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 [33] **Great Britain**
 [31] **6744/66**
Continuation-in-part of application Ser. No.
614,904, Feb. 9, 1967, now abandoned.

[56]

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[54] SPRAY NOZZLES

9 Claims, 24 Drawing Figs.

[52] U.S. Cl..... **239/543,**
 239/337, 239/434, 239/579
 [51] Int. Cl..... **B05b 1/26**
 [50] Field of Search..... 239/543,
 544, 426, 434, 306, 573, 579, 490, 491, 493, 337;
 222/547

ABSTRACT: A spray nozzle for the spraying of liquid particles, comprising a plurality of converging jet-forming passages for directing the flow of fluid, wherein a cavity is positioned at the location of the convergence of said passages. The nozzle opening for expelling the converging streams of fluid is formed at substantially the point where the axes of the jet-forming passages intersect or, in the case where the axes do not intersect, at substantially the point where the axes intersect if the axes are projected onto a plane in which one of the axes is located.

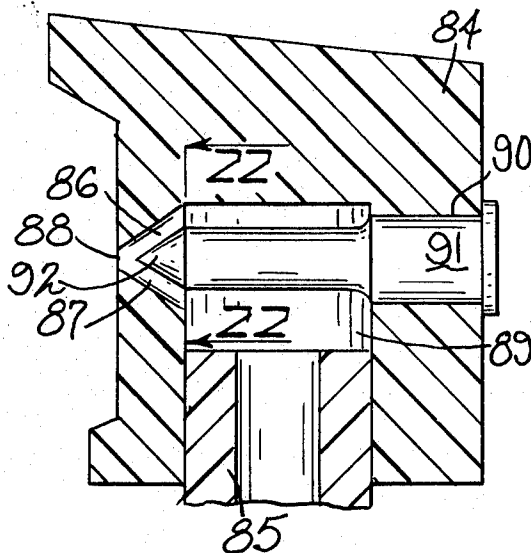


Fig. 1.

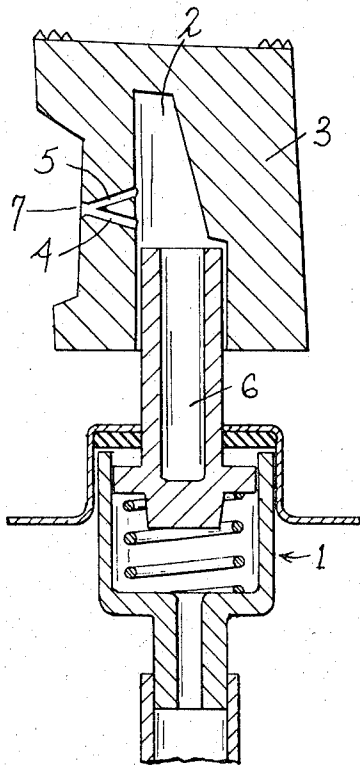


Fig. 2.

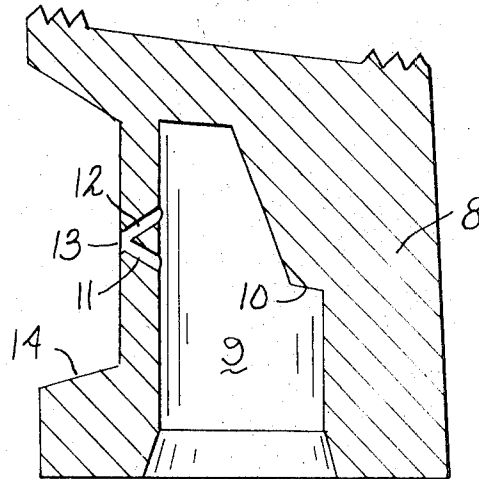


Fig. 3.

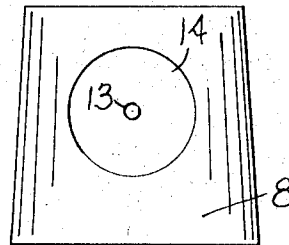


Fig. 4.

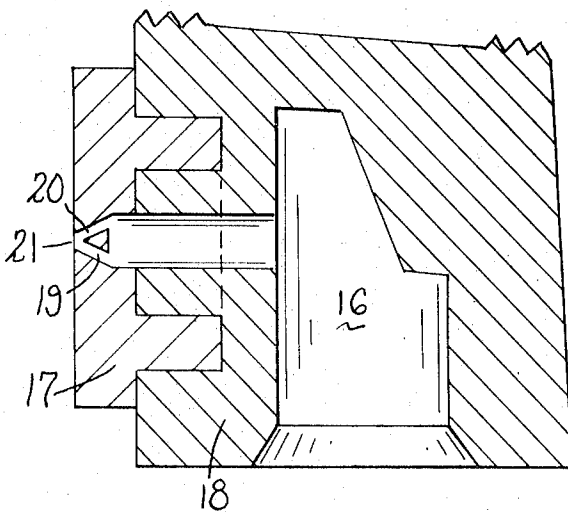
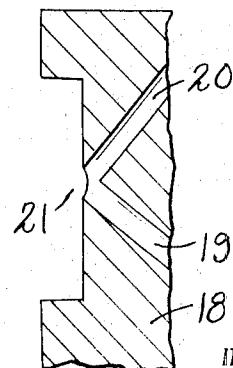


Fig. 5.



