United States Patent

[11] 3,567,116

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[54] ATOMIZING METHOD AND APPARATUS
6 Claims, 7 Drawing Figs.

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[51] Int. Cl. A01g 15/00
[50] Field of Search ..... 239/2 (S), 8, 399, 429, 430, 431, 487, 465, 601

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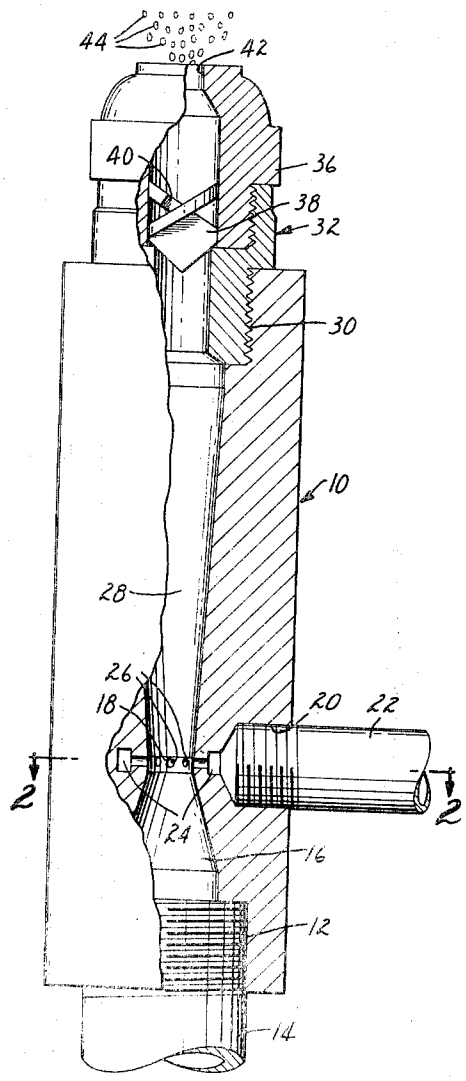
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ABSTRACT: A method for atomizing a liquid which comprises the steps of (1) forming a dispersion of minute gas bubbles in a flowing enclosed pressurized liquid, said liquid and gas being the continuous and dispersed phases respectively, and (2) subsequently forcibly expelling the dispersed system through an hydraulic atomizing nozzle into an ambient atmosphere to provide an expanding stream of minute droplets. The preferred apparatus for carrying out the method of the invention is a venturi tube fitted at one end with an hydraulic atomizing nozzle, the compressed gas being introduced into the liquid at the throat of the venturi.



