

[54] **GAS-ATOMIZING NOZZLE BY SPIRALLY ROTATING GAS STREAM**

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[51] Int. Cl. **B05b 7/10**

[58] Field of Search 239/404, 405, 406, 403, 239/493

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[57] **ABSTRACT**

A gas-atomizing nozzle composed of a truncated cone-shaped main body having semi-spiral grooves formed symmetrically on the tapered surface of the truncated cone body and a conical cover or sleeve covering the grooved surface for providing semi-spiral passageways of gas, said truncated cone body having at the center a passageway for a liquid to be atomized and said semi-spiral grooves having such configuration that the liquid discharged through the liquid passageway is finely atomized at the focus of the spirally rotating gas streams jetted through the semi-spiral passageways by the centrifugal force formed by the spiral motion of the gas streams in a confined conical space.

2 Claims, 9 Drawing Figures

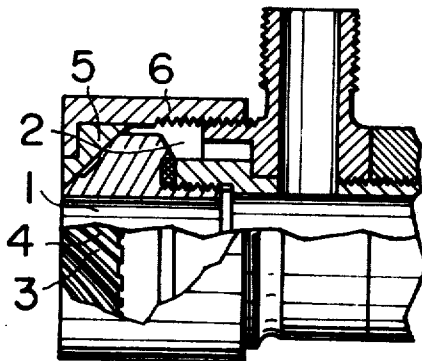


FIG. 1A

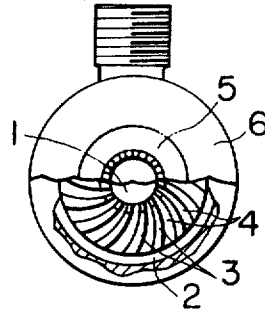


FIG. 1B

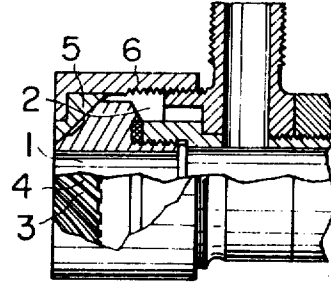


FIG. 2A

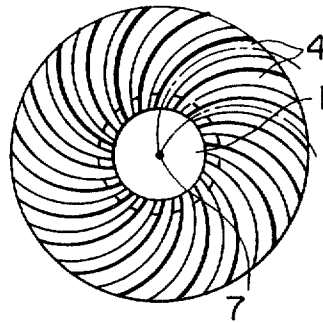


FIG. 2B

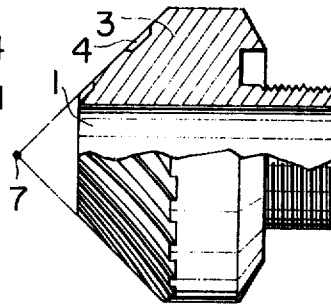


FIG. 3

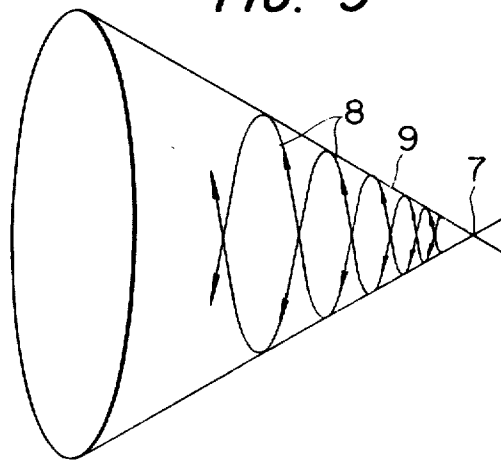


FIG. 4

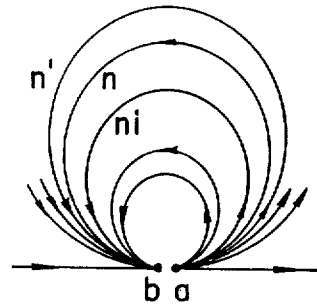
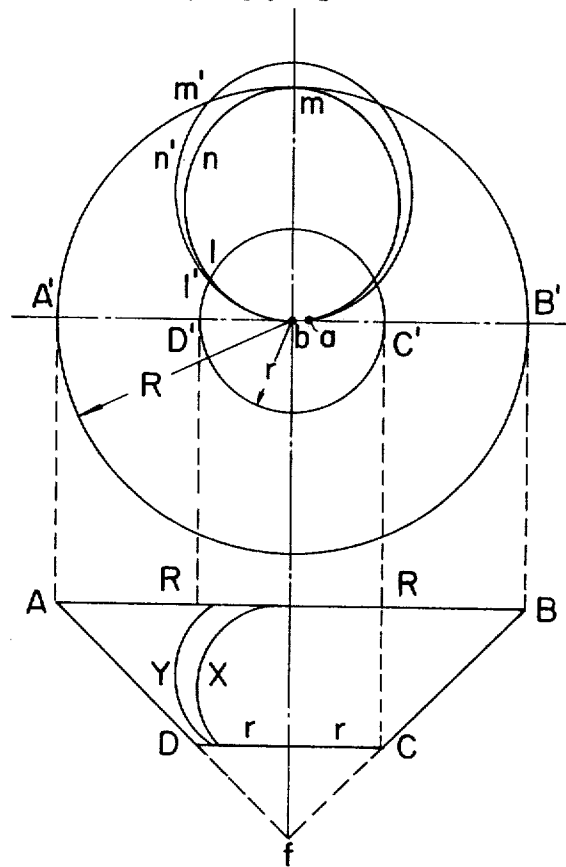


FIG. 5



GAS-ATOMIZING NOZZLE BY SPIRALLY ROTATING GAS STREAM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an improved gas-atomizing nozzle capable of finely atomizing a liquid for providing a confined conical shape of the cloud of spray, said nozzle being based on a principle completely different from conventional nozzles of liquid atomizers or sprayers by compressed air. More particularly, the invention relates to a gas-atomizing nozzle suitable for spray coating, atomizing fuels in oil burner or internal combustion engine, metal spraying, metalizing, spray welding of metal, application of insecticides, air and material moistening, etc.

2. Description of the Prior Art

