

Sept. 13, 1966

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3,272,441

ASPIRATING SPRAY NOZZLE

Filed Nov. 3, 1965

5 Sheets-Sheet 1

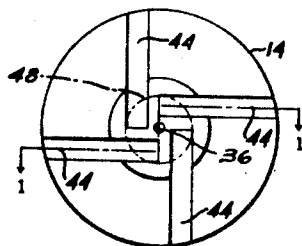


FIG. 2

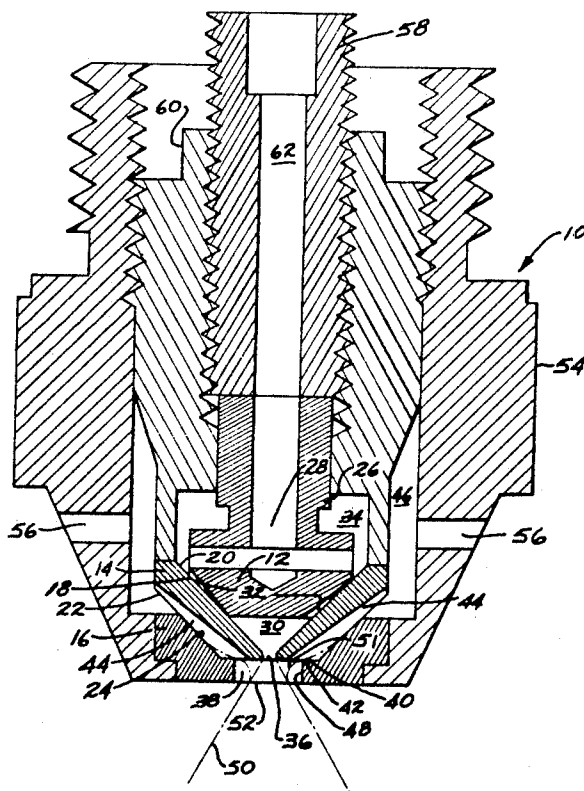


FIG. 1

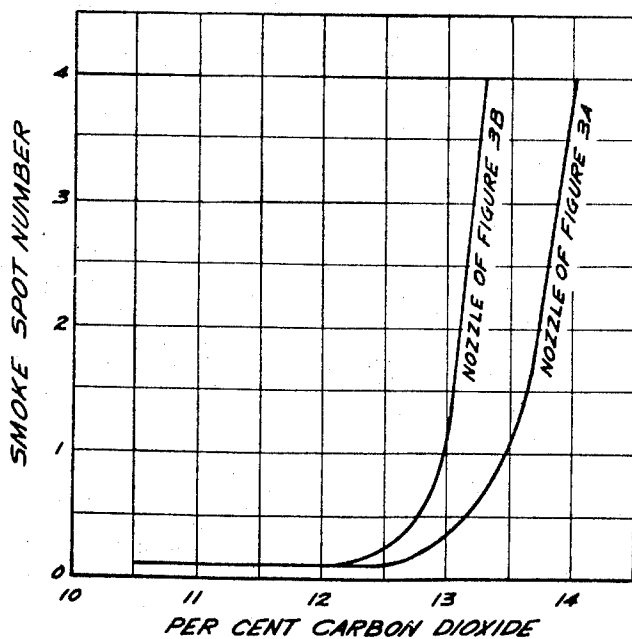


FIG. 4

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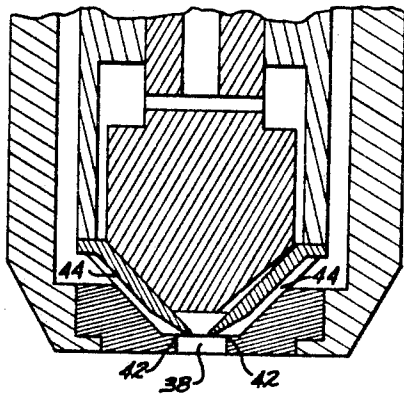


