

[54] **NEBULIZER**
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[51] Int. Cl. **B05b 7/24**
[58] Field of Search 239/338, 370;
128/194

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[57] **ABSTRACT**
A nebulizer for the generation of an aerosol having three major components mounted within a housing for containing a liquid and directing the resultant aerosol. The three components are designed for ease in assembly and disassembly for cleaning. The gas and liquid are uniformly mixed prior to depositing the liquid onto and spreading the liquid over a target surface for the final atomization.

8 Claims, 4 Drawing Figures

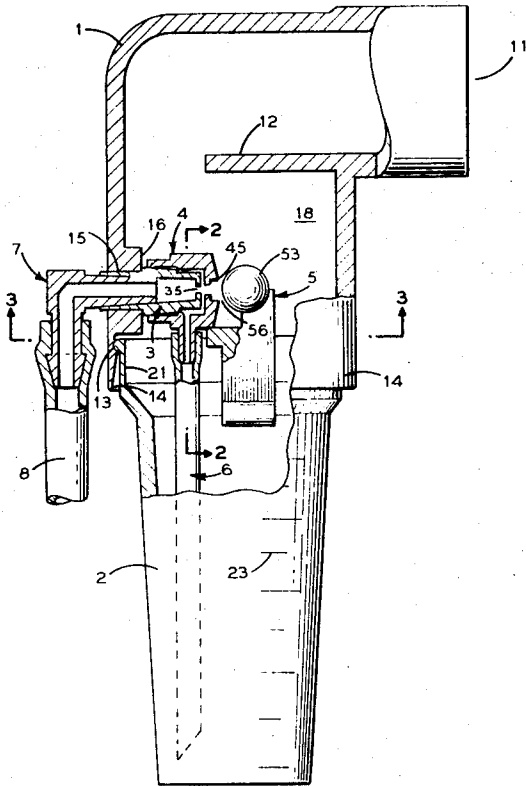


FIG. 1

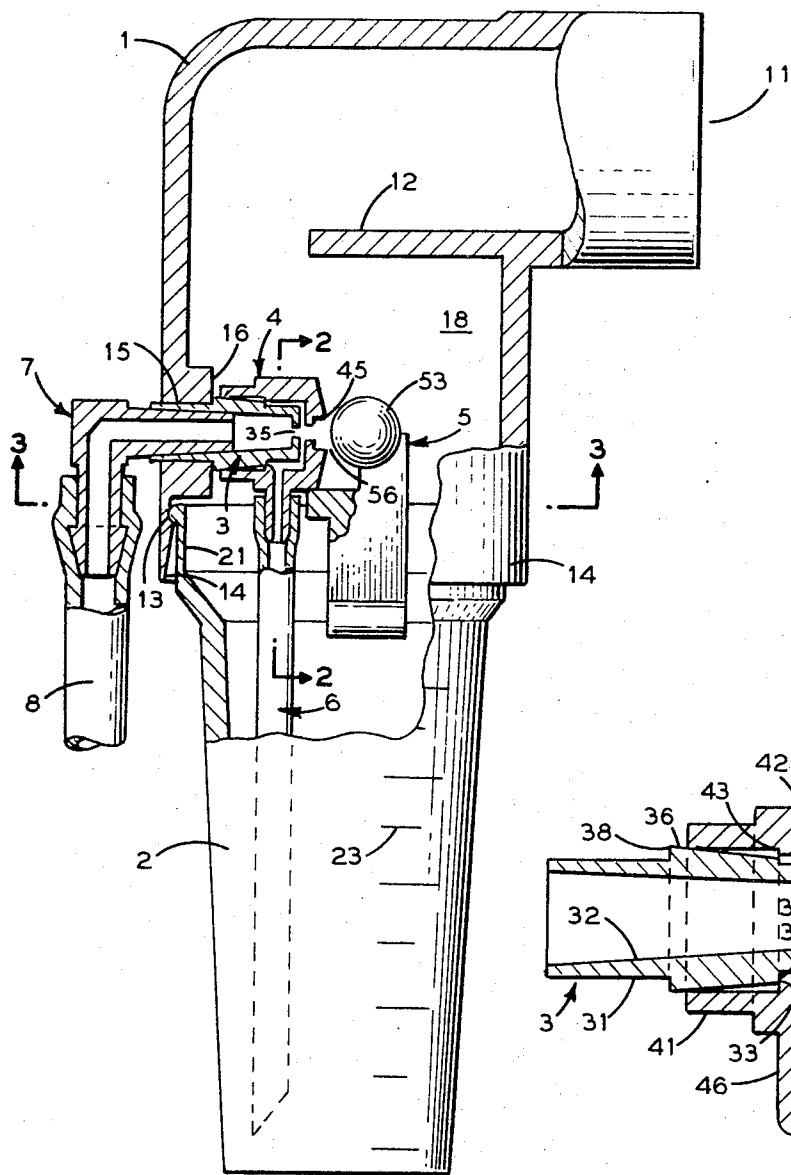
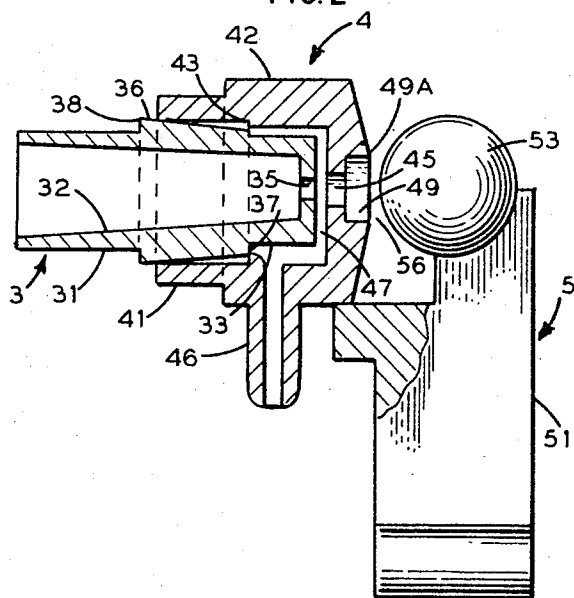


