United States Patent

Martinez et al.

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[54] PRESSURE IMPULSE APPARATUS FOR INITIATING FORMATION OF FLUID DROPS

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[21] Appl. No.: **60,394**

[52] **U.S. Cl.**.....**222/394,** 222/420, 346/75

[51] **Int. Cl.**.....**B65d 83/14**

[58] **Field of Search**.....222/420, 389, 61, 399, 422, 222/395, 394; 346/75, 140

[56] **References Cited**

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[57] **ABSTRACT**

To avoid large initial globs of liquid, or misdirected initial jets or liquid filaments, when starting one or more liquid drop generators, the flow through the orifice of the generator(s) is initiated with an abrupt and substantial pressure rise time, as by applying an initial hydraulic shock in starting the flow.

4 Claims, 3 Drawing Figures

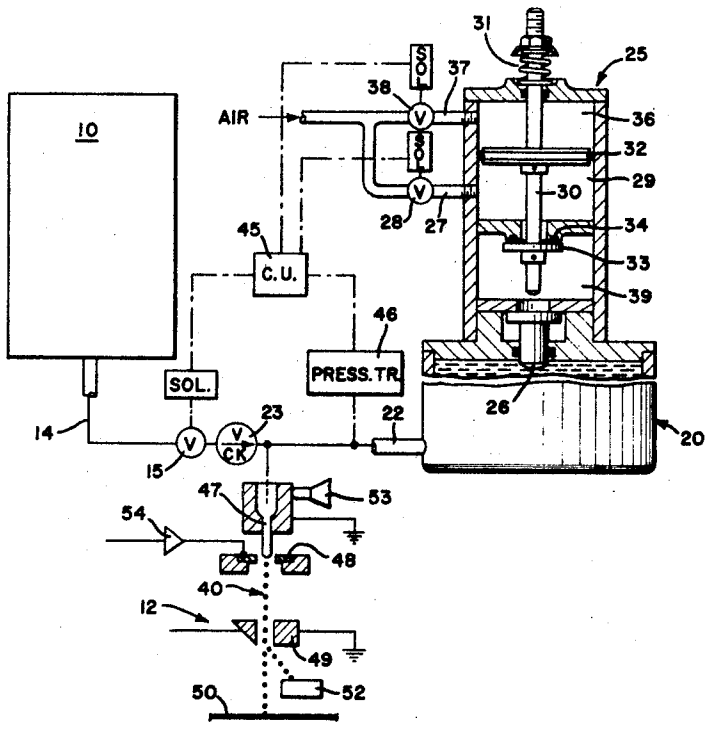

FIG-1

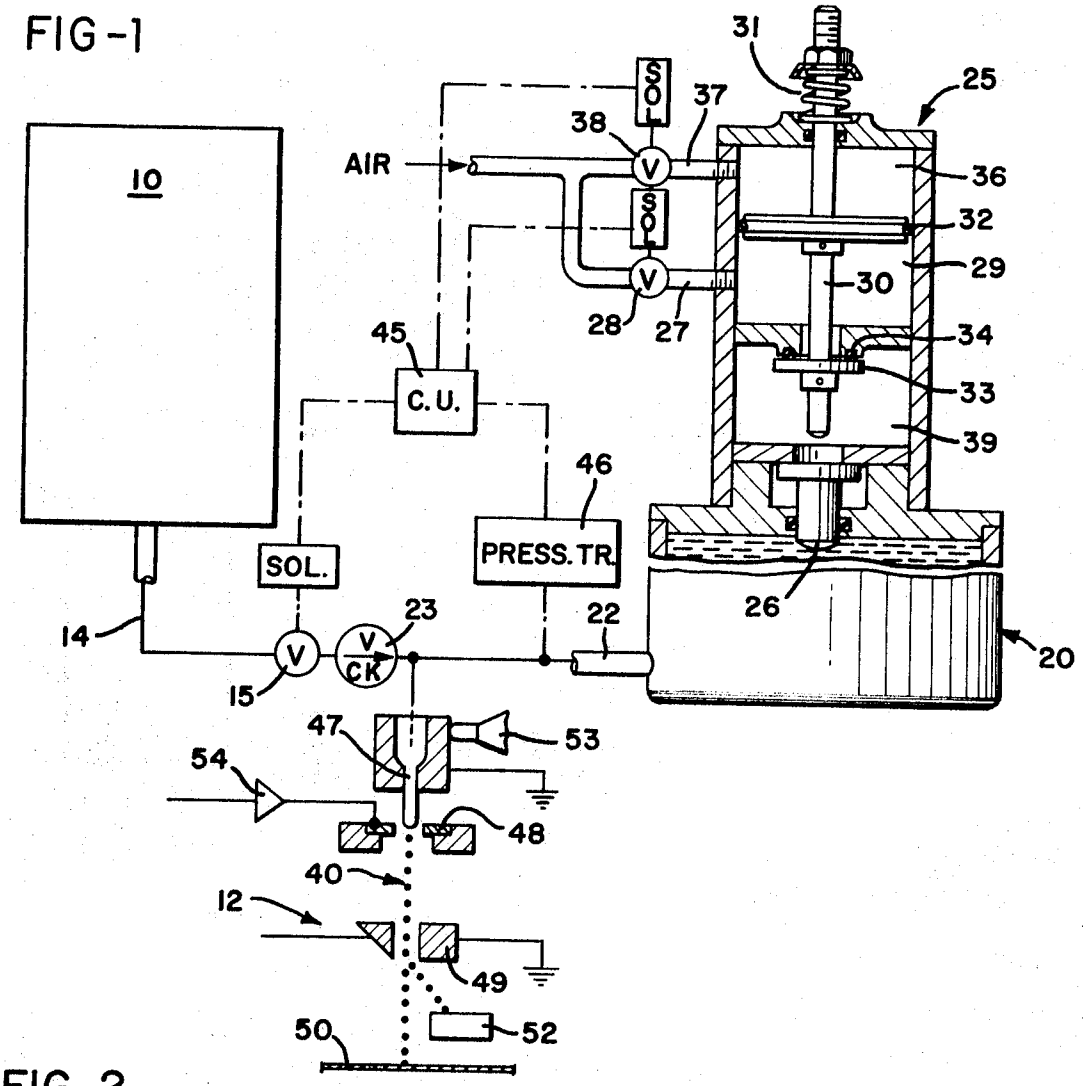

FIG-2

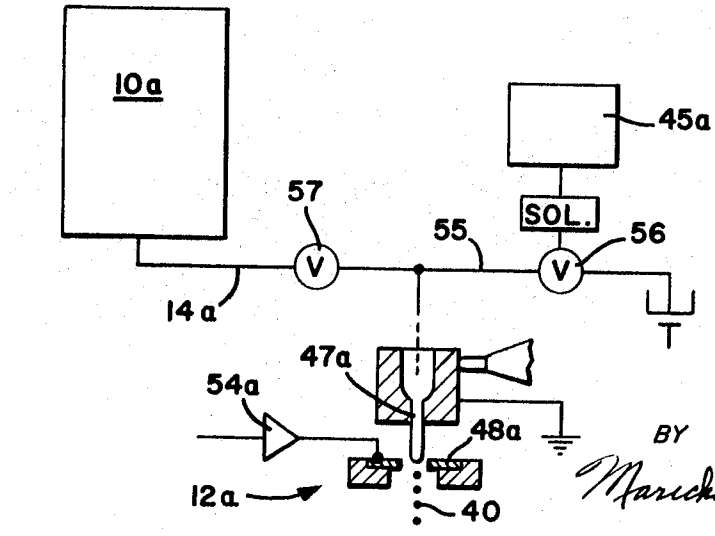

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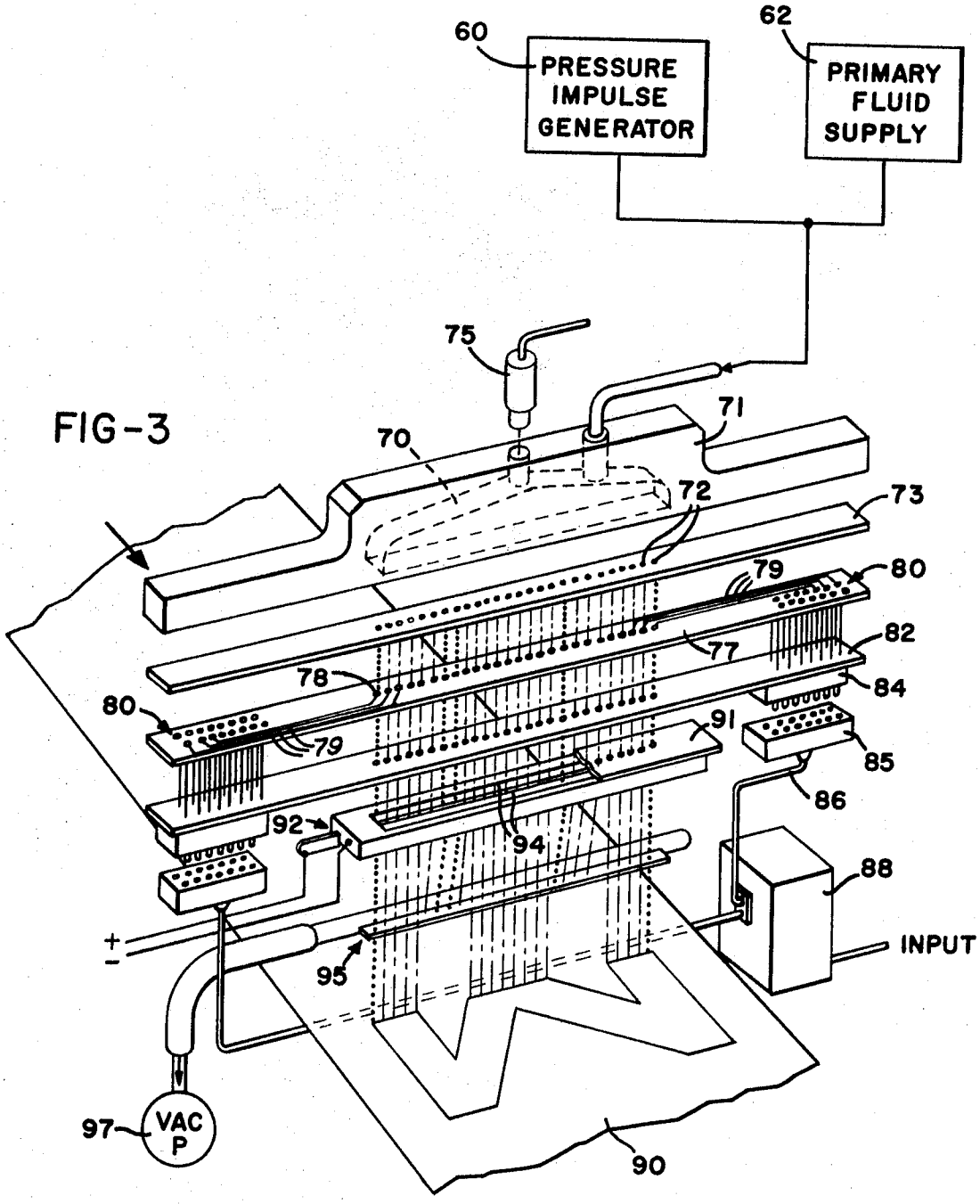
FIG-3


60
PRESSURE IMPULSE GENERATOR
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PRIMARY FLUID SUPPLY
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97
VAC P
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PRESSURE IMPULSE APPARATUS FOR INITIATING FORMATION OF FLUID DROPS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to copending applications entitled Image Construction System Using Multiple Arrays of Drop Generators, Ser. No. 768,790, filed Oct. 18, 1968, now U.S. Pat. No. 3,560,641 and Coordinate Placement of Ink Drops, Ser. No. 768,766, filed Oct. 18, 1968, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to systems in which discrete small uniformly sized drops of liquid, for example a marking liquid such as ink, are projected in a controlled manner to achieve a predetermined space-time correlation. A typical use of the invention is in high speed printing wherein the drops are selectively placed on a paper web moving at relatively high speed past a drop generating device.