FIG. 3A

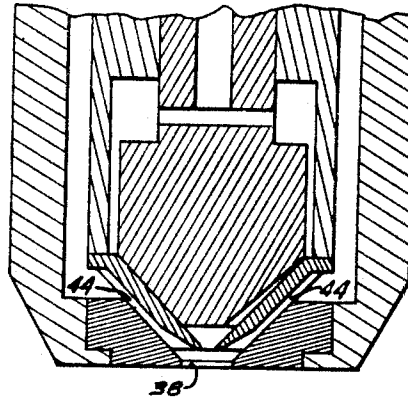


FIG. 3B

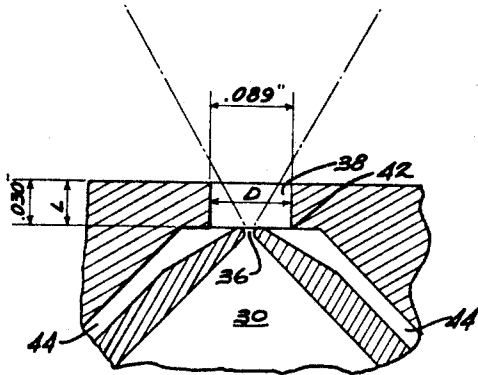


FIG. 5A

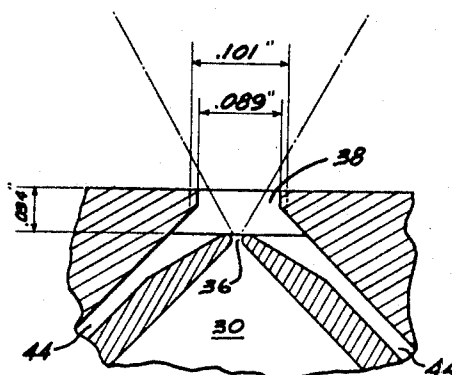


FIG. 5B

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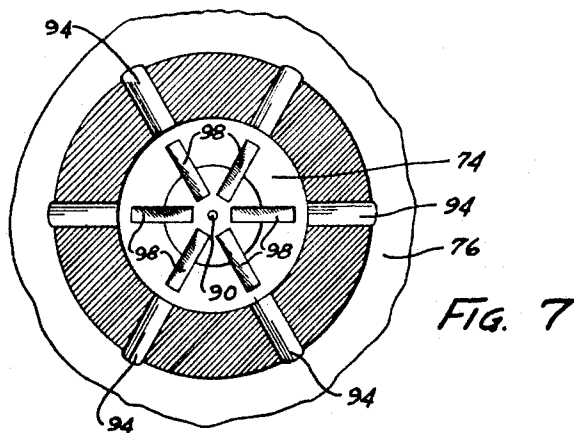
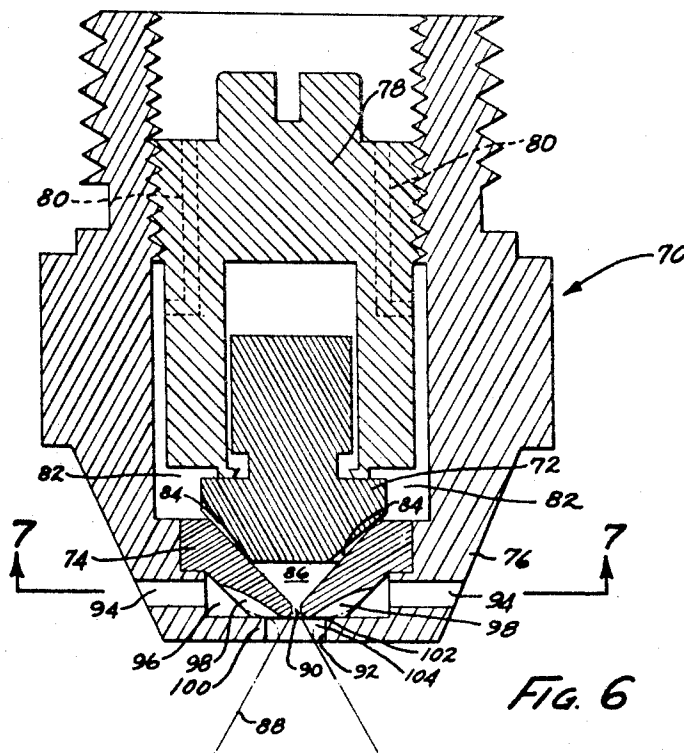
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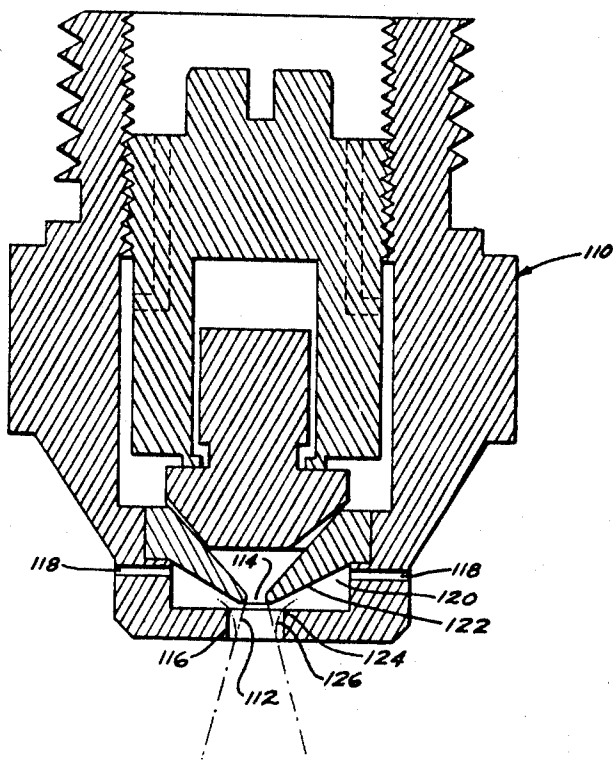


FIG. 8

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Fig. 9

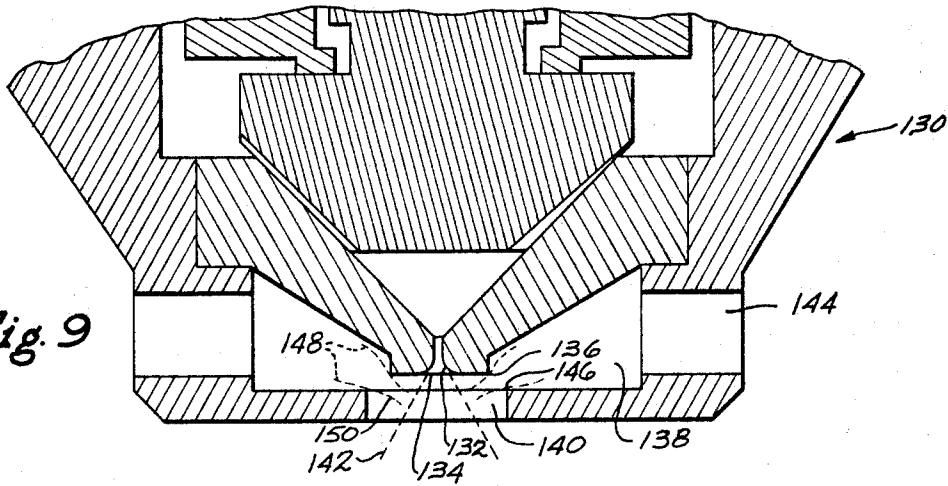


Fig. 10

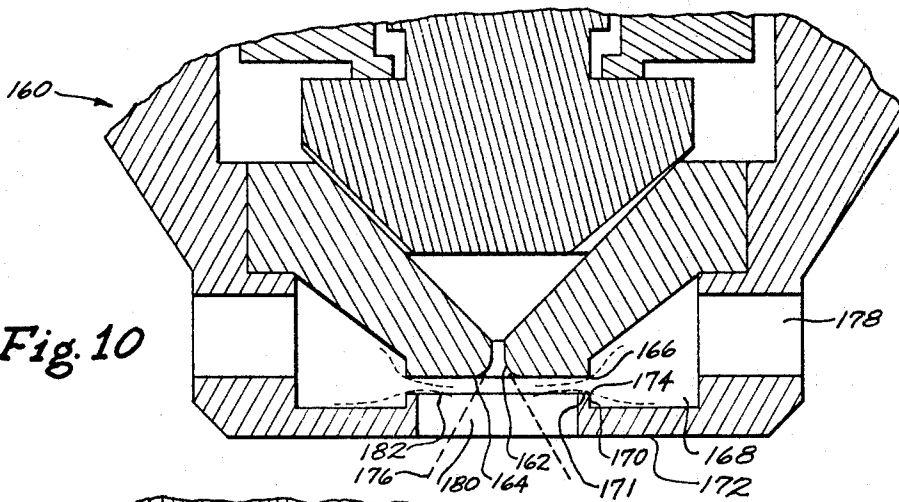
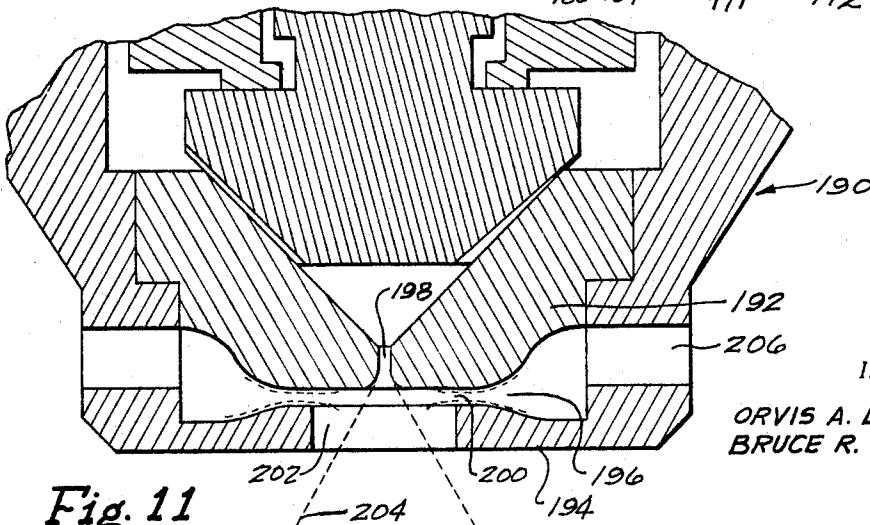