FIG. 2



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FIG. 3

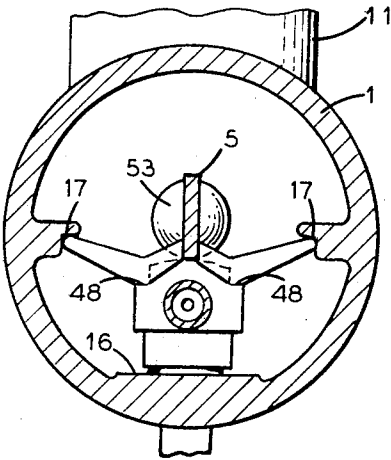
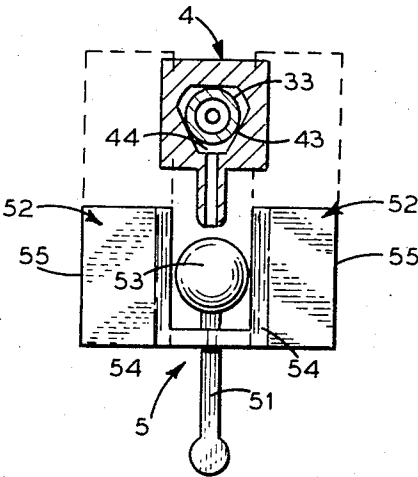


FIG. 4



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NEBULIZER

BACKGROUND OF THE INVENTION

This invention relates to a new and improved nebulizer, also called an atomizer or a vaporizer, used to atomize or generate an aerosol of a liquid-like medication. The medication is usually administered by inhalation to a patient affected with some disorder, such as emphysema or asthma. It may consist of a single liquid, a mixture of liquids, or solid compounds dissolved in a liquid, all possibilities of which will hereinafter be called "the liquid."

In the treatment of patients having disorders requiring an aerosol, it is very important that the size of the aerosol or suspended particles be within a certain size distribution in order for the particles to reach their intended destination. Generally the most useful size distribution should be between 0.5 to 5.0 microns. Particles larger than 5.0 microns are usually too heavy to ever reach their intended destination and particles smaller than 0.5 microns are too stable and when inhaled will probably never be deposited at their intended destination but will be discharged during exhalation. "Efficiency" of performance of a nebulizer is generally expressed as the quantity of useful aerosol produced per unit quantity of gas consumed.