In a conventional gas-atomizing nozzle or pneumatic nozzle by utilizing compressed air for, e.g., hand spraying or spray gun, a coating material passing through the nozzle is atomized by jetting a straight gas stream to the coating material and at the same time the spray zone of the atomized droplets is enlarged by other straight gas stream separately jetted from the side. In such a conventional gas-atomizing nozzle, the diameter of the orifice of the passageway for coating material or liquid to be atomized is usually not over 2 mm. when the pressure of the compressed air is 4.5 kg./cm.² and further the maximum diameter of the orifice of the liquid passageway of a conventional nozzle used for hand spraying is within the limit of 3 mm., which results in reducing the spraying faculty. Furthermore, such a conventional gas-atomizing nozzle is accompanied with large loss of the atomized liquid or coating material by scattering and repulsion thereof owing to the straight type jetting as well as having problems in such a conventional case involving the adherence of coating material and the gloss of coating surface.

Also, in a conventional gas-atomizing nozzle of a type of atomizing a liquid by utilizing spiral gas stream, the gas stream itself jetted from the nozzle is an unstable rotating gas stream having no sucking action and further the speed of the gas stream becomes lower as approaching the center thereof, which makes it quite difficult to atomize effectively the liquid jetted to the central portion of the gas stream.

SUMMARY OF THE INVENTION

An object of this invention is, therefore, to provide an improved gas-atomizing nozzle without causing the aforesaid faults and difficulties as encountered in conventional gas-atomizing nozzles.

Other object of this invention is to provide a gas-atomizing nozzle which can atomize liquid finely and efficiently and has a greatly improved spraying power and high atomizing faculty even when the diameter of the orifice of the liquid passageway is as large as 8 mm.

Further object of this invention is to provide a gas-atomizing nozzle capable of spraying finely atomized droplets of a liquid in a confined conical zone or space.

