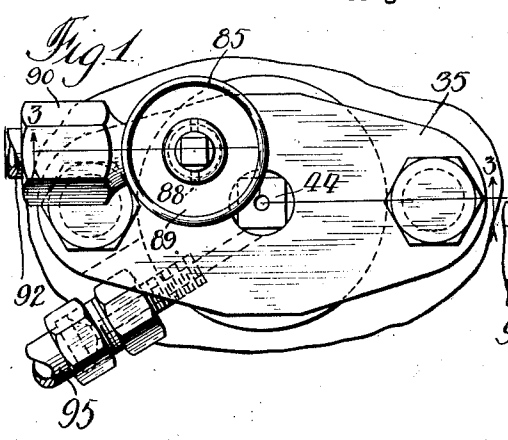
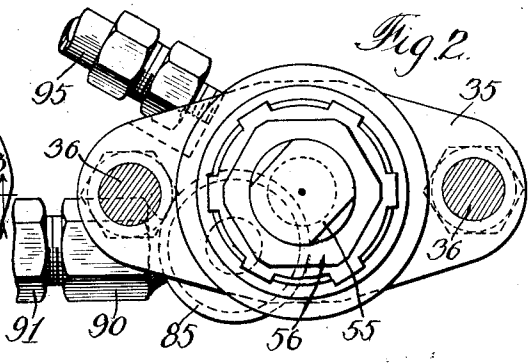
Oct. 16, 1928. 1,687,672

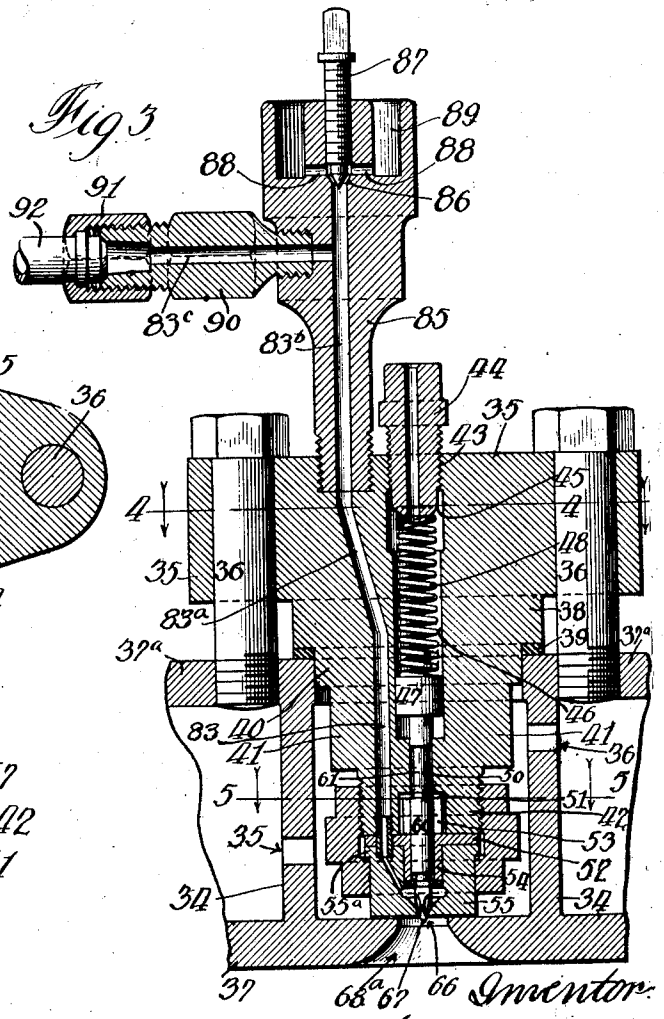
F. LANG

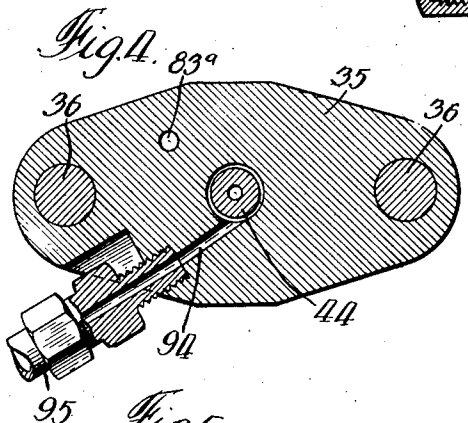
ATOMIZING DEVICE

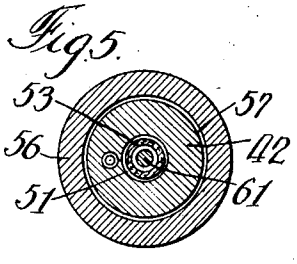
Original Filed June 22, 1923 2 Sheets-Sheet 1











Inventor
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By Luther Johnston Atty.