Most prior art nebulizers are constructed such that a gas is introduced into a chamber in the direction of some type of target arrangement. Prior to reaching the target arrangement, the gas passes over or through an aspirating means which includes a capillary tube, one end of which is submerged in a reservoir of a liquid. As the liquid is drawn up the tube, usually by the Bernoulli principle, it is propelled against the target arrangement to be fractured into aerosol particles. The particle size distribution will depend upon how the gas and liquid mix and the location of the target arrangement relative to flow of the gas-liquid mixture.

The invention of this application operates on the theory that due to the uniformity of mixing and flow distribution of the gas and liquid, the latter is uniformly deposited on the target arrangement. Due to the velocity of the gas-liquid mixture, the deposited liquid is then spread over the surface of the target. Since the surface area increases in the direction of movement of the spreading liquid, the liquid becomes increasingly thinner until its surface tension forces it to atomize into aerosol particles and leave the target arrangement.

Therefore, the principal object of this invention is to provide a nebulizer such that the quality of aerosol produced is generally uniform within a relatively narrow size range useful for medical purposes and other applications where a stable aerosol is desired.

Another object of this invention is to provide a nebulizer that has a high efficiency in the quantity of aerosol produced.

A still further object of the invention is to provide an efficient nebulizer having a design which is economical to manufacture but still very reliable in performance.

Another object of the invention is to provide an efficient nebulizer having a design in which the critical components are easily assembled, disassembled, cleaned, inspected, and/or replaced.

There are three essential and novel elements of this inventive nebulizer. One component, to be called a power jet piece, includes a gas inlet passage for connection to a source of pressurized gas and a primary orifice. Another component, to be called a cap piece, includes an inlet passage for connection to the liquid medication, a secondary orifice, and a recessed cavity on the exit side of the secondary orifice, the cavity having a rim-like surface. The power jet piece and cap piece are assembled having a loose press fit, so that the orifices are in alignment with each other and a chamber is formed between the exit plane of the primary orifice and the entrance plane of the secondary orifice. The chamber connects with the liquid inlet passage of the cap piece. As the pressurized gas passes between the two aligned orifices, there is a simulated venturi throat effect and a negative pressure develops in the chamber causing the liquid to be drawn into the chamber. Location of a secondary orifice downstream from where the gas and liquid meet insures a more thorough mixing. The third component, to be called a target piece, is slidably mounted on the exit plane side of the cap piece and has a target which is aligned with the two orifices and in close proximity to the rim-like surface of the cap piece's recessed cavity. A restrictive gap is formed between the target piece and the rim-like surface, so that the liquid flowing from the secondary orifice through the recessed cavity is deposited onto the target surface in a uniform manner. These three essential elements are held in rigid alignment, when the target piece is placed in position.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more thorough understanding of the invention, reference may be made to the following description of an exemplary embodiment, taken in conjunction with the figures of the accompanying drawings, in which:

FIG. 1 illustrates an overall view, partially in cross section, of the nebulizer assembly;

FIG. 2 illustrates the three assembled components of the aerosol generating subassembly, partially in cross section;

FIG. 3 is a cross-sectional view taken along the line 3—3 of FIG. 1; and

FIG. 4 is a view taken along the line 2—2 of FIG. 1, with the target piece being disassembled from the cap piece.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

Referring to FIG. 1, the nebulizer is constructed of three major subassemblies; a housing 1, a reservoir 2, and an aerosol generating subassembly. The aerosol generating subassembly is composed of three major components: a power jet piece 3, a cap piece 4, and a target piece 5. In addition, a dip tube 6, which is shown as a separate part but need not necessarily be, may be considered part of the aerosol generating assembly. Also, an inlet fitting 7 couples the aerosol generating subassembly to a compressed gas supply tube 8. It is preferable that many of these components be made, at least in part, of a molded material that is somewhat resiliently deformable, such as molded plastic. In the following description and discussion two digit numbers will be used for details and special features with the first digit identifying the appropriate singular component being described.