That is, according to the present invention, there is provided a gas-atomizing nozzle comprising a truncated cone-shaped or truncated sphere-shaped main body having semi-spiral grooves symmetrically disposed on the tapered surface of the truncated cone or sphere body and a conical cover covering said grooved surface of the truncated cone or spherical body for pro-

viding semi-spiral passageways of gas, said truncated cone or sphere body having at the center a passageway for a liquid and said semi-spiral grooves having such a configuration that the focus of said semi-spiral grooves on the tapered surface of the truncated cone or sphere coincides with the apex of the cone or the focus of the sphere of the main body for atomizing finely the liquid supplied to the focus portion of the spirally rotating gas stream jetted through the semi-spirally grooved passageways by the strong rotation motion of the gas stream and for carrying or spraying the atomized droplets of the liquid in a stable confined zone or space.

By employing the gas-atomizing nozzle of this invention as indicated above, the loss of the atomized liquid by scattering and repulsion can be minimized or prevented and moreover the atomized liquid can be applied uniformly onto a confined area.

DETAILED DESCRIPTION OF THE INVENTION

Now, the invention will further be explained in detail by referring to the accompanying drawings, in which

FIGS. 1A and 1B are front and side views respectively, partly in section, showing an embodiment of the gas-atomizing nozzle of this invention,

FIGS. 2A and 2B are enlarged front and side views respectively, partly in section, showing more particularly the semi-spirally grooved tapered surface of the truncated cone-shaped main body of the nozzle illustrated in FIGS. 1A and 1B,

FIG. 3 is a schematic view for explanation of the spray zone or space of the cloud of fine droplets atomized by the gas-atomizing nozzle of this invention,

FIG. 4 is an imaginative view of a two-dimensional stream line pattern forming the spiral gas stream paths,

FIG. 5 is a view for explanation of making the semi-spiral grooves on the tapered surface of the truncated cone-shaped main body,

FIG. 6A shows the pattern of coating formed by the gas-atomizing nozzle of this invention, and

FIG. 6B shows the pattern of coating formed by a conventional hand spraying.

In the embodiment of the air-atomizing nozzle of this invention illustrated in FIGS. 1A and 1B, a liquid, such as a coating material is supplied to the atomizing point through a liquid passageway 1 formed in a truncated cone-shaped main body of the nozzle, said liquid passageway being connected to a tank (not shown) for coating material and compressed air sent by means of a compressor (not shown) enters a large number of semi-spiral grooves 4 disposed symmetrically on the tapered surface of the truncated cone-shaped body 3 through an annular gas chamber 2, whereby said compressed air is provided forcibly with spiral motion having zero hydrodynamical curl. The spirally rotating compressed air is jetted into the air from the semi-spiral grooves and centers at the focus 7 (FIG. 2A) of the semi-spiral grooves on the tapered surface of the nozzle, where the rotating jet gas gives very strong rotating action to the fluid or coating material coming from the liquid passageway 1 of the nozzle and finely atomizes the fluid by the strong rotating action or the strong centrifugal force caused by the spiral jet gas stream. A conical cover 5 is closely mounted on the grooved surface of the truncated cone-shaped body 3 to cover air-tightly the semi-spiral grooves and to provide semi-spiral passageways of compressed air, said conical cover 5 being further supported by means of a cap

screw 6 for securing the close contact between the cover and the grooved surface of the nozzle. As shown in FIG. 1A and FIG. 3, the semi-spiral grooves 4 formed on the tapered surface of the truncated cone-shaped body 3 have such configuration that they surround the liquid passageway 1 of the nozzle, they are disposed symmetrically on the tapered surface of the body, and the focus 7 of the symmetrically disposed semi-spiral grooves coincides with the imaginative apex of the truncated cone of the body 3.

The compressed air jetted from the semi-spiral grooves 4 of the nozzle in air centers at the focus 7 of the semi-spiral grooves, which coincides with the apex of the cone, as shown in FIGS. 2A and 2B while continuing the strong spiral rotation, where the spirally rotating jet gas streams give very strong rotation action to the liquid or coating material coming from the liquid passageway 1 to atomize finely the liquid by giving to the liquid the strong rotating action and spray the atomized droplet of the liquid in a conical zone or space as shown in FIG. 3.