Fig. 11



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ASPIRATING SPRAY NOZZLE

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Filed Nov. 3, 1965, Ser. No. 507,992

20 Claims. (Cl. 239-403)

This application is a continuation-in-part of Serial Number 354,506, now Patent Number 3,217,986, which was filed March 20, 1964, as a continuation-in-part of Serial Number 298,970, filed July 31, 1963, now abandoned.

This invention relates to novel oil burner spray nozzles. More particularly, this invention relates to oil burner nozzles adapted for superior admixing of air into an oil spray. Still more particularly, this invention relates to oil burner nozzles adapted to aspirate atmospheric air into the nozzle and homogeneously admix the aspirated air into the oil spray.

It is advantageous in terms of combustion performance for burner nozzles which spray oil under pressure to aspirate air directly into the burner nozzle. However, pressurized oil burner nozzles which aspirate air directly into the nozzle can advantageously aspirate only a small proportion of the total amount of air required for combustion and in such nozzles increasing the quantity of air aspirated beyond a specific amount does not necessarily further improve nozzle combustion performance. For example, it is shown in this application that as the quantity of air aspirated into an oil burner nozzle increases in a specific range, combustion performance with the nozzle declines. The nozzles of this invention are adapted not only for aspiration of air directly into an oil burner nozzle but also to accomplish this aspiration in a manner which enables the aspirated air to exert an especially beneficial effect upon combustion performance.

The nozzles of this invention aspirate one or a plurality of streams of air into a forward nozzle chamber surrounding a swirling conical spray of oil droplets. The air enters the rear of the chamber outside of the periphery of the oil spray. The nozzles of this invention possess structure which causes the velocity of the aspirated air to increase as it approaches the conical swirling spray of fuel oil droplets so a high degree of admixture occurs between the air and the swirling oil spray.

Generally, in order to achieve a high degree of mixing of air into an oil spray, it is necessary to force pressurized air into the oil spray. However, if a jet of pressurized air is forced into a swirling conical oil spray, disruption of swirling and distortion of the shape of the spray is likely. Since a fundamental feature of a swirling spray process is the inducing of a high degree of oil atomization, any interference with the swirling process during the introduction of air to the oil spray is likely to retard oil atomization. In accordance with the present invention, a high degree of mixing of air into an oil spray is achieved with a spray nozzle without interfering with the oil spray pattern or hindering the atomization procedure.

In operation, the nozzle of this invention induces aspirated air to increase in velocity as it approaches the oil spray. An increase in velocity is imparted to the aspirated air stream directly at or very close to the oil spray, urging the air stream into close proximity with the oil spray. In this manner the oil spray is tightly encircled by a blanket of air and the air is facily positioned to be caught up by the swirling droplets in the oil spray to provide a homogeneous admixture of oil and air with minimum disturbance of the oil spray.

This invention and the advantages thereof are illus-

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trated by the following description in reference to the drawings in which—

FIGURE 1 is a cross-sectional view of a nozzle modified to show two tangential slots 44 in full view, and taken along the line 1—1 of FIGURE 2,

FIGURE 2 is a plan view of member 14 of FIGURE 1, FIGURES 3A and 3B are cross-sectional views of fragments of corresponding nozzles, the view of each nozzle being modified to show two tangential slots 44 in full, with FIGURE 3B showing a nozzle which is modified with respect to the nozzle of FIGURE 3A,

FIGURE 4 shows graphs illustrating the results of combustion tests obtained with the nozzles of FIGURES 3A and 3B,

FIGURES 5A and 5B are cross-sectional views of fragments of different nozzles, the view of each nozzle being modified to show two tangential slots 44 in full, with FIGURE 5B showing a nozzle which is modified with respect to the nozzle of FIGURE 5A,

FIGURE 6 is a cross-sectional view of a nozzle,

FIGURE 7 is a cross-sectional view indicated by the line 7—7 of the nozzle of FIGURE 6 showing the forward end of member 74 in full, and

FIGURES 8, 9, 10 and 11 are cross-sectional views of still other nozzles with the cutaway portions of the nozzles of FIGURES 9, 10 and 11 corresponding generally to corresponding parts of the nozzle of FIGURE 8.

Referring to FIGURE 1, nozzle 10 is comprised in part of three coaxial conically shaped elements including an inner cone 12, an intermediate cone 14, and an outer conical housing 16. Conical surface 18 of inner cone 12 and conical surface 20 of intermediate cone 14 abut firmly against each other in fluid tight engagement while conical surface 22 of intermediate cone 14 and conical surface 24 of outer conical housing 16 also abut firmly against each other in fluid tight engagement. The rearward portion of inner cone 12 comprises a stud 26 having a passageway means 28 extending axially and radially to zone 34. A conically shaped axial swirl chamber 30 is defined between inner cone 12 and intermediate cone 14. One or a plurality of shallow slots 32 extend the length of conical surface 18 connecting zone 34 and swirl chamber 30. Slots 32 approach swirl chamber 30 in a direction which is substantially tangential with respect to the swirl chamber wall surface. A central opening at the forward end of intermediate cone 14 defines an axial discharge orifice 36 for swirl chamber 30 leading into a second or forward chamber 38.

