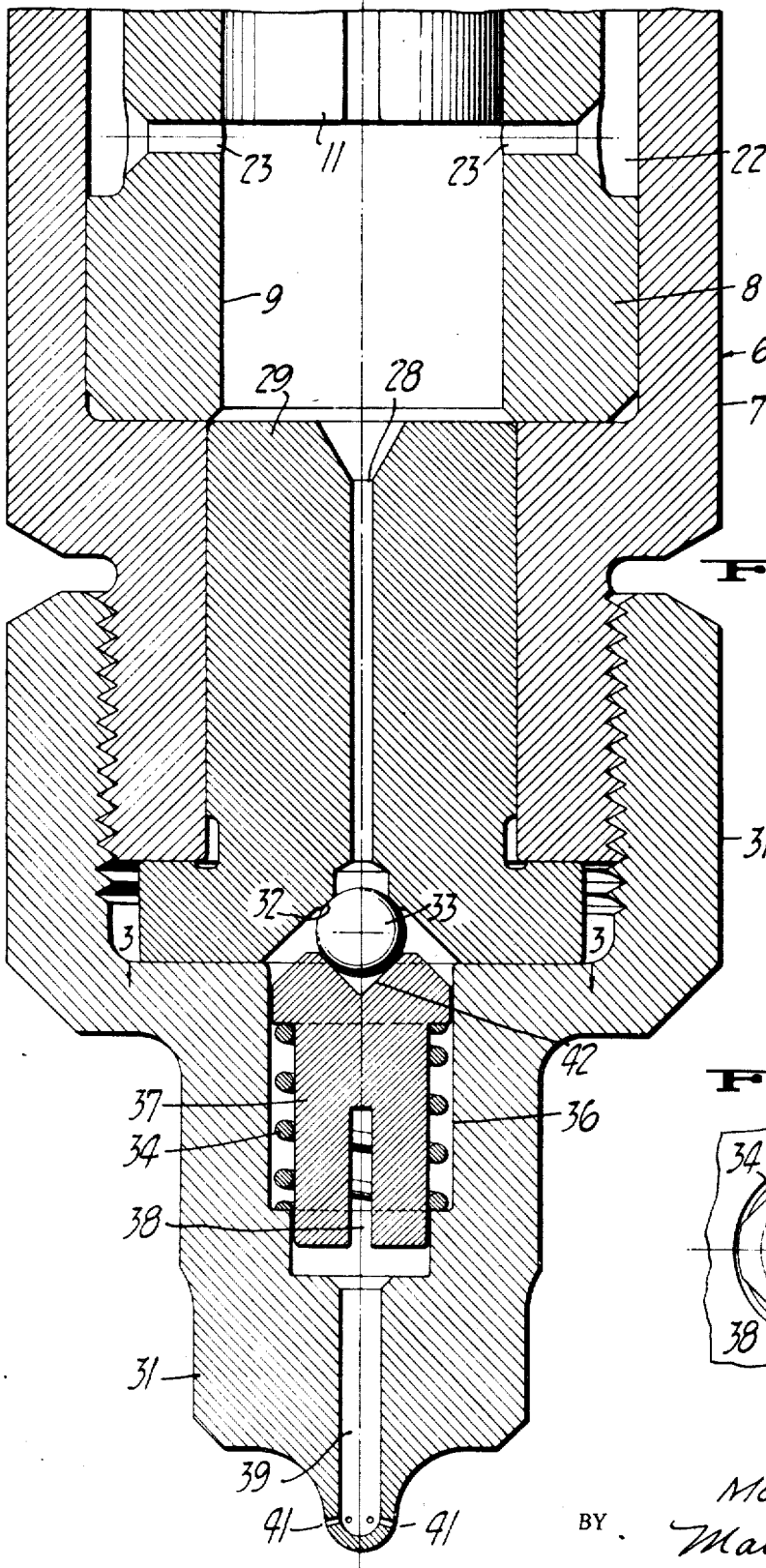
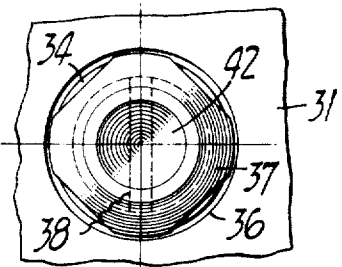


FIG. 2.

