

March 27, 1945.

L. KOOISTRA

2,372,283

FLUID ATOMIZER

Filed Feb. 11, 1941

2 Sheets-Sheet 1

Fig.1

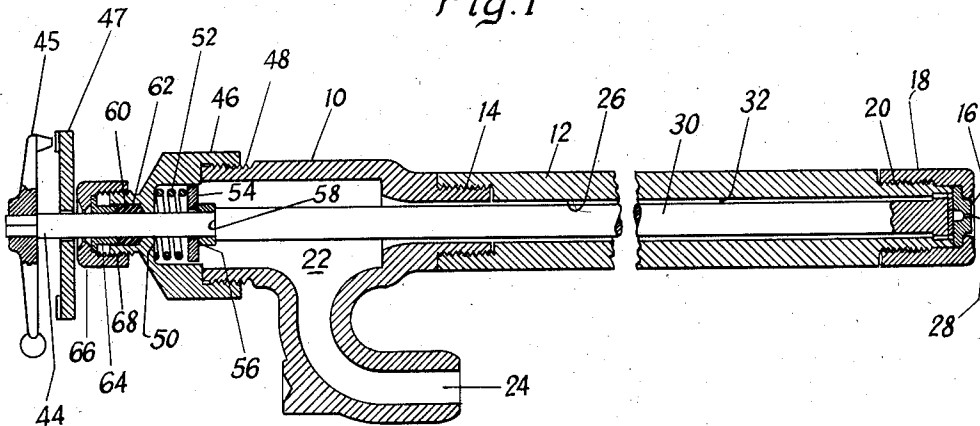


Fig. 3

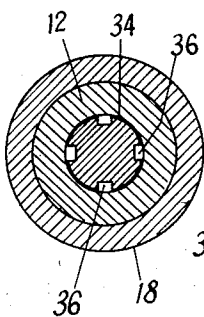


Fig. 2

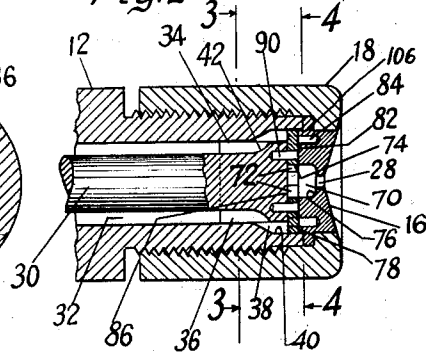


Fig. 4

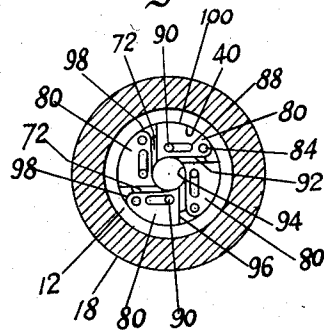
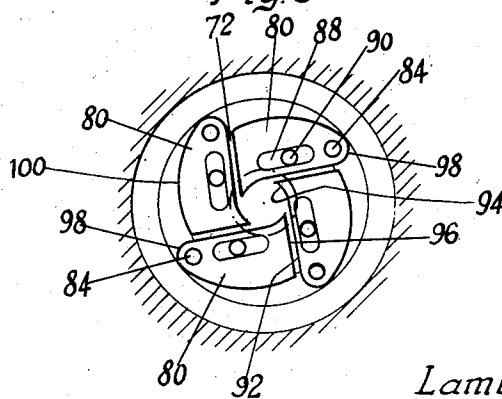


Fig. 5



INVENTOR.

Lambert Kooistra

BY

INVENTOR.
Lambert Kooistra
BY Joseph Moran
Attorney

March 27, 1945.

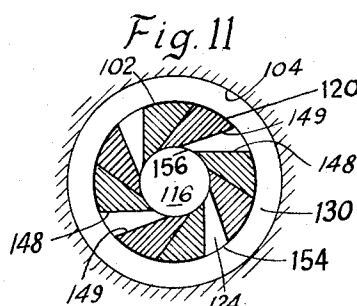
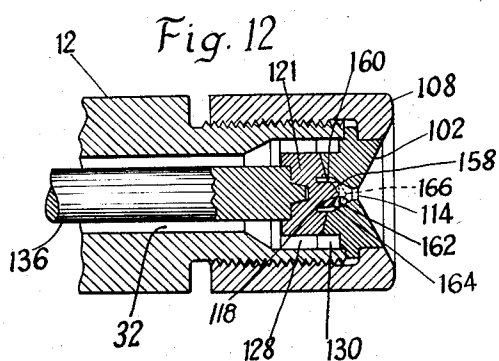
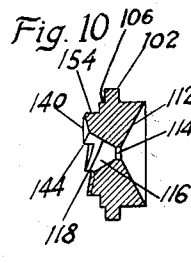
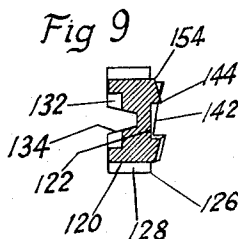
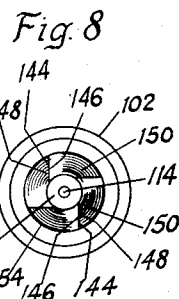
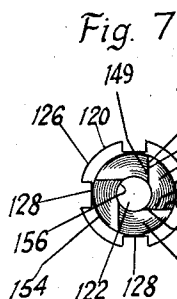
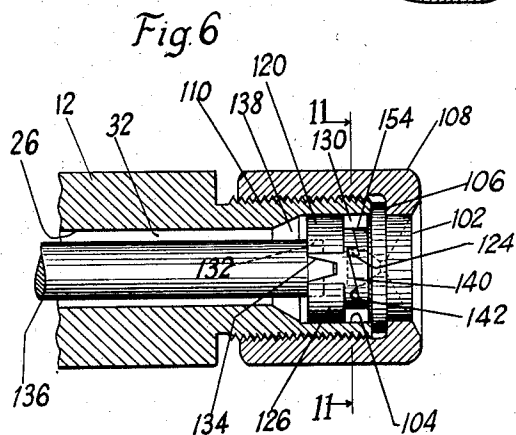
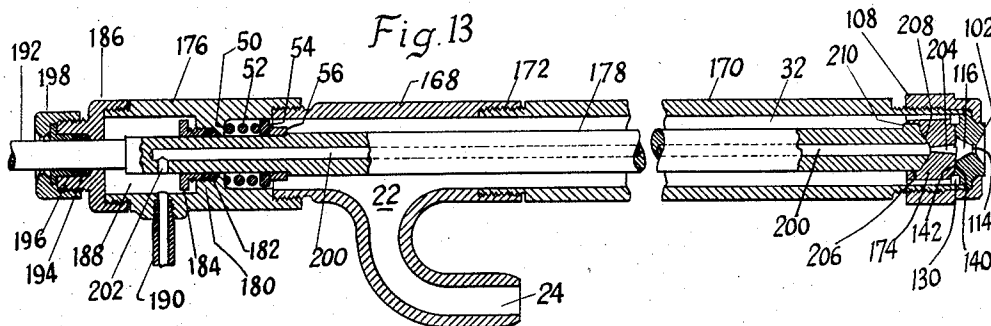
L. KOOISTRA

