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E. O. OLSON ET AL

2,703,260

DUAL ORIFICE ATOMIZING NOZZLE

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Fig. 1

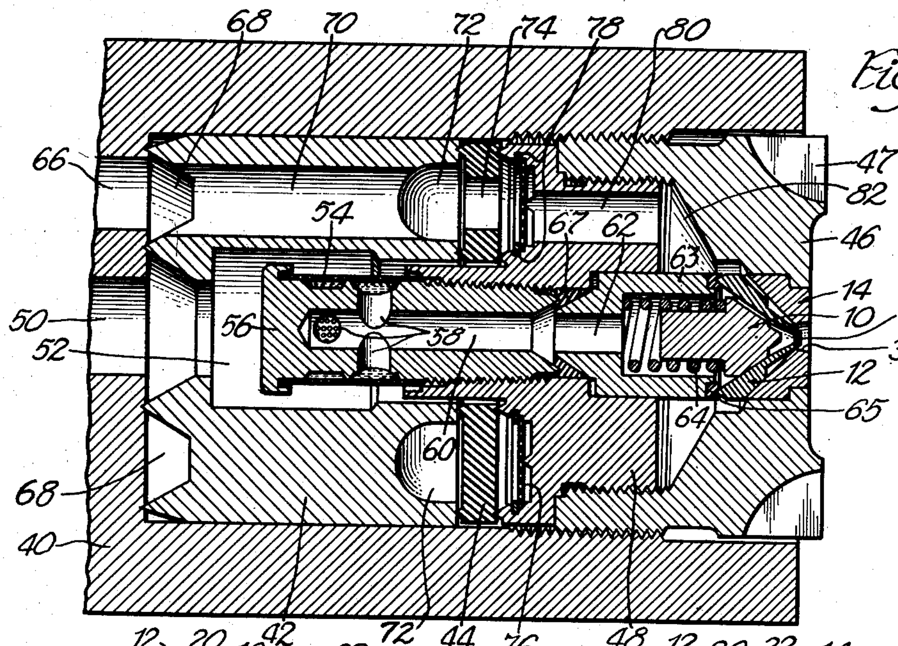


Fig. 2

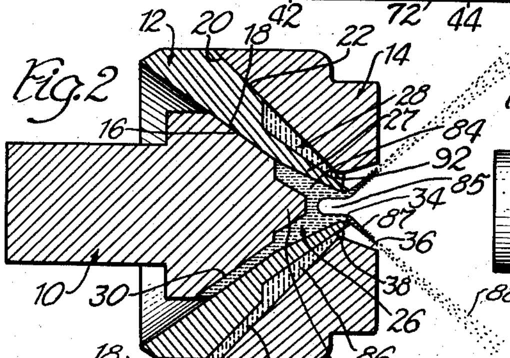


Fig. 3

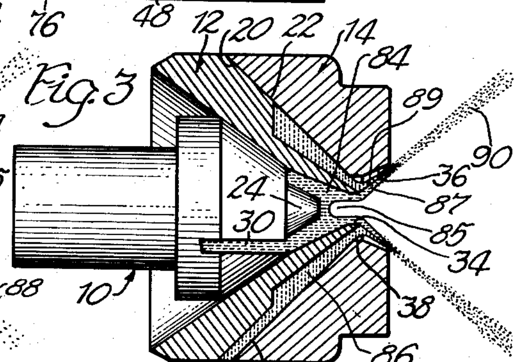


Fig. 4

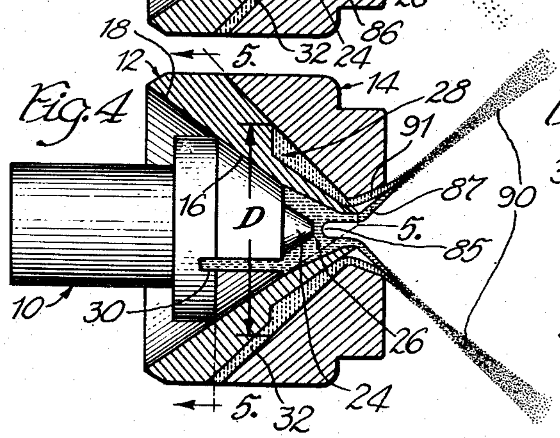
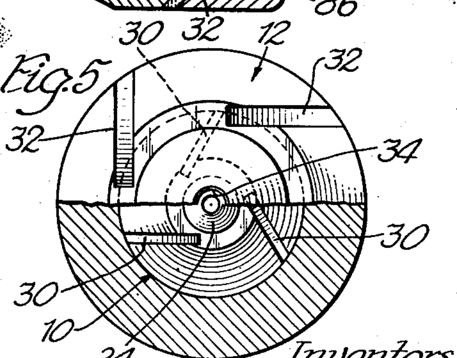


Fig. 5



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DUAL ORIFICE ATOMIZING NOZZLE

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6 Claims. (Cl. 299—114)

This invention relates to a dual orifice atomizing nozzle such as one that is adaptable for use in a jet engine.

One object of the invention is to provide a nozzle which is capable of a wide range of adjustment, with discharge ratios as high as 40:1 with satisfactory atomization at all flow rates within this range.

Another object is to provide a duplex type of nozzle which is so designed that a low flow rate of fuel or other liquid from only one swirl chamber of the nozzle can be projected with satisfactory atomization at relatively low pressures, or relatively high pressures may be used for increasing the rate of flow considerably without appreciably changing the spray pattern.

A further object is to provide a duplex type nozzle designed for a still higher flow rate by spraying from two swirl chambers, and at the same time maintain substantially constant the spray pattern whether the flow rate is low or high in the second swirl chamber.

Still a further object is to provide a duplex type of nozzle in which there are two discharge orifices as distinguished from a common discharge orifice in most dual type nozzles having two swirl chambers.

An additional object is to provide a nozzle which meters the primary flow and the secondary flow in such manner that where a group of nozzles are connected to a common fuel manifold or to parallel manifolds, the nozzles are substantially independent of each other as far as equal spraying from the nozzles is concernced, thus eliminating expensive flow dividers and other devices commonly used to insure equal flows from nozzles into an engine or the like.