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Fig. 6

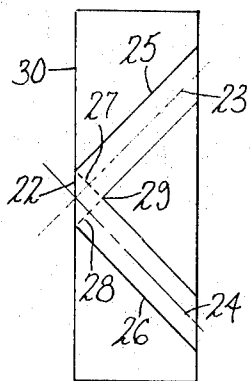


Fig. 7

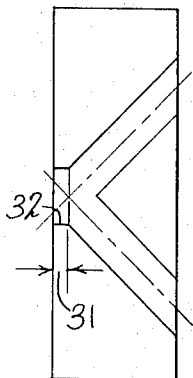


Fig. 8

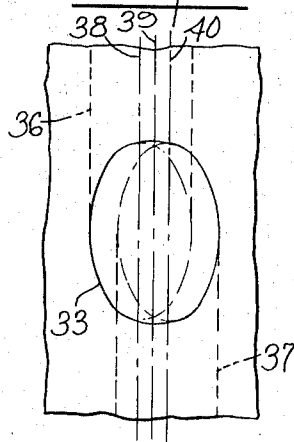


Fig. 9

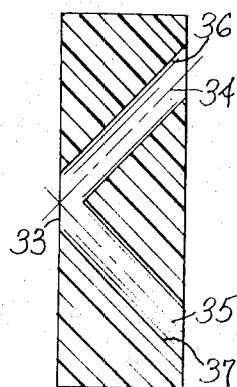


Fig. 10

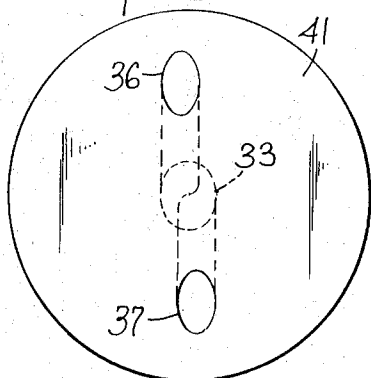


Fig. 11

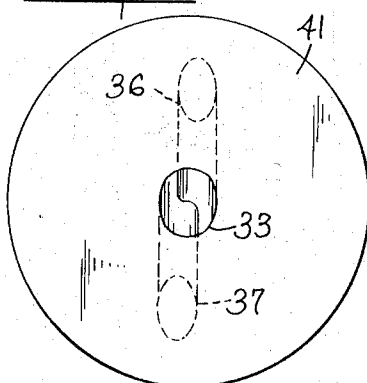


Fig. 12

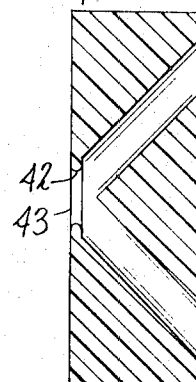


Fig. 13

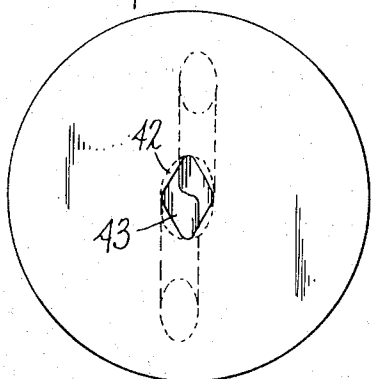


Fig. 14

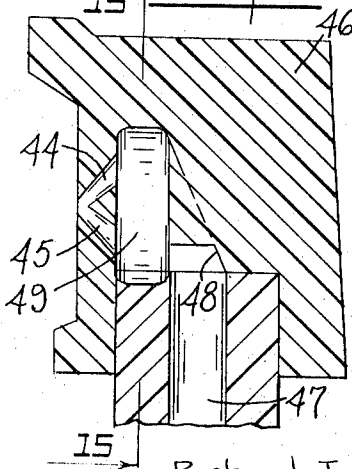
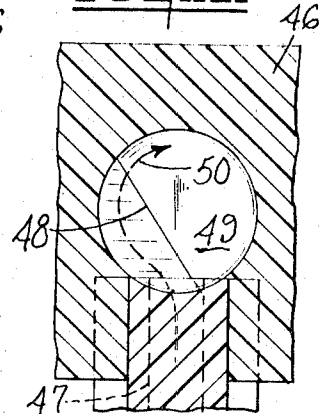


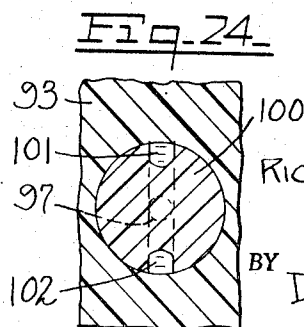
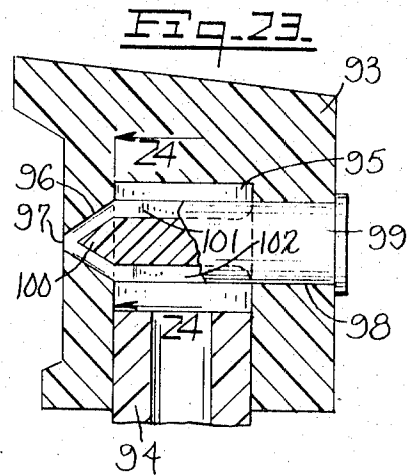
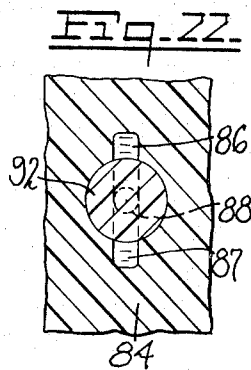
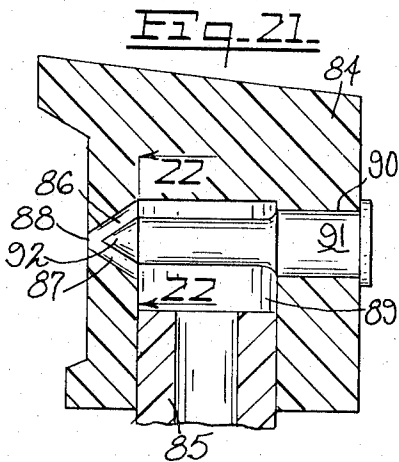
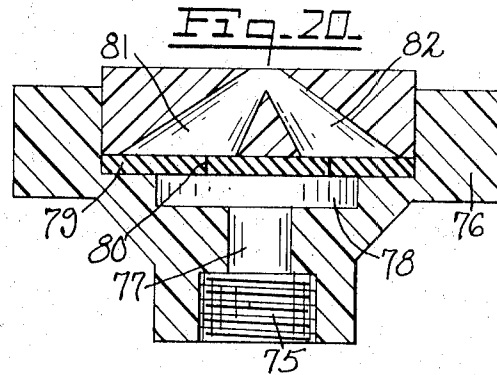
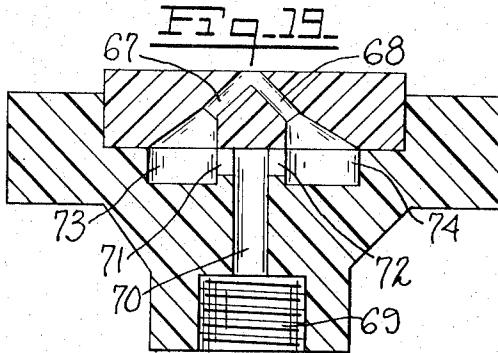
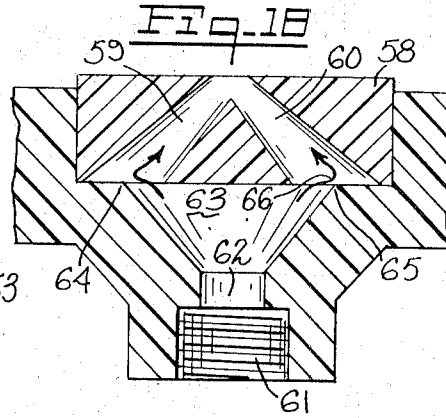
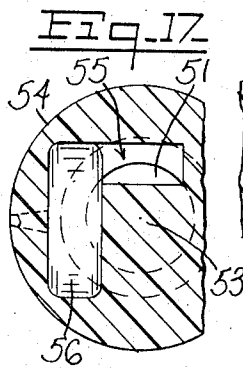
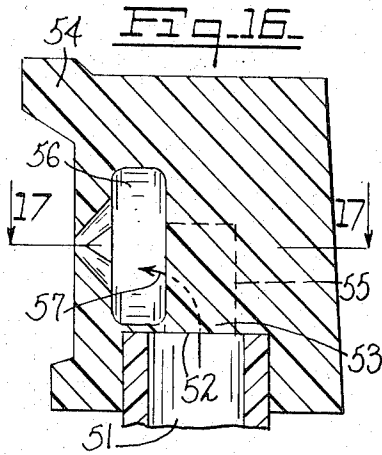
Fig. 15



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SPRAY NOZZLES

This is a continuation-in-part of application Ser. No. 614,904 filed Feb. 9, 1967, now abandoned.