In practice, starting a drop generator is not as instantaneous and as clean a process as conventional observation would indicate. Typically, as liquid under pressure begins to flow through the orifice of a drop generator, a small volume of liquid exits from the orifice of the drop generator and becomes attached to the face of the orifice body. This volume continually grows and assumes a somewhat hemispherical shape. Thereafter a protuberance begins to develop in the growing volume. This protusion continues to grow until a stream or jet of the liquid breaks through the free surface of the attached volume of liquid. This sequence which has been studied with the aid of high speed motion pictures has been observed to exhibit a strong dependency upon the fluid Weber's number (i.e. the ratio of fluid inertia to fluid surface tension) at the exit side of the orifice.

As the fluid reaches the exit side of the orifice it meets surface tension forces which resist formation of a jet. At the same time there is a strong capillary interaction between the fluid and the exit surface. This results in the above noted accumulation of surface fluid and the generation of non-symmetrical surface forces. Breakthrough and jet formation typically occur when the Weber's number reaches a value somewhere between about 3 and 10.

In the usual prior art system start-up is initiated by opening a fluid supply valve to permit fluid to flow from a supply tank down to the orifice. There is a relatively long time lag while the valve moves from a fully closed to a fully open position, and during this time there is a fairly substantial fluid flow at low pressure, inertia, and Weber's number. Consequently there is a sizeable accumulation of surface fluid prior to jet breakthrough with the result that the initial jet may be misaligned and may carry with it a large drop or glob of the liquid. In either event, quantities of the liquid may collect during starting on a charge ring or in other downstream passages, thus fouling the drop generator.

In other applications of streams formed by small diameter orifices the "start-up" phenomena described above may be of little consequence. However, when liquid jets are used as a means of precise drop placement, as in coating or printing, the "start-up" behavior of the fluid jets becomes important. This is especially true when an array of many jets is involved, requiring that large numbers of fluid jets pass through corresponding small openings. In such an array of jets the channels below the orifice plate very often become filled with globs of fluid when the jets are started. Thus it becomes necessary to remove the fluid from the downstream channels. This can usually be done by application of a vacuum to the orifice or by blowing the fluid out by air. However, both procedures are time consuming, and it is necessary that each of the orifices in the array be cleared.

SUMMARY OF THE INVENTION

The present invention relates to an apparatus and method which produces immediately a stream of liquid drops from the orifice of a drop generator without clogging or fouling downstream passages. In accordance with the practice of this invention a large amount of momentum is introduced into the fluid supply passages as an initial phase in the start-up process. This momentum is in the form of a fast rising pressure pulse or shock which travels down to the orifice temporarily creating a high effective Weber's number and producing a clean start-up.

The apparatus of the present invention includes a pressure impulse device in communication with an auxiliary liquid vessel which in turn is in communication with one or more drop generators. The pressure impulse device may be any of those well known in the art, e.g., a piston and cylinder arrangement powered by air pressure. In one embodiment of the invention, a piston is rapidly urged against the liquid in an auxiliary vessel, causing a sudden pressure rise in the liquid flow. This results in immediate formation of drops at the orifice of the drop generator. Thereafter, the liquid is supplied to the drop generator from a primary liquid supply by the operation of appropriate valves.

In another embodiment of the invention the liquid is supplied to the drop generator under a pressure slightly less than that required to initiate flow through the orifice. The liquid flows from a pressurized supply vessel through a master control valve and thence into two branch lines, one of which supplies the drop generator. The other branch line bypasses the drop generator and is equipped with a bypass valve which is opened prior to start-up. At start-up the master valve is opened and liquid flows from the supply vessel through the bypass line. Liquid also fills the drop generator line, but surface tension forces at the orifice contain the liquid in that line preventing formation of a drop stream. After the master valve has been opened and stabilized flow has been achieved through the bypass line, the bypass valve is abruptly closed. This generates a shock wave which travels back through the bypass line and down the drop generator line to the orifice. The shock wave overcomes the surface tension forces at the orifice and a rapid blob-free stream initiation ensues. The steady state pressure which follows the shock wave is sufficient to maintain a smooth steady flow through the orifice.