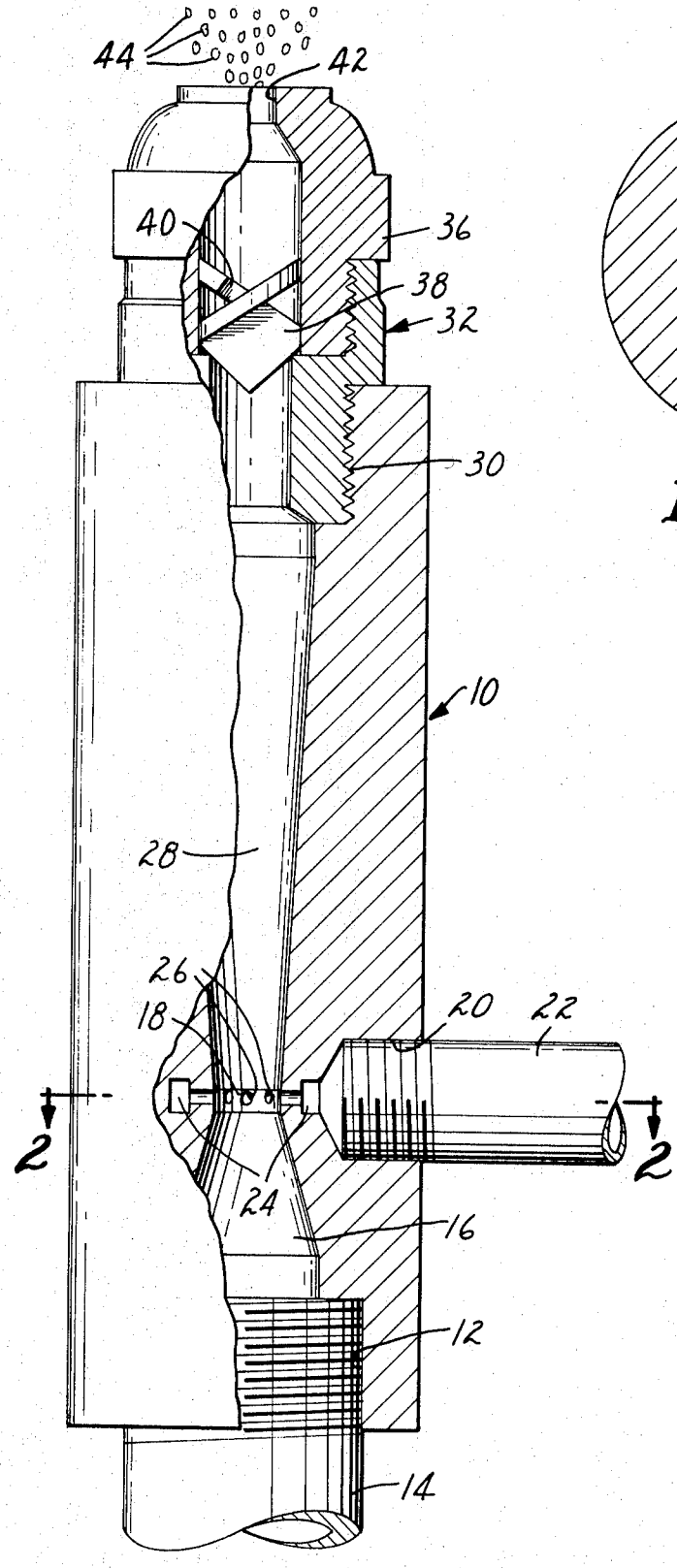


FIG. 1

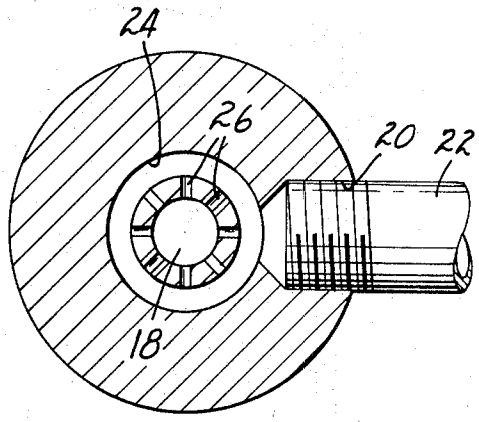


FIG. 2

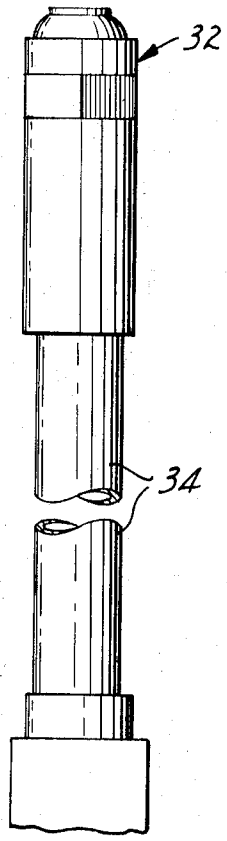


FIG. 3

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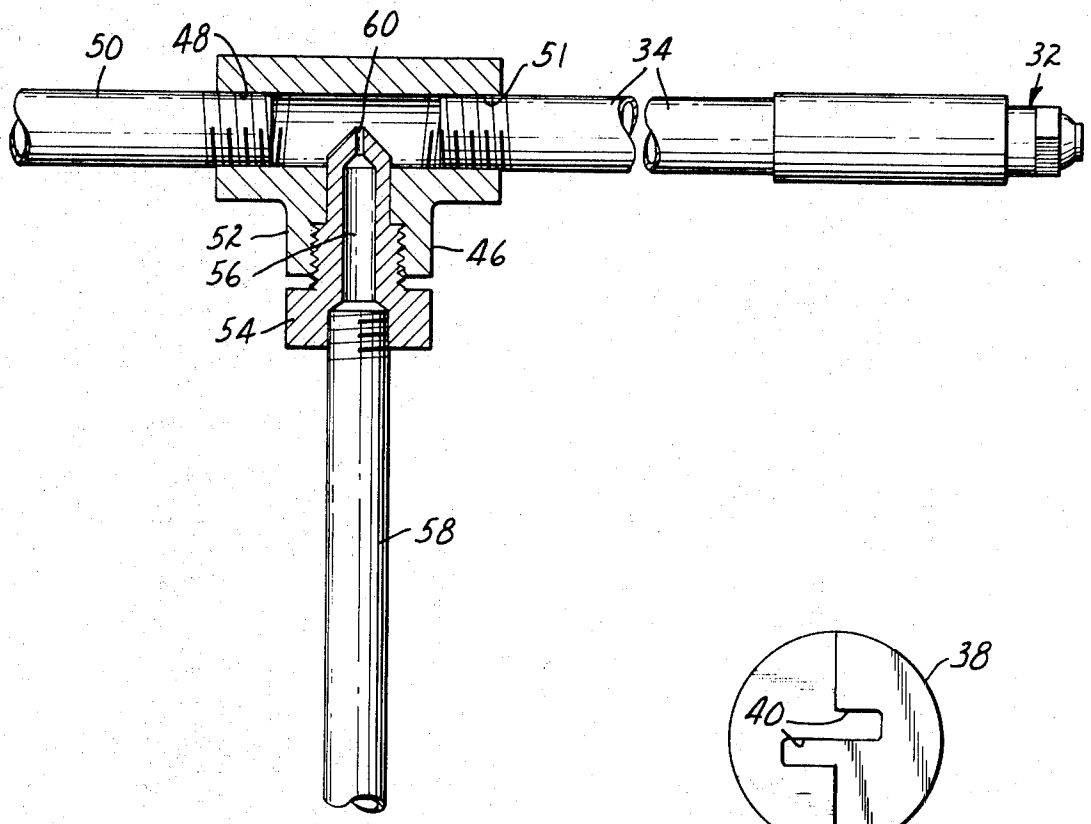


FIG. 4

FIG. 5

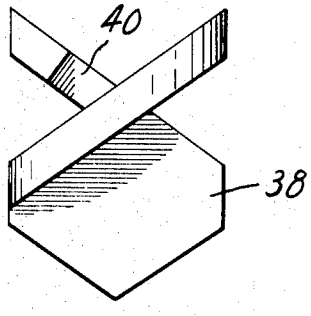


FIG. 7

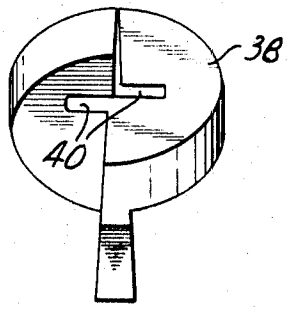


FIG. 6

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ATOMIZING METHOD AND APPARATUS

This invention relates to an improved method for atomizing liquids into small droplets for certain purposes and to an improved apparatus therefor. More specifically, the invention relates to an atomizing system which is particularly adaptable for the production of ice droplets or snow useful in winter sports as for example, skiing, though not limited to such use.

Presently known methods for producing "man-made" snow for winter sport areas normally employ pneumatic atomizing systems which involve either mixing a liquid with compressed gas prior to discharge through a nozzle or the simultaneous discharge of the two in close proximity so that the expanding energy of the gas imparts sufficient turbulence to the liquid to effect the formation of drops and droplets in varying sizes. After being forcibly expelled into freezing atmosphere, the drops are solidified while airborne and thereafter settle to the ground to form a "snow" cover. Thus, in short, compressed gas is used to break down or atomize the liquid. One widely used method (U.S. Pat. No. 3,301,485, Tropeano et al.) brings air and water together in a mixing chamber to form a mass of atomized liquid droplets which are suspended or conveyed by an excess of air through a nozzle.