This invention relates to the construction of nozzles which break up a stream of fluid into a fine spray and, in particular, to nozzles which may be used in association with discharge control devices on pressure packaged systems such as aerosol packages.

The nozzle system which forms this invention may be described as a mechanical breakup system even though the mechanism of the breakup process is partly a process which is effected by the movements and properties of the fluid stream and its environments.

In the present invention the nozzle may be formed as a part of the valve or discharge control mechanism, through which the fluid will pass, or may be formed as a special, separate member connected with or associated with the said valve mechanism.

Such mechanical breakup nozzles are of great importance in pressure packaging systems since, by their use, smaller quantities of propellents or lower pressures in such systems are possible. At the present time, mechanical breakup spray nozzles are of such complex configuration as to be difficult and costly to manufacture and utilize in large numbers. These disadvantages are of great importance in the field of consumer goods such as aerosols, where the end product price has to be kept as low as possible.

In such aerosol packages, it is often required to produce a spray formed of a large number of fine particles of a formulation and this is often effected by the discharge of fluids combined with or composed of fluids which are described as "low boiling point liquids" which provide a source of pressure inside a container in association with the fluids to be discharged.

Current products tend to utilize formulations containing a larger amount of fluids which are nonvolatile at room temperatures and it is for this reason that there is a need for a mechanical breakup spray nozzle of simple configuration which can be produced in large quantities at low cost.

In such current formulations, the discharge pressure is produced by the introduction of charges of compressed gas into the container, or by the incorporation of a low boiling point liquid such as liquid butane (L.P.G.). In most mechanical breakup spray nozzles the spray is formed by both mechanical and physical forces, often assisted by the simultaneous vaporization and expansion of liquid or gaseous propellents which may pass into the nozzle. Such a process is automatic and the discharge and spray production are controlled by the valve mechanism associated with the pressure package or aerosol.

At the present time, most mechanical breakup spray nozzles utilize a swirl chamber or similar system, wherein the fluid to be sprayed is made to move in a circular movement and this then passes through a small orifice, which process shears off the stream of fluid into a large number of fine particles caused by the breakdown of a conical sheet of fluid under the influence of surface tension and other effects. The swirling system of spray production suffers from the disadvantage that a hollow cone of spray particles is produced, with the size of the hollow center of the spray formation being a function of the internal pressure of the container, this effect being due to the centrifugal forces exerted inside the swirl chamber and the resultant centrifugal moment acting in the stream of fluid.

The present invention relates to a means of producing a more efficient spray by a process incorporating the impingement of a number of jets of the fluid to be sprayed. This invention further relates to a method whereby the mechanical simplicity of the impinging jet layout and construction is improved, so as to produce a system of spray production more effective and more suitable to the production of aerosol-type sprays than the swirl production method.

Accordingly, it is an object of the present invention to produce a new and improved spray nozzle for use in pressurized packaging systems and other spraying applications

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which will allow more effective spray production even when low pressures are used and will allow the production of a wide range of particle sizes and velocity and momentum to be produced from a nozzle which may be constructed at low cost and with mechanical simplicity.

Another object of the invention is to provide a new and improved spray nozzle which will produce a triangular spray flow pattern.

A further object of the invention is to provide a new and improved spray nozzle which will produce a three-peak spray flow pattern.

Still another object of the invention is to provide a new and improved spray nozzle which will produce a constant mass spray flow pattern.

This invention also relates to how such nozzles will lose less energy in the process of spray formation than the nozzles utilizing just the swirl system. As will be pointed out later, swirling action may be imparted to the fluid passing to the converging jet-forming passages.

According to the present invention, the spray nozzle comprises a nozzle head member formed from any suitable material, i.e. plastic, which will be associated with a discharge control system and with the source of the fluid movement. The source of fluid may, with advantage, take the form of an aerosol or other pressurized package and this invention does not preclude the use of a number of nozzles being associated with the source of the fluid movement. The nozzle head is formed such as to incorporate a central chamber or passage which will act as a main feed passage for the flow of fluid to be sprayed, and which will be in connection with the discharge control system. This central main feed chamber may be disposed at any suitable position inside the nozzle head and may, with advantage, project further into the mass of the nozzle to form one or more feed passages or chambers or such cavities.

A central feed chamber or expansion chamber in the nozzle head is desirable since it imparts desirable turbulence to the fluid so as to aid in the mechanical breakup of the converging fluid streams. The central feed chamber or any of its projections, is connected to the exterior of the nozzle body by two or more jet or stream-forming passages which merge into a common cavity prior to opening out to the exterior of the nozzle. By such a configuration, the fluid to be discharged from the nozzle will flow into the central main feed chamber or any of the projections thereof and will then pass into the jet or stream-forming passages which converge to a common point immediately before a common point of entry into a cavity formed in the exterior surface of the nozzle head. By this process, the jets or streams of fluid will be formed and will be directed closely to a point of impingement prior to the spray sheet being passed into the cavity on the exterior surface of the nozzle. The configuration of the nozzle required to promote this process can be produced in one piece, as a single member, or can be formed by the combination of two or more separate components.

It is an important feature of this invention that the process of impingement takes place within the confining walls of the nozzle body. The walls of the cavity in the exterior of the nozzle serve to confine and form the shape and thickness of the sheet of fluid which forms the spray produced by the device. The manner in which the nozzle opening is formed, which is a basic part of the present invention, will now be explained.

The nozzle opening is formed at substantially the point where the axes of the jet-forming passages intersect. In the case where the axes of the jet-forming passages do not meet or intersect, that is, misalignment, the nozzle opening is formed at the point where the axes of the jet-forming passages would intersect if the axes were projected onto the plane in which one of the axes is located.

Further, the impingement cavity is basically defined by the junction of the jet-forming passage walls that meet and the extension of the jet-forming passage walls that meet and the extension of the jet-forming passage walls that do not meet to the

vertical plane of the nozzle opening. This nozzle configuration produces triangular or parabolic spray flow pattern. However, it can be easily varied, as will be explained, to produce two-peak, three-peak and constant mass flow spray patterns.