Still another additional object is to provide a nozzle construction in which conical elements are so associated with each other that fuel enters the swirl chambers in a forwardly inclined direction instead of at right angles to the central axis of the nozzle as in other type dual nozzles, thus providing an arrangement less subject to plugging due to an accumulation of foreign matter in the swirl chambers and less subject to erosion caused by an abrupt change in direction of fluid flow.

Another additional object is to provide a nozzle construction in which cone elements are so associated with each other that there is positive and accurate alignment of the swirl chambers and orifices in order to produce uniform spray patterns from all nozzles assembled from the parts designed as herein disclosed.

A further additional object is to provide a dual orifice nozzle which has the characteristic of greater ease of installation than is common with most variable flow nozzles, the construction being such that piping to the nozzle need not be disturbed while removing or installing the nozzle, the nozzle being removable as a unit from a nozzle holder that is permanently connected to the supply piping.

Still a further additional object is to provide a nozzle design which permits improved control of the spray angle and the spray pattern which are extremely important especially in jet engine work where the combustion temperatures approach the critical temperature of the combustion chamber materials.

Another specific object of our invention is to provide a dual orifice nozzle in which the parts are so designed and related to each other that the desired range from very low flow to relatively high flow is had without substantial change in the spray pattern, and a high degree of atomization of the fuel or other material being sprayed from the nozzle is had at all flow rates.

With these and other objects in view, our invention consists in the construction, arrangement and combination of the various parts of our dual orifice atomizing nozzle, whereby the objects contemplated are attained, as hereinafter more fully set forth pointed out in our claims and illustrated in the accompanying drawings, wherein:

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Figure 1 is an enlarged cross section of a dual orifice atomizing nozzle embodying our present invention and showing it mounted in a nozzle holder.