Second chamber 38 comprises a cylindrically shaped bore extending axially completely through outer conical housing 16. The base portion of second chamber 38 is not coincident with but rather is removed from conical surface 24 by means of a continuous ledge 40 lying on a plane substantially normal to the longitudinal axis of nozzle 10. The interior surface of ledge 40 is coincident at one end with conical surface 24 and terminates at the other end with a relatively sharp edge 42, for example, the right angle shown. Sharp edge 42 extends along a continuous circular path and defines the periphery of the base of forward chamber 38. Slots 44 extend from zone 46 and open into the base of forward chamber 38. The depth of slots 44 can be tapered along the length of the slots, as shown, or the depth of slots 44 can equivalently be uniform along the length of the slots. Ledge 40 is a partial barrier and partially obstructs the front or discharge end of slots 44 by covering the portion of the terminus of slots 44 which is remote from orifice 36. Ledge 40 is sufficiently wide in relation to the depth of slots 44 at their juncture with second chamber 38 that it constitutes a significant effect upon flow therefrom. For example, ledge 40 may obstruct about one third, one half, or more, of the portion of the forward opening of slots 44 most

remote from orifice. This estimate is merely illustrative and the extent of obstruction of the terminous of air slots 44 by ledge 40 can vary widely depending upon the desired operating characteristics of the nozzle.

One or more slots 44 are provided. Slots 44 enter the bottom of forward chamber 38 in a generally forward direction, as shown in FIGURE 1, and also in a direction which is substantially tangential with respect to curved wall 48, as is shown in FIGURE 2. Orifice 36 enters chamber 38 axially at the base thereof. A swirling conical spray of oil droplets 50 from orifice 36 traverses the length of forward chamber 38 and leaves the nozzle through discharge opening 52 of forward chamber 38. Opening 52 is larger than orifice 36. The depth and diameter of forward chamber 38 are determined by the included angle of spray 50 and are such that the spray 50 passes close to but does not impinge upon the periphery of opening 52.

Nozzle 10 includes an outer nozzle body 54 having opening means 56 extending from the atmosphere to zone 46. The nozzle elements are secured fixedly into position by means of threaded member 58 and threaded member 60. Member 58 has an axial bore 62 in register with passageway means 28. Member 58, member 60 and outer nozzle body 54 are in threaded engagement, as shown, when the nozzle is assembled. Member 58 is threaded over its entire length to permit connection to a source of pressurized fuel oil and nozzle body 54 is provided with threads for mounting the nozzle during operation.

In the operation of the nozzle of FIGURE 1, oil under pressure is pumped through axial passageways 62 and 28 into zone 34, whence it passes through slots 32 which enter swirl chamber 30 in a forwardly and tangential manner with respect to the conical wall surface of swirl chamber 30. A thin film of swirling oil is discharged through orifice 36 which diverges conically in transit through forward chamber 38 and disintegrates into very small oil droplets.

Forward chamber 38 serves as both an air aspirating and air-oil mixing chamber. The relative depth and diameter dimensions of forward chamber 38 are determined by the included angle of conical oil spray 50. These dimensions are established so that oil spray 50 narrowly misses the forward edge of wall 48. In this manner, a suction is created within forward chamber 38 which draws atmospheric air through openings 56, zone 46 and elongated passageways 44. If oil spray 50 impinges upon wall 48, the nozzle drips liquid oil, aspiration fails, and the nozzle becomes inoperative for practical purposes. Also, if oil spray 50 clears the outer edge of wall 48 by too great a distance, the nozzle will be incapable of effective aspiration.

When the depth and diameter dimensions of chamber 38 are established in relation to the included angle of spray 50 so that spray 50 clears wall 48 by an amount resulting in substantially optimum aspiration, a stream of air flows forwardly through elongated passageways 44, past sharp edge 42, and into forward chamber 38. In passing sharp edge 42, the aspirated air is deflected so that as it enters forward chamber 38 it is urged close to oil spray 50, as indicated at 51. The air deflecting function of sharp edge 42 causes aspirated air stream 51 to be deflected laterally so that it closely encompasses oil spray 50 without disturbing the spray or hindering oil atomization. Air stream 51 travels with the spray in close proximity thereto so that the air is facily available to be caught up by the oil spray to provide a homogeneous admixture of oil and air with minimum disturbance of the oil spray. FIGURE 1 shows that the diameter of forward chamber 38 is sufficiently large not only for conical spray 50 to pass through without contact with the walls of forward chamber 38 but also for the air stream vena contracta indicated at 51 to develop around conical spray 50.

The air deflecting function of sharp edge 42 provides

greatly improved combustion performance. In a nozzle which is otherwise incapable of inducing a high velocity in the aspirated air stream, both the number and the size of air passageways 44 are advantageously relatively small in order to maintain a relatively high air velocity through each of these passageways. A relatively high air velocity in the region of sharp edge 42 is necessary if sharp edge 42 is to function as an orifice and adequately deflect air stream 51 in the direction of oil spray 50. In a nozzle wherein the velocity of the aspirated air is not great, it is advantageous to minimize the number and size of air passageway slots 44 even to the extent of severely restricting the total volume of air aspirated by the nozzle, since the higher air velocity which results thereby induces a higher degree of air deflection with ensuing improved air-oil mixing.

The highly superior mode of mixing air and oil provided by the nozzle of this invention produces better combustion characteristics than is possible by merely aspirating a greater quantity of air in the absence of the superior mode of mixing. Data presented below show that in a nozzle devoid of the air deflecting means of this invention, a mere increase in the quantity of air aspirated does not necessarily improve combustion performance and, in fact, can hinder combustion performance. In contrast, superior combustion performance occurs as a result of the more thorough admixing with oil of a relatively small volume of aspirated air which is accomplished by employing, in combination, a forward chamber 38 in which the depth and diameter dimensions are conducive to optimum air aspiration for superior mixing of air and oil, together with one or a plurality of air slots 44, each of relatively small cross section to provide a high air velocity therein, and a sharp edge 42 at the discharge terminus of the air slots 44.

Tests were conducted to illustrate the advantage during the combustion of the sharp edge air deflecting means 42. A first combustion test was made employing a nozzle generally similar to the nozzle of FIGURE 1 and 2 and having the specific construction as shown in FIGURE 3A, including a sharp edge 42 disposed at the discharge end of passageway means 44. Passageway means 44 approaches second chamber 38 in both a forwardly and a tangential manner. At the conclusion of the first combustion test, the nozzle of FIGURE 3A was modified for use in a second combustion test by eliminating sharp edge 42 by machining, as shown in FIGURE 3B. Except for this single change, the nozzle of FIGURE 3B is identical to the nozzle of FIGURE 3A and all conditions, including oil pressure, were otherwise held uniform in each test. The results of these tests are shown in the curves of FIGURE 4.