With respect to the sprays formed, it is noted that triangular spray patterns are the common type, where the greater part of the fluid flow is concentrated in the center of the pattern. With such sprays, if a uniform coating is desired, the sprays have to be overlapped, either by the use of a further spray coating or by using several nozzles on a common boom. Such nozzles are useful only when it is desirable to spray evenly a small area, or where an even spray coating is not necessary. In this respect, parabolic spray patterns are less desirable since the edges of the spray have a very thin coating.

The two-peak spray pattern is of interest when the spray is to be projected at high velocity over a distance. In this spray pattern the spray is concentrated at the edges of the spray pattern. As a result, the outer rim of the spray pattern which is sprayed at high velocity, is thinned out by air resistance. Thus, if extra fluid is concentrated at the edges of the spray, as in the two-peak system, the dilution of the outer edges of the spray by air resistance takes place and the actual spray striking the surface is of uniform mass.

Three-peak spray patterns are of importance when the sprays are to be projected at high velocities over a distance. Such sprays have fluid concentrated in the center of the pattern and at the outer edges of the pattern. If such spray flow patterns are projected at high velocities, they tend to merge their fluid concentrations due to air resistance, such that a constant mass flow pattern strikes the surface to be coated.

The most important and advantageous spray flow pattern is the constant mass flow pattern. A constant mass flow pattern will provide a uniform coating of a fluid on the surface to which the sprays are directed. Thus, with this type of spray, there is no need for overlapping the sprays to produce a uniform coating. This results in a saving of time and spray material. It should be noted that when mention is made in this application to "spray flow pattern," it refers to the fluid concentration of the spray in a plane parallel to the plane of the nozzle opening and not to the shape of the spray.

In addition to the type of spray formed, it should be noted that the spray nozzle of the present invention has the further advantage that it produces particles of substantially uniform size. This substantial uniformity of particles is obtained when the angle of impingement is between 35° and 145° and is most marked at low pressures. Thus, at low pressures, substantially uniform large-size particles are produced. Such particles are particularly desirable in crop spraying.

The mechanism of spray formation will now be described with particular reference to the invention.

Fluid enters the body of the spray nozzle from a connecting passage which may be associated with the discharge control system of a source of fluid. The fluid passes into a central chamber and may pass through projections of this central chamber, which may take the form of passages, hollow shafts or chambers, and then passes into two or more jet or stream-forming passages which converge at a point inside the body of the nozzle. The point at which these passages converge is defined by the angle at which the jet-forming passages impinge or are so disposed to one another. The jets of fluid impinge and form a sheet of fluid which forms the basis of the mechanism of spray production. This spray sheet is confined and shaped by the walls of the cavity opening out to the exterior of the nozzle and the confining of the shaping process plays an important part in the next process, the breakdown of the sheet into fine particles.

As the spray sheet is produced, it is subjected to a series of complex dynamic forces which take the form of aerodynamic and hydrodynamic shock waves which, combined with surface tension, serves to break the spray sheet down into a large number of fine particles and, thus, to produce a spray. The action of the shock waves upon the spray sheet has been investigated in relation to this invention and it has been found

these shock waves cause the spray sheet to flutter. It is this flutter which promotes the breakup of the spray sheet into a mass of fine particles. The actual process of spray formation is complex but it has been found that, initially, there is produced a spray sheet characterized by a raised rim which, as the pressure rises in the device upon actuation, breaks up into a fine spray.

Another advantage of this invention is that, while changes in jet diameter and length have little effect upon the spray formation process, it has been found that changes in jet velocity have a marked effect upon the shock wave formation (approximately 32 cycles/sec. per increase of each ft./sec. in velocity). Thus, there are marked advantages in limiting the length of the jet-forming passages. The construction of this invention allows the production of large angles of impingement and this is important since the Weber Number is dependent upon the square of the angle of impingement. Particle size is critically dependent upon the Weber Number, so that large angles of impingement are required to produce a large number of fine particles.

A further advantage of this invention is that random particle formation is arrested. In systems utilizing open impingement, i.e. jets impinging away from the nozzle, in common practice the formation of random particles interferes with the spray sheet and subsequent spray patterns.

It has been found that, in any impingement system, the degree of turbulence in the fluid jets or streams, immediately prior to impingement, has beneficial effect upon the spray formation. It is a feature of this invention that a controlled degree of turbulence can be given to the jets or fluid streams prior to impingement by variations in the configuration of the feed of jet-forming passages. The present invention indicates a method of producing fine sprays, independent of the exact physical nature of the formulation to be sprayed and it has been found that the higher the viscosity, the more the spray pattern becomes distinct, though in nozzles utilizing a degree of induced turbulence, the higher the Reynolds Number, the greater the degree of turbulence which could be induced, with the resultant production of finer sprays.

Accordingly, the present invention has the following advantages over normal jet impingement system nozzles wherein the impingement process takes place in the open, i.e. outside any nozzle body:

1. Random particles are arrested. With open impingement systems, random particles cause small droplets to form, which interfere with the breakup mechanism.

2. The form of the cavity in this new nozzle can be such that a limited degree of impingement can take place within the cavity and the shape of this cavity can be such as to control spray patterns. It has been found that the distribution across the spray pattern can be made almost uniform, triangular, or even trapezoidal, if necessary.

3. Greater manufacturing tolerances can be allowed in the nozzle of this invention, as the cavity tends to smooth out any irregularities in jet form.

4. Increased turbulence can be effected in the nozzle of this invention by offsetting jets prior to impingement.

5. The jet length before breakup on this new nozzle is shorter than in any external impingement of the prior art, so that energy losses are minimal. Particle velocity is thus found to be higher, so that lower pressures can be used in spray production.

6. It is important that the jet angle is wide, if small particles of spray are required. While angles of impingement may vary in the construction of this invention, between about 30° and 160°, according to requirement, the larger angles of impingement will produce finer and more uniform sprays. It has been found that large angles of impingement can be more easily accommodated, according to the present invention, since random particle formation is overcome.

7. The shape of spray flow pattern can be controlled. The basic nozzle configuration will produce a parabolic or triangular spray flow pattern. However, the basic nozzle configura-

tion can be modified slightly to produce a two-peak, three-peak, or constant mass spray flow pattern.