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F. LANG

ATOMIZING DEVICE

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Fig. 6

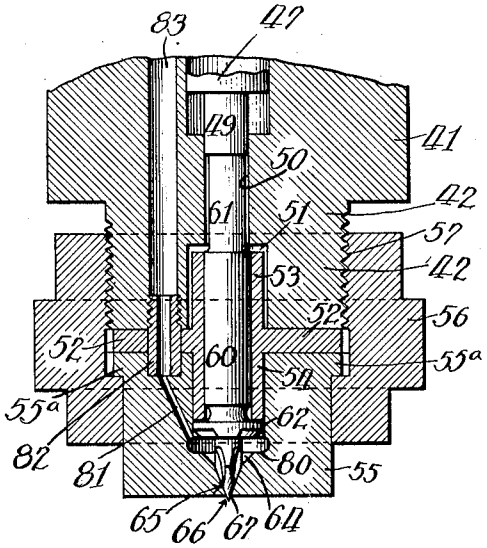


Fig. 12



Fig. 13

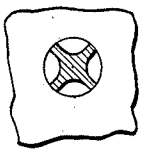


Fig. 11

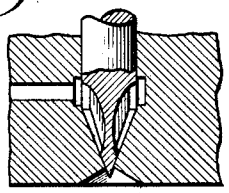


Fig. 10

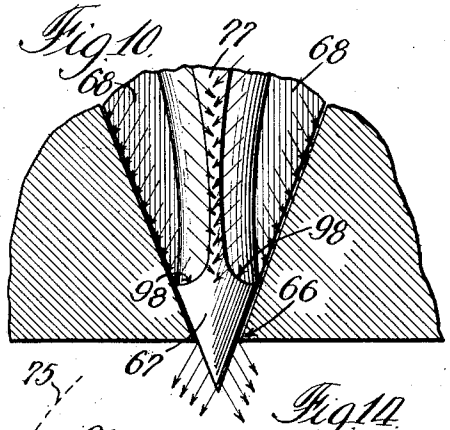


Fig. 7

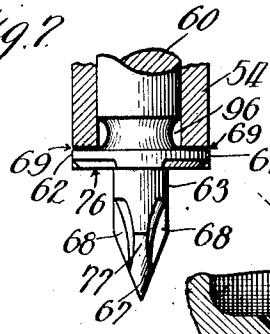


Fig. 9

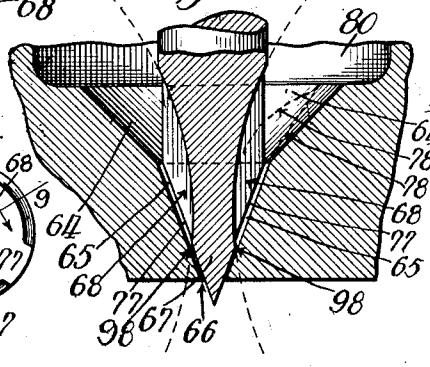


Fig. 14

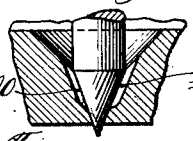


Fig. 8.

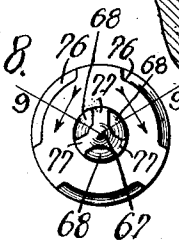
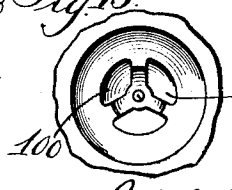


Fig. 15.



Inventor:
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By: Luther Johns Atty.

Patented Oct. 16, 1928. 1,687,672

UNITED STATES PATENT OFFICE.

FRANZ LANG, OF MUNICH, GERMANY, ASSIGNOR, BY MESNE ASSIGNMENTS, TO ACRO AKTIENGESELLSCHAFT, OF KUSSNACHT A/RIGI, SWITZERLAND, A CORPORATION OF SWITZERLAND.

ATOMIZING DEVICE.

Original application filed June 22, 1923, Serial No. 647,001, and in Germany October 14, 1921. Divided and this application filed January 12, 1925. Serial No. 1,940.

The present improvements relate to devices for delivering into the compression side of an engine cylinder or elsewhere for combustion liquid fuel in a highly divided state.

This is a division of my copending application known as Serial No. 647,001 filed June 22, 1923 on internal combustion engines, to which reference is made for a disclosure of the application of these improvements to a compression-ignition engine having many notable advantages. Another division of said copending application is filed concurrently herewith as Serial No. 1,939 on the improvements in fuel pumps in the first-mentioned copending application set forth and referred to herein.

The chief object of the present improvements is to increase efficiency both in the atomizing device as a unit and in the engine or other fuel-consuming device as a whole. It is a specific object to provide an atomizing device which, in its operative association with a suitable pump mechanism, for instance the one illustrated in my said copending applications, will reduce liquid fuel, of a large variety of kinds and of greatly differing specific gavities, to such an exceedingly fine state of subdivision as to result in the complete or substantially complete combustion of the combustible elements of the fuel when ignited, and thus to effect a saving in fuel per unit of work done or to increase the work done by a given unit of fuel, and thus to avoid, also, many objections to imperfect combustion. Other specific objects and advantages leading to increased efficiency will appear hereinafter, and also in my said first-mentioned copending application wherein notable advantages of an engine embodying the present improvements are set forth.

In the accompanying drawings which form a part of this specification, Figure 1 is a top view of my improved nozzle device; Fig. 2 is a bottom view of the same; Fig. 3 is a vertical section thereof as on the broken line 3—3 of Fig. 1 showing various parts in medial vertical section; Fig. 4 is a horizontal section on the broken line 4—4 of Fig. 3; Fig. 5 is a horizontal section on the line 5—5 of Fig. 3; Figs. 1 to 5 inclusive are drawn not only substantially to scale on the sheet submitted but also to size as applied by me to the engine shown in my said first-mentioned copending application; Fig. 6 is an enlarged fragmentary section corresponding to parts similarly shown in Fig. 3; Fig. 7 is a still further enlarged fragmentary view of the lower end of the nozzle valve device or spray point; Fig. 8 is a view of the device of Fig. 7 looking toward the spray point; Fig. 9 is a greatly enlarged sectional view of the spray point in its valve-opening position, taken on the broken line 9—9 of Fig. 8; Fig. 10 is a view fragmentarily showing the spray point in full lines and the seat member in section; Fig. 11 is a slightly modified form of nozzle tip construction and associated parts, partly in section; Fig. 12 shows an elevation of the nozzle tip of Fig. 11; Figs. 13 is a cross-section of the construction shown in Fig. 11; Fig. 14 is a fragmentary sectional view of a modified construction of nozzle element; and Fig. 15 is a top view of the construction of Fig. 14 with the spray point omitted.

