# United States Patent [19]

**Jakob et al.**

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[54] **PROCESS FOR MAKING ARTIFICIAL SNOW**


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**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 810,711, March 26, 1969, Pat. No. 3,596,476.

[30] **Foreign Application Priority Data**

Apr. 8, 1968 Austria ..... A 3459/68

[52] **U.S. Cl.** ..... **62/74**, 239/2

[51] **Int. Cl.** ..... **F25c 3/04**

[58] **Field of Search** ..... 62/74, 121, 347; 239/2, 424.5



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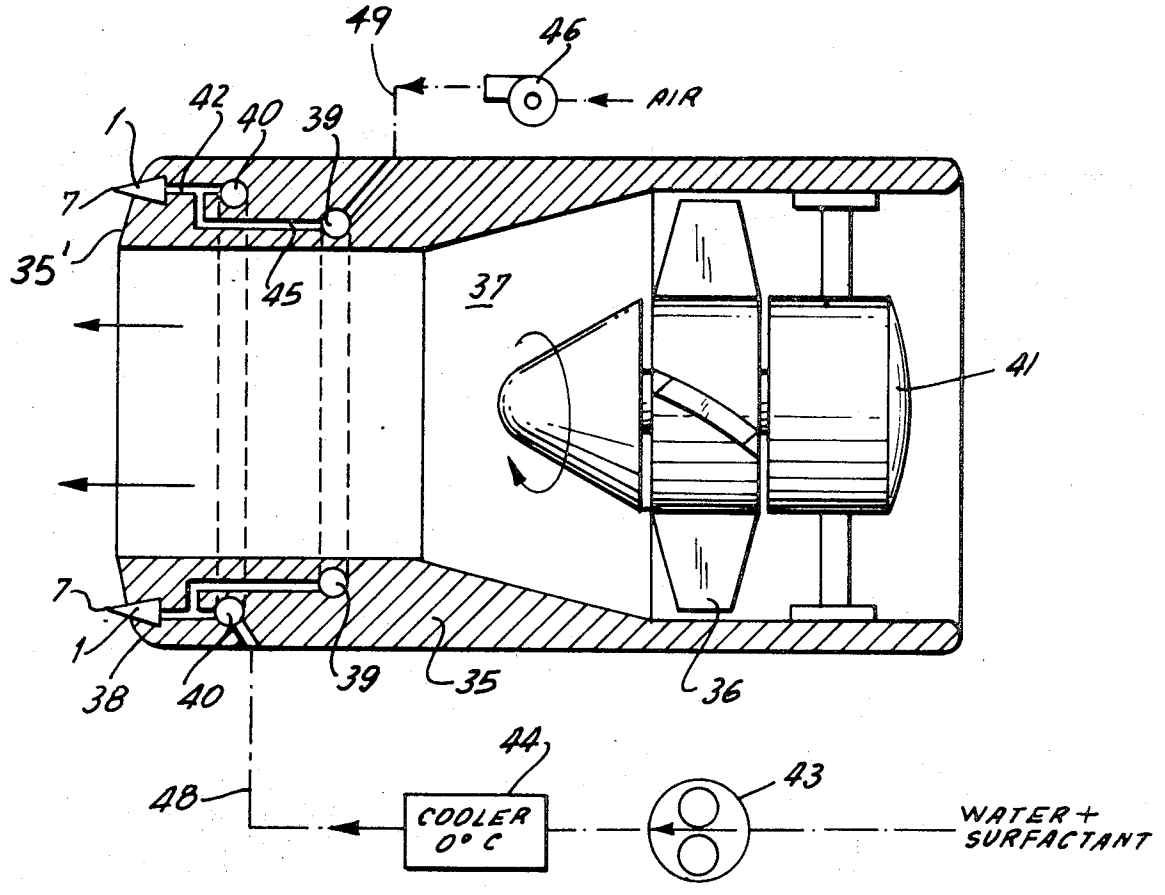
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[57] **ABSTRACT**

Water under high pressure and at a low temperature is fed to a set of nozzles, after it has been mixed with a high-pressure air flow. On leaving the nozzles the water is atomized into fine droplets and is rapidly depressurized on being discharged into a low-pressure air stream of subfreezing temperature generated by a fan. The weight ratio of high-pressure air and water, ahead of the nozzle orifices, is on the order of 1 : 400.