2,372,283

FLUID ATOMIZER

Filed Feb. 11, 1941

2 Sheets-Sheet 2



INVENTOR.
Lambert Kooistra
BY *Joseph Morgan*
Attorney

UNITED STATES PATENT OFFICE

2,372,283

FLUID ATOMIZER

Lambert Kooistra, Akron, Ohio, assignor to The
Babcock & Wilcox Company, Newark, N. J., a
corporation of New Jersey

Application February 11, 1941, Serial No. 378,369

18 Claims. (Cl. 299—119)

The invention herein disclosed relates to a fluid atomizer particularly applicable to a fluent fuel burner in which a liquid fuel is atomized mechanically as a result of being forced under pressure through a suitable outlet orifice. The fuel is preferably made to enter the orifice at a relatively high angular velocity by providing a whirl chamber within the burner tip and directing the liquid fuel into the chamber in one or more tangential streams to impart a rotary motion, thereby causing the fuel to be sprayed from the orifice in the form of a hollow cone as a result of the centrifugal action.

In burners heretofore constructed, it has been customary to maintain a fixed ratio between the area of the tangential flow passages through which fuel is delivered to the whirl chamber and the area of the orifice through which fuel is discharged from the chamber. Such burners have been available for operation at different flow capacities by regulating the pressure of the fuel supplied; however, the permissible range of capacity has been substantially limited, due to the necessity for maintaining an acceptable quality of atomization throughout for optimum combustion characteristics. In practice, the range of operation has been about 2:1 for pressures from about 50 lbs. per sq. in. at minimum capacity to about 300 lbs. per sq. in. at maximum capacity. In a boiler installation for example where a wider range of capacities might be desired it has been necessary to utilize a plurality of burners and operate a different number of burners for each step in capacity. The alternative would be to interrupt operation and substitute a different burner or different burner parts.

The more general objects of this invention therefore include the development of an atomizer which may be operated over an extended range of flow capacities as distinguished from the relatively narrow normal operating range of prior art devices for equivalent quality of atomization; an atomizer wherein the same assembly of parts may be used throughout the entire operating range; and, an atomizer operable over a wide range of capacities with the liquid to be atomized supplied either at a constant pressure, or at different pressures.

Additional objects of the invention pertain to a regulation of flow capacity by varying the ratio between the tangential passage or port area and the area of the outlet orifice; for example, for a given area of outlet orifice, the tangential flow area may be increased for an increase in capacity and decreased for a decrease in capac-

ity. The liquid may be supplied at a constant pressure, or at varying pressures, depending on the rate of capacity variation desired.

In a mechanical atomizer, the ratio of tangential port area to orifice area is a factor in determining the angle at which the liquid is sprayed from the orifice, and in general, the smaller this ratio, the larger will be the apex angle of the spray cone, for the same rate of flow through the orifice. Consequently, for a given orifice area, an increase in the flow area of the tangential port or ports which increases the ratio, will tend to reduce the spray angle, and a decrease in the flow area which decreases the ratio, will tend to expand the spray angle.

The effect on spray angle may be more pronounced in an atomizer of the wide range type wherein the ratio of port to orifice area is varied, than in an atomizer of a more limited range wherein the ratio of port to orifice area is fixed, due to variations in the relative effectiveness of forces acting on the liquid as it passes through the orifice; the centrifugal force resulting from the rotational movement within the whirl chamber tending to expand the angle and the axial force due to the pressure differential across the orifice tending to contract the angle. In an atomizer of the type shown, wherein the area of orifice is fixed, if the pressure of fuel at the entrances to the ports is maintained constant, an increase in capacity obtained by increasing the port area results in a decreased angle of spray; however, for an equivalent change in the rate of fuel flow if the entrance pressure is increased simultaneously with an increase in port area, it is found that the decrease in spray angle is less than with constant pressure. By combining the pressure variations in suitable relation to the variations in port area, assuming an orifice of constant area as shown, it is possible to operate over a substantial range of flow capacities, of at least 6 or 8 to 1 for example, without appreciable variation in the angle of spray. The flow capacity may also be regulated by continuously varying fuel pressure throughout the range in combination with step-by-step adjustment of the port area.