Several limitations are encountered in carrying out snow-making operations of the type described above. Perhaps paramount among these limitations is the considerable and sometimes prohibitive expense involved in the procurement and maintenance of large air compressors which are required in conventional snow-making operations. Since conventional systems normally effect a suspension of water droplets in air, the volume of air required greatly exceeds that of the water used. Thus an elaborate array of compressed air delivery conduits, usually in the form of 4 to 6-inch diameter hose, must be installed on the ski slopes to deliver the required amount of compressed air to the various discharge nozzles. Normally, a compressor system capable of providing approximately 40 to 50 horsepower for each discharge nozzle is required. Furthermore, fluctuation in temperature often necessitates a continuous adjustment of the air to water ratio, which adjustment is normally carried out by selectively changing the air and water valves at the individual discharge nozzles. Since the supply of air and water to the system is normally constant, an adjustment of the valves required by the fluctuating temperature will throw the system out of balance, thus requiring an almost continuous monitoring thereof with resultant manpower expense. In addition, a large amount of overspray of snow often results and said snow is normally not of a uniform density, the degree of atomization being proportional to the distance of the expelled particles of the discharge nozzle. This often results in snow of a wet consistency near the nozzle and snow of a dryer consistency further away from the nozzle owing to the variation in water particle size. Snow thus produced more closely resembles minute particles of ice than flakes as found in natural snow. The raucous noise emitting from the nozzle and large compressors normally employed is also often a determining factor in the decision of many ski area operators to carry out snow-making operations at night to avoid inconvenience to customers.

It is therefore an object of the present invention to provide an improved method and apparatus for producing frozen microparticles which overcome the limitations of the prior art, whereby a suspension of compressed gas bubbles in a liquid is forcibly expelled through an atomizing nozzle into a freezing atmosphere to provide frozen particles closely resembling natural snow. It is a further object of the invention to provide a method for producing frozen microparticles of substantially uniform density and closely resembling natural snow, which requires only a minimal volume of compressed air in relation to the volume of liquid employed when compared to prior art methods and which does not require the continuous adjustment of the gas to liquid ratio. Other objects will become evident from the following detailed but nonlimiting description.

The invention is based on the formation of a dispersion of air or other gas in a liquid such as water and the subsequent forcible expulsion of said system into the atmosphere through a hydraulic atomizing nozzle. By a hydraulic atomizing nozzle is meant one which imparts an internal turbulence within the nozzle to the liquid passing therethrough, usually be means of vanes or shaped members, so that on exit the turbulent stream separates into an expanding full conical discharge of drops and droplets. A very fine degree of atomization of the expelled liquid particles results from the mechanical atomizing effect of the nozzle on the liquid, and this effect is augmented by the rapid expansion of the gas suspended therein due to sudden pressure drop as the liquid is expelled. In a preferred atomizing nozzle, helical vanes are provided with notches which effect the formation of two streams of liquid within the nozzle, one having a rotary or centrifugal motion, the other having a forward motion. The mechanical atomization provided by this nozzle appears to result from a collision of the liquid stream having turbulence imparted thereto in the form of rotary motion with the liquid stream having a forward velocity. This collision of streams results in atomization of the liquid outside the nozzle after discharge and produces an expanding full conical discharge stream. The atomization thus imparted to the liquid is simultaneously augmented by the sudden decrease in pressure from that within the nozzle (normally about 90—100 p.s.i.g.) to atmospheric pressure outside the nozzle, producing a rapid expansion of suspended gas and a resulting flashing of dissolved gas which causes both further subdivision of the liquid droplets and cooling thereof. In addition, the flashing of dissolved gas provides for further disruption of the liquid structure, thus providing nucleation sites for initiation of ice crystallation.