**11 Claims, 4 Drawing Figures**



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SHEET 1 OF 2

FIG. 1

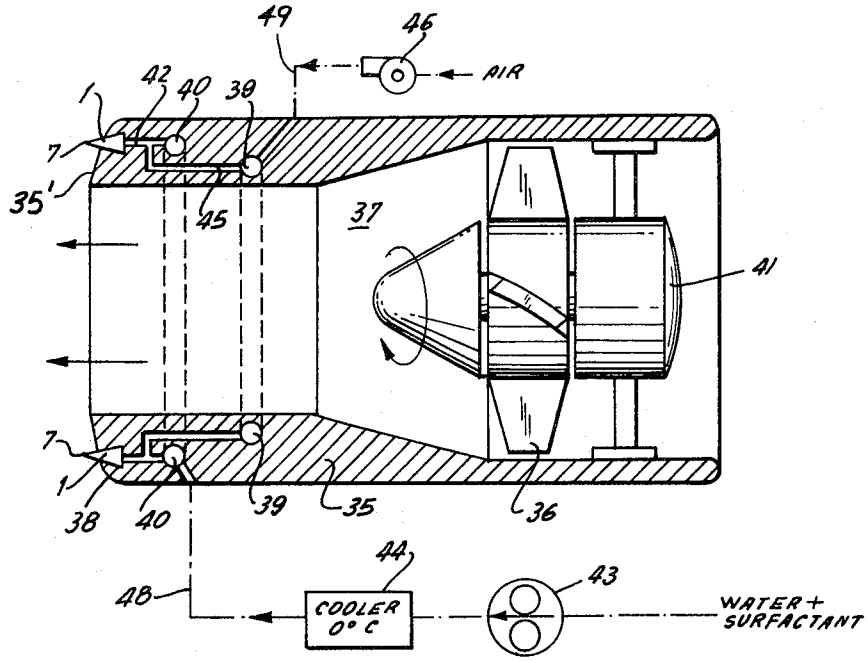
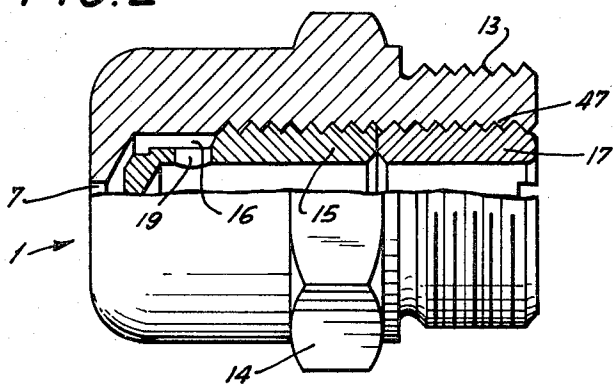