The curves of FIGURE 4 show the results of the combustion tests employing the nozzle of FIGURE 3A and the nozzle of FIGURE 3B in the form of a graph of smoke spot number versus percent carbon dioxide in a sample of flue gas produced during combustion with each nozzle in accordance with the method described in ASTM Standards on Petroleum Products, 1960, page 1041. For purposes of analyzing the test results, it is noted that best combustion results are indicated by the combination of a high carbon dioxide content, indicating a high degree of combustion, and a low smoke content. While the percent of carbon dioxide can be increased by reduction of air input, this will have the adverse effect of increasing smoke content. On the other hand, smoke content can be decreased by merely admitting a large excess of air but this will have the adverse effect of greatly diminishing the relative content of carbon dioxide. Optimum results are achieved with the combination of relatively high carbon dioxide content and relatively low smoke content.

Referring to FIGURE 4, at the steep slope of the curves, it is seen that at any particular percentage of carbon dioxide in the flue gas the lowest smoke content

is achieved with the nozzle of FIGURE 3A having sharp edge air deflecting means 42. Therefore, the removal of sharp edge air deflecting means 42, as shown in the nozzle of FIGURE 3B, resulted in increased smoke content at any particular percentage of carbon dioxide or, conversely, a lower percentage of carbon dioxide at any particular smoke level.

Another series of tests was conducted to demonstrate the ability of the sharp edge air flow deflector of the invention to induce superior combustion characteristics as compared to the combustion characteristics achieved by similar nozzles which are devoid of the air flow deflector, even nozzles which actually aspirate a greater quantity of air at a given fuel flow rate. The nozzles utilized in these tests are shown in FIGURES 5A and 5B. FIGURE 5A shows a nozzle having a sharp edge 42 and having a forward chamber 38 whose depth, designated as L, is 0.030 inch and whose diameter, designated as D, is 0.089 inch. These dimensions show that the diameter of forward chamber 38 is greater than its length. The reason the diameter of forward chamber 38 is greater than its length is that if L were as great as D the conical oil spray would impinge upon the walls of forward chamber 38, as is clear from observation of FIGURE 5A. Air slots 44 approach a second chamber 38 in a substantially forwardly and tangential direction. As shown in FIGURE 5A, the surface of discharge orifice 36 is curved and tapers outwardly in the direction of forward chamber 38 and is in direct communication with forward chamber 38 for discharging a distinctly conical spray from swirl chamber 30 through forward chamber 38 without interference, obstruction, or contact with any part of said nozzle. The oil spray issuing from orifice 36 of oil swirl chamber 30 had a 70 degree included angle and was found to exert a suction upon tangential air passageways 44 equivalent to 0.6 inch of water. As shown in Table 1, the flue gas from the nozzle of FIGURE 5A contained 12.7 percent carbon dioxide at a smoke spot number of 1.

FIGURE 5B shows another nozzle used in the same series of tests. The nozzle of FIGURE 5B is similar to the nozzle of FIGURE 5A except that the passageways 44 are each devoid of sharp edge 42 and except that its forward chamber 38 has certain L and D dimensions which are slightly different than those of the nozzle of FIGURE 5A. The oil pressure and included angle of the oil spray in the tests with the nozzle of FIGURE 5A were the same as in the tests with the nozzle of FIGURE 5B. The nozzle of FIGURE 5B was utilized in two tests in which the D dimension was 0.089 inch and 0.101 inch respectively. The results of these tests are shown in Table 1.

Table 1

Nozzle	Suction Exerted Upon the Air Passageways, Inches of Water	Percent of Carbon Dioxide in Flue Gas at a Smoke Spot Number of 1
Figure 5A.....	0.6	12.7
Figure 5B (D=0.089 inch).....	3.0	11.6
Figure 5B (D=0.101 inch).....	0.3	12.2

It is seen from Table 1 that the aspirational suction exerted at air slots 44 of the nozzle tested of FIGURE 5B varied considerably with dimension changes in the second chamber. It also seems from Table 1 that, in the tests made, an increase in air aspiration did not produce a corresponding improvement in combustion performance. In fact, the nozzle of FIGURE 5B which exerted an aspirational effect of only 0.3 inch of water was superior, in terms of combustion performance, to the other nozzle of FIGURE 5B which exerted ten times its aspirational effect upon atmospheric air. Table 1 also shows that better combustion performance was achieved with the nozzle of FIGURE 5A, equipped with sharp

edge 42 at the air passageways, than was achieved with either of the nozzles of FIGURE 5B, even though one of the nozzles of FIGURE 5B exerted a much greater aspirational suction upon atmospheric air. Table 1 shows that sharp edge 42 exerts an influence upon combustion performance independent of the amount of air aspirated.

Combustion tests were made to determine the effect of air deflector 42 when air was pumped through air slots 44 under a small pressure, such as 1 or 2 pounds per square inch gauge. These tests showed combustion results are also improved by the provision of sharp edge air deflector 42 when air is pumped under pressure through air slots 44.

FIGURES 6 and 7 illustrate a modified nozzle 70 of this invention. FIGURE 6 shows an inner member 72, an intermediate member 74, and an outer member 76. Outer member 76 comprises the body of the nozzle. Inner member 72 and intermediate member 74 have facing conical surfaces in engagement while intermediate member 74 and outer member 76 have flat facing surfaces in engagement. The various facing surfaces are urged into fluid tight engagement with each other by means of plug 78 which is in threaded engagement with nozzle body 76. Oil enters zone 82 through oil passages 80 in plug 78 whence it travels through slots 84 which enter swirl chamber 86 in a forwardly and tangential direction with respect to the conical wall surface thereof. A diverging, conical, swirling spray 88 of atomized oil droplets leaves axial swirl chamber discharge orifice 90.

Oil spray 88 clears wall 92 defining the forward nozzle chamber by an amount adapted to aspirate atmospheric air through a plurality of atmospheric air openings 94 which have access to a continuous air zone 96. Each air opening 94 is in general register with an arc-like groove 98 cut in intermediate member 74. As shown in FIGURE 7, each groove 98 extends to the forward nozzle chamber in a generally forward and nontangential direction. Although each groove 98 could also extend to the second chamber in a generally forward and tangential direction with respect to forward chamber wall 92, a forward but nontangential direction is preferred. The front of nozzle body 76 is directed inwardly to form a continuous circular ledge 100 having a sharp right angle edge 102 at its interior face which partially obstructs the portion of each groove 98 remote from orifice 90 in the region of the juncture of each groove 98 with the forward nozzle chamber. Sharp edge 102 causes aspirated air to be deflected, as indicated at 104, so that each air stream is urged laterally against oil spray 88. The air flow deflection caused by sharp edge 102 causes the air streams to encompass oil spray 88 so that the swirling spray of oil droplets can accept the concurrently flowing air and become homogeneously admixed therewith without disruption of the oil spray.