Referring to Figs. 1 to 12 inclusive, the illustrated structure comprises a main support (Fig. 3) which has an outer part 35 oblong in shape provided with holes accommodating bolts 36 threaded into the top wall 37ª of the cylinder head. This main support has a cylindrical part 38 between which and the wall 37ª a packing gasket 39 is positioned whereby when the bolts 36 are drawn down a tight fit is obtained between the main support and the cylinder head. The main support has also a smaller cylindrical part or extension 40 which fits into a hole bored into the top of the cylinder head. There is next a cylindrical extension 41, of smaller diameter, and next a cylindrical and threaded extension 42, of still smaller diameter. This main support consisting of parts 35, 38, 40, 41 and 42 is a single piece of steel with the successively reduced portions or extensions turned out therefrom. It is axiallly bored and screw threaded at 43 to accommodate the threaded pressure-controlling plug 44, the hole at 43 being sufficiently enlarged for some distance, as indicated at 45, to provide for inward adjusting movements of the plug. The axial hole is continued on a somewhat smaller diameter at 46 to accommodate a piston 47 which is normally forced downward by the coiled spring 48. The piston 47 has an in-

tegral stem 49 (see Fig. 6) projecting into a boring 50 of still further reduced diameter and which opens into an enlarged axial boring or recess 51 produced in the lower end of the main support.

Resting on the lower end of the main support is a disc or flange 52 integral with a collar which has a sleeve-like part 53 extending upwardly and a similar part 54 extending downwardly. Resting against the lower surface of the collar or flange 52 is the upper surface of a nozzle cap 55 which has an annular flange or extension 55ª. A threaded coupling 56 is bored to fit nicely around the cylindrical cap 55 and engages the flange 55ª thereof, and by means of the threading at 57 between the coupling and the threaded extension 42 of the main support the cap 55 and the members 52—53—54 are held securely upon the lower end of the main support. Referring to Fig. 3 the distance between the lower surface of the main support extension 38 and the top surface of the cylinder head wall 37ª is such that when the packing gasket 39 is in position as illustrated and the clamping screws 36 are tightened the lower surface of the nozzle cap 55 becomes firmly seated upon the cylinder wall 37, and to insure the desired tight pressure-proof fit between the parts at the cylinder wall opening 68ª the engaging surfaces between the cap and the wall 37 are nicely finished. A gasket might be employed also at this point, but I find that I can maintain a close and tight engagement of the parts by the construction illustrated and described.

Fitting nicely for relative movement within the sleeve-like parts 53—54 (Fig. 6) is a cylindrical member 60 having an upwardly extending cylindrical part 61 abutting the lower end of the projection 49 and thereby receiving the controllable pressure of the spring 48 (Fig. 3). The stem 60 has near its lower end a disc-like enlargement 62 which overlies the lower end of the sleeve-like part 54, and this disc 62 constitutes a stop which limits the upward movement of the stem 60. Extending co-axially with the stem 60 and the disc 62 is the nozzle valve member 63 (Figure 7) which has a cylindrical part and a conical end portion terminating in a point. The cap 55 is provided with a relatively wide conical fuel-holding depression 64 (Fig. 6) merging into another conical depression 65, serving as a seat and terminating in a small opening at 66 through which the point of the valve part 67 extends. The opening at 66 is small, and in my actual practice on the engine illustrated in my said first-mentioned copending application is one millimeter in diameter.

It will be noted that three excavations or pockets 68 are formed, equally spaced apart, in the member 63, and that these excavations terminate short of the point or apex of the conical structure leaving the apex or point portion a solid cone, which is highly finished, as is also the inner surface of the conical recess 65, and a part of this point or end portion 67 constitutes a valve adapted to close the opening 66 under pressure of the spring 48.

It will be noted from Fig. 7, which illustrates parts in their relation when the point portion 67 is in valve-closing position, that between the sleeve-like member 54 and the stop 62 there is a slight space 69. In my practice this space is only two one-hundredths of a millimeter in the device shown. The space or clearance at 69 may well vary however, say from one one-hundredth of a millimeter to four or five one-hundredths of a millimeter according to the size of engine in connection with which the device is used, assuming the opening 66 and the angularity of the conical valve point remain constant. I prefer to employ a valve stem point of about the angularity shown, but departure may be made therefrom in either direction. There is a functional relation between the lift of the valve and the angularity of the valve point and also the size of the discharge orifice which should be considered in making such departures. It is obvious that the more clearance there is provided at 69, the greater will be the lift permitted for the valve point 67, and the larger will become the passageway between the point 67 and the conical surface 65, thus admitting a greater quantity of fuel in a given unit of time at a given pressure. From the exceedingly small amount of lift thus provided and the very gradual incline of the conical point it is apparent that the passageway through which the fuel must escape is exceedingly minute at any point thereof and according to the device actually used by me on the engine illustrated, with a valve lift of two one-hundredths of a millimeter the fuel must escape through a passageway which is only about eight one-thousandths of a millimeter across, or a little more than three ten-thousandths of an inch.

