

May 6, 1952

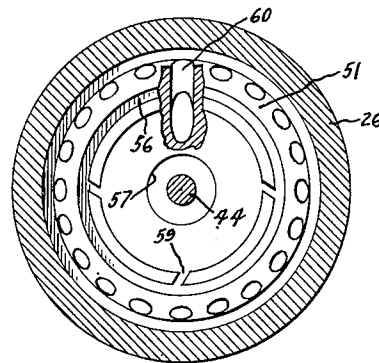
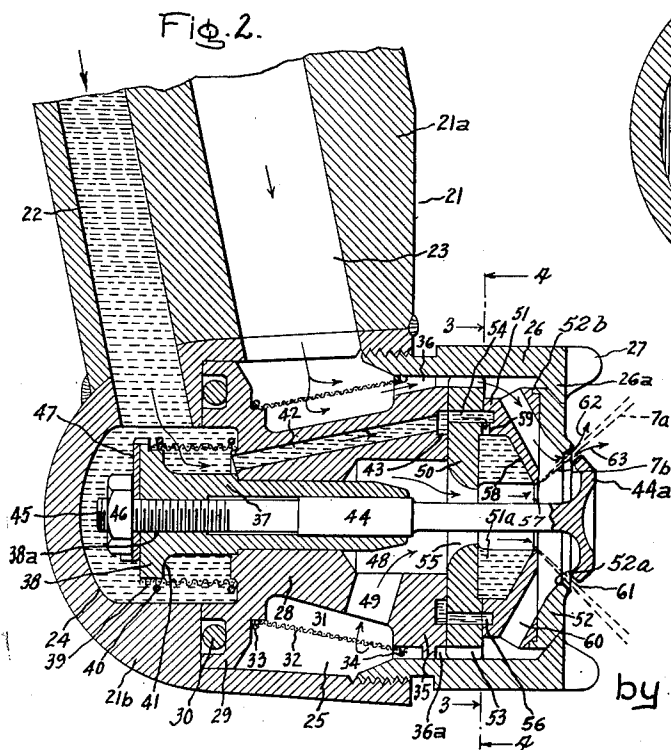
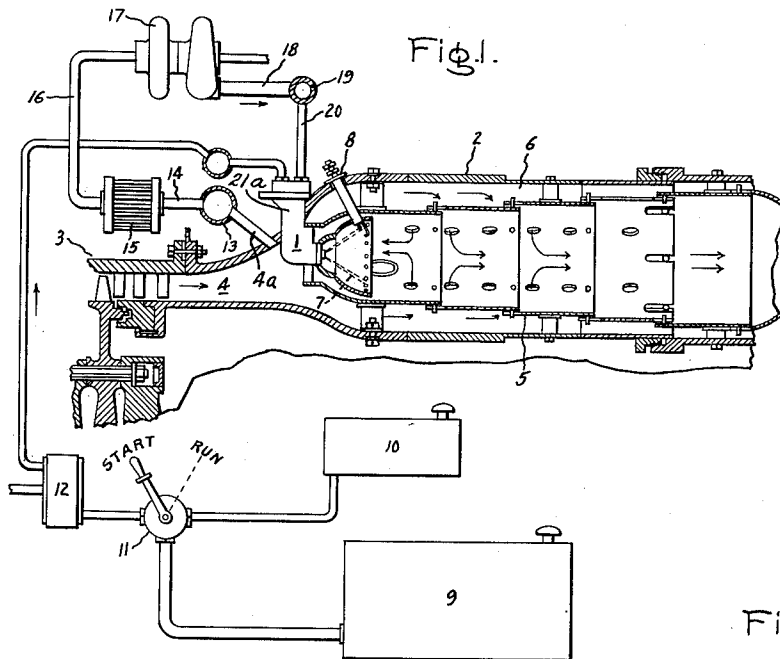
B. O. BUCKLAND ET AL