The present invention will now be illustrated by reference to the accompanying drawings, in which:

FIG. 1 is a sectional view of a spray nozzle according to the invention, shown coupled to the stem of a discharge control device;

FIG. 2 is another sectional view of a nozzle according to the invention;

FIG. 3 is a front elevational view of the nozzle according to the invention;

FIG. 4 is a sectional view of an alternate embodiment according to this invention;

FIG. 5 is another sectional view of a further alternate embodiment according to the invention;

FIG. 6 is a sectional view showing in detail the formation of the nozzle opening;

FIG. 7 is a sectional view of a modification of the nozzle of FIG. 6;

FIG. 8 a front view of an alternate embodiment of the nozzle of this invention;

FIG. 9 is a sectional view of the nozzle of FIG. 8;

FIG. 10 is the back view of the nozzle section of FIG. 9;

FIG. 11 is the front view of the nozzle section of FIG. 9;

FIG. 12 is a sectional view of a modification of the nozzle of FIG. 8;

FIG. 13 is a front view of the nozzle of FIG. 12;

FIG. 14 is a sectional view of a further embodiment of the nozzle with the use of an expansion chamber;

FIG. 15 is a view taken along line 15-15 of FIG. 14;

FIG. 16 is a sectional view of the nozzle of this invention with the use of an expansion chamber and turbulence-inducing means;

FIG. 17 is a view taken along line 17-17 of FIG. 16;

FIG. 18 is a sectional view of the nozzle of this invention with the use of an expansion chamber;

FIG. 19 is a sectional view of the nozzle of this invention with the use of swirl chambers;

FIG. 20 is a sectional view of the nozzle of this invention with the use of an expansion chamber and turbulence-inducing means;

FIG. 21 is a sectional view of the nozzle of this invention wherein it is formed from two members;

FIG. 22 is a view taken along line 22-22 of FIG. 21;

FIG. 23 is a sectional view of the nozzle of this invention wherein it is formed from two members; and

FIG. 24 is a view taken along line 24-24 of FIG. 23.

Referring to FIG. 1, there is illustrated a nozzle according to the invention, with the nozzle head 3 mounted in sealing engagement upon a hollow stem 6 of a discharge control device such as an aerosol valve 1. The head 3 has formed therein a chamber 2 with its further projection into the nozzle body and a stop to limit movement of the stem further into the nozzle body formed therein. The nozzle body has a cutback recess formed in the area adjacent the discharge orifice 7. The orifice 7 takes the form of the cavity in which the jets totally or partially impinge and in which the spray sheet is formed. A plurality of jet or fluid stream-forming passages 4 and 5 connect the cavity 7 with the chamber 2. The pressure of chamber 2 induces desirable turbulence to the fluid, such that the mechanical breakup of the converging fluid streams is promoted.

FIG. 2 is again a section through a nozzle, with the central feed passage 9 limiting movement of stop 10 formed in the head 3. The cutback or recess in the front of the nozzle is shown at 14 and 13 is the cavity formed in the nozzle exterior surface and connecting to the interior of the nozzle and central feed passage by the jet or fluid stream-forming passages 11 and 12.

Thus, fluid under pressure enters the nozzle head 3 by means of the central feed passage 9 and from there it passes to the jet or stream-forming passages 11 and 12, wherein a number of jets or fluid streams are forming and moving toward the exterior of the nozzle under pressure accruing from the

fluid source. The jets or fluid streams impinge in the area adjacent to the point at which the jet or stream-forming passages converge and this area includes the adjacent part of the cavity opening out to the exterior of the nozzle and part of the converging stream or jet-forming passages. A spray sheet is formed in the cavity, which then breaks up according to the influence of aerodynamic and hydrodynamic shock waves and a complex flutter mechanism to form a spray of fine particles.

FIG. 3 presents a view of a nozzle with the discharge orifice formed in a round shape as distinct from the more usual compound elliptical shape.

FIG. 4 illustrates the nozzle assembled from two components, with 18 being the main nozzle head and 17 representing the component incorporating the jet or fluid stream-forming passages 19 and 20 and the discharge orifice and cavity 21. In this embodiment, a projection of the central chamber 16 allows the movement under hydraulic pressure of a fluid stream into another chamber and from there to the jet or stream-forming passages formed in the spray insert component.

In this embodiment of the invention, provision is made for a retention of the spray insert component in the sealing contact with the main nozzle body.

Referring now to FIG. 5, there is represented a section through the spray-forming part of a nozzle according to the invention, wherein two jet or fluid stream-forming passages converge at a wide angle to give a wide angle of impingement, and wherein the entrance to the exterior wall cavity of the nozzle is of limited size to define the spray pattern produced by such nozzle.

This FIG. illustrates the nozzle head wall 18, the stream or jet-forming passages 19 and 20 and the discharge orifice and exterior opening cavity 21. It should be understood that, according to this invention, it is preferable that the plurality of jet streams converge at any suitable angle from about 30° to about 160° with respect to each other. This angle of impingement will produce the most efficient mechanical breakup of the particles. However, as pointed out previously, in order to obtain substantially uniform-size particles, it is preferred that the angle of impingement of the jet streams vary between 35° and 145°.

FIG. 6 is a sectional view showing in detail the formation of the nozzle opening of the invention. As can be seen, the nozzle opening of the invention 22 is defined in the vertical plane where the axes 23 and 24 of the jet-forming passages 25 and 26, respectively, intersect. This is the common denominator of the nozzle openings of all the embodiments of the present invention. It should be understood, however, that for the purposes of this invention, the nozzle opening is substantially in this plane. The internal sides of the opening do not necessarily have to lie at exactly the point where the axes of the jet-forming passages intersect. In particular, the plane of the opening can be a small, incremental distance to the left of this point. Further, the cavity which is defined by dotted lines 27 and 28 and the plane of opening 22 is formed by the junction of the walls of the jet-forming passages so as to form junction 29 and the extension of the walls of jet-forming passages 25 and 26 to substantially the vertical plane of the opening. It is particularly important that the junction 29 be a point, that is, it should not be flattened out or counterbored since undesirable turbulence will result and a random spray pattern will be produced whose shape cannot be controlled.

Further, in all the embodiments of the nozzle of this invention, the external sides of the nozzle opening lie on a flat surface 30. This is necessary since a flat surface will not effect the particular formation or spray flow pattern. However, it is to be understood that, according to the present invention, the external sides of the nozzle may also lie on a convex surface or on a member protruding from the nozzle head, so that the spray formation will not be affected. However, a closely concave surface is undesirable since it affects the spray formation and spray pattern.

It has been noted that the nozzle opening is defined by dotted lines 27 and 28. For the purposes of this invention, it

should be understood that the external limits of the nozzle opening will be determined substantially by the extension of the walls of the jet-forming passages to the plane of the opening. However, as will be pointed out later, the opening may be of a smaller size. The reason for having the opening at substantially the point where the passages intersect, is to have internal impingement of the converging fluid streams. This results in a better mechanical breakup of the fluid, which was discussed previously, the production of fluid particles of uniform size and, most important, control over the type of spray flow pattern formed.