The housing 1 has an outlet opening 11, which is connected to another type of device such as a face mask, a respirator, a vapor tent, or an atmospheric control chamber, etc., which is designed to use the aerosol cre-

ated by the nebulizer. Adjacent to the outlet opening 11 there is a splatter baffle 12 which prevents any large aerosol particles from reaching the outlet 11, causing them to coalesce on the baffle 12 and eventually fall back into the reservoir 2 for reuse. The housing 1 is coupled to the reservoir 2 by way of a sealing groove 13 and a skirt section 14. The housing 1 has an inlet aperture 15 in its side wall for accepting the aerosol generating subassembly and a planar surface 16 for accurate alignment of the aerosol generating subassembly. In addition, there are housing guideways 17—17 on opposite sides of the housing which assist in the alignment and the rigidity of the aerosol generating subassembly. The housing enclosure 18 must be of sufficient volume to allow the useful aerosol of the desired size to pass to the outlet opening 11 without excessive interference from the larger particles which fall back into the reservoir 2.

The reservoir 2 is a generally symmetrical cylindrically shaped container having a particularly thin wall collar and bead 21 at its upper surface that can be snapped into the sealing groove 13 of the housing 1 to prevent a leakage of gas or liquid and obviate the need for any type of gasket. Size and shape of the reservoir is independent of the aerosol generating function. However, for certain uses it may be convenient for the overall size of the reservoir to be such as to allow significant graduations 23 to indicate the level of the liquid in the reservoir. A typical inhalation therapy treatment may require measurements of as little as a 3 milliliters or less and less than 0.5 milliliters of a particular component. The graduations 23 preclude the need to use another device to measure, such as a graduated syringe.

The power jet piece 3 is a symmetrical, cylindrically shaped component having three different size sections along its length. Referring to FIG. 2, the inlet section 31 has an internal tapered section 32, which mates with the inlet fitting 7, and a thin wall which is expanded radially against the housing inlet aperture 15 (see FIG. 1) when the tapered inlet fitting 7 is inserted into the power jet piece 3. This expansion of the inlet section 31 of the power jet piece 3 against the walls of the housing inlet aperture 15 results in a simple, gasketless, leak tight seal, for the gas to pass through the housing wall, even though there is a free sliding fit for assembly and disassembly of the components. The outlet end of the power jet piece 3 has a reduced diameter stud section 33, the end face of which contains the outlet orifice 35, hereinafter the primary orifice. The center section 36 of the power jet piece 3 has an external taper for ease of assembly with the cap piece 4, to be discussed later. In addition, there is a shoulder 37 which is formed by the diameter change between the center section 36 and the stud section 33, and a shoulder 38 formed by the diameter changes between the center section 36 and the inlet section 31. The latter shoulder 38 provides a stop for aligning the power jet piece 3 with the reference to the planar surface 16 of the housing 1. (see FIG. 1).

The cap piece 4 has a thin-walled cylindrical entrance portion 41 designed to expand slightly for a leak tight fit over the external taper of the center section 36 of the power jet piece 3 and a blocked shaped exit portion 42. When these two pieces are assembled, the shoulder 37 of the power jet piece 3 abuts against a triple chord shaped shoulder 43 (see FIG. 4) within the exit portion 42, forming a triangular cavity 44 within

the cap piece 4. The exit portion 42 of the cap piece 4 also contains an outlet orifice 45, hereinafter the secondary orifice, and a small diameter nipple 46 for attachment to the dip tube 6, the latter being inserted into the reservoir 2. The opening of the nipple 46 connects with the triangular cavity 44 described above. In addition, there is a gap 47 between the external end face of the power jet piece 3 and the internal end face of the cap piece 4 which together with the triangular cavity 44 form a chamber. This chamber connects with the reservoir via the nipple 46 and dip tube 6. The secondary orifice 45 is centrally located and in alignment with the primary orifice 35. Preferably, the diameter of the secondary orifice 45 should be slightly larger than the diameter of the primary orifice 35. The end face of the exit portion 42 of the cap piece 4 contains two cap piece guideways 48—48 (see FIG. 3), which are parallel to the housing guideways 17—17, and which also assist in the alignment and the rigidity of the aerosol generating subassembly. The end face of the exit portion 42 of the cap piece 4 also contains a recessed cavity 49 having a rim-like surface 49a.