2,595,759

ATOMIZING NOZZLE FOR SPRAYING VISCOUS LIQUIDS

Filed Nov. 30, 1948

2 SHEETS--SHEET 1



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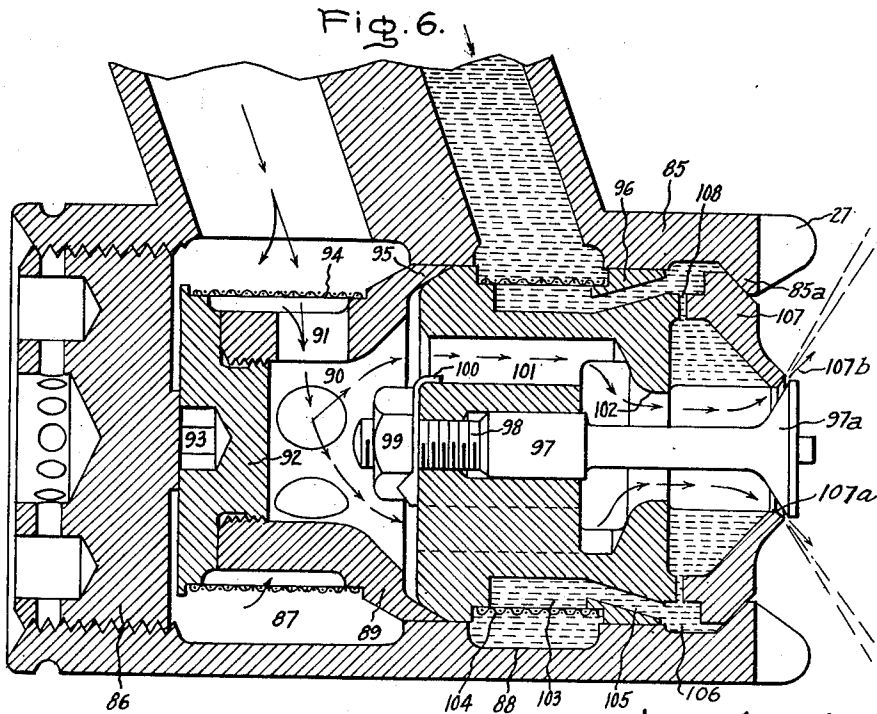
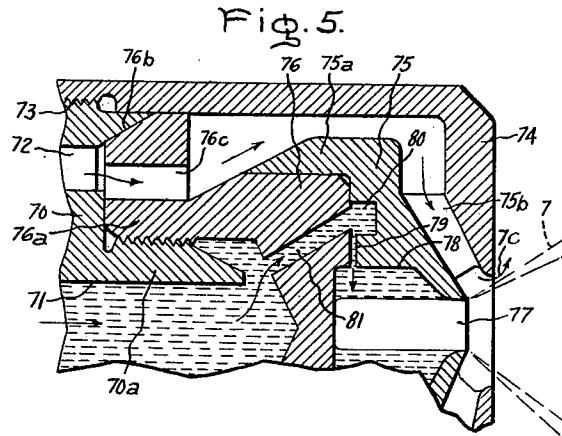
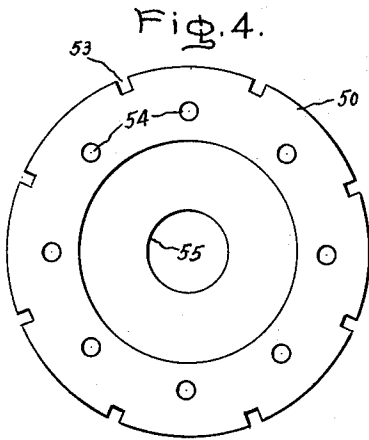
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2 SHEETS—SHEET 2



UNITED STATES PATENT OFFICE

2,595,759

ATOMIZING NOZZLE FOR SPRAYING
VISCIOUS LIQUIDS

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Application November 30, 1948, Serial No. 62,634

4 Claims. (Cl. 299—114)

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This invention relates to liquid spraying nozzles of the type in which an auxiliary fluid such as air or steam is used to facilitate the atomization process, particularly to such a nozzle as used to spray fuel in the combustor of a gas turbine power plant.

In power plants of the type described, it is, of course, desirable to use the least-expensive fuel oil possible, which is ordinarily that known commercially as "bunker C" oil, comprising the comparatively heavy residual fractions left from the refining processes which produce gasolines, diesel fuels, etc. These heavier oils are so viscous as to be difficult of atomization by pressure alone, as is readily accomplished in the case of kerosene and gasoline and similar light oils by means of the so-called pressure atomizing or "vortex-type" nozzles. The pressure atomizing nozzles are customarily used in fuel injection systems for diesel engines, while the vortex nozzle is most commonly used in gas turbine combustors burning kerosene or gasoline. While the use of comparatively expensive fuels, such as kerosene, is acceptable in the case of high performance gas turbine power plants such as jet engines for aircraft, in land-based power plants where fuel cost is important it is necessary to find an effective way of atomizing the heavy bunker C type fuel oil. The problem is complicated by the fact that the term "bunker C" covers a multitude of substantially different commercial oils resulting from various refining processes, this term being a generic one applicable to the heavy residual oils commercially obtainable for burning in steam generating plants, locomotives, ships, etc. In a gas turbine power plant for locomotive service, it is, of course, desirable that any of these readily available commercial oils may be used with good efficiency.

The nozzle known popularly as an "air atomizing nozzle," in which an auxiliary fluid under pressure (such as air, steam, or other suitable gas) is used to facilitate breaking up the liquid into discrete particles, seems to offer the best solution to the problem of providing an adequate fuel spray nozzle for use in gas turbine power plants burning heavy fuel oils. With conventional nozzles of this type known to the prior art, two principal difficulties arise: (1) it is almost impossible to obtain spray patterns sufficiently symmetrical about the axis of the nozzle; and (2) the spray from the known nozzles contains excessively large droplets. These difficulties with the prior art nozzles appear to arise from the practice of introducing the oil spray from a plurality of discrete orifices, and the fact that with many of the prior art nozzles the oil tends to flow along a surface of the nozzle until it is blown off by the blast of air in comparatively large particles.

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Having found the nozzles known to the prior art unsatisfactory for high performance service in a gas turbine locomotive power plant, the present invention has for its purpose the provision of an improved air atomizing type nozzle which will, over a wide range of flow rates, deliver the spray in finely divided form, the spray pattern being a conical sheet with an apex angle or "cone angle" which shows substantially no variation over an extremely wide range of operation. To produce the maximum atomizing effect, as required for spraying viscous liquids, the air and oil are brought into close contact when the air is at the maximum possible velocity. A still further object is to combine the features of the vortex and air atomizing nozzle to produce a nozzle giving a conical spray with good atomization and having completely uniform distribution of the fuel around the axis of the spray. Another object is to provide a nozzle of the type described giving good atomization and the desired spray angle at very low flow rates.

Other objects and advantages will be apparent from the following description taken in connection with the accompanying drawings, in which Fig. 1 shows schematically a fuel nozzle in accordance with the invention as applied to the combustor of a gas turbine power plant, the power plant being more specifically described in the co-pending application of Alan Howard, Chester S. Rice and Bruce O. Buckland, Serial No. 754,002, filed June 11, 1947, and assigned to the same assignee as the present application; Fig. 2 is a detail view in section of the fuel nozzle itself; Fig. 3 is a plan view partly in section of one of the elements of the nozzle taken at the plane 3—3 in Fig. 2; Fig. 4 is a plan view of another element of the nozzle taken at the plane 4—4 in Fig. 2; Fig. 5 is a sectional view of a modified nozzle incorporating the invention; and Fig. 6 is a sectional view of a still further modification.