It will be noted that the valve point 67 contacts the conical seat provided for it throughout the extent of the conical portion of the valve member, and I consider it important that contact of valve and seat should be made to a substantially large extent to avoid destructive wear upon these nicely fitted parts, and to avoid the formation of a ring-like indentation on the valve or seat or both which would result if the valve were seated on a relatively narrow annular surface. In my practice as shown, the seating of the valve member upon the conical seat is carried upward into the area defined by the excavations 68. Since the valve and its seat are of steel and highly polished the construction is peculiarly adapted to withstand the effect of

long continued use without resurfacing operations or the renewal of parts.

The excavations 68 may conveniently be produced by means of a substantially thin grinding disc indicated twice by dotted lines 75 on Fig. 9, the desired width of the excavations being accomplished through a rotative movement of the valve part on its axis during the grinding operation. This method provides flat surfaces at each side of the excavation, and the bottom of the excavation becomes slightly rounded or humped outward. The cutouts 76 on the disc 62 are merely incidental to the operation of the disc grinder and are of no functional importance, but in manufacturing practice the results being produced at 76 furnish a guide to the depth of the cut being taken from time to time in producing the excavations 68.

It will be noted from Fig. 9 that the excavations 68 terminate short of the valve portion or tip part 67 whereby the valve part 67 has a continuous conical surface. These excavations 68 terminate, however, close to the valve seat, and in the construction shown their lower edges partly define the valve seat. They constitute pockets for holding a quantity of the liquid to be atomized and provide sharp edges over which the liquid must travel. Their walls also cause the liquid to change its direction sharply after impinging a surface of the walls forming the discharge channel.

The conical formation of the valve seat continues upward a material distance, as does the conical construction of the valve point beyond the valve-seat-engaging surface or portion thereof, and the webs or metal walls 77 contact the wall of the conical recess when the valve is closed. The construction is therefore such that in the lower portion of the excavations 68 respectively pockets are formed adapted to contain a quantity of the fuel or other liquid to be atomized. I should mention that the pocket construction is highly preferable since it results in the provision of relatively long wear surfaces on the pocket-dividing or forming partitions 77, and the valve member is thus seated not only at the annular portion thereof constituting the valve proper, but also all along the outer surfaces of these partitions 77. It is pointed out in this connection that the rapid and strong impingement of the valve upon its seat would tend to produce an annular indentation on either the valve seat or the valve, or both, resulting in inefficiency and the requirement of resurfacing or replacement of parts. By giving the valve and seat a relatively long surface in the longitudinal direction this objection is avoided, and through the production of the pockets or excavations 68 the liquid is admitted to a place, when the valve is closed, closely adjacent to the valve and seat proper.

It will be noted that above the conical recess 65 there is a second conical recess 64, wider than the recess 65, and that the excavations 68 open into the enlargement 64. It is not essential that the enlargement 64 have the capacity shown and I may, for instance to increase velocity of fuel flow through the reduction of the volume of liquid back of the valve, enlarge the valve stem or spray-point element as indicated by the dotted lines 78 and 78^a in Fig. 9; or the capacity of the enlargement 64 may be otherwise reduced, if desired. The provision of a ring-like fuel space around the excavations 68 makes for an equal distribution of fuel and pressure around the point member.

Above the enlargement 64 is an annular space 80, well seen in Fig. 6, which is defined at the top by the disc 62 of the valve element. Into this space 80, which constitutes also a distributing reservoir for the liquid and which opens directly into the enlargement or feeder 64, there is a conduit or boring 81 (Fig. 6) which leads into the hollow interior of a short pipe section 82, which pipe section fits into aligning holes bored through the collar 52 and into the upper portion of the cap member 55. The pipe section 82 is threaded into the lower part 42 of the main support and constitutes a lock against relative axial movement of the several parts. The pipe 82 opens into a boring 83, which will be understood to have been produced from the bottom of the part 42, and which boring extends upward a considerable distance (see Fig. 3) and is met by a boring 83^a, produced slantingly from the top of the outer clamping part 35. A threaded recess is produced above the open end of the drift 83^a, and into this threaded recess is screwed a connection 85 through the centre of which there is a continuation 83^b of the passageways 83, 83^a. This passageway 83^b extends to a valve seat at 86, opened and closed by the threaded valve 87, and vents 88 open into an annular space 89 communicating with the outer air.

A nipple 90 is threaded into the connection 85 and is provided with a central boring 83^c which communicates with the boring 83^b. A union at 91 provides a ready connection with a pipe 92 leading to the pump illustrated and described in my said copending applications.

It will thus be seen that the liquid to be atomized passes directly from the pipe 92 to the open spaces immediately above the discharge orifice 66.

In beginning operations with a fresh supply of fuel air is likely to become trapped in the fuel line of which the passageways 83, 83^a, 83^b, and 83^c are a part, and by retracting the threaded valve 87 slightly this air is permitted to escape, whereupon the valve 87 is again tightened.

Reverting to the spray-point construction, let us assume that the outlet orifice 66 is closed

by the pressure of the spring 46 upon the valve and that all of the passageways for fuel, including the excavations 68, are filled with the liquid. Let us next assume that pressure has been applied upon the fuel. According to this construction the outlet valve thereupon automatically rises the slight distance permitted by the space 69, Fig. 7, hereinabove specified. The cylindrical part 60, Fig. 7, fits nicely within the sleeve 54 and constitutes a piston which responds to the fuel pressure below it and moves upward, communicating motion to the piston 47. A very small amount of leakage of the liquid takes place around the pistons 60 and 47, and eventually escapes through a passageway 94, Fig. 4, into an overflow pipe 95, which may lead back to the source of fuel supply.