For the above reasons, it is also necessary to have the external limit of the size of the nozzle opening substantially that defined by the extension of the sides of the passages to the plane of the internal sides of the nozzle opening. If the opening is substantially larger, random-size particle formation will result as well as poor mechanical breakup of fluid streams and irregular spray flow patterns.

With this type of nozzle opening, parabolic spray flow patterns are formed, that is, patterns in which the fluid flow is concentrated at the center of the spray.

With respect to the breakup mechanism in an impinging jet nozzle of the type discussed above, having jet-forming passages of circular diameter, it has been found that the breakup is critically dependent upon the parameter expressed as

$$\frac{P d V^2 \sin^2 \phi}{N}$$

wherein P = the liquid density

V = velocity of the fluid in the jet-forming passages

Φ = half the angle of impingement

N = surface tension

d = jet diameter

For such a nozzle, the fluid particle size formed can be determined by the formula

$$\text{Particle size} = \frac{4}{V^{0.79} \sin^{1.16} \phi} \quad \text{C.G.S. units}$$

Referring now to FIG. 7, it is seen that the thickness of the nozzle opening has been increased by a distance 31, which may also be represented by the value of μ . Thus, if it is desired to obtain an ideal triangular flow pattern for a given efflux angle, the value μ can be determined from the formula

$$\text{Efflux angle} = 2\lambda \left(\phi - \tan^{-1} \left(\frac{\mu \sin \phi \sin 2\phi}{d + \mu \cos \phi \sin 2\phi} \right) \right)$$

where λ is a constant dependent upon liquid viscosity. In most cases the ratio of μ/d for circular jet-forming passages will vary from 0 to .2. As can be seen, this is a very small value. This, the value μ does not have to be very large, so that the nozzle will form an ideal triangular spray flow pattern. An ideal triangular spray flow pattern is desirable over the parabolic pattern, in that there is a more uniform coating of fluid sprayed onto a surface. However, if the value of μ , that is, the thickness 31 of the wall 32 is increased, such that the ratio μ/d is in the range of .2 to .3, a two-peak spray flow pattern is produced. If the thickness 31 of wall 32 is further increased, such that μ/d is generally in the range of .3 to .5, a three-peak spray flow pattern will be produced. If the wall thickness 31 is again increased, such that μ/d is within the range of .5 to 1.0, then a constant mass flow pattern will be produced.

It is to be understood that the above values relate to circular jet-forming passages, having diameters in the range of .05 to .25 inches and impinging at angles in the range of 35° to 140°. Although the above comments have been made with reference to circular jet-forming passages, it should be further un-

derstood that the above principles also apply to jet-forming passages having other cross sections such as elliptical or rectangular. For such passages, however, the above values will not apply and the necessary thickness of the nozzle opening will have to be determined by simply increasing the thickness of the nozzle opening until the desired flow pattern is obtained.

It can be seen from FIG. 7, that the size of the nozzle opening is uniform, from the internal to the external sides of the opening. This is desirable since it allows good mechanical breakup of the fluid streams so as to form uniform size particles without inducing undesirable turbulence, while the thickness 31 of wall 32 determines the type of spray pattern formed. Thus, the spray flow pattern can be affected so as to change it from parabolic to triangular to three-peak to constant mass, by increasing the thickness of the wall 32.

It should also be understood that, for the purposes of the present invention, the jet-forming passages need not have the same diameter, although this is desirable.

Further, the shape of the nozzle opening of FIGS. 6 and 7 will be oval because of the circular cross section of the jet-forming passages. This will produce a spray having a generally oval shape in a plane parallel to the plane of the opening. However, the opening does not have to be so formed for the purposes of this invention, as will be explained below.

Additionally, the type of flow spray pattern formed can also be determined by reducing the size of the nozzle opening with a lip, as will be explained later in connection with FIGS. 12 and 13.

It has been found that good mechanical breakup of the fluid particles and wide efflux angles are obtained when the jet-forming passages are slightly misaligned, as shown in FIGS. 8-11. Again, the illustrations are with respect to circular passages but the principles discussed will apply to any other type of passages. By the term "misalignment," it is meant that the axes of the jet-forming passages do not actually intersect at the nozzle opening. Thus, the nozzle opening in this case is formed at the point the axes intersect if they are projected onto a vertical plane. This can be clearly understood by referring to FIG. 9, where it is seen that the nozzle opening 33 is formed at the point where the axes 34 and 35 seem to intersect. In all other respects the nozzle opening 33 is formed at the point where the axes 34 and 35 seem to intersect. In all other respects the nozzle opening is formed as explained with reference to FIGS. 6 and 7.

In FIG. 8, there is indicated the major axes of the ellipses formed by the jet-forming passages and the nozzle opening in the vertical plane of the side of the nozzle head. The two jet-forming passages, 36 and 37, converge to the nozzle opening. At the plane of the nozzle opening, the major axis 38 of the ellipse formed by passage 36 is to one side of the major axis 39 of the ellipse of the opening. Further, the major axis 40 of the ellipse formed by passage 37 is on the other side of axis 39. In the embodiment of FIGS. 6 and 7, all three major axes would merge. The misalignment referred to previously is the distance between axes 38 and 40. Where this distance (or misalignment) is less than 10 percent of the converging passage diameter, the spray pattern will be triangular. It should be understood that, in the case of circular passages, where the diameters of the jet-forming passages are not equal, reference would be to an average diameter. If it is desired to produce a constant mass flow spray pattern, then the value of the following ratio will have to be between .35 to .50:

the shortest distance between the axes of the passages

$$\sqrt{\frac{A_1}{\lambda}} + \sqrt{\frac{A_2}{\lambda}}$$

wherein A_1 and A_2 are the cross-sectional area of the jet-forming passages at the point of impingement of the converging fluid streams. The shortest distance between the axes is the distance between axes 38 and 40. As can be seen, the rim of the opening is formed by the extension of the walls of the jet-

forming passages at the points they do intersect to substantially the plane of the internal side of the opening, as with the nozzle of FIGS. 1—7.

FIGS. 10 and 11 illustrate the back and front of the nozzle member 41 in which the nozzle of FIGS. 8 and 9 is located. This nozzle piece fits into a nozzle head, such as explained in connection with FIGS. 3 and 4. As pointed out previously, the nozzle opening and the jet-forming passages of the present invention may be formed in a one-piece nozzle head. They may also be formed or molded in a single plastic piece, as shown in FIGS. 10 and 11, which piece is inserted into position on a nozzle head. As will be explained later, the nozzle of this invention may also be formed from two members.

