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[54] **FLUIDICALLY CONTROLLED DISPLAY FOUNTAIN**
12 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **239/23,** 137/81.5, 239/102, 239/468, 239/494
[51] **Int. Cl.** **B05b 17/08**
[50] **Field of Search** 239/17, 19, 22, 23, 102, 468, 494; 137/81.5

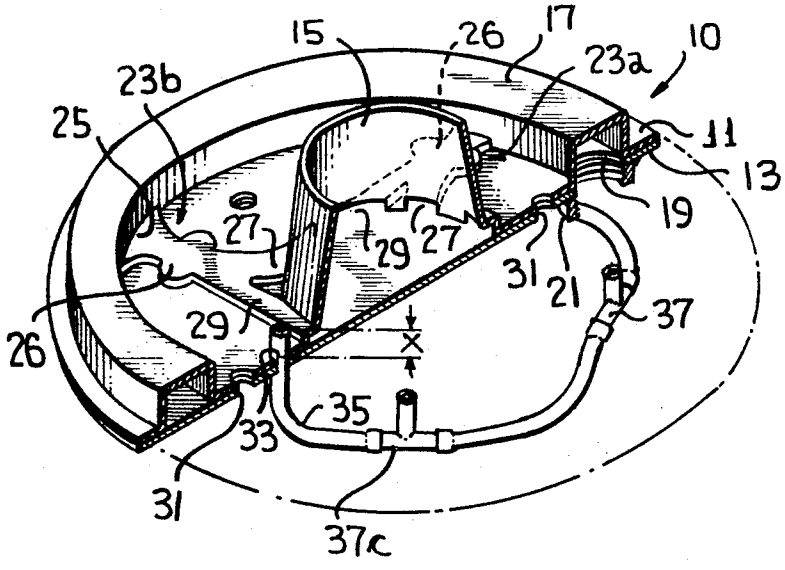
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ABSTRACT: A method and apparatus are disclosed for providing a sequentially varying flow pattern for a display fountain. A generally cylindrical chamber, having an upwardly directed open end, receives fluid from a plurality of fluidic diverter elements which are circumferentially spaced about the chamber periphery. One outlet from each diverter directs liquid radially into the chamber and the other diverter outlet directs liquid tangentially into the chamber. Tangential inflow to the chamber causes the liquid to issue from the open chamber end as an integral sheet which follows a generally parabolic trajectory in flowing toward a pool below the apparatus. The sheet continues to spin while falling, forming a bubble of size determined by the number of diverters which feed fluid tangentially into the chamber. By sequentially switching the diverters, the bubble can be made to grow and/or diminish in rhythmic sequential steps.