FIG. 2




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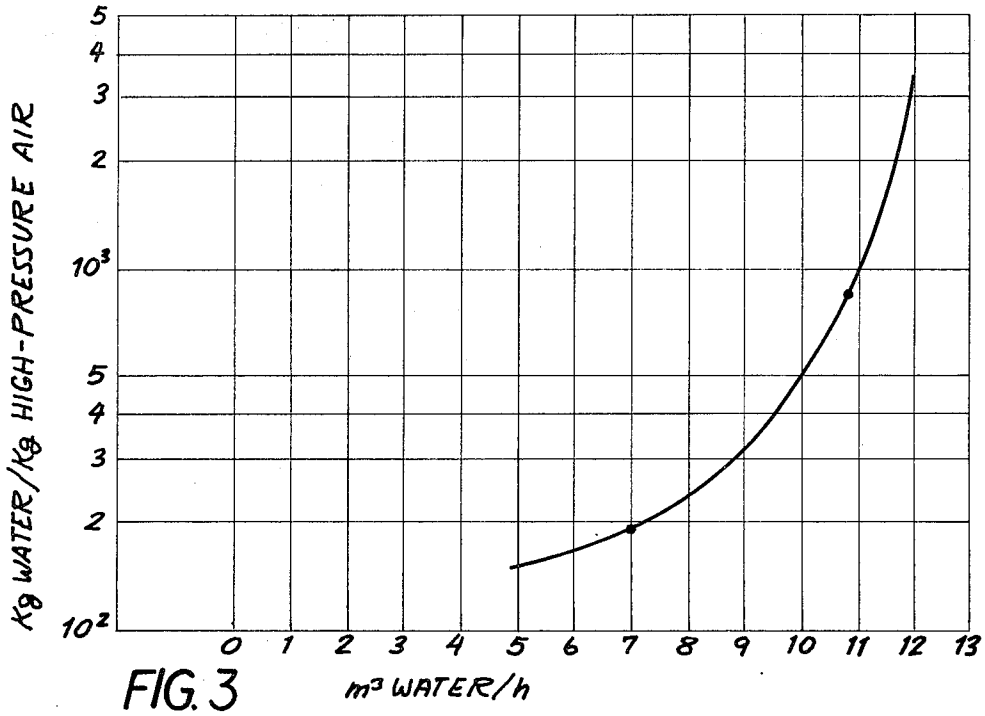



FIG. 3

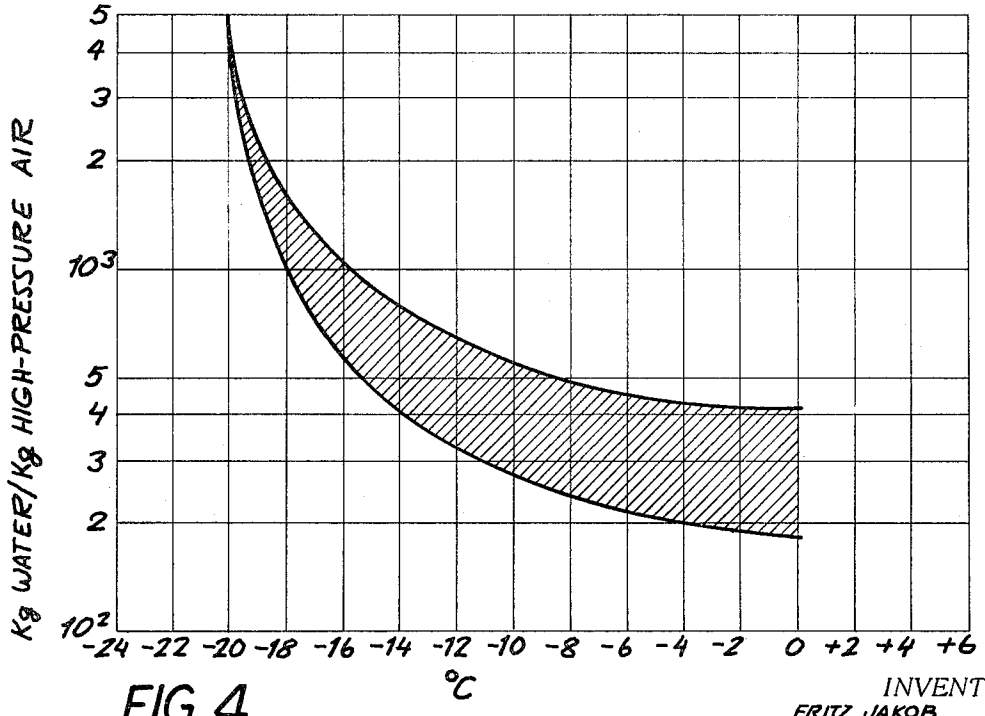



FIG. 4

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# PROCESS FOR MAKING ARTIFICIAL SNOW

This application is a continuation-in-part of our copending application Ser. No. 810,711 filed Mar. 26, 1969, now U.S. Pat. No. 3,596,476.

Our present invention relates to a process for making artificial snow.