With respect to FIGS. 8—11, if the misalignment is less than 10 percent of the jet diameter, such that the spray flow pattern is triangular, the spray pattern may be formed into a three-peak spray pattern or a constant mass flow pattern as explained in connection with FIG. 7, by increasing the thickness of the nozzle opening. Another way of doing this is shown in FIG. 12. This FIG. shows the formation of lip 42 on the nozzle of FIGS. 8—11, which restricts the size of the nozzle opening. The lip need not be entirely about the nozzle opening, but may be just partially about the nozzle opening. Such a lip may also be used to form nozzle opening 43 into a diamond shape, as shown in FIG. 13. Thus the spray, in a plane parallel to the plane of the opening, would have a diamond shape. It is to be understood that a lip such as shown in FIG. 12 may also be used in the nozzle configuration of FIG. 6 in place of extending the thickness of the nozzle opening, as in FIG. 7. In general, a lip having a small thickness is formed so as to restrict the cross-sectional area of the nozzle opening by 1—5 percent in order to change the triangular flow pattern to a two-peak flow pattern. Further, the cross-sectional area of the nozzle opening is restricted by 5 percent to 40 percent to produce a three-peak spray flow pattern. If it is desired to produce a constant mass flow pattern, the cross-sectional area of the nozzle opening should be restricted by 40 percent to 50 percent for circular passages. It should be understood that the above values were determined for circular jet-forming passages having diameters of .05—.25 inches and impinging at angles of 35°—140°. However, the above principles apply to other types of jet-forming passages.

Still another embodiment of the nozzle is shown in FIGS. 14 and 15. In this embodiment, the nozzle opening is formed as in any of the embodiments of FIGS. 1—13. However, in the embodiment of FIGS. 14 and 15, the jet-forming passages 44 and 45 are tapered, and may be so tapered by forming small steps in the walls of the passages or the passages may be molded smoothly tapered. The tapering of the passages promotes additional turbulence in the fluid streams which then promotes the mechanical breakup of the fluid streams so that the nozzle opening will emit small, substantially uniform-size particles.

The nozzle head 46 of FIGS. 14 and 15 also includes turbulence-inducing means which introduces the fluid into the jet-forming passages in a highly turbulent state. The fluid passing through channel 47 in the valve stem strikes the edge 48 of the partition 49 whose shape is more clearly shown in FIG. 15. The edge 48 imparts a swirling motion to the fluid as it passes into expansion chamber 49, as shown by the arrow 50, such that it swirls about the axis of the nozzle opening. The swirling fluid then passes through the jet-forming passages where its turbulence is increased by the tapered passages. As has been stated, the increased turbulence produces greater mechanical breakup, which is desirable for the previously stated reasons.

FIGS. 16 and 17 illustrate a different type of turbulence-inducing means in the nozzle head 46. In this embodiment, the jet-forming passages are tapered. The fluid passes up channel 51 and strikes the edge 52 of partition 53 located in nozzle head 54. As a result, the fluid passes into an opening 55 which leads into expansion chamber 56 as shown by arrow 57. Thus, there is generally imparted to the fluid an eddy current turbulence in expansion chamber 56. Again, this imparts desirable turbulence to the fluid for increasing the mechanical breakup of the converging fluid streams.

FIG. 18 shows another means, located in the nozzle head 58, for inducing turbulence to the fluid stream passing into the tapered jet-forming passages 59 and 60, which aids in the mechanical breakup of the converging fluid streams.

It should be noted that, in the embodiment of FIG. 18 as well as the embodiments of FIGS. 19 and 20, the jet-forming passages and the nozzle opening are formed or molded in a single nozzle piece which fits onto the nozzle head 58. In FIG. 18, the fluid passes up feed channel 61, through constricted channel 62 into the expansion chamber 63 before flowing into the jet-forming passages 59 and 60. The flow of the fluid around corners 64 and 65, as shown by arrow 66, (which corners partially block the entrance to the jet-forming passages) creates a desirable turbulence which aids in the mechanical breakup of the converging fluid streams.

FIG. 19 illustrates another method for inducing a desirable turbulence to the converging fluid streams. It has been discovered that if swirl motion is imparted to the fluid streams, such that it swirls about the axes of the nozzle opening, such swirling action does not produce desirable turbulence in cases where the jet-forming passages are not tapered. Such swirling action in the case of nontapered jet-forming passages 67 and 68 produces undesirable turbulence which has little effect on the mechanical breakup of the converging fluid streams. Such swirling motion, that is, swirling motion about the axes of the nozzle opening, only produces desirable results when the jet-forming passages are tapered, as in the embodiments of FIGS. 14 and 15. When the jet-forming passages are not tapered, the swirling motion must be about the axes of the jet-forming passages in order to aid the mechanical breakup of the converging fluid streams. In FIG. 19, the fluid passes through feed channel 69 into the narrow channel 70. From narrow channel 70, it then passes the side passages 71 and 72 which lead into individual swirl chambers 73 and 74 which impart a swirling motion to the fluid about the axes of jet-forming passages 67 and 68. As previously indicated, this swirling motion results in more efficient mechanical breakup of the converging fluid streams.

Another means for inducing desirable turbulent action to converging fluid streams is shown in FIG. 20. The means illustrated in this FIG. is especially effective for viscous fluids. The fluid passes through feed channel 75 in nozzle head 76, into narrow channel 77. From narrow channel 77 it passes into expansion chamber 78 where it strikes a diaphragm 79 which is constructed of rubber or other resilient material. Under the force of gas pressure or other pressure in the container, to which nozzle head 76 is attached, the fluid is forced through slits 80 in diaphragm 79 into tapered passages 81 and 82. The use of the diaphragm provides desirable turbulence, which aids in the mechanical breakup of the converging fluid streams as they pass through the nozzle opening.

Another method of promoting desirable turbulence, is to pass the fluid through two or more passages which converge into a single passage, whereupon the single passage converges with another single passage, whereupon the single passage converges with another single passage to form the nozzle opening.

As pointed out previously, in the case where the jet-forming passages are tapered, the nozzle opening is formed in the same manner as any of the nozzle openings described with reference to FIGS. 1—13. As explained in connection with FIGS. 1, 2 and 14—17, the jet-forming passages and nozzle opening may be formed directly on the nozzle head which may be a one-piece member. However, as also indicated in connection with FIGS. 18—20, the nozzle opening and jet-forming passages may be formed in a separate one-piece member which is inserted into the nozzle head.

FIGS. 21—24 illustrate an embodiment where the nozzle opening and jet-forming passages are formed from two separate members. In FIGS. 21 and 22, the nozzle head 84 seats on valve stem 85. Slotted channels 86 and 87 formed in the nozzle head come together to form a nozzle opening 88 in the nozzle head. The nozzle head also has a chamber 89 and bore 90 in its end wall. Plug 91, having a forward conical sec-

tion 92, is fitted into bore 90, such that the conical section 92 abuts the sides of channels 86 and 87 so as to close them and form a pair of converging jet-forming passages.