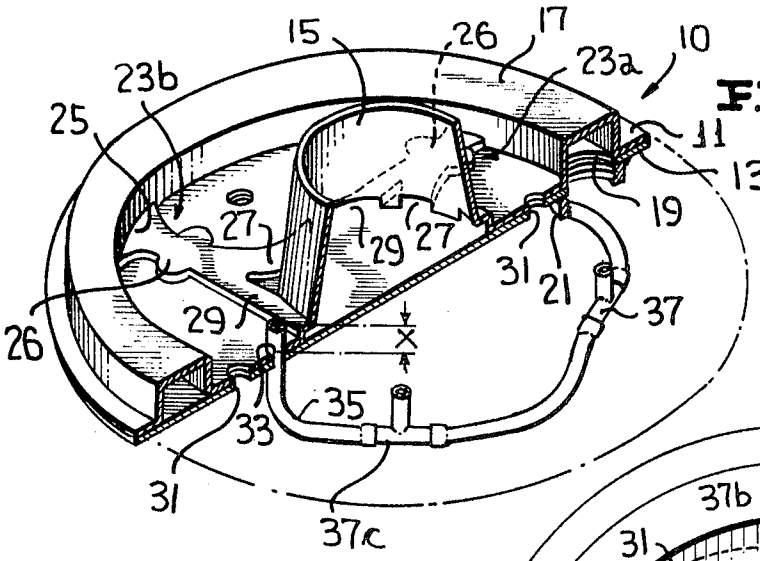


FIG.1

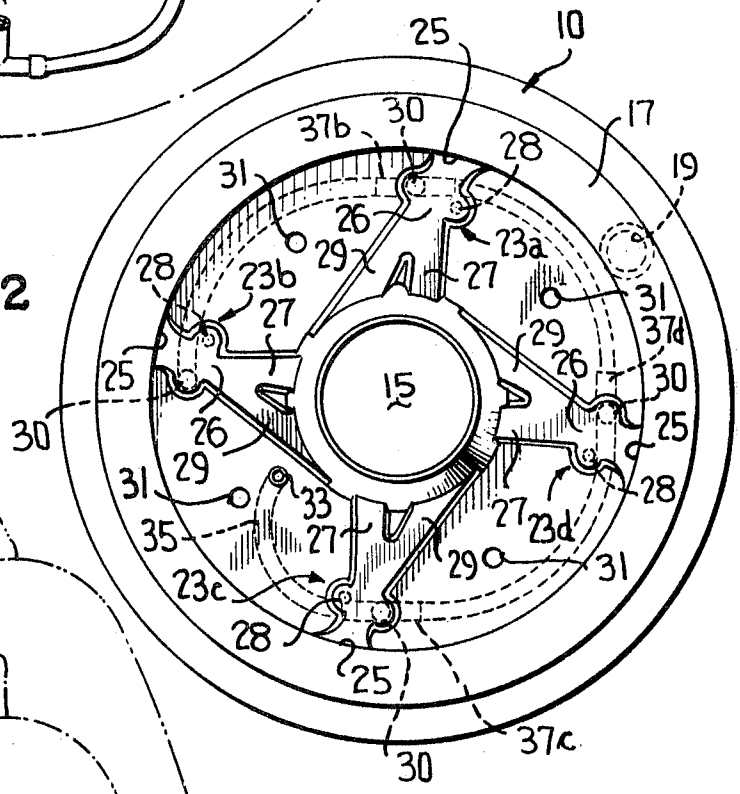


FIG.2

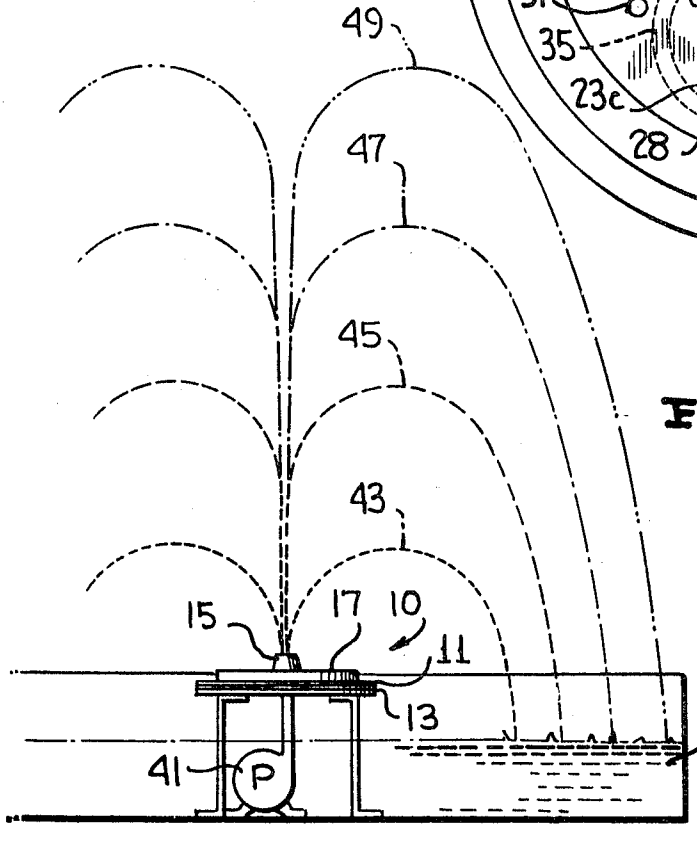


FIG.3

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FLUIDICALLY CONTROLLED DISPLAY FOUNTAIN

BACKGROUND OF THE INVENTION

The present invention relates to fountain displays and more particularly to a method and apparatus for providing a sequentially varying liquid flow pattern.

Display fountains in the prior art are able to provide various configurations of eye-appealing flow patterns; however, as a general rule, the more intricate flow patterns require increasingly expensive and complex equipment. The expense and complexity are further increased when sequencing controls are employed to produce rhythmic flow pattern variations. These controls are usually electrically or pneumatically actuated valves having moving parts which eventually wear out or otherwise fail.

A particularly decorative flow pattern which has not been achieved with complete satisfaction in the prior art is a bubble formed by a thin sheet of liquid which entraps air interiorly thereof as it flows down and away from some predetermined location above a display pool or pond. The problem has been one of maintaining the sheet integral to prevent its premature breakup so that a bubble of significant size may be achieved. Sheet integrity becomes even more of a problem where rhythmic variations in bubble size are desired because the variations in flow requirements for different size bubbles cause disturbances in the flow.