That is, the compressed air jetted into the air from the semi-spiral grooves 4 centers or collected at the focus 7 of the whole semi-spiral grooves 4 causing there a combined spirally rotating motion, which gives very strong rotation force to the liquid or the coating material coming from the liquid passageway of the nozzle. Therefore, the liquid or coating material is forced to rotate by the rotation motion of the spiral jet gas streams having quite high angular velocity around the focus 7 and is affected by the action of strong centrifugal force as shown in the following equations, whereby the bonding of the liquid by cohesion is destroyed and high atomization occurs;

$$\left. \begin{aligned} \omega r &= W r^2 = C \\ f &= \frac{m \omega^2}{\gamma} = \frac{m W C}{\gamma} \end{aligned} \right\}$$

wherein f represents centrifugal force, m represents a mass, ω represents a rotation velocity, W represents an angular velocity, r represents a distance from the center, and C represents a constant.

Because the centrifugal force which is the motive power for the atomization of this invention is in proportion to the square of the rotation velocity, the atomization of liquid by the rotation motion in this invention is practiced very effectively as compared with conventional techniques. In other words, the semi-spiral passageways of gas form rotating gas streams making stable potential motion, which provides a rotation motion of very high velocity to the liquid discharged at the central portion of the centering gas stream, whereby the binding by cohesion is destroyed and the liquid is highly or finely atomized at the central portion.

Since as described above, the atomizing action by the spirally rotating gas streams in this invention is completely different in mechanism from the atomizing action of conventional air-atomizing nozzles and also is very effective as compared with the conventional nozzles, the atomization can be practiced effectively even by the nozzle of 8 mm. in diameter of the orifice of liquid passageway in this invention while the diameter of the orifice in conventional air-atomizing nozzles is restricted to be not over 3 mm. and furthermore the nozzle of this invention can provide uniformly and finely

atomized droplets of liquid while conventional air-atomizing nozzles can provide only comparatively coarse droplets.

The spirally rotating gas streams combined at the focus 7 as in FIG. 3 atomize a liquid or coating material at the point and the atomized droplets of the liquid advance along a number of orbits 8 as shown by an arrow in a confined conical zone or space. Since the spirally rotating gas stream itself is essentially a stable gas stream and is restrained by the surrounding atmospheric pressure, the groups or cloud of the atomized droplets reduces the advancing velocity by the rotation motion of the gas streams and advance at a slow velocity together with the rotating gas streams in a stable or confined conical zone or space 9, which prevents or minimizes the loss of the atomized droplets by scattering and repulsion from the confined zone. In addition, it will be easily understood that the formation of the spirally rotating gas streams be not limited to the use of compressed air but can be obtained by employing a fan-type blower.

Now, the fundamental difference between the rotating gas stream by the semi-spiral passageways of this invention and the rotating gas stream by conventional spiral passageways is as follows. That is, the rotating gas stream making potential motion by the spiral passageways of this invention is formed in the field of scalar and the sucking action at the sink point of dipole occurs always at the no hydrodynamical curl state. On the other hand, the rotating gas stream by the shearing motion of gas stream from conventional spiral passageways forms in the field of vector having no sink point of dipole; the rotation gas stream occurs always at a hydrodynamical curl state. As described above, the spirally rotating motion formed by the air-atomizing nozzle of this invention is completely different in hydrodynamics from the vortex motion in conventional techniques.

Furthermore, the rotating velocity of the rotating gas stream by the potential motion in this invention is in inverse proportion to the radius of the vortex and increases as approaching the center of the vortex. Therefore, if the focus of the semi-spiral passageways of gas stream is disposed on the axis of the vortex and the sucking action of sink point is caused at the focus, the liquid discharged at the focus is provided with the strongest rotating force by the rotation motion of the jet gas streams centering at the focus, whereby the liquid is rotated vigorously and is finely atomized by the action of centrifugal force. On the other hand, the rotation of gas stream by conventional shearing motion increases its velocity from inside to outside of vortex contrary to the above case and further since the rotation motion of the gas stream does not cause sucking action, it is utterly impossible to provide rotation motion to the liquid discharged at the central portion of the rotating gas stream.