In carrying the invention into practice, a vortex type liquid spray nozzle is provided with a central "pintle" cooperating with the conical sheet of liquid produced by the liquid spray orifice to define an annular atomizing gas orifice so that a sheath of high velocity gas is brought into intimate contact with the conical sheet of liquid, the rapid acceleration of the gas at this point serving to vigorously disrupt the sheet of liquid and start the atomization process. In one form of the invention, the gas sheath is provided at only one side of the liquid sheet, while in another form an atomizing gas sheath is brought into contact with both sides of the liquid cone.

Referring now more particularly to Fig. 1, the fuel nozzle indicated generally at 1 is shown supported on a suitable mounting pad in the outer wall 2 of a gas turbine combustor having a suitable compressor, for instance, a multi-stage axial

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flow compressor, a part of which is shown at 3, arranged to supply air to the combustor through a transition passage 4. The combustion space is defined by an inner liner 5 consisting of a plurality of telescoping sections having suitable air inlet openings for the admission of combustion air to the reaction space within liner 5 from the air supply space or plenum chamber 6 defined between the outer housing 2 and liner 5. The mechanical details of the combustor are more particularly described in the above-mentioned application of Howard-Rice-Buckland, and the theory of operation and arrangement of the air inlet holes of the combustor are disclosed in the copending application of Anthony J. Nerad, Serial No. 750,015, filed May 23, 1947, and assigned to the same assignee as the present application. It will be seen that the nozzle 1 is arranged to produce a spray pattern in the form of a hollow cone 7 coaxial with the liner 5. It will also be observed that the igniting device, which may be in the form of a spark plug 8, is so mounted that the spark gap defined by the electrodes lies substantially in the spray cone 7 so that a suitable fuel air mixture will be delivered to the spark gap during the starting cycle.

Fuel is supplied to the nozzle 1, there being, of course, one nozzle for each of the multiple combustors in a gas turbine power plant, from either a main oil tank 9 or a starting oil tank 10 by means of a manually controlled selector valve 11. This arrangement is advantageous because of the difficulty of heating heavy fuel oils, such as bunker C, to make them fluid enough to be atomized properly during the starting process. In view of this difficulty, the power plant is started on diesel oil with the valve 11 in the starting position indicated in the drawing. After combustion is initiated, the valve can be thrown to the running position in which heavy fuel oil is supplied from the main tank 9. The supply of the fuels to the nozzle is effected by means of a suitable pump 12 which may be driven by a suitable power take-off (not shown) from the main turbine shaft which drives the compressor 3.

The atomizing air for the nozzle is supplied in the following manner. In the outer wall of the transition passage 4 are a plurality of circumferentially spaced outlets 4a communicating with an annular manifold 13 to which comparatively hot air compressed by the compressor 3 is bled. Air from manifold 13 is led by a conduit 14 to a suitable cooler 15, through which may be circulated cooling air, cooling water, or even the fuel on its way to the nozzle, in which case the heat of compression extracted in the cooler 15 is utilized to render the heavy fuel oil fluid enough to be properly sprayed by the nozzle. From cooler 15 the atomizing air goes by way of conduit 16 to an auxiliary atomizing air compressor, shown in the drawing as being a two-stage centrifugal compressor which may also be driven from the main turbine rotor. The compressor delivers the air at a pressure suitable for atomizing use in the nozzle 1. As will also be seen in Fig. 1, conduit 18 delivers air from compressor 17 to an annular manifold 19 connected by suitable branch conduits 20 to the respective fuel nozzles. Since the atomizing air delivered to the nozzle is at a pressure in the neighborhood of 135 pounds per square inch absolute, the cooler 15 is required in order to limit the air temperature to a value which can be conveniently handled by the compressor and which will not be so high as to result in dissociation or "cracking" of the fuel oil in the nozzle.

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Referring now to the mechanical details of the nozzle proper, it will be seen in Fig. 2 that the nozzle comprises an outer housing or casing 21, which may consist of a supporting post 21a, to which is welded a cylindrical nozzle casing 21b having its axis coaxial with the axis of the combustor. The supporting post 21a is provided with an axial drilled hole 22 for the oil supply and a larger parallel passage 23 for the air supply.

The nozzle casing 21b is provided with a central recess comprising an end bore 24 and a main cylindrical recess 25, the latter being threaded at its forward open end to receive the end cap 26. Cap 26 has at its forward end a radially inwardly extending flange 26a and a plurality of circumferentially spaced axially projecting "ears" 27 for protecting the pintle (described hereinafter) from mechanical damage.

Within the nozzle casing 21b is an inner nozzle body member 28 located in the recess 25 and having at one end a radially extending flange 29 defining a circumferential groove in which is located a compressible packing ring 30 adapted to prevent leakage of fluid from passage 22 to 23, or vice versa. The mid-portion of inner nozzle body 28 is of roughly conical configuration and defines a circumferential groove 31 enclosed by a fine mesh screen 32 which serves as a strainer for the air entering through passage 23. As will be apparent from Fig. 2, this strainer screen 32 is supported on circumferential shoulders of the inner body 28 and may be secured in place by means of circumferential clamping wires shown at 33, 34 or any other suitable equivalent means. The forward portion of the inner nozzle body 28 forms a circumferential flange 35 having peripheral portions engaging the central bore in the end cap 26. End portion 35 is also provided with a plurality of axially extending grooves 36, the function of which will be seen hereinafter.