In copending U.S. Pat. application Ser. No. 862,286 filed Sept. 30, 1969 by Ronald Stouffer and entitled "Fountain Display Element," there is disclosed a device for providing the aforesaid bubble-type flow pattern.

It is an object of the present invention to provide a simple and inexpensive approach to providing decorative flow patterns of rhythmically varying size.

It is another object of the present invention to provide a method and apparatus for producing a bubble-configured fountain display wherein the bubble size can be selectively or rhythmically varied.

It is still another object of the present invention to provide a decorative liquid flow pattern which can be varied in size without changing the flow rate of the supply liquid.

Still another object of the present invention is to employ fluidic elements to control the size of a decorative flow pattern.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention a fountain display element is provided with a generally cylindrical chamber having an open end and a closed end. Fluidic diverters are equally spaced about the chamber periphery, each diverter having one outlet arranged to issue liquid radially into the chamber and another outlet arranged to issue liquid tangentially into the chamber. When tangentially directed liquid issues into the chamber the liquid spins within the chamber and, due to centrifugal forces, clings to the chamber wall unit it issued from the open chamber end. When the latter is directed upward, the liquid so issued spins out and away from the chamber and falls in a thin rotating sheet of generally parabolic cross-sectional configuration. The spinning sheet, while flowing as described, forms a bubble of size dependent upon the tangential inflow to the chamber. Radial inflow to the chamber contributes to flow rate in the bubble but does not contribute significantly to the bubble size. Consequently, the bubble size at any time depends upon the number of diverters directing tangential flow into the chamber. By sequentially switching the diverters, the bubble size can be made to rhythmically increase and decrease in an interesting and decorative manner.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a view in perspective and partial section of a preferred embodiment of the present invention;

FIG. 2 is a top view of the embodiment of FIG. 1; and

FIG. 3 is a diagrammatic illustration of the various operational modes of the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. 1 and 2 of the accompanying drawings there is illustrated a display element **10** comprising a plate **11** and cover plate **13** secured together, with adjacent surfaces in fluidtight relationship, by means of screws, bolts, or suitable adhesives. Plate **11** is preferably, though not necessarily, made of a plastic material which can be suitably molded or otherwise formed to provide the various passages, ports and chambers described below.

A generally cylindrical chamber **15** is formed in plate **11** and has one end closed by plate **13**. The opposite end of chamber **15** is open to ambient pressure. As illustrated in the drawings, chamber **15** may be tapered slightly (convergent toward its open end) in order to facilitate removal of plate **11** from its mold during manufacture of element **10**; a variation on the order of 7° or 8° from the perpendicular to plate **13** does not produce an appreciable change in the operation of element **10**.

A supply passage **17** of generally circular configuration is disposed concentrically about chamber **15**. Passage **17** is formed as a recess in plate **11** and is sealed by plate **13**. An aperture or port **19** is defined through plate **13** in communication with passage **17** and is provided with a fluid fitting **21**. Aperture **19** serves as an inlet port for pressurized liquid to be supplied to passage **17**.

Four circumferentially spaces fluidic diverter elements **23***a*, **23***b*, **23***c* and **23***d*, formed as recesses in plate **11** and sealed by plate **13**, communicate between supply passage **17** and chamber **15**. The recesses forming the diverters are as deep as necessary to provide the desired flow rates through the diverters. Each diverter element includes an inlet port **25** which receives pressurized fluid from supply passage **17** and which converges to form a nozzle from which the inflowing fluid is issued into an interaction region **26**. Left and right control ports **28** and **30**, respectively, comprising apertures defined through plate **13**, communicate with respective sides of interaction region **26**. For reasons to be described hereinbelow, left control port **28** is appreciably smaller than right control port **30**, and the sides of interaction region **26** bulge outwardly in semicircular projections in the region wherein control ports **28** and **30** are defined. Downstream of these control port projections in the interaction region sidewalls diverge but at a sufficiently gradual rate to permit the Coanda effect phenomenon to cause a fluid stream flowing through interaction region **26** to lock into either sidewall.

The downstream end of interaction region **26** is defined by the ingress openings of left and right outlet passages **27** and **29** respectively, which are separated by a flow divider. Left outlet passage **27** is arranged so that fluid flowing therethrough issues radially into chamber **15** along plate **13**; right outlet passage **29** is arranged so that fluid flowing therethrough issues tangentially into chamber **15** along plate **13**.