Since it is desirable to operate with a substantially constant and reasonably wide angle of spray throughout a given capacity range, a further object of the invention is to maintain a condition of flow to and through the orifice such that the rotational velocity of the liquid at the various capacities is sufficient to modify the effect of the

axial force tending to cause a reduction in the spray angle as the output is increased.

Other objects of the invention will be apparent as the specification proceeds, as will the advantages which are derived from its utilization in various embodiments, as illustrated for example in the accompanying drawings, wherein:

Fig. 1 is a longitudinal section of a burner assembly;

Fig. 2 is a fragmentary detailed enlargement of Fig. 1;

Fig. 3 is a transverse section along line 3—3 of Fig. 2;

Fig. 4 is a transverse section along line 4—4 of Fig. 2 showing the relation of parts for maximum capacity;

Fig. 5 is a view similar to Fig. 4 showing the relation of parts for reduced capacity;

Fig. 6 is a fragmentary enlargement, similar to Fig. 2 and partly in section, illustrating a modification;

Figs. 7 and 8 are end views of parts shown cooperatively assembled in Fig. 6;

Fig. 9 is a diametral section of the part shown in Fig. 7;

Fig. 10 is a diametral section of the part shown in Fig. 8;

Fig. 11 is a transverse section of parts shown in Fig. 6, taken along line 11—11;

Fig. 12 is a fragmentary enlargement, in section, showing a modification of the structure of Fig. 6; and,

Fig. 13 is a longitudinal section, similar to Fig. 1, showing a modified burner arrangement.

In detail, the burner assembly of Figs. 1-4 includes a body portion 10 to which a barrel 12 is secured by a threaded connection 14, the barrel being fitted with an orifice plate 16 which is held in position at the end of the barrel by means of a cap 18 having a threaded connection with the barrel as at 20. The fuel to be atomized is admitted under pressure to an interior chamber 22 of the burner body through an inlet port 24 and passes through a passage 26 within the barrel 12, and through other passages to be described, for discharge through the outlet orifice 28 in plate 16. The spindle 30 which is rotatable to effect a control of fuel flow to the orifice, extends longitudinally of the barrel passage 26 and is supported concentrically therein to provide an annular fuel flow space 32, the support being provided by an enlargement 34 at one end of the spindle which is in circumferential engagement with the wall of the passage. The longitudinal grooves or slots 36 in the enlarged portion 34 provide passages for conducting fuel from the annular space 32 about the spindle to the annular space 38 within the counterbore 40 at the end of the barrel, each slot passage having a curved base portion 42 for directing each stream of fuel gradually into the counterbore space 38 at the greater diameter. The opposite end portion 44 of the spindle of reduced diameter is extended exteriorly of the body for convenient control of its rotative movement. The control may be accomplished manually for example by attachment of a hand wheel or lever 45 attached to the spindle extension 44 for rotation relative to a fixed dial or scale 47; or its movement may be automatically controlled by suitable known powering means, which in a boiler installation may operate to rotate the spindle in response to variations in pressure of the outgoing vapor, or to some other variable indicative of a demand for more or less fuel.

The adjacent end of the burner body 10 is closed by a housing 46 having a connection as by threads 48 with the body, and providing a seat 50 for a spring 52 which serves to continuously exert pressure longitudinally of the spindle 30 tending to force the spindle in the direction of the orifice plate for a purpose which will later be made apparent. The spring pressure may be transmitted to the spindle through a washer 54 and spacer collar 56 which latter part is seated against a shoulder 58. Leakage of pressure fluid from within the body 10 is prevented by the packing 60 which is confined within the counterbore 62 by a gland 64 and by a packing nut 66 having a threaded connection 68 with the housing 46.

Referring particularly to Figs. 2, 3 and 4, the fuel from the annular space 32 is directed substantially tangentially into a whirl chamber 70 of circular cross-section through one or more passages or ports 72 whereby the fuel attains a high angular velocity prior to its discharge through the axially disposed outlet orifice 28. The chamber 70 which may be formed in part within the orifice plate 16 as shown is of substantial depth and preferably includes a cylindrical base portion 74 through which fuel is admitted, the wall portion 76 adjacent the orifice being substantially normal to the orifice axis.

In the selected embodiment, the tangential passages are provided by a flow control unit 78 consisting of a series of plates 80 which are disposed in an annular band adjacent the inner surface 82 of the orifice plate 16, each plate being of generally sectoral outline and having a pin-bearing 84 on the orifice plate 16 for limited rotational movement relative to adjacent plates whereby the width of the tangential passages 72 may be varied. The depth of each port is constant, that is the dimension longitudinally of the burner axis, and is determined by the thickness of the plates 80 which are surfaced in parallel planes at opposite sides to provide close engagement with mating surfaces 82 and 86 on the orifice plate 16 and spindle 30, respectively. The contacting relation of the assembled parts is maintained throughout operation by means of spring 52 which continuously and resiliently holds the end of spindle 30 in contact with the plates 80 and the plates 80 in contact with the orifice plate 16.