The efficiency of the system is dependent largely upon the efficiency of the aeration of the liquid prior to exit through the nozzle. Thus it is important to disperse extremely small gas bubbles in the liquid, the permanence of the dispersion being a function of the degree of subdivision of the dispersed material as well as the relative proportions of the gas and liquid by volume. The dispersion mixture is limited in that the volume of gas is never allowed to exceed the volume of water within the piping system, which is preferably under a pressure of between about 50 and about 225 p.s.i.g. The preferred gas to liquid ratio is one part by volume of gas to three parts by volume of liquid. When the resulting dispersion is discharged through the nozzle and exposed to atmospheric pressures, the ratio is then reversed and the mixture is converted to a suspension of fog of finely divided liquid in a gas (the gas now being the atmosphere).

Since the present invention employs a dispersion of gas in a liquid, the liquid being the continuous phase, as opposed to the prior art which normally employs a suspension of liquid droplets in air, the air being the continuous phase, it can be readily observed that the volume of compressed gas required is drastically reduced when compared with prior art techniques. At a piping system pressure of 90 p.s.i.g., for example, a useful volume of compressed gas can be calculated as the equivalent of 0.8 standard cubic feet of air for each gallon of water. Acceptable operating conditions require that the volume of compressed air not fall below about 0.1 standard cubic feet per gallon of water, standard conditions of pressure and temperature being 760 mm. of mercury and 0° C. In order to accommodate normal fluctuation in pressure due to constrictions, etc. within the piping system the preferred value is 0.3 standard cubic feet for each gallon of water.

In a preferred embodiment of apparatus for practicing the invention, a venturi tube having an inlet section for pressurized water is provided, the throat section of which is provided circumferentially with a plurality of small orifices which are communicative with an inlet for compressed air and the water flowing through the throat section. The required dispersion of air bubbles in the water is effected by introducing compressed air through the orifices into the water at or near the throat of the venturi. The opposite end of the venturi is pro-

vided with a connecting conduit, usually in the form of a hose, the terminating end of which is adapted to receive a hydraulic atomizing nozzle, preferably one equipped with internal notched vane members which impart turbulence to the dispersed system as it is forced therethrough. The turbulence results from an internal collision of two differently directed streams within the nozzle. The liquid and suspended air thus issues from the nozzle as an expanding conical stream of freezable droplets.

While other aeration apparatus is acceptable for providing the required dispersion of air in water for snow-making operations, the use of the venturi, or other tubular member having a "throat" or cross-sectional area of reduced internal diameter, is preferred for the following reasons:

1. The reduced pressure of the liquid at the throat of the venturi facilitates introduction of the gas bubbles at that point of reduced pressure, thus reducing the need for high-pressure gas piping and large horsepower output compressors.

2. The gas bubbles introduced into the venturi throat at reduced pressures are compressed to a smaller size as they are carried downstream from the throat and subsequently subjected to higher pressure.

3. The accelerated velocity in the throat of the venturi carries the bubbles downstream rapidly and thus tends to minimize their combination or coalescence into larger bubbles.

4. The venturi additionally provides good mixing of the air and water.

The invention is more clearly illustrated in the accompanying drawings, in which:

FIG. 1 is a side elevational view with half in section of the apparatus of the invention;

FIG. 2 is a sectional view taken along the line 2–2 of the structure shown in FIG. 1;

FIG. 3 is an elevational view of the apparatus shown in FIG. 1, illustrating a connecting conduit between the nozzle and the exit connection section;

FIG. 4 is a side elevational view with half in section of an alternative embodiment of the aeration apparatus of the invention;

FIGS. 5, 6 and 7 are views of preferred nozzle insert members of the invention showing internal helical vanes having notches cut therein.