The object of the invention is to provide a clean starting of one or more drop generators by causing a rapid pressure rise time in the initial flow of liquid through the orifice of the generator, as by the inducing of a hydraulic shock in the liquid supply system at the moment of initiation of the flow.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a typical drop generating unit together with the primary and auxiliary liquid supply vessels and the pressure impulse generator;

FIG. 2 is a diagram of a modification; and

FIG. 3 is a diagram of another modification.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the primary or main liquid supply tank **10** is connected to supply coating or marking liquid, such as an ink, to a drop generator **12** through pipe **14**. A solenoid operated valve **15** controls the flow of liquid from tank **10** to the drop generator **12**. An auxiliary or starting liquid supply tank **20** is also connected to pipe **14**, and thus to the drop generator by a pipe **22**, and reverse flow toward the solenoid valve **15** is prevented by a check valve **23**. Pressure in pipe **14** can be created in any suitable way, for example by having tank **10** closed and imposing a suitable gas pressure over the liquid in the tank.

A pressure impulse generator **25** is mounted for delivery of a fast rise time shock to the fluid in tank **20**. The shock is created by driving rod **30** downwardly into impact with plunger **26**. This causes an extremely rapid acceleration of plunger **26** into tank **20** giving rise to the desired shock. Tank **20** is kept full of liquid so that there is no significant air space for shock attenuation.

Impulse generator 25 is cocked by opening valve 28 and admitting compressed air through pipe 27 into central chamber 29. Air pressure acting on the lower surface of piston 32 then combines with the action of return spring 31 to force plate 33 upwardly making a tight seal against "O" ring 34. Valve 28 may now be closed.

After impulse generator 25 has been cocked, it is fired by opening valve 38. This admits compressed air through pipe 37 into upper chamber 36 equalizing the pressure on both sides of piston 32. At this point the compressed air acting on the exposed upper area of plate 33 overcomes the restraining force of spring 31 breaking the seal at "O" ring 34. The air in chamber 29 is now vented downward into lower chamber 39 producing a rapid unbalance of forces on piston 32 and a consequent downward stroke of rod 30. The result is a hydraulic shock transmitted to the drop generator, and immediate formation of drops 40 in drop generator 12. The check valve 23 protects the solenoid valve and assists in having the shock transmitted directly to the drop generator.

A control unit 45, including start sequencing controls of conventional type, is connected to actuate the solenoid operated valve 15. It has been found important to sequence the starting procedure properly, such that the main liquid supply comes into operation immediately after drop generation is initiated. Thus, the control unit has appropriate connections to solenoid operated valves 28 and 38, and also has an input from a pressure sensing transducer 46 which is connected to sense the rapid pressure rise in pipe 22 when the impulse generator is actuated. Control unit 45 actuates valve 15 as soon as the pressure in pipe 22 has reached some predetermined level near the impulse peak.

The connected liquid supply pipes 14 and 22 lead to the orifice 47 of drop generator 12. In one typical form of generator, a charging electrode such as ring 48 is located at the point of drop separation, to induce charges on selected drops, and the drops then pass through an electrical field provided by the deflection electrodes 49. The drops follow their original trajectory if uncharged, or a different trajectory if charged and under the influence of the deflection field. Some of the drops, shown as those of the uncharged trajectory, can be deposited on a moving web, strip or sheet, indicated as a receiving surface 50. Relative movement between the surface 50 and the path of drops to be deposited will provide spacing between the drop deposits. Charged and deflected drops enter a catcher 52 and do not deposit. The arrangement can be converse if desired, with the uncharged drops being caught.

With this form of drop generator the size and spacing of the drops preferably is regularized by a stimulator 53. The stimulating frequency and the spacing movement between the surface 50 and the depositing drops is correlated to control the spatial relation of successive drop deposits. Charging intelligence for individual drops is received by an amplifier 54 which controls the potential of the charging electrode 48.

FIG. 2 illustrates another embodiment of the invention. Similar parts are designated by similar reference numerals with the suffix *a*. A primary supply tank 10*a* is connected to the drop generator 12*a* by line 14*a* which is controlled by master control valve 57. A by-pass line 55 is connected to the primary supply line 14*a* to form a return circuit to a collection tank T, as shown. By-pass line 55 is equipped with a solenoid operated valve 56 which is controlled by control unit 45*a*.