In the embodiments of FIGS. 23 and 24, the jet-forming passages are in the plug member. The nozzle head 93 rests on valve stem 94, such that there is present a chamber 95. There is also formed in the nozzle head a conical bore 96 and nozzle opening 97. At the other end of the nozzle head 93 a bore 98 is formed for the insertion of the plug 99. The plug 99 has a conical section 100 at one end and slotted channels 101 and 102 which extend from the sides of the plug along the sides of the conical section 100 and converge to form a cavity at the center of the conical section. When the plug is inserted into place, such that the conical section presses against the bore 96, the sides of the converging slotted channels are closed to form converging jet-forming passages.

In FIGS. 21-24, the jet-forming passages are shown as having uniform diameters. However, two members may be used to form a nozzle opening and converging passages, in accordance with any of the embodiments discussed previously.

It should be noted that the method of forming the nozzle opening and jet-forming passages, illustrated in FIGS. 21-24, is preferred in certain cases since the size and shape of the nozzle opening and jet-forming passages can be formed very accurately. However, the method of FIGS. 1, 2, and 18-20 is generally preferred where great accuracy is not required, since it is a less expensive method of producing the jet-forming passages and nozzle opening.

Another method for forming the nozzle head of this invention comprises forming the converging passages as channels on a conical tapered post which is constructed integral with the nozzle head. An insert having a nozzle opening therein is then fitted over the post, so as to form the converging passages and nozzle opening of the present invention. With this method the channels may also be formed on the insert instead of on the post and when the insert is positioned on the post, one side of the converging channels is closed so as to form the converging passages of the present invention.

Additionally, although the nozzles of this invention have been illustrated as being used with aerosol containers, it should be understood that they can be used with other types of containers and in other applications where it is desired to spray fluids. The advantages of the nozzle of this invention, as previously stated, is that it can produce good mechanical breakup of fluids with comparatively small back pressure on the fluid, which is important with aerosol containers. Further, it will produce fluid particles of a generally uniform size. Most important, however, is that the nozzles of this invention can produce a desired spray flow pattern, such as a constant mass spray flow pattern which is suitable for a particular application.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and since certain changes may be made in the above article without departing from the spirit and scope of the invention, it is intended that all matter contained in the foregoing description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the present invention covers all the generic and specific features of the embodiments herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

We claim:

1. A spray nozzle for spraying liquid particles from aerosol containers, comprising:

- a. a plurality of converging jet-forming passages directing the flow of streams of fluid;
- b. a cavity positioned at the location of the convergence of the passages where the streams of fluid meet, wherein the cavity is defined by the juncture of the walls of the jet-forming passages and the extending walls of the jet-forming passages that do not meet; and

c. a nozzle opening for expelling the converging streams of fluid, wherein the internal side of said opening is formed at substantially the point where the axes of the jet-forming passages intersect if the axes are projected onto a plane in which one of the axes is located, wherein the size of the nozzle opening formed is determined by extending the walls of the jet-forming passages surrounding the cavity to substantially the vertical plane where the internal side of said nozzle opening is formed, and wherein the external side of the nozzle opening lies on a flat surface;

wherein the jet-forming passages and cavity are formed as slotted channels in a conical bore in the nozzle head, which slotted channels lead to the cavity and the nozzle opening in the nozzle head, and wherein a conical plug is inserted into the nozzle head so as to abut said conical bore and close the slotted channels along their sides to form the jet-forming passages.

2. A spray nozzle for spraying liquid particles from aerosol containers, comprising:

- a. a plurality of converging jet-forming passages directing the flow of streams of fluid;
- b. a cavity positioned at the location of the convergence of the passages where the streams of fluid meet, wherein the cavity is defined by the juncture of the walls of the jet-forming passages and the extending walls of the jet-forming passages that do not meet; and

c. a nozzle opening for expelling the converging streams of fluid, wherein the internal side of said opening is formed at substantially the point where the axes of the jet-forming passages intersect if the axes are projected onto a plane in which one of the axes is located, wherein the size of the nozzle opening formed is determined by extending the walls of the jet-forming passages surrounding the cavity to substantially the vertical plane where the internal side of said nozzle opening is formed, and wherein the external side of the nozzle opening lies on a flat surface;

which spray nozzle is located in a nozzle head, wherein the nozzle head has a conical bore and nozzle opening on one side, wherein the jet-forming passages and cavity are formed as slotted channels in a conical section of a plug, and wherein the plug is inserted into the nozzle head such that the conical section abuts the conical bore to close the sides of the slotted channels to form the jet-forming passages and cavity which lead to the nozzle opening.

3. A spray nozzle for spraying liquid particles from aerosol containers, comprising:

- a. a plurality of converging jet-forming passages directing the flow of streams of fluid;
- b. a cavity positioned at the location of the convergence of the passages where the streams of fluid meet, wherein the cavity is defined by the juncture of the walls of the jet-forming passages and the extending walls of the jet-forming passages that do not meet; and

c. a nozzle opening for expelling the converging streams of fluid, wherein the internal side of said opening is formed at substantially the point where the axes of the jet-forming passages intersect if the axes are projected onto a plane in which one of the axes is located;

said spray nozzle including means defining a bore and a nozzle opening at one end of the bore, means providing a plug, said plug being disposed within the bore of said defining means, said bore and said plug defining the jet-forming passages therebetween.

4. A nozzle head in accordance with claim 3, wherein the jet-forming passages converge at an angle from about 30° to about 160°.

5. A spray nozzle in accordance with claim 3 wherein said plug abuts the bore and said passages are predominantly defined by slots in said plug.

6. A spray nozzle in accordance with claim 3 wherein channels are provided in said bore-defining means and said plug

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abuts said bore-defining means to close said slots and define said passages.

7. A spray nozzle in accordance with claim 3, wherein there are two jet-forming passages whose axes lie in parallel planes such that the distance between the planes at the internal side of the nozzle opening is less than 10 percent of the average diameter of the jet-forming passages, and wherein such spray nozzle produces a triangular spray flow pattern.

8. A nozzle head in accordance with claim 3, wherein there are two jet-forming passages whose axes lie in parallel planes,

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such that the following ratio

Ratio = $\frac{\text{the shortest distance between the axes}}{\sqrt{\frac{A_1}{\lambda}} + \sqrt{\frac{A_2}{\lambda}}}$

$$\sqrt{\frac{A_1}{\lambda}} + \sqrt{\frac{A_2}{\lambda}}$$

has a value of from .35 to .50, wherein A_1 and A_2 are the jet-forming passage cross-sectional areas at the point where they enter the cavity and wherein such spray nozzle produces a uniform mass spray flow pattern.

9. A nozzle head in accordance with claim 3, wherein the jet-forming passage converge at an angle of from about 35° to 145°.

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