Referring now in further detail to the drawings, reference is made to FIGS. 1—3 inclusive in which the numeral 10 refers generally to a venturi tube provided with a water inlet section 12 adapted to receive a conduit 14 through which pressurized water is introduced into the venturi entrance section 16, the initial diameter of which is shown as equal to that of the water conduit 14. The entrance section constricts gradually at a conical angle of approximately 25°—30° and leads into the venturi throat section 18 having a diameter of approximately one-fourth to one-half that of the initial diameter of the entrance section 16 and equal in length to approximately three-fourths the throat section diameter. A compressed gas inlet 20 adapted to receive a compressed gas conduit 22 is provided and adapted to transmit compressed gas into and through an annular passage 24 which in turn communicates with, and allows said compressed gas to flow through a plurality of orifices 26 and into the liquid flowing through the throat section 18. An exit section 28 having a conical angle of not more than 7° and a final diameter equal to that of the entrance section communicates with an exit connection section 30. As shown in FIG. 1 the exit connection section is adapted to receive a nozzle 32. However, preferably the exit connection section 30 is adapted to receive one end of a connection conduit 34, the terminating end of which is adapted to receive the nozzle 32, as is illustrated in FIG. 3.

The nozzle comprises a body member 36, formed to receive a rotatable vaned insert member 38 which has a notch 40 cut in each vane. The vaned insert member 38 is thus capable of imparting turbulence to the dispersed system as it flows therethrough, the turbulence resulting from the collision of the streams passing through the notches with the spiraling stream formed by the rotating vanes. The dispersed system is then forcibly expelled through the nozzle orifice 42 and exits from the nozzle in the form of an expanding conical stream, which in turn diverses and separates into discrete, freezable droplets 44. FIGS. 5, 6 and 7 are different views of the rotatable vaned insert member 38, illustrating vane configuration and notching 40. Preferred atomizing nozzles are of the type described in U.S. Pat. Nos. 3,146,678 and 3,104,829. For spraying operations requiring a large volume of discharge, e.g., snow-making systems for large ski areas, a plurality of nozzles may be placed in one discharge head.

While the venturi construction described above is the preferred embodiment for providing the required dispersed system, other aeration devices are acceptable. Such an alternative apparatus is illustrated in FIG. 4 wherein the numeral 46 refers generally to a pipe tee body provided with an inlet 48 for pressurized liquid flowing through a conduit 50. An outlet section 51 is provided on the end of the pipe opposite the inlet 48. The side leg 52 of said tee body is adapted to receive an insert 54, said insert being provided with a passage 56, the distal end of which is adapted to receive one end of a compressed gas conduit 58, the proximal end of said passage 56 being constricted to form a small orifice 60 which provides communication between said passage and the liquid flowing between the inlet 48 and the outlet sections 51. The protrusion of the insert 54 and orifice 60 reduces the internal cross-sectional area of the conduit at that point. The outlet section 51 is adapted in a manner similar to that of FIG. 1 to receive a connection conduit 34, the terminating end of which is adapted to receive the nozzle 32.

Since the stability of the dispersed system is a function of the size of the gas particles, it is important that the gas be introduced and maintained in the liquid in as finely divided state as is possible. Thus the diameter size of the gas transmitting orifice is as small as is practical to prevent clogging thereof. Orifice diameters of between about .0405 cm. and .0127 cm. are preferred since diameters smaller than the lower figure appear to be prone to clogging while diameters larger than the higher figure appear to offset the operational air to water ratio. As is evident from FIG. 4 a single orifice may be employed for aeration of the water; however, a plurality is preferred. The number of orifices should not be so great as to require a reduction in the pressure differential between the air and the water in order to maintain the proper ratio. If the air pressure is allowed to fall too far below that of the water pressure the bubbles exhibit a tendency to cling to the orifice because of surface tension at the water/air interface and the bubbles may combine or coalesce into an undesirably larger size before breaking loose. The result could be a disruption of the dispersed system of air in water.

The optimum pressure differential between the liquid and the gas is defined as that which allows the required amount of gas to be emitted into the liquid. Exact pressure limits for the liquid and the gas are of course dependent upon the design of the particular aeration device employed. Thus, if the gas pressure falls below that of the liquid pressure plus the optimum differential, spraying efficiency will fall off since an inadequate amount of gas will be admitted into the liquid. If the pressure differential is greater than optimum, gas is wasted. In the preferred apparatus as illustrated in the drawings, the preferred differential is provided by an air pressure of about 10 p.s.i.g. above that of the water pressure.