The annular recess 96 in Fig. 7 is produced merely to provide clearance for the tools used in grinding or otherwise nicely surfacing the piston and disc members there, and has no functional purpose.

Let us next assume that the liquid in the passageways leading from the pump to the valve 67 is violently put under pressure. The valve first rises a minute distance under the influence of this pressure and the liquid in the pockets or excavations 68 is violently forced against the wall of the conical recess, and thereupon abruptly changes its direction and follows along the side of the conical surface till the orifice 66 is reached. A considerable variety of actions of the liquid takes place. In Fig. 10 I have indicated by arrows how the fuel in these pockets 68 moves. Very importantly, at the bottom of these excavations it is made to impact sharply the conical wall where the valve seat begins, and in turning to pass along the valve seat it must pass over a sharp edge 98. The fuel is forced over sharp edges also where the excavation side walls 77 are slightly drawn away from the conical continuation of the valve-seat-surface, and the fuel passing along the outer surface of these walls 77 to the solid portion of the valve is also subjected to a sudden change in direction after passing over a sharp edge which is only minutely spaced from the facing wall. The movement of the liquid is downward and outward under the pressure applied, and since the sharp edges of the partition walls 77 gradually come closer to the axial line as they extend downward, the fuel is forced diagonally across the shearing sharp edges, and it then suddenly changes its direction and passes on through an exceedingly minute passageway. The fuel can escape to the valve seat only by passing across the sharp edges 98 at the bottom of the excavations or across sharp edges at the sides of the excavations, and after the fuel has passed over sharp edges and reached the minute space between the valve proper and its seat, and also between the outer surfaces of the partition walls 77 and their respective seats, currents or lines of fuel movement impinge each other in the minute space provided, and the particles are caused to pound upon the deflecting walls and upon each other.

The fuel issues from the orifice 66 in the most minute state of division seemingly possible.

In this connection it is to be pointed out that under the high fuel pressure used by me the atomized particles issue from the nozzle at an enormous rate of travel.

The charge of fuel emitted at the discharge orifice is unusually small in my practice and the amount required for each explosion in the engine is regulable at the pump (see my said copending applications) so that from any desired larger quantity, always relatively small, it may consist of a small fraction of the ordinary operating charge. An aid to the high velocity attained is the tapering construction of the valve and the upper continuation thereof, according to which the velocity of the particles within the nozzle device gradually, though rapidly increases, and which high velocities I consider to be made possible through the breaking-up of the fuel into fine highly mobile particles at the time the fuel passes into the highly restricted passageways or passageway through which the fuel ultimately must pass to reach the discharge orifice. It is not like giving solid fuel a high velocity but more like giving a highly diffused fuel such high velocity, and since this diffused fuel must constantly pass through a continuously reducing area within a given period of time the velocity increases to the relatively high ones which I am able to attain.

It will be noted from various figures that a portion of the valve member extends materially beyond the discharge orifice. I have shown this extending end as being a continuation of the conical formation terminating in a point, but the invention is not limited in this respect to such an extension in conical form beyond the discharge orifice. I consider such extension to be of much importance and believe it to be a novel feature. Its effect is to produce a surface against which the expanding, highly diffused fuel may react to throw the rapidly moving particles outward into the combustion chamber on lines substantially radiating from this valve extension, thus avoiding much coalescence of broken-up particles, and compelling their movement along a reaction surface for a materially great distance, or sufficiently to provide for a materially wide spread or expansion to take place in the outward direction from this projecting member. Since the discharge orifice is provided with a sharp edge at the protruding end of the valve member a further diffusion or breaking up of the fuel is accomplished through the shearing

effect of this sharp edge also, which shearing and further atomizing effect is increased by the presence of the protruding part, which does not permit expansion to take place except in the outward direction, expansion thus being limited and restricted immediately at the discharge orifice, and the particles are compelled to move past that sharp edge at the orifice. The protruding end of the valve member also has the effect of causing diffusion to take place outwardly over the surface defined by the protruding end, with the result that the atomized fuel is distributed over a wide area in the combustion chamber as distinguished from a more needle-like spray extending for a considerable distance in one direction before a material amount of diffusion can take place. I contemplate as being within the invention in this respect various forms of extensions of the valve member beyond the discharge orifice.

Heretofore nozzle velocities of 300 feet per second have been considered high, and I do not know of any engine ever produced or any device ever produced for the atomization of solid liquid in which a nozzle velocity of more than about 300 feet per second was attained. In the engine illustrated in my said first-mentioned copending application, and using the nozzle construction as illustrated in Figs. 1 to 10 inclusive, I am able to attain a nozzle velocity upwards of the amazing rate of 5,000 feet per second at the low engine speed of about 500 revolutions per minute. The engine illustrated in my said first-mentioned copending application is a low-speed engine as compared with engines commonly used in automobiles; and on fairly high speed engines the nozzle velocity provided by the same device could be made to reach upwards of 10,000 feet per second.

My experimentations have demonstrated that the desired atomization will take place in the present form of mechanisms which deliver the sprayed fuel as low as 500 feet per second. Since there is a relation between nozzle velocity and degree of atomization it is apparent that the greater and enormously greater nozzle velocities I am able to attain serve as a good index to the degree of atomization being accomplished and that an engine operating at nozzle velocities of the fuel is indicated would be more effective through the more complete utilization of the fuel on combustion thereof.