The target piece 5 consists of a tab-like structure 51 containing two wing plates 52—52 and a target surface 53. The wing plates 52—52 form an acute angle with each other to enhance the rigidity of the entire aerosol generating subassembly. When fully assembled, inner surfaces 54—54 of the wing plates 52—52 are in contact with the cap piece guideways 48—48 and outer edges 55—55 of the wing plates 52—52 are in contact with the housing guideways 17—17. This insures proper alignment and rigidity of the entire aerosol generating subassembly. The target surface 53, which may take many different shapes is shown as a sphere for ease of manufacture. When the target piece 5 is snugly mounted between the two sets of guideways, as described above, the target surface 53 is contiguous to the rim-like surface 49a of the cap piece 4 forming a restrictive passage 56.

In operation, a source of compressed gas is connected to the nebulizer by the supply tube 8 and with adequate pressure this gas will exit with a high velocity at the power jet primary orifice 35. As the gas passes from the primary orifice 35 to the secondary orifice 45, due to the simulated venturi throat formed therebetween, a negative pressure will be generated in the gap 47. The gap 47 is part of a chamber including triangular cavity 44, which has access to the liquid in the reservoir 2 via the nipple 46, and the dip tube 6. Therefore, the negative pressure in gap 47 has a tendency to draw the liquid into the gap 47. The combined gas and liquid will then pass through the secondary orifice 45 becoming thoroughly mixed and emerge into the cavity 49. As the liquid-gas mixture passes through the restrictive passage 56, the liquid is uniformly deposited upon the target surface 53. Due to the high velocity of the gas, the liquid will spread across the spherical surface and due to the increasing surface area in the direction of the spreading movement of the liquid, the layer of liquid will become increasingly thinner. This thin layer of liquid will eventually separate from the spherical target surface 53 in the form of an aerosol and will move in the general direction of the outlet opening 11 of the housing 1. The degree of thin-down of the liquid on the target surface 53 will be a function of the velocities of the gas and liquid, the amount of liquid initially deposited on the surface 53, the surface tension of the partic-

ular liquid being used, and the shape of the target surface 53.

Due to the smallness of the secondary orifice 45 and the existence of the restrictive passage 56, the entire gas jet is used in mixing with the liquid and depositing the liquid onto and spreading the liquid over a large portion of the target surface 53. There is no loss of efficiency due to any non-utilized gas as in the typical atomizer or nebulizer where usually aerosol production depends upon impact fracturing as discussed in the introduction, or is due to only a small portion of the target being exposed to the flow of the gas and liquid. Nebulizers constructed as described herein produce useful aerosol at rates in excess of 70 milligrams of pure water per liter of jet gas. It should be noted that the addition of medications of any type to the water can of course alter the surface tension and will have a pronounced effect on rates of aerosol generation.

The above-described embodiment of the invention is intended to be merely exemplary, and those skilled in the art will be able to make numerous variations and modifications of it without departing from the spirit and scope of the invention. All such variations and modifications are intended to be included within the scope of the invention as defined in the appended claims.

I claim:

1. A nebulizer for generating an aerosol using pressurized gas, comprising:

a housing having a reservoir containing material to be nebulized, said housing having an inlet, and nebulizing means mounted to said housing in fluid communication with said inlet and said reservoir and having jet power means for receiving pressurized gas through said inlet and transmitting a high-velocity gas jet, having tension means in front of said jet power means, having mixing means between said jet power means and said tension means, and having a space between said jet power means and said mixing means for said material to be drawn into the space between said jet power means and said mixing means, said tension means contiguous with said mixing means forming a restrictive passage therebetween for depositing the mixed gas and material solely on a first portion of said tension means causing the deposited mixture to move over the surface of said tension means to a second portion thereof at which point the tendency to move further and the surface tension of the mixture cause the mixture to atomize into aerosol particles of a predetermined size range minimizing unwanted small and large heavy particles.

2. The nebulizer of claim 1, wherein said mixing means has an orifice and a single recessed cavity on the exit side of said orifice enabling said gas and material to flow into said restrictive passage.

3. The nebulizer of claim 1, wherein said jet power means, said mixing means, and said tension means are slidably aligned with each other to facilitate assembly and disassembly as well as accurate alignment thereof.