The plates 80 are slotted as at 88 to receive pins 90 which are mounted in the end of spindle 30, the slot in each plate being elongated in a direction parallel to the edge 92 which is at the greater radial distance from the central axis of the whirl chamber 70. The edge 92 may be curved at its inner end portion as at 94 to coincide with the cylindrical wall portion 74 of the chamber, while the other edge 96 may extend in a substantially straight line toward the whirl chamber at a lesser radial distance from the axis. The tangential passages 72 are thus defined by the adjacent edges 92 and 96 of adjacent plates 80 which edges, in the illustrated embodiment, are parallel to each other and remain in that relation throughout their relative movement. With such an arrangement, each tangential passage is of substantially constant flow area throughout its extent in the direction of the whirl chamber, but it is contemplated that a varying flow area may be provided if desired by suitable formation of individual plates; for example, in an arrangement of four plates as shown, the angle between edges 92 and 96 is 90°, whereas a permissible deviation from this right angled relation would provide passages of tapering cross-section. It is also contemplated

that a different number of tangential passages may be provided, more or less than four, by suitable selection of the size and number of plates 80, and of the angle between edges 92 and 96 of each plate.

The width of the passages 72 is varied by rotating the spindle 30 through a desired angle and thereby causing the pins 90 acting in slots 88 to rotate the plates 80 through a proportionate angle about their respective bearing pins 84, the edge of each plate being rounded as at 98 to clear the wall of the counterbore 40 during rotation.

As seen in Fig. 4, the plates are at their extreme position of clockwise movement to provide the maximum width of tangential passages 72, in which position the wall of counterbore 40 at the end of the barrel 12 serves as a stop for the outer circumferential edges 100 of the plates which are of substantially the same radius as that of the counterbore. As seen in Fig. 5, the plates are in an intermediate position to provide an intermediate width of tangential passages 72, the plates having been rotated in a counterclockwise direction from their full open position (Fig. 4) by an opposite rotation of spindle 30 which carries the actuating pins 90. A fine degree of adjustment is available with this arrangement, since the angular displacement of plates 80 about their respective pivots 84 is substantially less than the angular movement of the operating spindle 30, the ratio being approximately 1:10 for parts of the proportions shown. The slots 88 are preferably of a length to permit counterclockwise rotation of the plates 80 to a fully closed position, that is where an edge 92 of one plate contacts an edge 96 of an adjacent plate; however, shorter slots may be provided, if desired, to limit the extent of closing movement and thus fix the minimum operating width of the tangential passages.

It will be noted from Fig. 5 that as the plates 80 are moved from the full open position, the curved inner portions 94 of the plate edges 92 are moved inwardly from their original circumferential location at the diameter 74 of the whirl chamber 70, thus gradually reducing the effective diameter of the whirl chamber at the point of fluid admission and causing an increase in the angular velocity of the whirling mass.

An additional feature of the arrangement is that there is a minimum possibility of liquid reaching the whirl chamber except through the tangential passages 72 through which flow is intended. The contacting planar surfaces on the flow control unit 78, the orifice plate 82 and the spindle 30 may be ground to an accurate fit to preclude leakage of liquid between the joint surfaces of the relatively movable parts, the continuous pressure of spring 52 automatically compensating for any wear of the companionate joint surfaces. It is also to be noted that with the described arrangement there is ample provision for expansion and contraction of the cooperating elements, due to temperature changes, without interference with the operating characteristics of the atomizer.

Fig. 6 illustrates a modified assembly of atomizer elements for controlling the flow of fuel to the whirl chamber and orifice. The barrel 12, having a bore passage 26 as in the former embodiment, is fitted with an orifice member 102 at its outer end, the orifice member being centered within the counterbore 104 by means of the shoulder surface 106 and rigidly held in position by means of the cap 108 which may be secured to the barrel as by threads 110.

The outer face of the orifice member 102 may be conically recessed as at 112 to provide a surface flaring outwardly from the orifice 114 at an apex angle of about 120°. The member 102 may also be recessed at its inner face to provide a whirl chamber 116 concentric with and immediately adjacent the orifice 114, and as shown, may include a conical surface portion 118 converging toward the orifice in the direction of fuel flow at an apex angle of about 60°.

A rotatable member 120 cooperates with the fixed orifice member 102 to provide a base surface 122 for the whirl chamber 116, an adjacent cylindrical wall portion 156, additional to and concentric with the conical wall portion 118, and to provide one or more flow passages or ports 124 of tapering cross section through which fuel is directed into the whirl chamber substantially tangentially of the cylindrical wall portion 156. The member 120 is supported within the counterbore 104 by circumferentially spaced ribs 126 while the intervening grooves or slots 128 provide passages for the flow of fuel into the annular counterbore space 130 at the entrances to the tangential passages 124. The member is formed at its inner end with a counterbore 132 and a tapered slotted recess 134 to receive the end of the operating spindle 136 which is shaped to fit. The spindle 136 is thus centered within the bore passage 26 and, being of smaller diameter, allows an annular space 32 for fuel flowing from within the body portion 10. An annular space 138 at the base of the counterbore 104 provides communication between the annular space 32 and the longitudinal flow passages 128.

The relatively movable members 102 and 120 have companionate facing surfaces 140 and 142 formed with intermeshing teeth 144 in a manner similar to the working surfaces of the spiral form of clutch as used for making and breaking a rotative driving connection between machine parts. In the device shown, each member is provided with four teeth of identical proportions and circumferential spacings to mesh with teeth of corresponding proportions and spacings on the companionate member. The arrangement of teeth is necessarily left-hand for one member and right-hand for the other, as indicated by Figs. 7 and 8.