Diverter elements **23***a*, *b*, *c* and *d* are of substantially the same dimensions and preferably, though not necessarily, are equally spaced about chamber **15**. It will also be understood that while four such diverter elements are illustrated and described herein for the preferred embodiment of this invention, any number of such diverters may be employed. The operation of the diverter elements is well known, and proceeds in accordance with the principles described in reference to the novel diverter element disclosed in my copending U.S. Pat. application Ser. No. 842,599, filed July 17, 1969. More particularly, pressurized liquid applied to inlet

port 25 issues into interaction region 26. In so doing it entrains ambient air from both sides of the interaction region through control ports 28, 30. If right control port 30, the larger of the two control ports, is unblocked, a greater amount of air is entrained at the right side of the power stream. This results in a greater pressure on the right side of the power stream than on the left side and causes the stream to attach to the left sidewall of interaction region 26. The resulting outflow is through left outlet passage 27 and issues radially into chamber 15.

If right control port 30 is now blocked to prevent aspiration of air therethrough by the power stream, the pressure on the left side of the power stream becomes greater than that on the right side and the power stream switches to a new position wherein it is locked on to the right sidewall of interaction region 26. Outflow now is via right outlet passage 29 and tangentially into chamber 15.

The purpose of the semicircular projections in the region of the control ports is as follows: a small outer portion of the power stream liquid is scooped off each side of the power stream and recirculated within the projections. The recirculated flow is of a vortical nature, centering about respective axes which extend through control ports 28, 30. The vortex core is a region of low pressure and consequently ambient air is positively drawn into the projection through the control ports. This vortex action in the control port projection thereby increases the ambient air aspiration or entrainment over that which would result from the simple flow of the power stream past the control port. The overall effect is a much more positive switching of the power stream when one or the other of the control ports is blocked.

Four drain apertures 31 are defined through plates 11 and 13 between respective adjacent diverter elements, apertures 31 being located intermediate supply passage 17 and chamber 15. In addition, a single control aperture 33 is defined through plates 11 and 13 between supply passage 17 and chamber 15. In the illustrated embodiment control aperture 33 is located between diverter elements 23*b* and 23*c*. A flexible tubing 35 is slidably engaged in control aperture 33 and has an open end extending to a height X above plate 11. The portion of tubing 35 which extends below plate 13 follows a generally circular path whereby it connects, in sequence, to the right control ports 30 of diverter element 23*c* (via tee fitting 37*c*), 23*d* (via tee fitting 37*d*), 23*a* (via tee fitting 37*a*), and 23*b*. The outside diameter of tubing 35 must be such as to permit engagement thereof in control aperture 33. The inside diameter of tubing 35 must be greater than that of the left control ports 28 of the diverter elements so that when tubing 35 is unblocked a greater rate of ambient air inflow is permitted through right control ports 30 than through left control ports 28. Each section of tubing 35 which extends between adjacent diverter elements is preferably of the same length, though this is by no means a limiting factor for the present invention.

In operation, with additional reference to FIG. 3, element 10 is usually supported above a display pool or pond 39 with plate 11 facing up, and is supplied with pressurized liquid at inlet port 19, such as by means of pump 41. Initially, the pressurized liquid is supplied to supply ports 25 of each diverter element and flows through the left outlet passage 27 of each such diverter element. This is so because tubing 35 is unblocked and ambient air is aspirated through right control ports 30 at a greater rate than through left control ports 28. The outflows through left outlet passages 27 enter radially into chamber 15, gradually filling the latter with liquid. When chamber 15 fills it begins to overflow onto plate 11, and the overflowing water is trapped in the region between supply passage 17 and chamber 15. A portion of this trapped liquid drains into pond 39 via drain holes 31; however, the drain holes are made sufficiently small to assure that the overflow rate from chamber 15 is greater than the combined drain rate through all of drain holes 31. In this manner the liquid level begins to rise in the region between supply passage 17 and chamber 15 until such time as the level exceeds the height X to which the open end of tubing 35 extends above plate 11. At this time the liquid blocks aspiration of ambient air through tubing 35, which in turn causes the diverter elements 23*a*, 23*b*, 23*c* and 23*d* to switch. More specifically, when tubing 35 becomes blocked, the liquid flows in tubing 35 and, after a short delay determined by the tubing length between the open end and tee fitting 37*c*, blocks right control port 30 of diverter element 37*c*. Since the ambient air inflow through left control port 28 now exceeds that through the right control port 30 at element 23*c*, outflow through this element is switched to right outlet passage 29. At this point in time, therefore, diverter element 23*c* issues liquid tangentially into chamber 15 and the remaining diverter elements issue liquid radially into chamber 15. The tangential flow component imparted to the liquid in chamber 15 by element 23*c* causes the liquid therein to spin at a relatively low rate. As a consequence of the centrifugal forces acting on the spinning liquid, the latter clings to the inner wall of chamber 15 and is pushed toward the open chamber end by the pressure of the upstream liquid. Upon reaching the open chamber end the liquid issues therefrom in a spinning sheet 43 which is initially thrown upward and away from chamber 15. As gravity begins to overcome the upward thrust, the liquid, still in the form of a spinning sheet, begins falling toward pond 39. If considerations to be described subsequently are adhered to, the spinning sheet remains integral throughout its entire trajectory into the pond, thereby forming a bubble of entrapped air interiorly of the sheet. The trajectory is generally parabolic in cross-sectional configuration, and the bubble is substantially symmetrical about the longitudinal axis of chamber 15.