Figure 2 is an enlarged sectional view of the essential parts of our nozzle and the design of which parts produce the desired results as set forth in our objects and claims, this figure showing pressure applied to only the primary nozzle.

Figure 3 is a similar sectional view showing pressure applied to both the primary nozzle and the secondary nozzle but with the secondary pressure relatively low.

Figure 4 shows the spray action when both the primary and secondary sprays are operating at relatively high pressure; and

Figure 5 is a partial sectional view showing in the upper half the forward face of an intermediate cone element and in the lower half the forward face of an inner cone element of our nozzle as taken on the indicated line 5—5—5 of Figure 4.

On the accompanying drawing we have used the reference numeral **10** to indicate an inner cone element, **12** an intermediate cone element, and **14** an outer cone element. These elements may be of stainless steel or any suitable metal turned in an automatic lathe or the like since they are circular in cross section.

The inner cone element **10** is provided with an outer cone face **16** and the intermediate cone element **12** is provided with an inner cone face **18**. These are at substantially the same angle so as to fit snugly together as illustrated. Likewise the elements **12** and **14** are provided with outer and inner cone faces **20** and **22** respectively fitted against each other. The manner for supporting all three cone elements in interfitted position may vary considerably but since the elements are cone shape, when they are fitted together, assurance is had that they are concentrically located with respect to each other.

The inner cone element **10** has a tip **24** which is reduced in relation to the outer cone face **16** so as to provide between the tip **24** and the inner cone face **18** of the intermediate cone element **12**, a primary swirl chamber **26**. Similarly, the intermediate cone element **12** has a tip **27** to provide a secondary swirl chamber **28** between it and the inner cone face **22** of the outer cone element **14**.

Primary swirl slots **30** are cut in the inner cone element **10** and particularly across the outer cone face **16** thereof, these being tangentially arranged as shown in Figure 5. Similar secondary swirl slots are cut in the intermediate cone element **12** across the outer cone face **20** thereof. These likewise are tangentially arranged as shown in Figure 5, there being illustrated three of the primary slots **30** and four of the secondary slots **32**. The number of slots may vary, however, and our claims are not limited to the exact number shown.

The right hand end of the intermediate cone element **12** in Figure 2 terminates in a primary orifice **34**. This orifice has a predetermined area and the total area of the slots **30** is desirably as great or greater than the area of the primary orifice **24**, or the ratio of primary slot area to primary orifice area is greater than unity, in order to secure a satisfactory spray issuing from the primary orifice while the nozzle is operating on primary pressure only or on high primary pressure plus low secondary pressure.

The outer cone element **14** is provided with a secondary orifice **36**. This orifice has a long outlet cone leading thereto, the small end of which constitutes a constriction **38** which is located slightly upstream from the discharge end of the primary orifice **34**. Where the secondary orifice **36** meets the right hand face of the outer cone element **14**, which may be considered the discharge edge of the orifice **36**, the size is such as to permit the projection of a primary spray from the primary orifice **34** as shown in Figure 2 without striking this edge and thus interfering with the spray pattern. These proportions and relationships are important in the proper functioning of our nozzle from the low range to the high range with satisfactory atomization throughout the entire range.

Another important relationship we have determined is that between the diameter of the secondary swirl chamber indicated by the dimension line D in Figure 4 and the diameter of the secondary orifice at the constriction 38, the ratio should be greater than 2.

While any suitable means may be provided for mounting the three cone elements of Figure 2, by way of example we show in Figure 1 a nozzle holder 40 in which a seal seat 42 may be press fitted. A primary-secondary seal 44 of copper or similar soft metal is interposed between the seal seat 42 and a body bushing 48. A nozzle body 46 has the spacer 48 threaded into it and in turn the nozzle body is threaded into the nozzle holder 40.

The nozzle body 46 is formed to receive the outer cone element 14 with the intermediate and inner cone elements 12 and 10 arranged as disclosed and held in position by means which will later be described.