The top 146 of each tooth is the edge formed by the intersection of the planar face 148 with the curved face 150; the face 148 being substantially parallel to the central axis of the whirl chamber and substantially tangent to the inner wall of the chamber; the face 150 being essentially formed as a helicoid sloping gradually from the top edge 146 to the root line 152 of the adjacent tooth, the surface being generated by a straight line element maintained at a fixed distance from the central axis and advanced angularly and longitudinally relative to that axis.

The companionate surfaces 140 and 142 of the members 102 and 120 are maintained in their assembled contacting relation as shown in Fig. 6 by the resilient pressure of spring 52 which is transmitted through the spindle 136 to the movable member 120. The tangential passages or ports 124 are formed between the planar faces 148 of teeth on the fixed member 102 and the corresponding planar faces 149 of teeth on the movable member 120, the longitudinal dimension or depth of the passages being constant and determined by the height of the teeth. The circumferential dimension or width of each passage is progressively varied from a relatively wide inlet dimension at the outer circumference 154 to

a relatively narrower discharge dimension at the circumferential wall 156 of the whirl chamber 116, as indicated in Fig. 11, thereby providing a gradual reduction of flow area in the direction of fluid flow.

The width of the slots is regulable and dependent on the angle through which the member 120 is rotated relative to the orifice member 102. Figs. 6 and 11 show the members 102 and 120 in an intermediate relative position to provide tangentially directed passages 124 of intermediate circumferential extent. It will be understood that a clockwise rotation of member 120, as viewed from the left in Fig. 6, will reduce the width of each passage and that a counterclockwise rotation will increase the width. At the extreme limit of clockwise movement the passages are substantially closed due to the planar faces 149 of teeth on member 120 being in contact with the corresponding faces 148 of teeth on member 102. Throughout the entire range of adjustment, with surfaces 140 and 142 formed as described, each tooth surface 150 on the rotatable member 120 has a portion of its area maintained in contact with a corresponding portion of the companionate tooth surface 150 on the stationary member 102, thereby forming a joint precluding leakage of fluid into the whirl chamber and causing fluid to be admitted to the chamber only through the tangentially directed passages 124.

The small degree of slope of surfaces 150 in an angular direction relative to a plane normal to the axis of rotation, and the parallel relation of straight line elements of the surfaces to such a plane, minimizes the possibility of the members 102 and 120 becoming rotatably shifted from their adjusted relative positions by the pressure exerted continuously by spring 52, as compared with surfaces of steeper inclination. Since the generating elements of the surfaces 150 are substantially straight lines tangent to a common circumference in planes normal to the central axis, the direction of fluid flow through tangential passages 124 is at all times parallel to such normal planes so that the maximum rotational movement of fluid is maintained in the whirl chamber throughout the capacity range.

For each advance in the opening direction, the increase in the flow area of each passage 124 is accompanied by an increase in the angle of convergence between the side wall faces 148 and 149. The variation in flow area of the passages 124 is also accompanied by a variation in the depth of the whirl chamber which in the specific form shown constitutes an increase in depth for an increase in flow area, and a decrease in depth for a decrease in flow area, due to the relative movement of the contacting sloping tooth surfaces 150. This feature has been found advantageous in controlling the angle of spray at low operating capacities.

The tapered formation of the tangentially directed passages 124 results in a velocity of fluid flow through each passage increasing gradually to a maximum at the point of discharge of each tangential stream into the whirl chamber, each passage having the effect of a converging nozzle to reduce the friction and entrance losses in the passages themselves to a minimum, so that most of the available energy can be employed to impart an intensely whirling motion to the fluid in the whirl chamber.

In the modification of atomizer according to Fig. 12, the movable component 121, being simi-

lar to part 120 of Fig. 6, cooperates with the relatively fixed orifice component 102 to form the tangential passages or ports 124 shown in Fig. 11. The part 121 is provided with an axial extension or plug 158 which projects into the whirl chamber 116 to form an annular space 160 within the circumferential wall 156 to receive the liquid entering the whirl chamber through ports 124. The plug is movable axially of the orifice in unison with part 121, thereby regulating the area available for fluid flow through the annular space 162 between the conical end surface 164 of the plug and the conical end surface 118 of the whirl chamber, the area of space 162 being varied from maximum to minimum in accordance with a corresponding variation in flow area of the tangential passages 124. If desired, the conical end 164 of the plug 158 may be arranged to contact the conical surface 118 in an extreme closed position as indicated by the dotted lines 166. The coordination of controls thus provided, one for tangential flow of liquid into the whirl chamber and another for the flow of whirling liquid within the chamber, tends to increase the effectiveness of the centrifugal force available for maintaining a wider angle of spray at increasing capacities. Moreover, the quality of atomization has been found to be satisfactory throughout a wide range of capacities, including such low capacities at which with other wide range burners it is normally difficult to maintain combustion.

Fig. 13 illustrates a further embodiment of the invention in which an auxiliary supply of fluid is admitted to the whirl chamber in addition to the fluid admitted through the tangential ports, a purpose of which is to control the angle of spray at varying flow capacities. In this arrangement, in a burner for example, the body portion 168 is fitted at one end with a barrel 170 as at 172, the orifice member 102 being removably held in fixed relation to the barrel by the cap 108 as in Fig. 6. The movable atomizer component 174 is similar to the previously described part 120 except for certain details pertaining to the admission of auxiliary fluid to the whirl chamber.