In addition, the semi-spiral passageways of gas in this invention will further be explained in detail. FIG. 4 shows the stream of two-dimensional potential of dipole (a) and (b) when the stream lines from the source point (a) of the dipole return along each definite orbit to the sink point (b) of the dipole and orbits (n) and (n') are the stream lines selected for making one semi-spiral groove or passageway for gas. Another orbit of stream line is designated as (n₁).

A method of making the semi-spiral grooves or passageways of gas on the tapered surface of a truncated cone-shaped body of the nozzle of this invention with the focus (f) of the spiral gas streams is illustrated in FIG. 5. The radii of the base and the upper-face of the truncated cone, the cross section of which is designated by A, B, C, and D, as the nozzle body are determined by the radii (R) and (r) of the two circles stating below. The stream lines (n) and (n') are selected from the stream lines, which are generally denoted as (n_i), as shown in FIG. 4 according to desired power of jet stream and the sink point (b) of the stream lines is so selected that the point coincides with the projection point of the focus (f). Then, the selected stream lines (n) and (n') are drawn as shown in FIG. 5 so that the source point (a) and the sink point (b) of the dipole are on the line (A') and (B') and a circle having radius (R) is drawn with the sink point (b) as the center so that the circle is in the tangent relation with the inner stream line (n), the tangent point between the circle and the stream line (n) being designated as (m) and the intersection point of the circle and the stream line (n') being designated as (m'). Then, a small circle having radius (r), the radius being selected according to the desired shape of the truncated cone as the nozzle body, and intersection points of the small circle and the stream lines (n) and (n') are designated a (l) and (l'), respectively. Then, a truncated cone is formed, of which the radius of the base is R and the radius of the upper face is r , and the pattern of the curve $m-l$ and the curve $m'-l'$ are transcribed on the tapered surface of the truncated cone body as the pattern of the curves (X) and (Y). A number of the patterns having the same figure are also formed on the whole tapered surface of the truncated cone and the surface is grooved in the area between the curves (X) and (Y) in a desired depth, which provide the semi-spiral passageways of gas.

The above is the case of forming a truncated cone after determining the radii of the base and the upper face thereof but the shape of the necessary semi-spiral groove may be determined after forming a truncated cone. In this case, the inner stream line (n) is so selected that it is in the tangent relation with the circle same as the shape of the base of the truncated cone.

The area (m , m' , l' and l) between the two stream lines for making the semi-spiral groove and the number of grooves formed on the tapered surface of the truncated cone are selected according to desired power of the jet stream.

The feature of the atomizing mechanism of the air-atomizing nozzle of this invention is in the point that a number of the semi-spiral grooves or passageways as described above are formed symmetrically on the tapered surface of the nozzle and the spirally rotating gas streams jetted from the gas passageways is collected at the common focus (f) having a sucking action at sink point of gas stream, whereby the liquid discharged to the focus (f) is rotated at high speed and atomized there by the rotation motion of the gas streams to improve greatly the atomizing and spraying faculty of the nozzle.

FIG. 6 shows, in comparison, the density distributions of atomized droplets of a coating material by means of air-atomizing nozzles each having 2 mm. in the diameter of the orifice of the liquid passageway at 3.5 kg./cm². in the pressure of compressed air and with

a coating distance of 15.0 cm. FIG. 6A shows the density distribution of the atomized droplets of coating material by the air-atomizing nozzle of this invention at the cross section of the conical zone 9 in FIG. 3, while FIG. 6B is a pattern showing the density distribution of the atomized droplets of coating material by a conventional hand sprayer or a spray gun.