The nozzle holder 40 has a primary supply passageway 50 communicating with a primary bore 52 in the seal seat 42. The fuel from 50 flows into 52 and then through a screen 54 mounted in a screen support 56 which in turn is mounted as by screw threading in the body bushing 48. The screen support 56 has pasasgeways 58 to its center where there is a bore 60 to conduct the fuel into a bore 62 of a spacer 63. This spacer has therein a spring 64 to hold the cone element 10 seated in the intermediate cone element 12 and a gasket 65 between the spacer 63 and the cone element 12 holds this latter cone element seated in the cone element 14.

Another gasket 67 is interposed between the spacer 63 and the screen support 56 so that when the screen support is tightened in position the elements 63, 12 and 14 will also be tightened, with the gaskets 65 and 67 sealing any leakage between the parts. We then have a unitary nozzle consisting of the parts 10, 12, 14, 46, 48, 56, 63, 64, 65 and 67 removable as a unit from the nozzle holder 40 for replacement of the nozzle. The cone elements 10, 12 and 14 are readily removable from the nozzle unit by unscrewing the body bushing 48 from the body 46. For this purpose the body has wrench slots 47 and the body bushing 48 may be removed with a spanner type wrench made to fit into the fuel passages 80.

The nozzle also includes a screen 76 and screen retaining rings 78. Such fuel is supplied to a secondary supply passageway 66 in the nozzle holder 40 from which it enters an annular distributing groove 68 in the adapter 42. This adapter has several secondary passageways 70 therein leading to a second annular distributing groove 72 which communicates with the screen 76 through several openings 74 in the primary-secondary seal 44. Finally the body bushing 48 is provided with several passageways 80 through which the fuel flows into a chamber 82 in the body 46 and from there through the swirl slots 32 to the secondary swirl chamber 28.

As to the primary flow, obviously it is from the bore 62 through the primary swirl slots 30 to the primary chamber 26.

Practical operation

In the operation of our dual orifice nozzle, and beginning with an initial flow rate at or near the minimum rate possible for the nozzle, pressure is supplied to the primary fuel only at a value which will deliver the desired flow rate. This rate may start, for instance, at 20 p. s. i. with a fuel line pressure of 20 pounds per square inch and obtain satisfactory atomization. This is illustrated in Figure 2 where the primary fuel is shown at 84 and the secondary fuel at 86. To distinguish between the two, the fuel 84 has been cross-sectioned in the usual manner for liquid and the fuel 86 has been similarly cross-sectioned but with the section lines extending vertically instead of horizontally.

The primary fuel 84 flowing through the slots 30 has imparted to it a tangential component which causes the fuel to swirl in the primary swirl chamber 26. Accordingly, centrifugal force results in a vortex at 85 and a hollow cone-shaped film or stream of liquid, or primary liquid cone 87 which finally breaks up into a primary spray cone 88, a cross section of which is shown in Figure 2, in which the liquid is in atomized form. The spray cone has a substantially constant angle which does not strike the discharge edge of the secondary orifice 36 regardless of the pressure applied to the primary fuel 84 and this is important in some jet engine combustion chambers as the spray must be tailored to the shape of the chamber.

As the flow rate of the primary fuel 84 is increased, by increasing the pressure up to a value of for instance 80 pounds per square inch, the spray pattern will remain substantially the same. The increase in pressure from 20 to 80 is in the ratio of 1:4 but the flow rate increase would be approximately in the ratio of 1:2.

When the primary spray is well established, for instance at 115 p. s. i. or greater, the flow from the nozzle may be further increased by applying a very low pressure to the secondary fuel 86, as shown in Figure 3. For instance, the pressure may be only 1 p. s. i. or a small fraction of 1 p. s. i. The primary spray cone 88 has a very high velocity close to the primary orifice 34 and with a very low pressure on the secondary fuel 86 (too low to produce independent atomization) the secondary liquid flows very slowly through the secondary swirl chamber 28 and through the constriction 38 of the secondary orifice 36 and is combined with and accelerated by the higher velocity primary flow which under the conditions described has enough momentum to dissipate the secondary stream into a finely divided spray.