The opposite end of the body 168 is fitted with a housing 176 through which the operating spindle 178 extends, and within which a partition wall 180 provides a seat 50 for spring 52 which maintains the companionate surfaces 140 and 142 of the fixed and movable components respectively in cooperative relationship. The packing 182 and packing gland 184 prevent leakage of pressure fluid from within the body 168. The outer end of the housing 176 is closed by a cap 186 to provide a compartment 188 for an auxiliary fluid, preferably air or steam, which may be admitted under pressure through the inlet connection 190. The spindle 178 has an extended end 192 exteriorly of the housing for the attachment of a suitable device or mechanism for rotating the spindle. The compartment is sealed against leakage by the packing 194, the gland 196, and packing nut 198.

The spindle 178 is provided with a central passage 200 to which the auxiliary fluid is admitted from the compartment 188 through an opening 202 adjacent one end, the passage 200 being open at its opposite end for delivering auxiliary fluid to the axial passage 204 extending through the movable atomizer component 174. The end of the spindle is supported concentrically of the barrel within the counterbore 206 and forms a fluid-tight joint with the conical seat surface 208 as a result of the pressure exerted by spring

52. A driving connection between the spindle and part 174 may be provided by a lug or key 210 on one part engaging a suitably recessed portion of the other part.

In this modification, the passages provided for fuel flow are the same as described for Fig. 6, the liquid entering the burner body under pressure through inlet port 24 and being conducted through the annular barrel passage 32 and slot passages 128 to the annular space 130 from which it passes through tangential ports 124 to and through the whirl chamber and orifice.

The auxiliary fluid which may be a gaseous fluid, for example, such as air or steam, is maintained under pressure within the compartment 188 and passes through the spindle passage 200 and axial passage 204 into the whirl chamber 116 where it exerts an axial pressure against the body of fuel within the chamber. The flow area of passage 204 as shown is preferably progressively enlarged in the direction of the whirl chamber to increase the area over which the pressure of the auxiliary fluid is effective upon discharge into the chamber. The auxiliary fluid may be supplied at a constant pressure, or at different pressures for different capacities, as desired. At low capacities, the pressure exerted by the auxiliary fluid may be adjusted to produce a greater effective axial velocity of fluid flow through the orifice and thereby cause a reduction in the angle of spray. At higher capacities, the flow of auxiliary fluid is automatically cut off, or substantially reduced, due to the increased fuel pressure within the chamber 116, whereby a practically normal angle of spray is produced for the particular capacity involved.

The utilization of an auxiliary fluid in the manner described therefore introduces an additional factor contributing to a reduced variation in spray angle over a given range. As already discussed, a burner embodying the features of Figs. 6-11, independent of an auxiliary fluid supply, may be operated over a wide range of capacities with a smaller variation in spray angle than other burners due to the increased effectiveness of the centrifugal forces relative to the axial forces as capacities are increased. In a burner such as shown in Fig. 13, the increase in spray angle thus obtainable at the higher capacities is not affected by the use of an auxiliary fluid since the effect of the fluid at such capacities is negligible. However, the effect of the fluid is maximum at the lower capacities and causes the angle of spray to be decreased. The modifying effects on spray angle are therefore combined; first, a narrowing effect at the higher capacities incident to the control of fuel flow, and second, a narrowing effect at the lower capacities incident to the automatic supply of the auxiliary fluid.

The auxiliary fluid also has a supplemental effect on fuel atomization which enables the burner to be operated at capacities below the normal low limit of capacity determined by the regulation of fuel pressure and tangential port area. There is a further advantage in providing the maximum effect of the fluid at low capacities, since it is at such capacities that the combustion characteristics of the spray become critical.

Burners embodying selected features of the present invention have been successfully operated at various pressures and capacities, and an improvement noted specifically in the available capacity range with effective atomization and ef-

ficient combustion for a given variation in spray angle as compared with the lower capacity range of other burners for a corresponding spray angle variation. Moreover the improved range of operation is obtainable with the same assembly of parts instead of requiring a different combination of parts for each limited range which would necessitate an interruption of operation for dismantling and reassembly.

While the invention is disclosed specifically with reference to its use in an oil burner, it is to be understood that its application is more general, that its essential elements are useful in various combinations, and that it is in nowise limited except as defined by the appended claims.

I claim:

1. In a fluid fuel burner, means forming a whirl chamber having an outlet orifice, said chamber and said orifice being formed about a common central axis, means for directing fluid fuel into said chamber in substantially tangential relation thereto, and means for varying the effective cross-section of said chamber transversely of said axis.

2. In a fluid fuel burner for operation at different flow capacities, means forming a whirl chamber having an outlet orifice, means for directing fluid fuel into said chamber in substantially tangential relation thereto comprising a plurality of plates circumferentially spaced in an annular band about said whirl chamber to form fluid flow passages, and means for moving said plates relatively to regulate the flow area of said passages and thereby control the flow of fuel into said chamber.

3. In a fluid fuel burner for operation at different flow capacities, means forming a whirl chamber having an axially disposed outlet orifice, means for conducting fluid fuel to said chamber comprising a plurality of plates circumferentially spaced in an annular band about said whirl chamber and defining fluid flow passages for directing fuel into said chamber in substantially tangential relation thereto, and means for controlling the flow of fuel to said chamber including means for rotating said plates about separate axes.

4. In a liquid fuel burner having a circular outlet orifice for atomized fuel, means forming a whirl chamber of circular cross section in axial communication with said orifice, said means including components one of which is movable relative to another, said components defining an inner cylindrical surface portion of said chamber of substantially larger diameter than said orifice and at a location longitudinally removed from said orifice said components forming passages of regulable flow area for directing fuel into said chamber in substantially tangential relation thereto at said location of larger diameter, each passage being formed and arranged to provide a median line of flow into said chamber in a plane substantially normal to the central axis of said chamber, and means for moving one of said components relative to another for regulating said flow area.