The central portion of inner body 28 defines an axial bore in which is received a pintle support sleeve 37 which is pressed, shrunk or otherwise suitably secured in the body 28. The left-hand end of the pintle support sleeve 37 is provided with a radially extending flange 38 adapted to support a cylindrical strainer screen 39, the other end of which is received on a cylindrical shoulder of the inner nozzle body 28. Strainer screen 39 may be retained in place by means of clamping wires 40. It will also be apparent that the strainer screen 39 may be made as an integral cylinder and assembled between the pintle support sleeve 37 and the inner body 28 at the time the two are pressed together. It will now be apparent that oil from the inlet passage 22 flows through the screen 39 into the annular chamber 41 defined within the screen, whence it flows through a plurality of circumferentially spaced drilled holes 42 extending longitudinally through the inner body 28. It will also be seen in Fig. 2 that the forward end of the drilled holes 42 are connected by an annular groove 43 machined in the end face of inner body 28.

The purpose of the sleeve 37 is to adjustably support a central pintle 44 having a portion snugly fitting the bore of support sleeve 37 and an end portion threaded at 45 to receive a lock nut 46 which is in turn held by a suitable lock washer 47. It will also be noted that the end 45 of pintle 44 is threaded received in the end portion 38a of sleeve 37. With this arrangement the pintle 44 may be adjusted axially a limited amount by turning the pintle so that it moves longitudinally in the bore 38a. The nut 46 and

lock washer 47 then serve to hold the pintle in its desired adjusted position. The purpose of this adjustment will be noted hereinafter. As will be seen in Fig. 2, the forward end of the pintle support sleeve 37 projects into a central bore 48 of body 28, which bore forms an air supply chamber connected by a plurality of circumferentially spaced, radially extending passages 49 with the annular chamber 31. The extreme forward end of pintle 44 carries an end disk 44a.

Between the inner body 28 and the end cap flange 26a is a series of three disk members 50, 51, 52, the arrangement and function of which will now be considered. The metering disk 50 is seen in cross section in Fig. 2 and in plan in Fig. 4. At its extreme outer periphery it is provided with a plurality of circumferentially spaced square slots 53 adapted to communicate with the axial grooves 36 by way of the annular groove 36a machined in the outer circumferential portion of inner body end portion 35. It will be apparent from Fig. 2 that the grooves 53 communicate with the annular chamber defined between the end cap 26 and the outer circumference of the disk member 51. It should be particularly noted that the grooves 53 have an aggregate cross section or effective area which presents a substantial restriction to the flow of air there-through. In other words, grooves 53 constitute metering orifices for limiting the rate of flow of air, as pointed out more particularly hereinafter. Spaced inwardly from the grooves 53 is a circumferential row of drilled holes 54 arranged to communicate with the annular groove 43 in the end face of body 28. At the center of disk 50 is a circular orifice 55 having a smoothly rounded entrance and cooperating with the adjacent portion of the pintle 44 to define a restricted annular orifice which likewise meters the flow of air from the chamber 48.

The second disk member 51 is shown in section in Fig. 2 and in plan view in Fig. 3. It comprises an annular rearward portion having an annular groove 56 adapted to communicate with the transverse holes 54 in metering plate 50. The forward portion of plate 51 defines a radially inwardly extending portion forming a liquid spray discharge orifice 57. The rearward annular portion of plate 51 and the inwardly extending forward portion with the conical forward surface 58 cooperate with the adjacent surface of meter plate 50 to form the "vortex whirl chamber" from which the liquid fuel is discharged through orifice 57. The rearward surface of disk member 51 is provided with a plurality of tangentially arranged grooves 59, there being four of these grooves in the present case which communicate between the annular supply groove 56 and the whirl chamber. It will be appreciated by those skilled in the art that these grooves 59 are metering orifices or nozzles for delivering liquid into the whirl chamber at high tangential velocity so as to produce a strong vortex whirl therein.

The forward portion of disk member 51 is provided with radially and axially extending drilled holes 60, one of which is shown in the cutaway sectional portion of Fig. 3. In the present case there are sixteen of these holes equally spaced circumferentially. It should be observed that these holes 60 are not intended to be restricted metering orifices or nozzles, but are merely generously proportioned passages for delivering the air with a minimum pressure drop to the annular chamber defined between the nozzle tip plate 52 and the pintle disk 44a.

As will be readily apparent from Fig. 2, the nozzle tip plate 52 is a simple circular disk defining a central recess 52a and having an outer circumferential portion 52b defining a rabbet fit for locating the tip plate 52 relative to the disk member 51. The outer circumference of tip plate 52 is also provided with a beveled conical surface adapted to be engaged by the flange 26a of the end cap 26.

The disk member 51 and nozzle tip plate 52 are illustrated as being formed separately merely for manufacturing convenience. Those skilled in the art will appreciate that they can be formed integral, or fabricated separately and brazed or welded together to form a "nozzle tip member."

The method of assembly and relation of the parts will now be obvious. The pintle support sleeve 37 is pressed into place in the inner body 28 with the screen 39 in assembled relation after which the disk members 50, 51, 52 may be placed adjacent the inner body 28 and the pintle 44 threaded into the support sleeve 37. The axial adjustment of the pintle 44 in the sleeve 37 provides a ready means for adjusting the effective width of the annular orifice 61 defined between the pintle end disk 44a and the adjacent portion of tip member 52. With the lock nut 46 and lock washer 47 secured so as to hold the pintle in desired axial position, the entire assembly may be positioned in the nozzle housing 21b and the end cap 26 assembled so as to clamp members 52, 51, 50, 28 and sealing ring 30 into tight engagement with one another. The assembly now provides an oil passage from the inlet 22 by way of chamber 24, filter screen 39, annular chamber 41, drilled holes 42, annular groove 43, drilled holes 54, annular groove 56, orifice slots 59, into the whirl chamber 51a.