FIG. 3.



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FUEL INJECTOR

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Application May 10, 1937, Serial No. 141,674

5 Claims. (Cl. 299—107.2)

My invention relates generally to means for introducing fuel into internal combustion engines, although it likewise concerns any discharge device for releasing fuel under pressure in a predetermined manner. A typical arrangement of a fuel injector in an internal combustion engine wherein the injector has some of the same physical characteristics as the fuel injector of this case is disclosed in my copending application Serial No. 743,339, filed September 10, 1934, entitled "Fuel injection apparatus," and of which as to some matters this application is a continuation.

In the discharge of liquid fuel, such as fuel oil, from a conduit for combustion, it is important to have the discharge as carefully regulated and metered as possible, since the efficiency of combustion is directly dependent upon the character of discharge of fuel from its conduit. This is particularly true in the case of internal combustion engines employing compression ignition, since the character of the fuel discharge largely controls the efficiency of operation and performance characteristics of the engine. In larger engines, where the absolute quantity of fuel handled per cycle is large, an error of a certain magnitude is proportionately insignificant and inconsequential, and variations in engine performance ascribable to fuel error are not especially noticeable or objectionable; but when the engine size is reduced and the absolute quantity of fuel per cycle is correspondingly reduced, then an error of comparable magnitude is far larger proportionately and adversely affects the operation and efficiency of combustion to a serious degree.

It is therefore an object of my invention to provide a fuel injector which is capable of providing an efficient release of fuel for combustion.

Another object of my invention is to provide means for dispensing relatively small quantities of fuel per cycle, with injection errors which are also relatively small.

A further object of my invention is to provide an injector which has excellent characteristics when dispensing relatively small quantities of fuel.

Another object of my invention is to provide an injector which conforms generally to good engineering practice yet has improved characteristics.

Another object of my invention is to provide an improved means for releasing fuel under pressure from its conduit,

An additional object of my invention is to provide means for releasing fuel according to a predetermined cycle of operation.

The foregoing and other objects are attained in the embodiment of the invention illustrated in the drawings, in which—

Fig. 1 is a cross-section on an axial plane, showing a fuel injector in accordance with my invention, certain portions being shown in side elevation and part of the figure being broken away to reduce its size;

Fig. 2 is a cross-section similar to Fig. 1 but showing the terminus of the fuel injector to an enlarged scale;

Fig. 3 is a cross-section the plane of which is indicated by the line 3—3 of Fig. 2, a portion of the figure being broken away to reduce its size.

In its preferred form, the fuel injector of my invention comprises an injector body having a bore and an outlet from the bore, combined with a plunger reciprocable in the bore to discharge fuel through the outlet, and having a means, such as a spring-loaded check valve operated by the fuel, for repeatedly interrupting the discharge of fuel through said outlet during a single reciprocation of said plunger.

Although the fuel injector of my invention is well adapted to use under various different circumstances, and in fact wherever fuel is to be released from a conduit according to a predetermined cycle of operation, it finds especial adaptation in conjunction with an engine operating upon the compression ignition cycle as described in my copending application hereinabove identified, and in the present instance it is likewise disclosed in such an embodiment as typical.

In an engine installation, the injector body 6 is seated in a suitable socket in the engine head (not shown), so that the depending portion 7 of the body is in proximity to the combustion chamber. Within the injector body 6 there is an injector barrel 8 having a central bore 9 therein within which reciprocates a plunger 11. The plunger is suitably guided and extends to a cross-head 12 carrying roller cam followers 13 at its opposite forks. Both of the followers 13 are urged to respond to the contour of driving cams 14 on cam shafts 16, by reason of a plurality of nested coil springs 17 abutting a cap 18 suitably fixed with respect to the injector body 6. During rotation of the cam shafts 16 the cams 14 simultaneously lift the rollers 13 and the cross-head 12 against the

urgency of the springs 17 and, correspondingly, lift the plunger 11. During further rotation of the cam shafts 16, the springs 17 return the plunger 11 within the bore 9 so that the plunger 11 is continually and cyclically reciprocated during operation of the engine.