Finally, the differences in capacity or performance between a conventional liquid atomization by compressed air and the atomization of this invention will be explained by referring to the case of hand spraying. Since in the conventional atomization by compressed air, the atomization of a coating material or liquid is conducted by straight jet and at the same time the spray range is enlarged by straight gas stream jetted separately from the side, the atomized droplets of the coating liquid advance straightly to the plane to be coated and hence the formation of defects of the coating by pinholes owing to the repulsion of the droplets of the coating material at the coating plane. Therefore, the coating tends to be conducted with a remotest distance from the plane to be coated as well as the spray zone of the atomized droplets of the coating material by the jet gas stream from the side as described above, which results in increasing inevitably the loss of the droplets of the coating material by scattering from the coating zone. Furthermore, such scattering of coating material gives hygienic troubles or air pollution in continuous run. On the other hand, since a liquid or coating material is atomized by rotating gas stream in this invention and hence the advancing velocity of the atomized droplets to the plate to be coated is low, the repulsion of the atomized coating material at the coating plane is less, which makes it possible to practice the coating operation from a short distance. Furthermore, since the shape of the cloud of the atomized coating material thus sprayed is in a confined definite zone, the loss of the coating material by scattering and repulsion is quite less regardless of the coating or spraying distance. Still further, it has experimentally been confirmed that a period of time required for discharging the whole coating material in a bath by means of a conventional hand sprayer nozzle having 1.5 mm. in the diameter of the orifice of the liquid passageway, which is a standard orifice size, at 4.5 kg/cm². pressure of compressed air by compressor is 3-4 minutes and the period of time is also 1.5-2.0 minutes in the case of using a nozzle having 2 mm. in the orifice diameter, while in the present invention an air-atomizing nozzle having large diameter of orifice which has never been employed in conventional air-atomizing nozzles can be used owing to the employment of spirally rotating gas streams, that is, the whole coating material in bath can be discharged in 25 seconds at 5.0 kg/cm². in the pressure of compressed air by compressor by means of the air-atomizing nozzle of this invention having 8 mm. in the diameter of the orifice of the liquid passageway and further more uniform and finer droplets of liquid or coating material than conventional case can be formed.

Moreover, in the nozzle of this invention, if the jetting of compressed air is stopped, the discharge of the liquid or coating material stops since the liquid returns automatically in the bath by the action of air flowing to a so-called vacuum zone formed near the focus in front of the orifice of the liquid passageway without necessary of a check valve preventing the flow out of the liquid or coating material. Therefore, the present inven-

tion provides great changes to the spraying mechanism of conventional air-atomizing nozzles.

The invention was explained by referring to the embodiment, in which the nozzle body is a truncated cone-shaped body, but it will be easily understood that a truncated sphere-shaped body can be similarly used as the nozzle body, there being of necessity a tapered body of this type created by a tapered surface of revolution.

As mentioned above, the air-atomizing nozzle of this invention has extremely high spraying faculty as compared with conventional liquid spraying mechanisms, gives less loss of atomized droplets by scattering and repulsion, and further prevent the formation of air pollution by noxious materials. Thus, the air-atomizing nozzle of this invention can be widely utilized for various industrial purposes. In addition, the above explanation was described mainly about the application of coating by hand spraying but it can of course be applied to the techniques of atomizing fuels in oil burner or internal engine for, e.g., automobiles, metal spraying, metallizing, spray welding of metal, application of insecticides, air or material moistening, etc.

What is claimed is:

1. An air-atomizing nozzle comprising: a truncated

main body forming a tapered surface of revolution, semi-spiral grooves being identical in form and configuration and symmetrically disposed at circumferentially spaced positions within the tapered surface of the body, a correspondingly tapered cover closely covering said grooved surface of the truncated body and forming semi-spiral air passageways, said truncated body having at its axis a passageway for liquid and said semi-spiral grooves being of such configuration that the focal point of said semi-spiral grooves on the tapered surface of the truncated body coincides with the imaginative apex or focal point of the main body, and wherein said semi-spiral grooves comprise grooves formed by transcribing on the tapered surface of the truncated body of the nozzle a pattern comprising a pair of stream lines on the sink side of a hydrodynamic dipole by plane projection and forming said semi-spiral grooves in conformance with the transcribed pattern at each circumferentially spaced groove location such that the focal point of the semi-spiral grooves coincides with the dipole sink point and with the axis of the truncated body.

2. The nozzle as claimed in claim 1, wherein said main body is of truncated cone shape.

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