The vortex whirl created in chamber 51a by the nozzles 59 leaves an annular air passage between the pintle 44 and the whirling body of oil. Atomizing air is supplied to this "air core" in the whirl chamber by way of the metering orifice 55 and the communicating passages 48, 49, chamber 31, filter screen 32 and annular air supply space 25. Atomizing air from space 25 also passes through filter screen 32, chamber 31, the axial grooves 36, annular groove 36a, axial grooves 53 in metering plate 50, thence through the radial air supply holes 60.

In operation the whirling body of oil in the vortex chamber spills continuously in a smooth uniform conical sheet over the edge of the discharge orifice 57. This liquid tends to leave the discharge orifice 57 in the form of a hollow conical sheet having a substantially fixed vertex angle, the value of which depends on the diameter of the orifice, the velocities in the whirl chamber, the viscosity of the liquid, and numerous other factors with which those skilled in the art are thoroughly acquainted. It need only be noted here that, by well-known principles, the sizes of the orifices, nozzles and whirl chamber may be so designed that the spray pattern 7b emerging from orifice 57 will have a known desired vertex angle, known as the "intrinsic angle" of the whirl chamber. In accordance with the invention, the design of the liquid discharging nozzle 57 is so related to the location and size of the annular orifice 61 that the conical liquid sheet 7b will normally be directed substantially at the middle of annular orifice 61. It may be noted that the "cone angle" of the atomized spray 7a emerging from orifice 61 need not be the same as the "intrinsic angle" of the

vortex whirl chamber 51a. By properly proportioning the annular orifice 61 so that it is longer (in the direction of flow) than it is wide, the angle of spray cone 7a emerging from orifice 61 may be made to conform to the direction of the orifice 61. Thus, a single set of nozzle parts forming the vortex whirl chamber can be utilized to provide a range of various ultimate discharge angles, simply by substituting a tip plate 52 and pintle 44a forming an orifice 61 of the proper shape and direction. In other words, the basic nozzle parts are designed so the whirl chamber 51a produces a spray cone 7b which intersects the entrance to orifice 61, while the shape and direction of orifice 61 determine the final cone angle of spray pattern 7a, the two air streams 62, 63 serving to prevent the spray from contacting the surfaces of orifice 61.

It may also be noted that the final spray cone angle may be altered somewhat by changing the size of the annulus 61 relative to the size of the "free" spray cone 7b produced by the whirl chamber 51a. If annular orifice 61 is smaller than the "free" spray pattern at the location of the orifice 61, then the final cone angle of spray pattern 7a will be decreased. Conversely, making orifice 61 larger than the "free" spray results in an increase in the final spray angle. There is a substantial annular air passage on either side of the sheet of liquid 7b. Thus, with the conical sheet of liquid 7b passing through the orifice 61, as shown in Fig. 2, there are provided two separate paths for atomizing air, one indicated by the flow arrows 62 on the outside of the cone of liquid, the other being indicated by arrow 63 on the inside of the liquid cone. It will be observed that while there is a substantial pressure drop across the metering orifices formed by the grooves 53 and the central metering orifice 55 in meter plate 50, there is also a substantial further drop in pressure of the atomizing air across the annular orifice 61. This pressure drop, of course, produces a very substantial increase in velocity of the air flowing through orifice 61 on either side of the liquid cone. Thus, the cone of liquid in which the particles move at substantially uniform velocity after leaving the discharge orifice 57 is surrounded both inside and out by a stream of air which is being rapidly accelerated as it passes through the orifice 61. This increase in relative velocity of the air and oil produces a very strong "shearing" effect on the oil particles, and this shearing effect has a powerful tendency to break up the solid cone of liquid into discrete atomized particles. Thus, it will be seen that the air and oil are brought together at a point where the velocity of the atomizing air is highest. For this reason, and in view of the acceleration of the air through the orifice 61, there is a maximum "tearing effect" produced by the air on the sheet of liquid.

The spray pattern 7b is prevented from collecting on the surfaces of orifice 61 and is maintained substantially centered in the orifice in the following manner. As indicated above, the inherent design characteristics of the liquid discharging parts of the nozzle determine the intrinsic angle of the spray, which will tend to deviate somewhat from the desired design value in various parts of the range of operation. Assume, for instance, that the conical sheet should tend to deflect outwardly so that the cone angle increases, with the result that the sheet approaches closer to the perimeter of the orifice in tip plate 52. The result is that the size of the air passage between the conical sheet and tip

plate 52 is decreased and the flow of air as indicated by the arrow 62 is decreased. The result of this is that the static pressure of the atomizing air tends to build up in the passages 60 and the annular space defined between the conical sheet of liquid 7 and the adjacent portions of tip plate 52. At the same time, the correspondingly increased passage for the flow of air indicated by arrow 63 results in a decreased static pressure between the conical sheet of liquid and the pintle end disk 44a. Thus, there is established across the conical sheet a static pressure differential in a direction to force the cone of liquid inwardly to its original position. The converse action takes place if the conical sheet should tend to collapse so as to decrease the cone angle. Thus, it will be seen that the two streams of air on the inside and outside of the conical sheet of liquid have a very definite stabilizing action tending to maintain the conical sheet of liquid substantially in the center of the annular orifice 61. It has been found that this arrangement produces a uniformly finely divided spray, with a substantially constant spray angle.