For larger systems such as those required for snow-making operations, the water pressure may be 100 p.s.i.g. greater near the bottom of the slope than near the top, where there would be little loss of gas pressure due to height. Thus, preferably, a pressure regulated control valve is installed in the liquid line upstream from the aeration device so that the water pressure available to the aeration device is controllable in order to maintain at least the optimum pressure differential. Also, pressure control methods and devices known to those skilled in the art may be alternately used in conjunction with suitable filters and solenoid valves.

It has been found that the aerated liquid can be carried through several hundred feet of piping and hose from the point of aeration to the discharge nozzle with little apparent loss of spraying efficiency. On the other hand, the apparatus is fully effective when there is little or no separation between aeration and discharge nozzle. Proper piping practice, such as splitting of the flow equally out of side runs of tees, reducing pipe size appropriately and assuring adequate gas dispersion, facilitates branching of the piping subsequent to the aeration so as to supply a plurality of widely separated spraying locations. Such branching, however, may result in some change in the gas to liquid ratio at different spraying locations which may effect a variation in spraying efficiency. Thus, it is preferred to provide a separate aeration device for each spraying location, where it is understood that a spraying location may comprise a single nozzle or a multitude of small nozzles grouped together as one spray head. In all cases, however, it is important to employ pipe or hose of the smallest size consistent with good piping practice to move the aerated liquid rapidly, since at very low velocities there exists a tendency for the liquid and the gas to separate within the conduit.

While it is anticipated that compressed air will normally be employed as the gas for snow making operations, it is within the scope of this invention that other compressed and/or liquified gases such as compressed nitrogen, halocarbons and hydrocarbons, carbon dioxide, etc. may also be used for certain application. Surfactants may also be added to the liquid in certain instances to facilitate production of minute bubbles. Furthermore it is to be understood that the practice of the present invention is not limited to snow-making operations but may be employed in other systems where a fine degree of atomization is required. Examples of other applications for the invention include spray drying or spray freeze drying of liquified foods, humidification systems, water cooling, paint spraying and the like.

I claim:

1. Apparatus for introducing compressed gas in the form of minute bubbles into a contained flowing stream of pressurized liquid so as to form a dispersion of minute gas bubbles in said liquid, the liquid and the gas being the continuous and dispersed phases respectively and for subsequently atomizing said liquid, said apparatus comprising in combination a tabular, liquid transmitting member having an area of reduced internal diameter, one end of said member being adapted to receive a conduit for a pressurized liquid, a hydraulic atomizing nozzle mounted in the opposite end of said liquid-transmitting member, and means for introducing compressed gas into the liquid at the point of minimum cross-sectional area of said reduced internal diameter of said liquid-transmitting member to form minute bubbles therein.

2. The apparatus of claim 1, wherein the tubular, liquid-transmitting member has an area of reduced internal diameter, and said area of reduced diameter is provided with a plurality of orifices spaced circumferentially therearound as the means for introducing compressed gas, said orifices being communicative with a source of compressed gas and with a liquid flowing through said area of reduced diameter and being of a size adapted to provide a dispersion of minute gas bubbles in said liquid passing therethrough.

3. The apparatus of claim 1, wherein the tubular liquid-transmitting member is in the form of a venturi, and the throat section of said venturi is provided with a plurality of orifices spaced circumferentially therearound as the means for introducing compressed gas, said orifices being communicative an with a source of compressed gas and with a liquid flowing through said throat section and being of a size adapted to provide a dispersion of minute gas bubbles in said liquid passing therethrough.

4. The apparatus of claim 3, wherein regulating means is provided to afford a volume ratio of liquid to gas of at least 1.

5. The apparatus of claim 3, wherein said orifices have a diameter of between about .0405 cm. and .0127 cm.

6. The apparatus of claim 1, wherein said means for introducing compressed gas is a single orifice communicative with a source of compressed gas and with the liquid flowing through the tubular liquid-transmitting member, the orifice having a diameter size sufficient to provide a dispersion of minute gas bubbles in a liquid within the tubular member.