Fuel oil is supplied to the injector body 6 by any suitable means, and enters into a channel 21 which communicates by means of a longitudinal annular passage 22 with radial passages 23 opening into the bore 9 beneath the plunger 11. Relief passages 24, communicating radially with the passage 22, are likewise in communication with the bore 9 through spiral grooves 26 provided in the plunger 11. Rotation of the plunger 11 by suitable mechanism varies the time of cut-off of fuel injection which may be established at any appropriate or selected point to terminate the injection period. But, prior to cut-off, fuel which has been trapped within the bore 9 due to covering of the passages 23 and 24 by the descent of the plunger, is therefore metered as it is segregated from the general body of fuel in the passage 22.

This metered quantity of fuel is expelled from the bore 9 by further descent of the plunger 11, through an outlet 28 which preferably is a cylindrical bore coaxial with the bore 9 and piercing a thimble 29. The thimble is held in the end of the injector body 6 by a threaded cap 31 engaging the body 6. The diameter of the passage 28 is made relatively small, and its length is also relatively short. Under preferred operating conditions there is turbulent flow therethrough. At the terminus of the outlet 28 and formed in the thimble 29, there is a valve seat 32 which preferably is conical in contour and is coaxial with the outlet 28.

Adapted to rest upon the valve seat 32 is a check valve, preferably in the form of a ball 33, of relatively small diameter and urged upon the seat 32 by a coil spring 34 seated within a recess 35 within the cap 31. The force of the spring is exerted through a centralizer 37 contacting the ball 33 and freely slidable within the recess 35 because of ample clearance provided between the walls of the recess and the centralizer. The centralizer 37 is provided with a passage 38 therein, so that fuel passing the ball 33 flows past the square head of the centralizer and both around the body thereof and through the passage 38 into a discharge channel 39 coaxial with the outlet 28, finally communicating with injection orifices 41, usually six in number, arranged equidistantly and radially about the discharge passage 39 as a center.

The structure so far described, adjacent the check valve 33, is shown in enlarged detail in Fig. 2, since the proportions of the ball 33, the channel 28, the spring 34 and the centralizer 37 are such that during the normal reciprocatory movement of the plunger 11 within the bore 9, and particularly during the injection period of the operating cycle except possibly at highest engine speeds, the valve 33 chatters upon its seat 32. The elastic fuel flowing through the channel 28 dislodges the ball 33 from its seat just far enough to release the fuel. Movement of the check 33 is accompanied by translation of the centralizer 37 and compression of the spring 34, but the proportion, elasticity and strength of the parts are such that the spring 34 overcomes the force of the initial discharge pressure of the fuel and reseats the ball valve 33 upon the valve seat 32. After such initial re-

seating, the subsequently increased pressure in the channel 28, due to further discharging reciprocation of the plunger 11, again unseats the valve 33, recompressing the spring 34. This alternate unseating and seating of the ball 33 during the injection period preferably occurs repeatedly and with such rapidity as to give rise to an audible buzzing sound when the injector is discharged at low engine speeds; hence the ball 33 is referred to herein as fluttering, vibrating or chattering upon its seat with audible frequency.

The frequency of vibration varies with engine speed, and the system may be such that the frequency increases from an audible one at low engine speeds to a superaudible one at high engine speeds. The decreasing amplitude of vibration with increasing frequency may even be so related to engine speed that adjacent maximum engine speed the amplitude is virtually zero; that is, the check valve may remain continuously open during the injection interval.

The vibration characteristics are affected by many factors other than the elasticity of the fuel itself and the unbalance of the check valve 33. For example, the length and the volume of the fuel column defined by passage 28 are kept relatively small to reduce pressure reflection waves and surges therein and to maintain a relatively high natural resonance therein. Similarly, the length and the volume of the fuel column between the check valve 33 and the orifices 41 are kept relatively small to reduce the effect of fuel elasticity and to maintain substantially undamped the surges travelling from the check valve to the orifices. It is emphasized that the centralizer 37 and the spring 34 are of small mass and are out of frictional contact with the surrounding walls to avoid the effect of sliding friction and large inertia forces.