It will be appreciated that there are a number of design factors which must be carefully watched in the construction of a nozzle in accordance with the invention. In the first place, the air supply passages are generously proportioned so that the pressure of air supplied to the metering grooves 53 and the central metering orifice 55 in meter plate 50 is approximately the same. Likewise the air passages in the disk member 51 are generously proportioned so that the pressure of the air supplied to the upstream side of annular orifice 61 on either side of the liquid sheet is equivalent to that existing at the downstream sides of the orifices 53, 55. Then the rate of air flow to the opposite sides of the liquid sheet may be accurately controlled by careful design of the effective size of the orifices 53, 55. These sizes may be so selected that an equal rate of flow of air to the inside and outside of the conical sheet of liquid is provided. The result of this arrangement is that the static pressure inside and outside the liquid cone 7 at the upstream side of orifice 61 is equalized, as is also the rate of flow of air indicated by arrows 62, 63 through the orifice 61. If, for some reason, the rate of air flow to the inside and outside of the liquid cone should become unbalanced, the result will merely be that the cone will not be maintained exactly in the center of the annular orifice 61, but will be maintained stable in some equilibrium position with the air paths 62, 63 of unequal size corresponding to the unequal rates of flow. The stabilizing effect of the two streams of air on the cone angle will be the same as described above. It is desirable that the rates of flow in the two streams of air be equal so that the liquid cone will be centered approximately in the orifice 61.

With respect to the pressures existing in this improved nozzle, it may be noted that the combustion chamber pressure will, during operation, vary from zero to a value in the neighborhood of 70 pounds per square inch gage. Since the atomizing air compressor 17 is driven from the main turbine rotor, the atomizing air pressure will likewise vary with speed of the power plant, the maximum air supply pressure being in the neighborhood of 140 pounds per square inch. The orifices in the metering plate 50 are so designed that the atomizing air pressure ratio across the whole nozzle can vary in a wide range up to 2 or more. During starting, the atomizing air pres-

sure ratio is usually about 1.05, while the air pressure ratio during running is about 1.6. The pressure drop through metering orifices 53, 55 is in the neighborhood of 7 per cent of the total pressure drop across the nozzle.

The oil nozzles formed by the slots 59 in disk member 51 are designed to give liquid velocities in the whirl chamber sufficiently high to produce good symmetrical distribution of liquid in the spray cone at the lowest desired operating speed. Also, the diameter of the air metering orifice 55 is somewhat less than that of the oil discharge orifice 57, the difference being sufficiently great that there will be no tendency for oil in the whirl chamber to spill over the edge of the orifice 55 into the air supply chamber 48.

Representative values of the more critical dimensions of a sample nozzle are as follows:

Table of dimensions of a representative nozzle

[For delivering maximum flow of 90 gal./hr. at oil supply pressure of 450 lb./in.² and air pressure of 120 lb./in.²]

	Inches
Orifice 55, diameter	.30
Pintle 44 at orifice 55, diameter	.156
Vortex chamber 51a, max. diameter	.875
Orifice 57, diameter	.375
Pintle end disk 44a, diameter	.75
Width of annular orifice 61	.036
Oil nozzle slots 59, square cross section with each side	.031

In starting the power plant of Fig. 1, the main turbine rotor is turned over by means of a suitable starting motor with the fuel selector valve in the starting position so that diesel oil is supplied from tank 10 to the nozzles. At low speeds, the auxiliary atomizing air compressor supplies comparatively low-pressure air, but the inherent nozzle design will insure sufficiently good and even distribution of particles in the liquid spray cone to fire the power plant at oil supply pressures as low as perhaps 3 pounds per square inch. At a speed of about 10 per cent of full rated speed, the igniting device 8 is energized and combustion begins. As the speed increases, the pressure of the atomizing air increases, and, of course, the discharge pressure of the fuel pump increases correspondingly. At idling speed, which may be approximately 70 per cent of the full rated speed, the fuel selector valve may be switched so that heavy fuel oil is supplied from the main tank 9.

With this improved fuel nozzle, the use of the vortex type of liquid spray nozzle insures an even circumferential distribution of the liquid. The use of an auxiliary atomizing gas insures good atomization of heavy liquid fuels, and the novel arrangement of the atomizing air on both the inside and outside of the spray cone pattern serves to give still better atomization and at the same time provides the novel stabilizing effect on the cone angle. Thus the invention achieves a particularly effective arrangement for spraying heavy fuel oils with satisfactory operation over an extremely wide operating range, as required in gas turbine power plants.

While a preferred form of the invention has been described above in connection with Figs. 1-4, it should be understood that many modifications are possible, including the following: Fig. 5 illustrates an arrangement in which the atomizing air is supplied only to the outer surface of the fuel spray cone. In the construction shown, the nozzle body 70 defines a central bore

71 forming the oil supply passage, a plurality of circumferentially spaced air supply passages 72 and a thread at 73 on the outer surface for receiving the end cap 74. Secured between end cap 74 and body 70 are a nozzle tip member 75 and an intermediate member 76.

Member 75 defines a central liquid discharge orifice 77, a cylindrical recess 78 forming the vortex whirl chamber, the oil nozzle slots 79 and an annular oil supply passage 80. As will be apparent from the drawing, member 75 has an axially extending portion 75a surrounding the outer circumference of member 76 so that the two are held in proper coaxial relation.

The forward surface of the nozzle tip member 75 is provided with axially extending ribs 75b which cooperate with the adjacent conical surface of cap 74 to provide axially and radially inwardly extending air supply passages.

The intermediate member 76 defines a plurality of circumferentially spaced drilled holes 81 through which oil passes from the supply bore 71 to the nozzle slot supply groove 80. Member 76 has a threaded portion 76a engaging an axial extension 70a of the nozzle body. The end portion 76a also includes a radially extending flange having a conical sealing surfaces at 76b engaging a similar conical surface formed in the nozzle body 70.

A plurality of axially extending openings 76c convey air from the supply passage 72 to the annular chamber formed between the end cap 74 and the outer surface of nozzle tip member 75.