In conventional systems of this type, large quantities of compressed air are admixed with relatively small amounts of entrained water which, upon subsequent expansion of the mixture into an atmosphere of sufficiently low temperature and high humidity, crystallizes as snow flakes. The successful operation of a snow machine based on this principle is generally possible only at ambient temperatures well below freezing, e.g., less than −5 °C, and requires an air compressor of large capacity to deliver a constant flow of compressed air at the rate heretofore considered necessary.

The general object of our present invention is to provide an improved method of operating a snow machine, based upon a novel process of making artificial snow, which avoids the above drawbacks and which is effective at ambient temperatures just below the freezing mark while being substantially insensitive to veriations in relative humidity.

We have found in accordance with the present invention that the aforestated object can be realized by allowing a continuous flow of water under high pressure to issue from one or more expansion orifices in the form of small droplets into a low-pressure air stream of subfreezing temperature, i.e., a temperature up to about 0 °C. The temperature of the water should be as close to 0 °C as possible to provide a satisfactory operation, but we have found that the temperature of the water may be several degrees above 0 °C if the temperature of the surrounding air is low. As a rule of thumb it can be stated that the temperature of the water may be approximately as many degrees above 0 °C as the temperature of the air is below 0 °C.

We have further found, in accordance with the present invention, that the aforestated object can be realized more efficiently by adding a high-pressure gas, such as air, to the water before its discharge from the expansion orifices. While the air which is contained in the water in tiny bubbles before reaching the expansion orifices does not play a part in atomizing the water, it expands suddenly after having left the orifices, thus lowering its temperature down to −70 ° or −80 °C. This lowering of the temperature leads to a quick formation of ice crystals in the boundary layers between the bubbles of expanded air and the surrounding small droplets of water, thereby generating nuclei for the promotion of the transformation of water into snow. The high-pressure air is preferably under a pressure slightly higher than that of the water flow to which it is added, in a proportion ranging between substantially 1 and 4 $m^3$ STP per $m^3$ of water. A particularly advantageous ratio is 3 $m^3$STP of air for each cubic meter of water.

Another adjuvant capable of promoting the snow formation is a nucleating agent admixed with the air-permeated water flow in finely comminuted crystalline form. While ice could be used for this purpose if injected into the flow at a location close to the discharge orifices, other compounds of similar crystalline structure (such as silver iodide) are more stable so as to be admixable with the water ahead of the high-pressure pump. The quantity of such nucleating agent should substantially exceed the saturation rate of the water and, in the case of silver iodide, is advantageously on the order of the equivalent of $10^{-4}$N.



Alternatively, or in addition, a surfactant in powered or liquid form may be added to the water to reduce its surface tension, thereby facilitating its dispersion into fine droplets. Any commercially available household detergent may be used for this purpose. In the case of a powder, such as an alkylaryl sulfonate, a quantity of about 10 – 15 grams per $m^3$ of water has been found highly satisfactory; in the case of liquid detergents, such as an ester of polyethylene glycol, a proportion of roughly 100 ml per $m^3$ of water is suitable.

The above and other features of our invention will become more fully apparent hereinafter from the following detailed description given with reference to the accompanying drawing in which:

FIG. 1 illustrates, somewhat diagrammatically and in axial sectional view, the basic structure of a snow machine operable by the process according to our invention;

FIG. 2 is a side-elevational view, partly in section and on an enlarged scale, of a nozzle forming part of the machine of FIG. 1;

FIG. 3 is a graph illustrating the dependence of the quantitative ratio of high-pressure air and water upon the amount of water fed to the snow machine in the process according to the invention; and

FIG. 4 is a graph illustrating the decrease of the amount of high-pressure air needed in comparison with high-pressure water with decreasing temperatures in the process according to the invention.

In FIG. 1 we have shown a tubular nozzle carrier **35** of cylindrical configuration whose inner bore **37** accommodates an electric fan **36** driven by a motor **41**. Fan **36** generates a circulation of air passing axially through the front end **38** of body **35** which carries an annular array of nozzles **1** with discharge orifices **7** pointing in the direction of the air flow; the air velocity may range between about 20 and 50 m/sec, being preferably 33 m/sec. The nozzles **1** are connected in parallel, via internal conduits **42**, to a manifold **40** in the form of an annular channel to which water is continually supplied under high pressure by a pump **43**, followed by a cooler **44**, via a pipe **48**.