4. The nebulizer of claim 1, including pressurized gas supply means slidably mating with said jet power means and pressing said jet power means against the inside wall of said inlet forming an air tight fit between said inlet, said jet power means, and said gas supply means.

5. A nebulizer for generating an aerosol using pressurized gas, comprising:

a housing having an outlet for the discharge of the aerosol and an inlet aperture;

a supply tube coupled to the source of pressurized gas and said inlet aperture;

a reservoir mounted to said housing for containing the material to be nebulized; and

an aerosol generating subassembly within said housing including,

a power jet piece having an inlet section coupled to said supply tube at the inlet aperture for receiving said pressurized gas and a primary orifice for the gas to exit therefrom,

a cap piece having a secondary orifice and a recessed cavity on the exit side of the secondary orifice including a rim-like surface, said cap piece being mounted on said power jet piece such that a chamber is formed between said orifices which is connected to the material to be nebulized, and

a target piece mounted in alignment with said cap piece and having a target surface with a portion thereof being in close proximity to the rim-like surface forming a restrictive passage such that the material to be nebulized is uniformly deposited on said target surface as it passes through the restrictive passage and is spread over the target surface prior to separating from the target surface in the form of an aerosol,

the housing further including a planar surface contiguous to the inlet aperture and two housing guideways on opposite sides of the housing,

the power jet piece inlet section including a shoulder for aligning said power jet piece against the planar surface of the housing, and

the target piece further including two wing plates for locating said target piece against the housing guideways.

6. A nebulizer for generating an aerosol using pressurized gas, comprising:

a housing having a reservoir containing material to be nebulized, said housing having an inlet, and nebulizing means mounted to said housing in fluid communication with said inlet and said reservoir and having jet power means for receiving pressurized gas through said inlet and transmitting a high-velocity gas jet, having tension means in front of said jet power means, and having mixing means between and spaced from said jet power means and said tension means and having the center point thereof aligned with the center point of said jet power means and said tension means, said housing including a planar surface contiguous to said inlet and two housing guideways on opposite sides of said housing,

said power jet means including a shoulder for aligning said power jet means against said planar surface, and

said tension means including two wing plates for locating said tension means against the housing guideways.

7. A nebulizer for generating an aerosol using pressurized gas, comprising:

a housing having a reservoir containing material to be nebulized, said housing having an inlet, and nebulizing means mounted to said housing in fluid communication with said inlet and said reservoir and having jet power means for receiving pressurized gas through said inlet and transmitting a high-

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velocity gas jet, having tension means in front of said jet power means, and having mixing means between and spaced from said jet power means and said tension means and having the center point thereof aligned with the center point of said jet power means and said tension means, said housing having guideways, said mixing means having guideways, said tension means fitting between said housing and tension means guideways for proper alignment and to enhance the rigidity of said nebulizing means. 5 10

8. A nebulizer for generating an aerosol using pressurized gas comprising

- a housing having an outlet for the discharge of the aerosol, an inlet aperture, a planar surface contiguous to said aperture, and two housing guideways on opposite sides of the housing and removed from said planar surface, 15
- a supply tube coupled to the source of pressurized gas and said inlet aperture; 20
- a reservoir mounted to said housing for containing the material to be nebulized; and
- an aerosol generating subassembly within said housing including, 25
- a power jet piece having an inlet section coupled to

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said supply tube at the inlet aperture for receiving said pressurized gas, said inlet section including a shoulder for aligning said power jet piece against the planar surface of the housing, and a primary orifice for the gas to exit therefrom, a cap piece having, a secondary orifice, a recessed cavity on the exit side of the secondary orifice including a rim-like surface, and guideways on the exit side of the secondary orifice, said cap piece being mounted on said power jet piece such that a chamber is formed between said orifices which is connected to the material to be nebulized, a target piece designed to snugly fit between the housing guideways and cap piece guideways for proper alignment and to enhance the rigidity of the aerosol generating subassembly, and having a target surface with a portion thereof being in close proximity to said rim-like surface forming a restrictive passage such that the material to be nebulized is uniformly deposited on said target surface as it passes through the restrictive passage and is spread over the target surface prior to separating from the target surface in the form of an aerosol.

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