FIGURE 8 shows a cross-sectional view of nozzle 110. In nozzle 110, a hollow, swirling, diverging oil spray 112 issuing from first orifice 114 narrowly clears the downstream end of second chamber 116 and thereby aspirates atmospheric air inwardly through a plurality of radial passageways 118. Air passageways 118 lead into a continuous annulus 120 which completely surrounds conical member 122. Air drawn inwardly through passageways 118 flows into annulus 120, and thence flows past sharp right angle edge 124 which causes it to be deflected toward the oil spray 112, as is shown in FIGURE 8. FIGURE 8 shows that the outer conical surface of member 122 is continuous with and tapers rearwardly and outwardly substantially conically from the curved and tapered surface of discharge orifice 114 toward the rearward end of annulus 120 with the forwardmost projection of the outer conical surface of member 122 being substantially at the curved and tapered surface of the discharge orifice so that an aspirated air stream drawn inwardly through passageways 118 and annulus 120 can approach discharge orifice 114 from the rear along the outer conical surface

of member 122 and can closely encompass oil spray 112 directly upon discharge of said oil spray from discharge orifice 114.

It is noted in regard to nozzle 110 of FIGURE 8 that oil discharge orifice 114 is disposed rearwardly with respect to the rearward end of second chamber 116. This structure provides an important functional advantage because the portion of oil spray 112 closest to orifice 114 comprises a substantially continuous swirling film of oil. However, this film tends to quickly disintegrate, resulting in atomization into a great plurality of very small oil droplets. By virtue of the fact that oil discharge orifice 114 is disposed to the rear of sharp edged corner 124, oil spray 112 has a chance to become atomized before reaching the vicinity of sharp edge 124 and therefore before reaching the zone wherein it becomes admixed with the air stream deflected toward it by sharp edged corner 124. Since the oil is accorded an opportunity to become atomized before the aspirated air is deflected toward it, a high degree of admixture of air and oil is achieved. On the other hand, if oil discharge orifice 114 were disposed on the same plane with or forwardly with respect to air deflecting edge 124, the air passing edge 124 would be deflected into an incompletely atomized film of oil and therefore could not admix as intimately and thoroughly with the oil spray, in which case the effectiveness of sharp edge 124 would be sharply diminished. In an actual test a marked improvement in combustion performance was achieved by disposing oil discharge orifice 114 about .015 inch to the rear of the plane of sharp edge 124, as compared to the observed combustion performance when the oil discharge orifice was disposed on the same plane as the sharp edge.

It is important that air passageways 118 enter continuous annulus 120 at a position therein which is decidedly to the rear of the plane on which sharp edged corner 124 lies. Air passageways 118 should preferably enter annulus 120 at a position as close as possible to the rear of annulus 120 and should have a relatively small width so that air only enters annulus 120 near the rearward end of said annulus. This permits the aspirated air to travel in a forwardly direction past sharp edge 124 permitting sharp edged corner 124 to function as a sharp edged orifice plate. The forward or axial component of movement of air past sharp edge 124 permits sharp edge 124 to function as an orifice plate, deflecting the air stream and forming the vena contracta 126. On the other hand, if air passageway 118 were disposed on about the same plane as sharp edge 124, the aspirated air would approach sharp edge 124 from a direction which is substantially completely lateral with little or no forward or axial component of movement, thereby preventing formation of a vena contracta.

An advantageous feature of nozzle 110 is that air passageways 118 approach annulus 120 in a radial rather than a tangential direction. A tangential approach would impart swirling to the aspirated air and the centrifugal force of a swirling air stream passing through second chamber 116 would tend to fling the air away from the oil spray, thereby counteracting the effect of sharp edge 124 which is to deflect the aspirated air toward the oil spray.

Another advantageous structural feature of nozzle 110 is that the individual air passageways 118 each lead into a common annulus 120, which annulus 120 is bounded by sharp edged corner 124. In this manner a circumferentially uninterrupted stream of air is deflected toward and encompasses the oil spray providing a uniform admixture of air and oil, thereby insuring a uniform flame. In contrast, if continuous annulus 120 were absent and each air passageway 118 individually approached sharp edged corner 124, a plurality of streams of air would be deflected toward the oil spray rather than a circumferentially continuous blanket of air. A plurality of individual jets of air would produce alternate air-rich and air-

lean streaks in the oil spray and consequently could produce a non-uniform flame. Continuous annulus 120 is advantageously utilized in a nozzle in which the velocity of aspirated air through even an enlarged annulus is sufficiently high that sharp edge 124 can induce a vena contracta, while a plurality of individual air passages, as is shown in FIGURES 1 and 6, is required to produce individual high velocity air jets where the velocity of the total stream of aspirated air flowing in an enlarged annulus would not be sufficiently high for a sharp edge to induce a pronounced vena contracta.

The structure shown in nozzle 130 of FIGURE 9 and nozzle 160 of FIGURE 10 each produces superior results during combustion as compared to nozzle 110 of FIGURE 8. Nozzle 130 and nozzle 160 each possesses two opposing sharp edges facing each other across an air passageway, as contrasted to the single sharp edge in nozzle 110 of FIGURE 8. The double sharp edges are disposed near the juncture of a continuous air annulus and the forward chamber. The functional advantage of the two facing sharp edges in nozzle 130 and nozzle 160 is that a double surfaced air stream vena contracta is defined at a position downstream from the sharp edges themselves substantially at or in very close proximity to the surface of the oil spray. Since the highest velocity in the air stream is at the vena contracta, the facing sharp edge structure projects the zone of highest air velocity downstream from itself to the region of the surface of the swirling oil spray, thereby inducing an unusually high degree of admixing of air and oil.

In nozzle 130 of FIGURE 9, curved and outwardly tapered surface 132 defining the oil discharge orifice extends to a contiguous flat surface 134 which extends laterally from the discharge orifice and lies on a plane normal to the axis of the oil discharge orifice. The outer periphery of flat surface 134 defines a continuous circular sharp edge 136 facing annulus 138 in the region thereof near forward chamber 140. Flat surface 134 and the oil discharge orifice are disposed rearwardly with respect to the rearward end of forward chamber 140.