Prior to start-up, valve 56 is open while valve 57 is closed. As a first step in the start-up sequence, valve 57 is opened to establish a steady flow from tank 10*a* through lines 14*a* and 55 to tank T. Fluid also flows down to drop generator 12*a*, but the surface tension forces at orifice 47*a* prevent any fluid passage past that point. The start-up sequence is then completed by rapid closure of valve 56 causing a hydraulic shock to be sent back through line 55 and down to orifice 47*a*. The shock overcomes surface tension forces producing a fast clean stream initiation. Following the shock there is a steady state pressure of sufficient magnitude to maintain flow through the orifice.

FIG. 3 shows in an exploded view the adaptation of this invention to an array of drop generators where close spacing makes it desirable to minimize the number and size of parts. One array is shown projecting parallel streams of drops, but additional such arrays can be provided with the drop paths arranged to track adjacent lines on the web for more thorough coverage. The close spacing of the parts makes clogging during starting a more acute problem, and more difficult to clean up.

As in FIG. 1, liquid is supplied from a pressure impulse generator and starting tank 60, and during running from primary liquid supply tank 62, into the chamber 70 in a top bar 71, and passes to a plurality of orifices 72 formed in a plate 73 fastened beneath the chamber. Each of the resulting liquid filaments breaks into drops, and a stimulating means in the form of a vibrator 75 causes equally sized drops to form at a frequency which is common to all filaments. Details of the impulse generator and the starting controls are the same as shown in FIG. 1.

Beneath the orifice plate is a plate 77 having openings in which charging electrode rings 78 are carried, each ring being connected through a separate conductor 79 to an individual terminal in a terminal area 80 at one end of the plate 77. Suitable electrical insulation (not shown) is provided between plates 73 and 77. An insulating spacer plate 82 is fastened below the charging plate 77 and provides at its ends a mounting place for terminal plugs 84 which have separate circuit connections for each conductor 79. These plugs engage receptacle units 85 which are connected through suitable cables 86 to the master control and switching unit 88 that in turn receives input signals representing intelligence to be reproduced on the moving web 90.

Below the spacer plate is a grounded guard electrode plate 91, on top of a deflection assembly comprising an insulating support bar 92 mounting deflection electrodes 94 across which a substantial potential difference is applied. Uncharged drops follow a straight trajectory and deposit on web 90, which is moved at constant velocity correlated to the drop generating frequency so that a continuous succession of drops will cause a continuous trace along the web. Charged drops will follow a curved trajectory due to the deflecting field, and these drops are removed from the system through a common catcher assembly 95.

While the method and forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise method and forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the following claims.

What is claimed is:

1. Apparatus for initiating flow of a fluid through an orifice into a space and under conditions to cause immediate formation of a liquid filament and its separation into drops, comprising a primary liquid supply, a pipe extending from said supply and communicating with the orifice, means for applying a constant pressure to liquid in the supply, starting means for applying an initial higher pressure impulse to liquid in the pipe to initiate flow through the orifice, said starting means including an auxiliary liquid supply also connected with said orifice, valve means controlling the connection of said primary liquid supply to said orifice, means for applying a pressure impulse to the liquid in said auxiliary liquid supply to commence flow through said orifice with said valve means in a closed starting position, and control means operative in response to the pressure impulse to open said valve means thereafter and to continue the liquid supply from said primary liquid supply.

2. Apparatus defined in claim 1 wherein said means for applying a pressure impulse includes a closed auxiliary supply tank filled with the liquid, and a piston movable to impart an impulse to the fluid in said auxiliary tank.

3. Apparatus as defined in claim 1, wherein said control means includes a pressure transducer connected to said auxiliary liquid supply for sensing the impulse in the liquid.

4. Apparatus for initiating flow of a fluid through an orifice into a space and under conditions to cause immediate forma-

tion of a liquid filament and its separation into drops, comprising a primary liquid supply, a pipe extending from said supply and communicating with the orifice, means for applying a constant pressure to liquid in the supply, a bypass pipe connected to said pipe for conducting liquid away from said orifice, and a rapidly closable valve means located in said bypass pipe and providing means for applying an initially higher pressure impulse to liquid in the pipe to initiate flow through the orifice.

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