Conduits **42**, which represent the inlets to the nozzles **1**, also communicate via passages **45** with another manifold **39** which is connected to the output end of an air compressor **46** by way of a pipe **49**, the output pressure of blower **46** being slightly higher than the delivery pressure of pump **43**.

The restricted passages **45** exert a throttling effect upon the air flow entering the nozzles **1** from annular channel **39**. This throttling effect is desirable to insure a substantially uniform rate of air flow at each nozzle, despite the fact that the several passages **45** are at different distances from the supply line **49**.

A similar but less pronounced throttling action is exerted upon the water flow by the passages **42** linking the nozzles **1** with the annular channel **40**.

The circulation of air generated by fan **36** creates a suction effect on the surrounding atmospheric air due to friction in the boundary layers between the stream generated by the fan and the surrounding air. As a result, atmospheric air is sucked into the stream which helps spread the water/air mixture from the nozzle **1** over the transverse land **35'** of the carrier **35** along the

axis of the land past the inner peripheral edge thereof. Moreover, it promotes a quick evaporation of water from the surfaces of the small droplets whereby an intense cooling of the droplets is achieved, thereby transforming them into snow, without requiring additional cooling of the system. The maximum initial diameter of these droplets, under the operating conditions specified above, is on the order of 0.1 mm. The desired ratio of water to air, within the range previously set forth, can be varied by adjusting the relative speeds of pump **43** and blower **46.**

FIG. **2** shows a preferred construction of any of the nozzles **1** illustrated schematically in FIG. **1.** The nozzle **1** of FIG. **2** has a tubular housing **11** terminating at its front end in the orifice **7,** housing **11** being formed with internal threads **47** engaged by mating threads on a tubular insert **15** and on a locking ring **17.** Insert **15** defines with the inner front wall of housing **11** a vortex chamber **16** into which water, with the admixed air, flows by way of lateral apertures **19** in insert **15** after entering same from the rear through ring **17.** The apertures **19** (only one shown) are centered on generally tangentially inclined axes, as is well known per se, so as to impart to the exiting fluid a swirling motion in its travel toward orifice **7.** Male threads **13** on the rear of housing **11** enable the nozzle **1** to be screwed into a threaded seat in the carrier **35** of FIG. **1** or in the outer surface of an annular carrier member supplied from within and discharging into a surrounding low-pressure air stream as described more fully in our copending application and patent identified above; the midportion **14** of the nozzle housing is formed for this purpose into a polygonal flange engageable by a wrench.

In the operation of the illustrated machine, the discharged droplets of water, especially if charged with a nucleating agent and/or a surfactant as described above, crystallize upon contact with the atmosphere so as to turn into snow flakes.

If the volumetric ratio of high-pressure air to water has a value corresponding to the lower limit of the range given above, i.e., 1 : 1, the weight ratio can be calculated as 1 : 775; at the top of the range, with a volumetric ratio of 4 : 1, the weight ratio becomes 1 : 194. Thus, the quotient

$$R = W_w/W_a$$

is on the order of 400 (this value equaling approximately the geometric mean of the upper and lower range limits), $W_w$ being the weight of the water and $W_a$ being the weight of the high-pressure air ahead of expansion point **7.**

FIG. **3** shows the effect of the amount of water delivered by pump **43** to nozzles **1** upon the proportion of water to high-pressure air ahead of the nozzles **1.** As can be seen, the proportion is the higher the more water is delivered to the nozzles. It should be remarked that the quality of the snow produced increases with a decrease in the proportion of water to high-pressure air.