Oil spray 142 aspirates atmospheric air into the nozzle through a plurality of radial slots 144 and continuous annulus 138. Continuous circular sharp edge 146 which is opposite from the oil discharge orifice defines the juncture between annulus 138 and forward chamber 140. The diameter of forward chamber 140 is substantially greater than the length thereof. Continuous, circular sharp edges 136 and 146 face each other across the region of annulus 138 near forward chamber 140 and lie on a plane which is at an acute angle of about 45 degrees with respect to the axis of oil spray 142. Sharp edges 136 and 146 deflect the flow of aspirated air stream 148 to induce a circular vena contracta 150 at which the velocity of air stream 148 is a maximum. Vena contracta 150 is formed downstream from the sharp edges themselves and substantially at or in very close proximity to the surface of oil spray 142. In this manner, the air stream is directed toward the surface of the oil spray in a direction substantially normal to said surface and is at its maximum velocity substantially simultaneously with its impingement upon the outer periphery of the oil spray whereby a high degree of intermixture between the air stream and the oil spray is accomplished. Although a continuous annular aperture is defined between sharp edges 136 and 146 in the most preferred embodiment of nozzle 130, the continuous aperture could be replaced by a plurality of smaller apertures each provided with separate facing sharp edge surfaces. If a plurality of smaller apertures are utilized, the separate facing sharp edges in each aperture could be joined to form a continuous sharp edged orifice plate or replaced by a circular sharp edged orifice plate.

Nozzle 160 of FIGURE 10 shows another embodiment of a double sharp edge structure for inducing a

vena contracta in an air stream substantially simultaneously with impingement of the air stream upon an oil spray. Referring to FIGURE 10, the curved and outwardly tapered surface 162 defining the oil discharge orifice extends to flat surface 164 which lies on a plane normal to the axis of the oil discharge orifice. At the outer periphery of flat surface 164 a right angle sharp edge 166 is defined. Sharp edge 166 extends as a complete circle and defines one extremity of continuous annulus 168. Another extremity of annulus 168 is defined by axially inturned lip 170 at the forward end 172 of the nozzle body which possesses a right angle sharp edge 174 facing continuous annulus 168. Sharp edges 166 and 174 lie on a plane which is parallel to the longitudinal axis of nozzle 160 and recessed laterally from forward chamber 180.

Oil spray 176 aspirates atmospheric air through a plurality of radial slots 178 and annulus 168. The air enters forward chamber 180 by traversing the aperture between facing sharp edges 166 and 174. A double surfaced annular vena contracta 182 is induced downstream from the sharp edges 166 and 174 substantially at or in close proximity to the periphery of oil spray 176. Since the downstream distance from sharp edges 166 and 174 at which vena contracta 182 is formed is proportional to the size of the aperture between the sharp edges, the maximum permissible thickness 171 of lip 170 is limited by the size of said aperture. By making the thickness 171 of lip 170 less than the size of said aperture, and preferably less than half the size of said aperture, the vena contracta will form downstream from lip 170 and close to oil spray 176. Sharp edges 166 and 174 direct the air stream into the oil spray along a path close to flat surface 164 and in a direction which is substantially normal to the axis of the oil spray. Since lip 170 is relatively thin, the locale of vena contracta 182 is significantly downstream from lip 170 and in close proximity to the oil spray so that the air stream impinges upon the oil spray while it is substantially at its maximum velocity, whereby intimate admixture occurs between the air stream and the oil spray.

Nozzles 190 of FIGURE 11 utilizes means other than sharp edges for impinging an aspirated air stream upon an oil spray while the air stream is flowing substantially at its maximum velocity. In nozzle 190, the surfaces of intermediate member 192 and outer member 194 are contoured to define a continuous circular venturi tube 196 whose axis is normal to the axis of oil discharge orifice 198. Less advantageously, the axis of venturi tube 196 can be inclined with respect to the axis of discharge orifice 198 so that the venturi tube is directed toward the nozzle axis and forward chamber 202 in a forwardly as well as a lateral direction, rather than in a purely lateral or radial direction as shown. Venturi tube 196 has an annular throat 200 directly at the terminal passageway opening of venturi tube 196 in the direction of the nozzle axis and forward chamber 202. Although venturi tube 196 is preferably a continuous annulus extending around a 360 degree arc, it can be divided into a plurality of individual, relatively elongated venturi tubes each having its throat coinciding with the terminal opening of the venturi in the direction of forward chamber 202. Although each individual venturi can approach the forward chamber in a tangential direction, it is preferred that the approach to the forward chamber be purely radial, or forwardly and radial, rather than tangential.

Oil spray 204 aspirates a stream of atmospheric air through radial slots 206, venturi tube 196 and venturi throat 200. The aspirated air is at its highest velocity at venturi throat 200 and, since venturi throat 200 is in the region of the venturi tube which is closest to the forward chamber, the air stream enters the forward chamber while flowing at its maximum velocity. The air approaches oil spray 204 in a direction which is sub-

stantially normal to the axis of the oil spray and this coupled with the fact that it approaches the oil spray while flowing at substantially its highest velocity results in a high degree of intermixture between the aspirated air stream and the oil spray.

Comparative tests were conducted using a standard commercial air blower oil burner apparatus to compare the combustion performance of nozzles as shown in FIGURES 9 and 10 with the combustion performance of a nozzle as shown in FIGURE 8. The nozzle as shown in FIGURE 8 which was tested was rated at 1.0 gallon per hour of oil and an included oil spray angle of 60 degrees, and had dimensions adapted for substantially optimum combustion performance at this rating. The nozzle as shown in FIGURE 9 and the nozzle as shown in FIGURE 10 were each also rated at 1.0 gallon per hour of oil and an included oil spray angle of 60 degrees. Tests performed under the nozzle ratings showed that under substantially identical test conditions, except for the particular nozzle utilized, at identical smoke spot numbers of 1.0 the nozzle as shown in FIGURE 8 produced a flue gas having a carbon dioxide content of 13.1 percent; the nozzle as shown in FIGURE 9 produced a flue gas having a carbon dioxide content of 13.6 percent; and the nozzle as shown in FIGURE 10 produced a flue gas having a carbon dioxide content of 13.5 percent. Therefore, under the substantially identical conditions of the tests, the nozzles of FIGURES 9 and 10 produced improved combustion results as compared to the nozzle of FIGURE 8.

Tests were also conducted using a standard commercial air blower oil burner apparatus to compare the combustion performance of a nozzle as shown in FIGURE 11 with the combustion performance of a nozzle as shown in FIGURE 8. The nozzle of FIGURE 8 which was tested was rated at 1.10 gallons per hour of oil and an included oil spray angle of 60 degrees, and had dimensions adapted for substantially optimum combustion performance at this rating. The nozzle as shown in FIGURE 11 was also rated at 1.10 gallons per hour of oil and an included oil spray angle of 60 degrees. Tests performed under the nozzle ratings showed that under substantially identical test conditions, except for the particular nozzle utilized, at identical smoke spot numbers of 1.0 the nozzle as shown in FIGURE 8 produced a flue gas having a carbon dioxide content of 12.8 percent while the nozzle as shown in FIGURE 11 produced a flue gas having a carbon dioxide content of 13.2 percent. Therefore, under the substantially identical conditions of the tests, the nozzle of FIGURE 11 produced improved combustion results as compared to the nozzle of FIGURE 8.