At a point close to the primary orifice, the primary and secondary fuels are in the form of a liquid cone 87—89 as shown in Figure 3 which does not break into particles or become atomized until the liquid has traveled some distance from the orifice, the combined primary and secondary spray cone being illustrated at 90 in Figure 3. The construction of the primary orifice and its relation to the secondary orifice are such that the secondary liquid is picked up or combined with the film of the primary spray as illustrated due partially to an aspirating effect of the primary flow upon the secondary flow and partially to the forward motion of the secondary liquid into the primary spray. The liquid cone 87 of Figure 2 then becomes thicker in Figure 3 because of the addition of the secondary fuel cone 89 and the atomization of the primary fuel induces like atomization of the secondary fuel to produce the spray 90.

As the secondary pressure is increased, the velocities in the secondary swirl chamber and secondary orifice likewise increase and finally become sufficient to cause atomization of the secondary spray independent of the primary spray as shown in Figure 4. The primary liquid cone is again indicated as 87 in this figure and the secondary liquid cone caused by independent atomization is indicated as 91 to distinguish from the aspirated secondary liquid cone 89 of Figure 3. It will be noted now that the centrifugal action of the secondary swirl chamber is effective to cause the secondary liquid cone 91 to follow the secondary orifice 36 after passing the constriction 38.

The two liquid cones 87 and 91 finally meet and provide a spray cone 90 of primary and secondary fuel and of substantially the same included angle as the initial spray cone 88 in Figure 2. This condition obtains throughout further increases of pressure such as to 150 p. s. i. on the primary fuel and 10 p. s. i. on the secondary, 200 p. s. i. on the primary and the 100 p. s. i. on the secondary and finally equal pressure on both such as 250 p. s. i. During this range of pressures, the two atomized sprays continue to merge into one and after the pressure on the secondary is brought up to the same level as that on the primary, both pressures may be increased simultaneously to give a further increase in the discharge rate up to the maximum possible from the nozzle. All four of the spray cones 87, 89, 90 and 91 in Figures 3 and 4 are also illustrated in cross section as in Figure 2, it being understood that these representations are of hollow cones.

In reducing the flow rate the reverse of the process just described is used. For this purpose proper control devices are necessary. They are usually provided by the engine manufacturer and form no part of our present invention.

The use of conical shapes for the functional parts of our nozzle has definite advantages. This design assures positive centering of the nozzle parts. This is important in producing sprays which are uniform around the entire periphery. The cone shape also provides the secondary fuel flow with an axial component even at low pressures which carries the liquid forward past the constriction 38 and into the secondary orifice 36 to merge with the primary spray as disclosed in Figure 3. The nozzle, being made up of conical elements, causes the fuel as it enters the swirl chambers to do so in a forwardly inclined direction which minimizes both the tendency to plug the orifices due to foreign matter accumulating in the swirl chambers and the erosion tendency experienced with those types of nozzles in which the swirl chambers are in planes normal to the nozzle axis.

We have found that the optimum angle for the matching cone faces **16, 18, 20** and **22** lies between 60° and 100° included angle depending upon other limiting dimensions of the nozzle construction. As disclosed, we have shown an angle of 70° between the faces **16** and **18** and 90° between the faces **20** and **22**.

The relation of the axial position of the forward edge of the primary orifice with reference to the forward edge of the secondary orifice is important since the discharge edges of the orifices are the points of origin of the diverging spray cone. The point of origin of the primary spray must be such that for a given spray angle the sides of the primary spray will clear the discharge edge of the secondary orifice and not impinge upon it. This is illustrated in Figure 2. Any such impingement would result in larger droplet size and drooling from the face of the secondary orifice.