The result of such operation of the check 33 is to provide an interrupted or noncontinuous discharge of fuel from the passage 28 into the outlet 39, so that for a given quantity or volume of fuel metered by entrapment within the bore 9, while the average velocity of efflux of the fuel through the ball check is probably the same in reference to a given injection period as though no chattering occurred, nevertheless the average fuel velocity during the time each individual discharge is taking place is considerably more than would be the case if the ball 33 remained continuously unseated. Hence, it is found in practice that a relatively small quantity of metered fuel can be introduced into the cylinder at considerably more than would be its velocity if the ball 33 did not chatter. Improved practical results in engine operation are thus attained.

For example, with a continuously open check valve and a high engine speed, let it be assumed that satisfactory injection occurs. But as the engine speed is reduced, the injection pressure also reduces, but at the 2.7 power of the engine speed. At idling speed, the injection pressure is therefore so low as to give very poor injection. If the injection pressure at idling speed is arbitrarily increased to a minimum satisfactory value, then at high or normal engine operating speeds the injection pressure is excessive—in a representative case being about 12,000 pounds per square inch. Yet when the design is changed to afford a vibrating check valve and interrupted injection, particularly at idling speeds, entirely satisfactory idling injection is obtained without

increasing the injection pressure above 4000 pounds per square inch at high or normal engine operating speeds.

The arrangement of the outlet check valve in seating and unseating repeatedly during the discharge of the fuel is not to be confused with a system (especially a system including a long fuel line between the pump and the valve) in which the valve 33 is not completely opened by the initial pressure and wavers irregularly in semi-open and open positions during the time of injection without in fact interrupting the fuel flow. In the present instance, the parts are so arranged and proportioned that the valve 33 actually contacts its seat 32 repeatedly during the injection period, so that each injection is really a series of successive spurts or bursts of fuel, each slug following the preceding one with great rapidity, yet with a definite interval therebetween.

This repetitive stream of bursts of fuel which emerges from the apertures 41 during the injection period not only is materially different from the standard continuous injection, in the shape of the gas envelope surrounding the central fuel core and in the streamlined shape of the fuel particles themselves, but likewise varies materially in penetrating power and dispersion within the combustion chamber. The different effect is particularly noticeable at low engine speeds or during prolonged engine idling, since the velocity of efflux of the individual fuel bursts is considerably higher than it would be if there were a continuous discharge or injection of a comparable amount of fuel during the same injection period. The practical results are, materially improved characteristics during operation on minute quantities of fuel, and good penetration and excellent combustion even though idling of a relatively small engine is prolonged.

In the present instance, the beneficial and improved results are attained without materially altering the design of the injector so far as its general aspect is concerned, but are attained primarily by designing the passage 28, the valve seat 32, the check valve 33, the spring 34 and the centralizer 37 with such proportions and relationships that a vibrating system is provided to afford a means for interrupting or repeatedly severing the stream of fuel being injected during the injection period. This interrupting means, being operated by the fuel itself, and entailing the use of only a few very simple parts, is capable of operation without difficulty over protracted periods.

As illustrative of a typical embodiment of my invention in an engine cylinder of about 170 cubic inches volume, by which the results herein described are attained, the drawing of Fig. 2 shows the plunger 11 having a diameter of .4 inch. The passage 28 has an internal diameter of .062 inch, while the total length of the thimble is about .75 inch. The valve seat 32 is a cone the included angle between elements of which is 90°, having a minimum diameter of .078 inch and a maximum diameter of .098 inch. The material is S. A. E. No. 52100 steel and is treated to attain a Rockwell hardness of C63-65. The ball valve 33 itself is .125 inch in diameter and is held to a limit of sphericity of .000025 inch, being made of high chrome steel and hardened. The centralizer 37, which abuts the ball 33, is .406 inch in overall length, has a maximum diameter of about .24 inch and a body diameter of about .175 inch. The conical seat 42 thereof has an included angle between elements of