The discharge orifice 66, while being, as stated, in my practice as illustrated, one millimeter in diameter, the effective area of the orifice is very much less than that when the valve is normally opened. I have stated that the fuel must escape through a passageway which is only about eight one thousandths of a millimeter across or a little more than three ten thousandths of an inch. The effective opening is a space in ring form which is somewhat over three millimeters in circumference and about eight one thousandths of a millimeter in thickness. The actual effective area of the orifice is about .025 square millimeters as distinguished from .7854 square millimeters if the valve were entirely retracted. In terms of the diameter of the hole or discharge orifice at 66 (one millimeter in diameter) the perpendicular distance between the valve and the seat thereof at the orifice is less than one per cent of the diameter of the orifice.

By the perpendicular distance between the valve and its seat I mean the distance measured on a line which is perpendicular to a surface which may be on the valve or on the seat, since the valve and the seat interfit, and this term is used to denote the effective width or thickness of the passageway through which the liquid must pass.

It will be noted that the disc-like stop 62 is relatively close to the valve-seat-engaging surface of the valve, and this has the important function of so limiting the distance between the stop and the seat-engaging surface as to render negligible the expansion of the valve stem 63 under the influence of heat.

I may mention also that a very unusual condition exists with respect to the temperature of the spray issuing from the discharge orifice. I have noted, for instance, that when the fuel enters the nozzle device at a temperature of fifteen degrees centigrade it issues from the discharge orifice at forty degrees centigrade. This very great rise in temperature can be occasioned only by frictional considerations and serves as an index to what takes place directly at and closely within the discharge orifice.

An important feature of construction resides in the fact that owing to the exceedingly small lift of the valve the parts at the space 69 at the stop 62 are saved from objectionable pounding and wear, and this pounding and wear are further avoided by the minute film of oil necessarily present between the parts. I wish to point out further that no lateral pounding of the valve upon its seat takes place, notwithstanding the great fuel velocities present, since the minute passageway between the seat and the valve is filled with the liquid at all places equally under pressure. I might mention in this connection that according to my methods of operation, the fuel is first suddenly and violently forced through the passageways at the discharge opening and that the pressure upon the liquid is not only thereupon suddenly released to permit the spring 48 to close the valve opening, but the liquid is actually withdrawn from the minute passages or passage around the valve, whereby both the valve and its seat are cleaned by withdrawing fuel away from the discharge

orifice whereby no carbonization takes place between the valve and its seat when explosion of the charge takes place.

Referring to Figs. 11, 12 and 13, the spray point construction is essentially as already described, but in that form of nozzle I have provided four pockets or excavations instead of three. The number of such pockets may vary, and in providing nozzles for relatively large engines such pockets, up to six in number or even more, may be employed, or, as stated hereafter, these pockets may be dispensed with. Through the provision of such pockets the fuel is permitted to come substantially close to or immediately at the beginning of the valve seat while providing means such as the webs 77 which also become seated when the valve is closed, and thus give to the valve as a whole a relatively large seat while the actual and effective seat at the orifice is relatively small. These advantages can be had while still compelling all of the fuel to pass over sharp edges and then suddenly change its direction in passing into and along the minute passageway leading to the discharge orifice. I consider it important that the distance from where abrasive effects are produced upon the fuel to the discharge orifice or to the place where further abrasive effects are produced be substantially short in order that the best effects of the abrasion may be had, and I therefore consider as of great importance the abrasion of the fuel at the lowermost sharp edges of the excavations 68. Furthermore, the provisions for abrasion and pulverization through impact at the lower end of the excavations are those which are utilized when running on light load or in idling, at which time only a fraction of the fuel at the bottom of these pockets may be forced through the orifice. The invention is not limited to means providing pockets, although the provision of them as indicated herein is highly advantageous.

In this connection it may be pointed out that in the atomizing device actually used by me in the engine illustrated and described in my said first-mentioned copending application the distance from the bottom of the pockets 68, or from the lines marked 98 on Fig. 10, to the discharge opening at 66, is only about three-tenths of a millimeter, and since the ribs or vanes 77 are only about one-tenth of a millimeter in thickness where they seat upon the adjacent conical walls it is evident that the great bulk and substantially all of the fuel which at any instant is ready to be discharged is at a distance of only about three-tenths of a millimeter from the discharge orifice at 66.

What I consider to be a feature of great importance to the exceedingly fine atomization accomplished is the presence of means for creating a prediffusion or breaking up of the fuel only a very short distance from where the final diffusion or breaking up thereof takes place, whereby the effect of the prediffusion is not lost, but the effect of the final diffusion is supplementary thereto; or, otherwise stated, whereby the final diffusion at the orifice as 66 is a diffusion of previously highly diffused fuel. Referring to the greatly enlarged section Fig. 10, for instance, the prediffusion occurs at the sharp edges 98 and the final diffusion at 66—only three tenths of a millimeter beyond—and from one diffusion place to the other the fuel must pass, in the construction illustrated in Fig. 3 (drawn to size used), through a space only about eight one-thousandths of a millimeter across. In this exceedingly thin passageway the effect of the prediffusion is maintained for the short distance thence to the discharge orifice.

It follows from the construction illustrated and described that capacity can be increased without sacrifice of the fineness of atomization by increasing the perimeter of the band-like passageway while maintaining the thickness, or rather thinness, of the band-like area, and while maintaining the shortness of the distance between the prediffusion and final diffusion means respectively. For all sizes of engines, therefore, there should be a passageway at the discharge orifice which is exceedingly minute and which has the longest perimeter necessary to provide the desired capacity. For the various engine loads I vary the duration of the injection by the fuel pump, and thus the conditions for atomization remain constant.