Various changes and modifications can be made without departing from the spirit of this invention and the scope thereof as defined in the following claims.

We claim:

1. A burner nozzle comprising axial swirl chamber means, second chamber means of substantially cylindrical configuration disposed forwardly with respect to said swirl chamber means, said swirl chamber means having at its forward end axial discharge orifice means with the surface of said discharge orifice means being curved and tapered outwardly in the direction of said second chamber means and being in unobstructed communication with said second chamber means for discharging a swirling distinctly conical oil spray from said swirl chamber means through said second chamber means without interference or obstruction and without substantial contact with said nozzle so that said conical oil spray aspirates a stream of air through said second chamber means from the rearward end to the forward end thereof, air passageway means open at one end to the exterior of said nozzle and open at the other end in the direction of said second chamber means for channeling air into said second chamber means, substantially flat surface means contiguous with said curved and tapered surface of said discharge orifice means lying on a plane substantially normal to the longi-

tudinal axis of said nozzle extending laterally outwardly from said discharge orifice means and terminating with first flow deflecting means having first relatively sharp edge means facing said air passageway means in the region thereof near said second chamber means for inducing a vena contracta in said aspirated air stream downstream from said first sharp edge means and in the region of said oil spray, and second flow deflecting means having second relatively sharp edge means which is exposed to said air passageway means in the region thereof near said second chamber means and opposite from said discharge orifice means for inducing a vena contracta in said aspirated air stream downstream from said second sharp edge means and in the region of said oil spray, said cylindrical second chamber means having a diameter which is substantially greater than the length thereof and which is sufficiently large for the conical spray from the swirl chamber means to pass through without substantial contact with the walls of said second chamber means and for each air stream vena contracta to develop around said conical spray.

2. The nozzle of claim 1 wherein said first flow deflecting means and said second flow deflecting means face each other on a plane which makes an acute angle with respect to the axis of said nozzle.

3. The nozzle of claim 1 wherein said first flow deflecting means and said second flow deflecting means face each other on a plane which makes about a 45 degree angle with respect to the axis of said nozzle.

4. The nozzle of claim 1 wherein said first flow deflecting means and said second flow deflecting means lie on a plane which is parallel to the axis of the nozzle and which is recessed laterally from said second chamber means by a distance which is less than the distance between said first and second sharp edge means.

5. The nozzle of claim 1 wherein said flow deflecting means are relatively sharp edged right angles.

6. The nozzle of claim 1 wherein said air passageway means extends to said second chamber means in a substantially forwardly direction.

7. The nozzle of claim 1 wherein said air passageway means is a continuous annulus.

8. The nozzle of claim 1 wherein said swirl chamber discharge orifice means is disposed rearwardly with respect to the rearward end of said second chamber means.

9. The nozzle of claim 1 wherein said swirl chamber discharge orifice means is disposed rearwardly with respect to the rearward end of said second chamber means and said air passageway means is a continuous annulus.

10. The nozzle of claim 1 wherein said air passageway means comprises a plurality of air passageways.

11. A burner nozzle comprising inner, intermediate, and outer members, axial swirl chamber means defined by said inner and intermediate members, air passageway means defined by said intermediate and outer members, said air passageway means extending to the exterior of said nozzle, axial swirl chamber discharge orifice means defined at the forward end of said intermediate member, the forward end of said outer member defining axial forward chamber means of substantially cylindrical configuration, said axial swirl chamber discharge orifice means disposed in the region of the rear of said forward chamber means, the surfacing defining said discharge orifice means being curved and tapered outwardly in the direction of said forward chamber means and being in unobstructed communication with said forward chamber means for discharging a swirling distinctly conical oil spray from said swirl chamber means through said forward chamber means without interference or obstruction and without substantial contact with said nozzle so that said conical oil spray aspirates a stream of air through said air passageway means and said forward chamber

means, substantially flat surface means on said intermediate member which is contiguous with said curved and tapered surface of said discharge orifice means, said flat surface means lying on a plane substantially normal to the longitudinal axis of said nozzle extending laterally outwardly from said discharge orifice means and terminating with first flow deflecting means having first relatively sharp edge means facing said air passageway means in the region thereof near said forward chamber means for inducing a vena contracta in said aspirated air stream downstream from said first sharp edge means and in the region of said oil spray, said forward end of said outer member defining second relatively sharp edge flow deflecting means opposite from said discharge orifice means and facing said air passageway means in the region thereof near said forward chamber means for inducing a vena contracta in said aspirated air stream downstream from said second sharp edge means and in the region of said oil spray, said cylindrical forward chamber means having a diameter which is substantially greater than the length thereof and which is sufficiently large for both the conical spray from the swirl chamber means to pass through without substantial contact with the walls of said forward chamber means and for each air stream vena contracta to develop around said conical spray.

12. The nozzle of claim 11 wherein said first flow deflecting means and said second flow deflecting means face each other on a plane which makes an acute angle with respect to the axis of said nozzle.

13. The nozzle of claim 11 wherein said first flow deflecting means and said second flow deflecting means face each other on a plane which makes about a 45 degree angle with respect to the axis of said nozzle.

14. The nozzle of claim 11 wherein said first flow deflecting means and said second flow deflecting means are one a plane which is parallel to the axis of the nozzle.

15. The nozzle of claim 11 wherein said forward end of said outer member includes an axially inturned lip which defines said forward chamber means, the terminus of said lip having relatively sharp edge means recessed from said forward chamber means and facing said air passageway means to constitute said second flow deflecting means, the thickness of said lip being less than the distance between said sharp edges so that vena contracta formation is downstream from said lip in the region of said oil spray.

16. The nozzle of claim 11 wherein said flow deflecting means are relatively sharp edged right angles.

17. The nozzle of claim 11 wherein said air passageway means extends to said forward chamber means in a substantially forwardly direction.

18. The nozzle of claim 11 wherein said swirl chamber discharge orifice means is disposed rearwardly with respect to the rearward end of said forward chamber means.

19. The nozzle of claim 11 wherein said swirl chamber discharge orifice means is disposed rearwardly with respect to the rearward end of said forward chamber means and said air passageway means is a continuous annulus.

20. The nozzle of claim 11 wherein said air passageway means comprises a plurality of air passageways.

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