From the above description of the structure, it will be apparent that air is supplied through the passages 72, 76c and 75b to the annular space surrounding the nozzle spray orifice 77, the air leaving in the manner indicated by the arrow 7c through the small annular space defined between the spray cone 7 and the adjacent perimeter of the central orifice in nozzle cap 74. Here again it will be apparent that any tendency of the spray cone 7 to open up so as to increase the cone angle and bring the spray pattern nearer to the annular edge of the nozzle cap 74 will result in an increase in static pressure to the atomizing air, tending to deflect the cone back to its original condition so as to maintain substantially constant the size of the annular air gap surrounding the spray pattern. Here, of course, there is no corresponding tendency to prevent decrease of the spray cone angle, as was described in connection with Fig. 2. With some nozzles, and for some applications, this type of nozzle may be adequate since it obtains the same symmetrical distribution of the liquid spray with good atomization and a substantially stable spray cone angle.

The converse arrangement, in which atomizing air is supplied only to the inside of the spray cone is illustrated in Fig. 6. Here the nozzle body 85 has at one end a central opening defined by a radially inwardly extending flange 85a. The other end of the central bore through the nozzle body is closed by a threaded plug 86. The nozzle body 85 also defines a first bore portion 87 forming an annular air inlet passage and a second bore portion 88 forming the oil inlet.

Within the bore portion 87 is a casing member 89 defining a central air supply chamber 90 with a plurality of circumferentially spaced holes 91. The left-hand end of the central recess 90 is threaded to receive an end cap 92 which may have a hexagonal socket at 93 for inserting a

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hexagonal wrench for assembly purposes. A suitable air strainer screen 94 may be formed as an integral cylinder supported on shoulders formed on the member 89 and the end cap 92, respectively. It will be apparent that this screen may be assembled on member 89 and the end cap member 92 then threaded into place. The right-hand end of the inner casing member 89 forms a rather thin annular extension 95 having a conical sealing surface for engaging a similar cooperating surface on the adjacent end of the second inner casing member 96. Member 96 has a central bore receiving the pintle 97 and is threaded at 98 so that the pintle may be adjusted longitudinally as described above in connection with Fig. 2. The lock nut 99 and lock washer 100 are similarly arranged and perform the same functions as the corresponding elements 46, 47 in Fig. 2. The second inner casing member 96 also defines a plurality of circumferentially spaced axially extending drilled holes 101 communicating with a passage 102 formed in the end wall of casing member 96. The outer circumference of casing 96 is recessed to form an annular oil supply passage 103 enclosed by a strainer screen 104 in a manner which will be apparent from the drawing. From the supply space 103, oil is carried by a plurality of drilled holes 105 to an annular oil nozzle slot supply chamber 106 defined between the end of casing 96, the end cap 85, and the outer circumference of the nozzle tip member 107. Oil is supplied through the four tangential nozzle slots 108 to the whirl chamber defined in the tip member 107 and the adjacent end face of the inner casing member 96. Here the pintle 97 is provided with an end disk 97a which defines an annular orifice 107a with the adjacent circumference of the nozzle tip member 107 in the same manner described in connection with Fig. 2. The difference is that oil from the whirl chamber spills over the edge of the nozzle tip member through the annular orifice 107a, atomizing air being supplied through the passages 91, 90, 101, 102, to the air core within the vortex chamber, thence between the inner surface of the spray cone and the adjacent surface of the pintle and disk 97a, as indicated by arrow 107b.

This arrangement also provides good atomization of heavy fuel oils with the desired even distribution of oil symmetrically about the axis of the nozzle, while maintaining a substantially stable cone angle. The modifications of Figs. 5 and 6 may have some advantages over the structure of Fig. 2 from the standpoint of mechanical complexity.

It will be apparent to those skilled in the art that an almost infinite number of mechanical modifications may be made in the three types of nozzles illustrated herein, and we desire to cover by the appended claims all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a liquid spray nozzle of the type employing an auxiliary gas to facilitate atomization, the combination of a nozzle body having walls defining a vortex whirl chamber with a first central circular discharge orifice, walls defining passages for supplying liquid at high tangential velocities to the outer circumferential portion of the whirl chamber whereby liquid is discharged from said orifice with a spray pattern in the form of a hollow cone, walls defining a second discharge ori-

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fice of substantially larger diameter than and coaxial with the first and spaced axially forward therefrom, the second orifice surrounding the normal spray pattern from the first orifice and defining a restricted annular passage therewith, a central pintle supported on the nozzle body and having an end disk member disposed within the spray pattern, the circumference of said disk forming a restricted annular passage with the inner surface of the normal spray cone pattern, said second discharge orifice and pintle end disk defining an annular gas and liquid discharge orifice spaced axially forward and radially outward from said first orifice, and walls defining passages for supplying an atomizing gas under pressure to both the inside and the outside of the spray cone pattern so that a conical sheet of atomizing gas flows through said annular orifice on both sides of the spray cone.

2. In a liquid spray nozzle of the type employing an auxiliary gas to facilitate atomization, the combination of a nozzle body having walls defining a vortex whirl chamber with a first central circular discharge orifice, walls defining passages for supplying liquid at high tangential velocities to the outer circumferential portion of the whirl chamber whereby liquid is discharged from said orifice with a spray pattern in the form of a hollow cone, walls defining a second discharge orifice of substantially larger diameter than and coaxial with the first and spaced axially forward therefrom, the second orifice surrounding the normal spray pattern from the first orifice and defining therewith a restricted annular passage, a central pintle supported on the nozzle body and having an end disk member disposed inside the spray pattern, the circumference of said disk forming a restricted annular passage with the inner surface of the normal spray cone, said second discharge orifice and pintle end disk defining an annular gas and liquid discharge orifice spaced axially forward and radially outward from said first orifice, walls defining passages for supplying an atomizing gas under pressure to both the inside and the outside of the spray cone pattern so that a conical sheet of atomizing gas flows through said annular orifice on both sides of the spray cone, and means defining a metering orifice associated with at least one of said air supply passages for equalizing the rate of flow of atomizing air to the inside and outside of the spray cone pattern.