In Figs. 14 and 15, I have shown nozzle construction substantially following in general the lower part of Fig. 6, but in this form of structure instead of providing pockets or excavations in the valve member I have provided three similar pockets 100 in the seat member. The fuel fills these pockets 100 and when pressure is put upon the fuel the valve rises and the fuel is made to impact violently the conical valve member opposite the bottom of the recesses 100 respectively, and to change its direction suddenly, and in doing so to pass over a sharp edge immediately at the valve seat. This construction also provides the two diffusion means only slightly spaced apart, with a narrow conical band-like passageway of large perimeter and minute thickness. It is essentially merely a reversal of the position of the pockets hereinabove described and requires no further description.

A summary of various of the characteristics of the atomization features at and near the discharge orifice 66 is that the effective discharge opening is exceedingly minute and has substantially the longest perimeter to provide the desired capacity; that said passageway is very short (in my practice only about three-tenths of a millimeter in length); that prediffusion of the fuel takes place at the inner end or beginning of said passage-

way, and that chief or final diffusion takes place at the outer end of said passageway; that prediffusion and final diffusion are caused by forcing the fuel over sharp edges immediately at the beginning and end respectively of the passageway, with change of fuel direction; that the projecting end of the spray point cooperates in defining a sharp edge at the outer end of said passageway, and provides a reaction surface for expanding the stream of diffused particles; that the lifting of the valve is a constant and occurs through fuel pressure; that the valve is seated by regulable spring means upon the lowering of fuel pressure within the nozzle device; that means for limiting the lift of the valve are substantially close to the discharge orifice to avoid material modifications in the lift of the valve through temperature expansion and contraction of valve stem parts adjacent to the discharge opening; that through the provision of pockets the fuel for atomization is brought very close to the discharge orifice while maintaining a relatively large seat for the spray point valve; that the spray point valve is freely movable on its axis whereby it may turn under fuel action and thus provide better conditions of wear than if it always seated in a given relative position; that the minute passageway illustrated is in the form of a frusto-conical band smaller at the discharge orifice, whereby velocity under a given pressure increases while the fuel is being discharged; that the prediffusion of the fuel at the beginning of said passageway is a factor of such increase in velocity; that such increase in velocity and prediffusion of the fuel are factors of the final or main diffusion; and that as a result of the construction the fuel issues in such an exceedingly fine state of subdivision that when discharged into the open air it remains long suspended therein as smoke or fog, and when discharged into the cylinder of an internal combustion engine ignites with explosive force as distinguished from slow burning, and with complete or substantially complete combustion, and in a compression-ignition engine ignites at a markedly low compression pressure.

In view of the present teaching of the principles involved it will be apparent to those skilled in the art that various changes and modifications of and departures from what is herein specifically illustrated and described may be made without departing from the spirit of the invention or improvements herein set forth, and I contemplate as being included herein all such changes, modifications and departures as fall within the scope of the appended claims.

I claim:

1. In a nozzle device for liquid atomization, the combination of means having a tapered recess terminating in a discharge orifice having a sharp edge, a valve member having a tapered part encompassed by said recess, means for limiting the lift of the valve whereby the surface of said recess and that of said tapered part are only minutely spaced apart at the time of atomization, and means for prediffusing the fuel a very slight distance from the discharge orifice, the end of said tapering part projecting beyond said orifice at the time of atomization to cooperate with said sharp edge in producing abrasive effects upon the fuel.

2. Nozzle construction for liquid atomization, comprising in combination a female member having a recess which includes a tapered valve seat terminating in a discharge orifice having a sharp edge, a male valve member having a tapered part normally resting on said seat to close the orifice, said valve member having a part projecting beyond said orifice, one of said members having in a wall thereof closely adjacent to and facing a wall of the other of said members a recess forming with said facing wall a pocket for liquid, the bottom wall of said last mentioned recess being very close to the discharge orifice and terminating in a sharp edge and being directed toward said facing wall whereby when the male member is retracted and pressure is applied to said liquid the liquid is forced against said facing wall before it can escape through said orifice.

3. Nozzle construction for liquid atomization, comprising in combination a female member having a recess which includes a tapered valve seat terminating in a discharge orifice having a sharp edge, a male valve member having a tapered part normally resting on said seat to close the orifice, said valve member having a part projecting beyond said orifice one of said members having in a wall thereof closely adjacent to and facing a wall of the other of said members a plurality of recesses each forming with said facing wall a pocket for liquid, each of said pockets terminating in a sharp edge less than a millimeter from the discharge orifice and being directed toward said facing wall whereby when the male member is retracted and pressure is applied to said liquid the liquid is forced against said facing wall before it can escape through said orifice.

4. Nozzle construction for liquid atomization comprising in combination means providing a recess terminating in a discharge orifice having a sharp edge, a valve member normally seated in said recess and having a part projecting through and beyond said orifice and being mounted for retraction by fuel pressure to permit fuel to pass through the orifice, said valve member having a reduced area with relation to the recess to provide with the wall of the recess a pocket for fuel terminating very closely adjacent to the discharge orifice, means for confining such liquid against normal escape except through

said pocket and said orifice, said confining means being open to fuel pressure and said valve member having means cooperating with the confining means to lift the valve member when pressure is applied upon the fuel, the projecting part of said valve limiting the spread of fuel at the orifice to cooperate with said sharp edge in a final diffusion of the fuel, said valve member being adapted to seat at a place spaced from the discharge orifice and at said place being provided with a sharp edge for prediffusing the fuel.