5. In a fluent fuel burner for wide range operation, means forming a whirl chamber having an outlet orifice axially thereof, means for connecting said chamber with a supply of fluent fuel under pressure including means forming one or more fluid flow passages of progressively decreasing flow area in the direction of flow for directing fuel into said chamber in substantially tangential relation thereto, said last named means

comprising coaxially arranged parts one of which is rotatable relative to the other, each passage having axially spaced defining walls formed of straight line elements in angular succession, each of said elements extending in substantially tangential relation to said whirl chamber in a plane substantially normal to the central axis of said chamber, and means for rotating said one part relative to the other for varying the flow area of each passage while maintaining the axial depth thereof substantially constant.

6. In a fluent fuel burner for wide range operation, means forming a whirl chamber having an outlet orifice axially thereof, means for connecting said chamber with a supply of fluent fuel under pressure including means forming one or more fluid flow passages of reducing taper in the direction of flow for directing fuel into said chamber in substantially tangential relation thereto, each passage being formed to provide a median line of flow therethrough in a plane substantially normal to the central axis of said chamber, and means for varying the degree of taper of a passage.

7. In a fluent fuel burner having a whirl chamber and an outlet therefrom formed about a common axis, means forming passages for directing fuel into said chamber in substantially tangential relation thereto comprising members one of which is rotatable relative to the other about said axis for regulating the flow area of said passages, said members having companionate facing portions formed with intermeshing teeth defining passages having their axes of flow extending in substantially tangential relation to said chamber in a common plane normal to said common axis.

8. In a fluent fuel burner having an outlet orifice, means forming a whirl chamber from which fuel is discharged through said orifice, said chamber and said orifice being formed about a common central axis, means forming passages for conducting fuel to said chamber comprising parts one of which is rotatable relative to the other about the axis of said chamber, said parts being formed with intermeshing teeth defining passages of regulable flow area extending in substantially tangential relation to said chamber, each part having tooth surfaces cooperating with similar tooth surfaces on the other part to define passages having circumferentially spaced walls converging inwardly toward said chamber and axially spaced walls substantially parallel throughout, said axially spaced walls being formed of straight line elements in angular succession, each of said elements extending in substantially tangential relation to said chamber in a plane substantially normal to said axis, and means for rotating one of said parts for varying the relative positions of said cooperating tooth surfaces whereby the flow area of said passages may be increased or decreased.

9. In a fluent fuel burner having an outlet orifice, means forming a whirl chamber from which fuel is discharged through said orifice, said chamber and said orifice being formed about a common central axis, means forming passages for conducting fuel to said chamber comprising parts one of which is rotatable relative to the other about the axis of said chamber, said parts being formed with intermeshing teeth cooperatively defining passages of regulable flow area directed substantially tangentially of said chamber, each tooth having a top portion disposed between a substantially planar surface at one side and a non-planar surface of helicoid formation

at the opposite side, said tooth surfaces on said parts cooperating to determine the circumferential width of a passage between corresponding planar surfaces and the axial depth of a passage between corresponding non-planar surfaces said planar surfaces being arranged parallel to said axis in substantially tangential relation to said chamber and said non-planar surfaces being formed of straight line elements directed substantially of said chamber in planes substantially normal to said axis, said formation and arrangement of surfaces providing passages each having its median line of flow directed substantially tangentially of said chamber in a plane substantially normal to said axis.

10. In a fluent fuel burner, means forming a whirl chamber having an axially disposed outlet orifice, said means comprising members forming a cylindrical wall portion of said chamber nearer to the base of said chamber than to said orifice and forming a passage for directing fuel into said chamber substantially tangentially, said passage having its outlet in said cylindrical wall portion and having its median line of substantially tangential flow into said chamber in a plane substantially normal to the common axis of said chamber and orifice, one of said members being rotatable relative to the other about said axis, and means including said members for varying the depth of said chamber and simultaneously varying the flow area of said passage substantially throughout its length.

11. In a fluid atomizer having an outlet orifice connected to a source of liquid under pressure, means for imparting a whirling motion to liquid from said source in a zone coaxial with said orifice and for causing said whirling liquid to be moved longitudinally of said zone for discharge through said orifice at varying rates to provide an expanding spray, said means comprising parts having cylindrically formed surface portions defining a cylindrical boundary for said whirling zone at a diameter substantially greater than the diameter of said orifice, said parts having other surface portions defining a passage for directing said liquid into said whirling zone substantially tangentially of said cylindrical boundary at a distance from said orifice requiring said whirling liquid to move longitudinally of said zone before entering said orifice, said passage having its axis of flow in a plane substantially normal to the axis of said whirling motion, one of said parts being rotatable relative to another of said parts for varying the flow area of said passage substantially throughout its length while limiting the variation in the cross section of said passage to a direction substantially parallel to said normal plane.

12. In a fluid atomizer having a whirl chamber and its outlet orifice formed about a common longitudinal axis, said orifice being of substantially smaller diameter than said chamber to provide a restricted outlet therefrom, means comprising parts having surface portions forming a cylindrical wall portion of said chamber at a location adjacent the base of said chamber, said parts having other surface portions forming a passage for directing liquid into said chamber substantially tangentially of said cylindrical wall portion to impart a whirling motion to said liquid at a distance from said orifice requiring the whirling liquid to move longitudinally of said chamber before entering said orifice, said passage having its walls arranged to provide a median line of flow through said passage in a plane

substantially normal to said common axis, said parts including a part movable relative to another of said parts, and means for moving said movable part to include rotation relative to said other part for regulating a cross sectional dimension of said passage.