3. In a wide-range atomizing nozzle for spraying viscous liquids, the combination of a nozzle support member having a liquid inlet passage and an atomizing gas inlet passage, a body secured to the support member and having a central longitudinal bore of circular cross section including a first end portion communicating with the liquid inlet passage and an intermediate portion communicating with the gas inlet passage, a nozzle end cap of circular cross section threadedly engaging the nozzle body to define a forward continuation of the central recess in the nozzle body, a first inner nozzle body member of circular cross section located in said intermediate recess and having a central bore supporting a sleeve member with an end portion projecting into said first bore portion, said projecting sleeve end portion having a radially extending flange, a cylindrical filter screen member supported at one end on said end flange and at the other end on a circumferential shoulder formed on the adjacent end portion of said inner nozzle body, a central pintle member having a stem portion supported in said

sleeve with a threaded end portion projecting from the sleeve and having at the other end a pintle end disk member axially spaced from said sleeve, the threaded end of the pintle stem being threadedly received in said sleeve whereby the pintle may be adjusted axially, lock nut means engaging the projecting end of said threaded pintle stem for securing the pintle in a desired axially adjusted position, a circular metering plate member supported in said end cap and abutting the end face of the inner nozzle body member, said metering plate defining a first central circular orifice of larger diameter than the pintle stem so as to define therewith a restricted annular metering orifice, the metering plate having also a circumferential row of axial passages of restricted cross-section area forming second metering orifices, and a circular nozzle tip member located within the end cap, the end cap having a radially inwardly extending flange clamping said nozzle tip member in abutting relation with the forward face of said metering disk member, said nozzle tip member forming a cylindrical vortex whirl chamber coaxial with the pintle stem and a third circular liquid discharge orifice forming an annular passage with the pintle stem, said nozzle tip member also defining a fourth coaxial discharge orifice of a substantially larger diameter than said third orifice and spaced axially away therefrom, the circumference of the pintle end disk being adjacent and cooperating with said fourth orifice to form a restricted annular discharge passage of a width which is adjustable by axial adjustment of the pintle member, the inner nozzle body member, metering plate and nozzle tip member cooperating to define passages for supplying liquid from the annular chamber defined between said first filter screen and the pintle support sleeve to the outer circumferential portion of said vortex whirl chamber with a high tangential velocity component whereby a strong vortex whirl of liquid is created, the inner nozzle body member, metering plate and nozzle tip member defining passages for supplying atomizing gas from said inlet passage to the annular spaces formed at either side of the normal spray pattern by the pintle end disc and fourth orifice respectively, the restricted gas passages in said metering plate being of such a size as to supply gas substantially uniformly to both sides of the spray cone, whereby the atomizing gas flows through the annular discharge orifice on both sides of the normal spray cone pattern so that the gas and liquid are brought into close contact where the gas acceleration and velocity are a maximum.

4. In a wide range atomizing nozzle for spraying viscous liquids, the combination of a nozzle body member with a liquid inlet port adjacent the rearward end thereof and a gas inlet port in an intermediate portion thereof, said body defining a central longitudinal bore of circular cross section including a first rearward end portion communicating with said liquid inlet port and an intermediate portion communicating with said gas inlet port, a nozzle end cap of circular cross section secured to the forward part of the nozzle body to define a forward continuation of the central recess in the nozzle body, a first inner nozzle body member of circular cross section located in said intermediate recess and having a central bore, a central pintle member having a stem portion adjustably secured in the bore of said inner nozzle body member and having at the forward end thereof a pintle end disk member,

a circular metering plate member supported in said end cap and abutting the forward end face of the inner nozzle body member, said metering plate defining a first central circular orifice of larger diameter than the pintle stem so as to define therewith a restricted annular metering orifice, the metering plate having also a circumferential row of axial passages of restricted cross-section area forming second metering orifices, and a circular nozzle tip member located within the end cap, the end cap having a radially inwardly extending flange clamping said nozzle tip member in abutting relation with the forward face of said metering disk member, said nozzle tip member forming a cylindrical vortex whirl chamber coaxial with the pintle stem and a third orifice forming an annular liquid discharge opening with the pintle stem, the outer diameter of said vortex whirl chamber being substantially greater than the diameter of said third orifice and said third being at least slightly greater in diameter than said first orifice, said nozzle tip member also defining a fourth coaxial discharge orifice of a substantially greater diameter than said third orifice and spaced axially forward therefrom, the circumference of the pintle end disk being adjacent and cooperating with said fourth orifice to form a restricted annular discharge passage of a width which is adjustable by axial adjustment of the pintle member, the inner nozzle body member, metering plate, and nozzle tip member cooperating to define passages for supplying liquid from the liquid inlet port in the body to the outer circumferential portion of said vortex whirl chamber with a high tangential velocity component whereby a strong vortex whirl of liquid is created having an air core of a diameter greater than said first orifice and less than that of said third orifice, the inner nozzle body member, metering plate, and nozzle tip member defining passages for supplying atomizing gas from the gas inlet port to the annular spaces formed at either side of the normal spray pattern formed by said third orifice, the orifices in said metering plate being of such size as to supply gas substantially uniformly to both sides of the liquid spray cone, whereby atomizing gas flows through the annular discharge orifice on both sides of the normal liquid spray cone pattern so that gas and liquid are brought into close contact at the point where gas acceleration and velocity are a maximum.

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