The graph shown in FIG. **3** was taken from measurements with a snow-making machine having 180 nozzles, each having a diameter of approximately 1 mm. The pressure of the water amounted to 14 atm.abs. while the pressure of the high-pressure air amounted to 15 atm.abs. The temperature of the water was +2 °C, and the temperature of the surrounding air was −2 °C. The speed of the low-pressure air stream generated by the fan **36** amounted to 33 m/sec.

FIG. **4** shows the effect of the variation of ambient temperature upon the proportion of water to high-pressure air. As can be seen, the proportion becomes the greater the lower the temperature of the ambient atmosphere.

This graph was also taken with a snow-making machine having 180 nozzles each having a diameter of approximately 1 mm. Water was fed to the nozzles in an amount of 150 liters/min which corresponds to an amount of 9 $m^3$/h. The temperature of the water fed to the nozzles was varied within a small range according to the temperature of the ambient air. It was possible to produce snow of satisfactory quality with water temperatures up to 10 °C if the temperature of the ambient air was −10 °C or lower.

The mass-flow rate $W_o$ of the available low-pressure air and its flow velocity $c_o$ also affect the conversion rate. Thus, the quotient

$$A = W_o c_o/W_w$$

should range, with $W_o$ and $W_w$ given in comparable units such as kg/h, between 6.6 and 1,300 (m/sec) if $c_o$ is given in m/sec. The preferred range is 56 to 670; in the tests represented by FIG. **3** the value of A approximated 160.

We claim:

**1.** A process for making artificial snow, comprising the steps of feeding a continuous flow of water under high pressure and at a low temperature to at least one orifice, continuously admixing with said flow of water a stream of compressed air at a rate amounting to a minor proportion by weight of said air with reference to the water and discharging the resulting water/air mixture from said orifice in the form of small droplets into a low-pressure air stream of subfreezing temperature generated by a fan and flowing past an edge of a generally transverse land bearing said orifice, the proportion of high-pressure air to water ahead of said orifice ranging substantially between 1 and 4 $m^3$ STP of air per $m^3$ of water.

**2.** A process as defined in claim **1** wherein said compressed air is fed into a conduit conveying said flow of water to said orifice.

**3.** A process as defined in claim **1** wherein the water has a nucleating agent admixed therewith.

**4.** A process as defined in claim **3** wherein said nucleating agent is silver iodide.

**5.** A process as defined in claim **4** wherein the concentration of said silver iodide is on the order of $10^{-4}$N.

**6.** A process as defined in claim **1** wherein the proportion of air to water ahead of said orifice is substantially 3 $m^3$ STP of air per $m^3$ of water.

**7.** A process as defined in claim **1** wherein said orifice has a diameter between substantially 0.5 and 2.5 mm, the pressure of the water at said orifice being upward of substantially 5 atmospheres absolute.

**8.** A process as defined in claim **1** wherein a surfactant is admixed with the water ahead of said orifice.

**9.** A process as defined in claim **1** wherein said land is annular and said low-pressure air stream is blown along the axis of said land past the inner peripheral edge thereof.

**10.** A process for making artificial snow, comprising the steps of feeding a continuous flow of water under high pressure and at a low temperature to at least one

orifice, continuously admixing with said flow of water a stream of compressed air at a rate amounting to a minor proportion by weight of said air with reference to the water, and discharging the resulting water/air mixture from said orifice in the form of small droplets into a low-pressure air stream of subfreezing temperature generated by a fan, the quotient $W_o c_o / W_w$ ($Wo$ = mass-flow rate of low-pressure air, $Ww$ = mass-flow rate of water, given in kg/h, and $C_o$ = flow velocity of low-pressure air given in m/sec) lying between 56 and 670.

11. A process for making artifical snow, comprising the steps of feeding a continuous flow of water under high pressure and at a low temperature to at least one orifice, continuously admixing with said flow of water a stream of compressed air at a rate amounting to a minor proportion by weight of said air with reference to the water, further admixing with said water a surfactant ahead of said orifice, and discharging the resulting water/air mixture from said orifice in the form of small droplets into a low-pressure air stream of subfreezing temperature, the proportion of high-pressure air to water ahead of said orifice ranging substantially between 1 and 4 $m^3$ STP of air per $m^3$ of water.

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