The included angle of the intermediate cone element **12** extending into the secondary orifice **36** is important in controlling the blending of primary and secondary sprays as in Figure 3 when the secondary fuel is at low pressure. This angle must be such that the upstream edge of the secondary orifice constriction **38** is at a point upstream from the face or right hand end of the primary orifice **34** and the angle must be acute enough to take advantage of the forward motion of the secondary fuel at low pressure into the primary spray as illustrated in this figure. It must also be of such a value that the meniscus of the secondary liquid at zero secondary pressure shown at **92** in Figure 2 does not extend to the face or discharge edge of the primary orifice in which case there would be erratic performance of the primary spray alone.

Our construction also creates a low pressure area surrounding the primary spray and downstream from the constriction of the secondary orifice during operation as in Figure 3 which serves to aspirate the secondary fuel from the secondary swirl chamber without the secondary fuel following the secondary orifice **36** as in Figure 4, thus causing uniform blending of the secondary fuel with the primary spray while the secondary fuel is at low pressure. Without this feature the secondary fuel would simply drool from the lower edge of the secondary orifice **36** instead of being properly atomized. We have found that the cone angle necessary to accomplish these results, that is the angles inside and outside the tip **27**, lies between 45° and 80° included angle depending upon the nozzle capacity.

The position of the primary orifice face with respect to the secondary orifice face is also of importance in our dual orifice design. As the spray leaves the primary orifice it travels at very high velocity, the velocity decreasing as the spray gets farther from the orifice. It leaves the primary orifice in the form of the cone-shaped sheet **87** or film of liquid and as this cone gets farther away from the nozzle, it ruptures and breaks up into small droplets or atomizes as indicated at **88** in Figure 2, at some distance in front of the primary orifice depending upon the pressure and the discharge rate. It may atomize at a point even beyond the discharge face of the secondary orifice **36**.

The introduction of the secondary flow at low pressure must occur at a point where the primary spray is still in the form of an unbroken hollow cone of liquid and must merge with that cone of liquid in a uniform manner before the cone separates into droplets. This is illustrated in Figure 3. Therefore the location of the face of the primary orifice must be just forward of the narrow portion or constriction of the secondary orifice in order that the low velocity secondary flow will be uniformly combined with the primary flow.

The relation of the primary spray angle to the secondary orifice diameter must be maintained in order to provide uniformly satisfactory atomization throughout the entire pressure range of operation. The primary spray must not impinge upon the secondary orifice and for that reason the control of the primary spray angle is very important to good operation. This spray angle, however, must be wide enough to insure the proper merging of the secondary spray with it so that the combined spray does not resolve itself into two separate spray cones.

The relationship of the secondary swirl chamber diameter to the secondary orifice diameter is important from the standpoint of secondary spray quality. We have found that this ratio must be above 2. If the ratio is less, the pressure in the secondary swirl chamber is not uniform at the orifice and the resultant spray is marked by non-uniform distribution. In that event, each swirl slot **32** causes a heavier concentration of spray which is not only visible but causes non-uniform combustion in the combustion chamber. The use of a wider secondary swirl chamber permits the establishment of uniform pressures and streamlined flow in that swirl chamber resulting in uniform distribution of the secondary spray over a wide range.

There are various methods which might be used to control spray angles, but we have found that, for controlling the spray angle of the secondary spray in our disclosed type of nozzle from an annular type of orifice, a long outlet cone in the orifice is required. This construction permits control of the angle of spray which may be varied either by using a deeper or shallower cone opening or by using a wider or narrower cone outlet angle. For each size of nozzle there will be a different combination of these two factors but in all cases the variations lie within the ranges specified in our description and claims.

Some changes may be made in the construction and arrangement of the parts of our dual orifice atomizing nozzle without departing fwrom the real spirit and purpose of our invention, and it is our intention to cover by our claims any modified forms of structure or use of mechanical equivalents which may be reasonably included within their scope.