90° and a maximum diameter of .125 inch, being lapped to fit the ball 33 with a seat entirely therearound. The material of the centralizer 37 is drill rod hardened to Rockwell hardness of C63-65. The spring 34 which surrounds the centralizer 37 is made of No. 16 music wire gauge, having a diameter of .037 inch. The coiled spring has an internal diameter which is a slip fit on a mandrel of .176 inch diameter, and an outside diameter which is a slip fit in a hole having a diameter of .256 inch. The total number of coils is four and a half, with three of the coils being active. The solid height of the spring—that is, when it is compressed with all coils in abutment—is a maximum of .172 inch; while, when assembled, the height of the spring or its axial dimension is .25 inch, at which time the load is permissibly variable between 8.9 and 10.3 pounds. So far as the cap 31 is concerned, the recess 36 has a diameter of .261 inch, while the passage 38 has a diameter of .062 inch, and the outlet orifices 41, of which there are six, are each .01 inch in diameter.

The proportion of the parts and their relative arrangement as disclosed herein provide a vibrating check valve system producing consistent interruption of the injection fuel during the injection period.

I claim:

1. In a fuel injector having a pump barrel and a plunger working in said barrel, a spray nozzle having a discharge orifice of constant area, a check valve controlling the passage of fuel from said barrel to said nozzle, and closing means for said valve, means promoting a chattering action of said check valve comprising an outlet from said pump barrel of reduced volume and the check valve and its closing means being of small mass to reduce their inertia, and means for maintaining substantially undamped the surges traveling from the check valve to the nozzle.

2. In a fuel injector having a pump barrel and a plunger working in said barrel, a discharge outlet from said barrel having a spray nozzle structure at its outer end with a spray orifice of constant area and less than that of the outlet from said barrel, the combination of a check valve intermediate the ends of said outlet, and spring means for closing said valve, said outlet from said barrel to said valve being of an effective volume to keep the fuel column therein relatively small to reduce pressure reflection waves and surges therein and to maintain a relatively high natural resonance therein, said valve and its closing means being of small mass and said parts being so constructed, proportioned, and arranged that said valve is caused to chatter on its seat during the discharging stroke of said plunger, the length and volume of said outlet between said valve and said nozzle being relatively small to reduce the effect of fuel elasticity and maintain substantially undamped the surges traveling from the check valve to the nozzle.

3. In a fuel injector having a pump barrel and a plunger working in said barrel, the spray nozzle having a discharge orifice of constant area, the combination of an outlet from said barrel so constructed as to reduce the fuel flowing therein to a small stream to reduce pressure reflection waves and surges therein and to maintain a relatively high natural resonance therein, a check valve for controlling the passage of fuel from said outlet, a spring for closing said valve, a centralizer cooperating with said spring, the mass of the valve and centralizer being small to re-

duce the inertia of these parts said parts being so constructed, proportioned, and arranged so that under the action of the pressure of the fuel from said outlet the valve chatters on its seat, the centralizer and spring being disposed ahead of the valve in a space between said valve and nozzle and acting to reduce the volume of said space to a small amount so as to reduce the effect of fuel elasticity and maintain substantially undamped the surges traveling from the check valve to the nozzle.

4. In a fuel injector having a pump barrel and a plunger working in said barrel, the combination of a restricted outlet from said barrel, a check valve controlling said outlet, a centralizer abutting said valve and spaced from the walls of said body, a spring abutting said centralizer, and a nozzle of constant discharge area and less than

that of the outlet from said barrel, said parts so constructed, proportioned, and arranged as to cause said valve to chatter under the pressure of fuel from said outlet.

5. In a fuel injector having a pump barrel and a plunger working therein, the combination of a restricted outlet from said barrel, a ball check valve controlling the discharge from said outlet and a discharge passage beyond said valve having an outlet of constant area and less than that of the outlet from said barrel, a spring in said discharge passage urging said valve to its seat and a centralizer interposed between and contacting said valve and spring, the above parts so constructed, proportioned, and arranged as to cause said valve to chatter during a single discharge from said barrel.

MOYES J. MURPHY.