13. In a fluid atomizer having a whirl chamber and its outlet orifice formed about a common longitudinal axis, said orifice being of substantially smaller diameter than said chamber to provide a restricted outlet therefrom, means comprising parts having surface portions forming a cylindrical wall portion of said chamber at a location adjacent the base of said chamber, said parts having other surface portions forming a passage for directing liquid into said chamber substantially tangentially of said cylindrical wall portion to impart a whirling motion to said liquid at a distance from said orifice requiring the whirling liquid to move longitudinally of said chamber before entering said orifice, said passage having its walls arranged to provide a median line of flow through said passage in a plane substantially normal to said common axis, said parts including a part movable relative to another of said parts, and means for moving said movable part to include rotation relative to said other part for effecting a variation in the cross section of said passage greater in a direction transversely of said axis than in a direction parallel to said axis.

14. In a fluid atomizer having a whirl chamber and its outlet orifice formed about a common longitudinal axis, said orifice being of substantially smaller diameter than said chamber to provide a restricted outlet therefrom, means comprising parts having surface portions forming a cylindrical wall portion of said chamber at a location adjacent the base of said chamber, said parts having other surface portions forming a passage for directing liquid into said chamber substantially tangentially of said cylindrical wall portion to impart a whirling motion to said liquid at a distance from said orifice requiring the whirling liquid to move longitudinally of said chamber before entering said orifice, said passage having its walls arranged to provide a median line of flow through said passage in a plane substantially normal to said common axis, said parts including a part movable relative to another of said parts, and means for moving said movable part to include rotation relative to said other part for regulating the flow area of said passage while limiting the variation in the cross section of said passage substantially to a direction transversely of said axis.

15. In the atomization of liquid fuel wherein fuel under pressure is directed tangentially of a whirling zone for subsequent discharge through an orifice to produce a divergent spray of atomized fuel, and wherein at widely varying rates of fuel flow the angle of spray varies from a relatively wide angle at the lower rates to an appreciably narrower angle at the higher rates, the method of maintaining minimum variation in the angle of spray throughout a predetermined range of fuel flow rates which comprises directing said fuel in a plurality of streams tangentially into a whirling zone of cylindrical formation at a location remote from its outlet orifice of restricted diameter, each of said streams having its direc-

tion of flow in a plane substantially normal to the axis of whirl, varying the rates of fuel flow by varying the cross-section of said streams while maintaining their axial dimensions substantially constant and their points of entry into said whirling zone substantially fixed in relation to said orifice, and admitting an auxiliary fluid into said whirling zone at a location rearwardly of the points of entry of said streams of fuel, said auxiliary fluid being admitted to said zone in a stream axially aligned with said orifice and at a pressure less than the pressures existing within said zone at the higher rates of fuel flow to increase the effective axial velocity of fluid flow through said orifice only at the lower rates.

16. In a liquid fuel burner for wide range operation, means comprising parts forming a whirl chamber having a cylindrical wall portion adjacent its base and an axially disposed outlet orifice of restricted diameter at its opposite forward end, said parts including a part movable relative to another of said parts, said parts having surface portions mutually forming a passage through a circumferential wall of said chamber for directing fuel under pressure into said chamber substantially tangentially, said passage being formed to provide a median line of flow there-through in a plane substantially normal to the central axis of said chamber, means for moving said movable part to vary the flow area of said passage, and means forming an axially disposed secondary orifice through the base of said chamber for supplying an auxiliary fluid under pressure to said chamber.

17. In a liquid fuel burner for wide range operation, means comprising parts forming a whirl chamber having a cylindrical wall portion adjacent its base and an axially disposed outlet orifice of restricted diameter at its opposite forward end, said parts including a part movable relative to another of said parts, said parts having surface portions mutually forming a passage through said cylindrical wall portion of said chamber for directing fuel under pressure into said chamber substantially tangentially, said passage being formed to provide a median line of flow therethrough in a plane substantially normal to the central axis of said chamber, means for moving said movable part to vary the flow area of said passage throughout its length while maintaining its axial dimension substantially constant, and means forming an axially disposed secondary orifice through the base of said chamber for supplying an auxiliary fluid under pressure to said chamber.

18. In a liquid fuel burner for wide range operation, means forming a whirl chamber of circular cross-section having an outlet orifice, said chamber and said orifice being formed about a common central axis, means forming a passage for directing fuel into said chamber in substantially tangential relation thereto comprising members one of which is rotatable relative to the other about the axis of said chamber, means for rotating said one member for regulating the flow area of said passage substantially throughout its length and thereby the flow of fuel into said chamber, and means on one of said members movable longitudinally of said axis for controlling the flow of fuel into said orifice.

LAMBERT KOOISTRA.

Certificate of Correction

Patent No. 2,372,283.

March 27, 1945.

LAMBERT KOOISTRA

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 68, for the word "office" read *orifice*; page 5, second column, line 57, claim 4, after "orifice" insert a comma; page 6, second column, line 5, claim 9, after "surfaces" insert a comma; line 12, for "havinng" read *having*; page 7, second column, line 24, claim 16, for "a circumferential wall" read *said cylindrical wall portion*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 12th day of November, A. D. 1946.

[SEAL]**LESLIE FRAZER,***First Assistant Commissioner of Patents.*