We claim as our invention:

1. In a dual orifice nozzle, inner, outer and intermediate cone elements, a primary swirl chamber defined between said inner and intermediate elements, a secondary swirl chamber defined between said intermediate and outer elements, said intermediate element having a primary orifice, said outer cone element having an annular shaped secondary orifice, defined between said intermediate and outer elements, said secondary orifice having a constriction surrounding the discharge end of said intermediate cone element and located upstream from the discharge end of said primary orifice, said secondary orifice being flared downstream of said restriction to a larger diameter than said restriction and constituting a guide for the liquid from said secondary chamber when the nozzle is operating at high capacity.

2. In an atomizing nozzle of the character disclosed, concentric inner, outer and intermediate cone elements, a primary swirl chamber of cone shape defined between said inner and intermediate cone elements, said inner cone element having primary swirl slots therein upstream from said primary swirl chamber, a secondary swirl chamber defined between said intermediate and outer cone elements, said intermediate cone element having secondary swirl slots therein upstream from said secondary swirl chamber, said intermediate cone element having a primary orifice, said outer cone element having a secondary orifice surrounding the discharge end of said intermediate cone element and located upstream from the face of said primaray orifice, said secondary orifice diverging downstream of said primary orifice and terminating short of the path of a primary spray issuing from said primary orifice.

3. A nozzle structure comprising inner, intermediate and outer cone elements, the outer surface of said inner element and the inner surface of said intermediate element having cone faces fitted against each other, the outer surface of the intermediate element and the inner surface of the outer element having cone faces fitted against each other, said elements having portions downstream from said cone faces fitted against each other to define a cone-shaped primary swirl chamber between said inner element and said intermediate element and a secondary swirl chamber between said intermediate element and said outer element, said intermediate cone element having a primary orifice at substantially the axial center of said elements, said outer cone element having a secondary orifice provided with a constriction surrounding the discharge end of said intermediate cone element, said secondary orifice diverging downstream relative to said constriction, the dis-

charge face of said outer cone element being located sufficiently upstream that the intersection between said secondary orifice and said face is upstream with relation to the outer limits of a spray discharged from said primary orifice only, said secondary swirl chamber tapering in cross-section for increasing the velocity of the fluid flowing therethrough so that its highest velocity is at said constriction, and the taper of the outer surface of said intermediate cone element defining one side of said secondary swirl chamber being such as to take advantage of the axial flow component of the secondary flow into the primary spray for impinging the liquid of the secondary flow against the outer surface of the primary spray cone.

4. A nozzle structure comprising an assembly of cone elements defining primary and secondary swirl chambers, a primary orifice, and a secondary orifice having a constriction surrounding said primary orifice and located upstream with respect thereto and with respect to the discharge end of said secondary orifice, said secondary swirl chamber tapering in radial cross-section for increasing the velocity of the fluid flowing therethrough so that its highest velocity is at said constriction.

5. A nozzle structure comprising inner, intermediate and outer cone elements to define a cone-shaped primary swirl chamber between said inner element and said intermediate element and a secondary swirl chamber between said intermediate element and said outer element, said intermediate cone element having a primary orifice at substantially the axial center of said elements, said outer cone element having a secondary orifice provided with a constriction surrounding the discharge end of said intermediate cone element, the discharge end of said secondary orifice being located sufficiently upstream that the intersection between said end and the discharge face of said secondary orifice is upstream with relation to the outer limits of a spray discharged from said primary orifice, the discharge from said secondary swirl chamber being so directed toward said primary spray as to take advantage of the axial flow component of the secondary flow into the primary spray when the secondary spray is in operation at low pressure.

6. In a dual orifice nozzle, inner, outer and intermediate cone elements, a primary swirl chamber defined between said inner and intermediate elements, a secondary swirl chamber defined between said intermediate and outer elements, said intermediate element having a primary orific, said outer cone element having an annular shaped secondary orifice, said secondary orifice having a constriction surrounding the discharge end of said intermediate cone element and so located relative to said primary orifice as to project liquid from said secondary orifice into the spray from said primary orifice when said secondary swirl chamber is fed with insufficient pressure to cause the formation of a divergent atomized spray, independent of the primary spray.

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