5. Nozzle construction for liquid atomization comprising in combination means providing a recess terminating in a discharge orifice having a sharp edge, a valve member normally seated in said recess and having a part devoid of the function of a valve projecting beyond said orifice, the valve member being mounted for retraction very slightly, said valve member having a reduced portion forming with the wall of the recess a passageway for fuel extending very close to the discharge orifice, said valve member being adapted to seat at a place closely adjacent to the discharge orifice and being provided with a sharp fuel-prediffusing edge at said place, the arrangement being such that the fuel first passes over said prediffusion edge and then over the sharp edge at the discharge orifice.

6. Nozzle construction for liquid atomization comprising in combination means providing a tapered recess terminating in a discharge orifice, a tapered valve member normally seated in said recess and having a part projecting beyond said orifice and being mounted for retraction under liquid pressure very slightly to open the orifice very slightly to provide a band-like passageway, of minute thickness, said valve member having an excavation in the side thereof forming with the wall of the recess a pocket normally closed at its bottom by the recess wall for holding a body of liquid, means for confining such liquid against normal escape except through said orifice, said confining means being open to liquid pressure, the bottom wall of said excavation having a sharp edge spaced less than half a millimeter from the discharge orifice and being directed toward the wall of the recess whereby when pressure is applied to such body of liquid and the valve member is retracted thereby the liquid is forced against said recess wall over a sharp edge and then between the valve member and the recess wall, and means under the control of the pressure of the liquid for retracting the valve member to open said orifice.

7. A valve member for an atomizing nozzle adapted to operate through a very slight amount of longitudinal movement and having an annularly continuous conical valve-seat-engaging surface and adjacent thereto a continuation of the conical formation and in said conical continuation an excavation formed to provide sharp edges where the excavation meets the surface of said conical formation.

8. In an atomizing nozzle the combination of a valve member adapted to operate through a very slight amount of longitudinal movement and having an annularly continuous conical valve-seat-engaging surface and adjacent thereto a continuation of the conical formation and in said conical continuation a plurality of relatively long and narrow excavations formed to provide sharp edges where the excavations respectively meet the surface of said conical formation, and a conical female member having a discharge orifice, said valve member tightly fitting upon the female member from the discharge orifice throughout a materially large part of said continuation.

9. A valve member for an atomizing nozzle adapted to operate through a very slight amount of longitudinal movement and having an annularly continuous conical valve-seat-engaging surface and adjacent thereto a continuation of the conical formation and in said conical continuation a plurality of relatively long and narrow excavations extending longitudinally and being wider respectively where the conical continuation has a greater diameter and being narrower respectively where the conical continuation has a smaller diameter, said conical continuation being defined by relatively narrow portions thereof between adjacent excavations, said excavations being formed to provide sharp edges where the excavations respectively meet the adjacent narrow surfaces of said conical formation.

10. An atomizing device comprising in combination means providing a tapering valve seat terminating in a discharge orifice, a tapering valve normally resting on said seat, said valve being movable to provide a passageway of minute thickness between the valve and seat, and means for prediffusing the liquid at the beginning of said passageway, said passageway being of band-like form and less than three-fourths of a millimeter in width, and means for further diffusing the liquid at the discharge orifice.

11. An atomizing device comprising in combination means providing a tapering valve seat member terminating in a discharge orifice, a tapering valve member normally resting on said seat member, and means respectively for prediffusing and finally diffusing the liquid at respective places not more than half a millimeter apart, one of said places being at the discharge orifice.

12. An atomizing device comprising in combination a member having a tapering valve seat terminating in a discharge orifice, a member having a tapering valve normally resting on said seat, and means on one of said members terminating in a sharp edge not more than half a millimeter from the dis-

charge orifice and formed to direct the liquid flow sharply against the other one of said members, said edge being arranged transversely of the liquid flow and being close to said seat and in the path of travel of the liquid to the orifice, over which edge the liquid must flow and thereby change its direction of flow in reaching said orifice.

13. An atomizing device comprising in combination means providing a tapering valve seat terminating in a discharge orifice, a tapering valve member having a seat portion extending to the discharge orifice, means for conducting liquid to a place not more than four-tenths of a millimeter from the discharge orifice, and means for prediffusing the liquid at said place.

14. An atomizing device comprising in combination means providing a valve seat and a discharge orifice having a sharp edge, a valve member mounted to lift and having a seat portion terminating in a sharp edge a short distance from said orifice, means for limiting the lift of the valve to provide a minute passageway constant at all discharges of liquid therethrough and having a large perimeter to provide for capacity, said sharp edges being spaced apart so short a distance that the prediffusion of the liquid by one thereof is maintained until the fuel reaches the other thereof.

15. In a nozzle device for fuel atomization, the combination of means providing a passageway terminating in a discharge orifice, valve means mounted to open said passageway for discharge of fuel therethrough, means for limiting the opening movement of the valve whereby the thickness of the passageway at the valve is less than four one-hundredths of a millimeter, means including a sharp edge at the valve and at said orifice respectively for respectively prediffusing and finally diffusing the fuel, the distance between said sharp edges being substantially small whereby prediffusion of the fuel is maintained until it reaches the discharge orifice.

16. In a nozzle device for fuel atomization, the combination of means providing a passageway terminating in a discharge orifice, valve means mounted to open said passageway for discharge of fuel therethrough, means for limiting the opening movement of the valve whereby the thickness of the passageway at the valve is less than four per cent of the diameter of said orifice, means including a sharp edge at the valve and at said orifice respectively for respectively prediffusing and finally diffusing the fuel, the distance between said sharp edges being substantially small whereby prediffusion of the fuel is maintained until it reaches the discharge orifice.

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