After a further delay, occasioned by the time required for liquid to flow from tee fitting 37*c* to tee fitting 37*d*, diverter element 23*d* also switches to provide tangential inflow to chamber 15. This increases the tangential flow component in the chamber, producing a greater rate of spin in the liquid, and a greater thrust of the spinning liquid up and away from the chamber. The resulting flow pattern 45 is similar as pattern 43, but provides a higher and wider spinning sheet and a concomitantly larger bubble.

In like manner, after respective delays, diverter elements 23*a* and 23*b* are switched to provide tangential inflow to chamber 15, resulting in larger flow patterns 47 and 49 respectively. When all four diverter elements are thusly switched, all four continue to aspirate liquid via tubing 35 and right control port 30, thereby, along with drainage through drain holes 31, lowering the level of liquid trapped on the surface of plate 11. When the liquid falls below level X, tubing 35 is opened to ambient air which is then aspirated through the right control ports 30 of the diverter elements. The latter are switched thereby, providing only radial inflow to chamber 15, and causing the spinning sheet to collapse. The liquid once again begins to overflow onto plate 11 and the cycle repeats.

It is to be noted that drain holes 31 may be dispensed with, leaving aspiration by the diverter elements as the sole means for lowering the liquid level on plate 11. This of course would reduce the speed at which the level of the liquid recedes and therefore the cycle would dwell longer at "full bubble" (i.e. pattern 49) than would be the case where drain holes are provided.

The distance X to which tubing 35 extends above plate 11 can be varied by simply sliding tubing 35 in aperture 33. If X is made large, the dwell time at "full bubble" is relatively short and the "no bubble" condition predominates the cycle. This is because it takes a relatively long time for the overflowing liquid from chamber 15 to achieve level X and a relatively short time to recede below level X. Likewise, for short distances of X, the cycle has a relatively long dwell time at "full bubble" and relatively short dwell time at "no bubble."

It has been found that in order to provide an integral "bubble sheet" throughout the entire pattern trajectory, it is important that the flow issued from chamber 15 be well into the laminar regime. To clearly satisfy this requirement, a Reynolds number, based on the thickness of the spinning liquid sheet at the point of discharge from chamber 15, below

100 is acceptable. In addition, sheet integrity for most applications requires a Weber number at or below 30. The Weber number is a dimensionless ratio which interrelates the effects of inertial forces and surface tension forces of the liquid; it is given by the formula:

$$W=\rho\lambda v^2/\sigma \qquad (1)$$

where W is the Weber number, ρ is the mass density of the ambient fluid (air for present purposes) in slugs per cubic foot, V is the velocity of the liquid in feet per second, σ is the surface tension of the liquid in pounds per foot, and λ is the wavelength, in feet, of the characteristic undulating waves in the liquid sheet. The undulating waves are a characteristic phenomenon associated with the "sheet bubble" flows pattern; the waves are primarily produced by perturbations in the pressurized liquid supply and become significantly longer as the perturbations are reduced. It follows that a relatively smooth, unperturbed supply permits formation of "sheet bubbles" which remain integral over appreciably longer trajectories than is the case for noisy, variable pressure supplies.

An example of the bubble size which can be achieved in accordance with the above-described principles can be best appreciated from the parameters listed in the table below:

TABLE

Parameter	Value in Example
length of chamber **15**	2 in.
diameter of closed chamber end	4 in.
diameter of open chamber end	3.5 in.
I. D. of passage **17**	6 in.
O. D. of passage **17**	9 in.
height of passage **17**	0.5 in.
average cross section of passages **27, 29**	⅜ in. × ⅜ in.
water pressure in passage **17**	28 in. of H_2O
height of open chamber end above pond **39**	14.5 in.

With the above parameters, the flow pattern was observed to begin breaking up about four inches above pond **39**; the peak of the pattern trajectory was 15¼ inches above the pond; the diameter of the bubble at its widest integral location was 32 inches; and the thickness of the liquid sheet was 0.075 inches. The characteristic wavelength, λ, was measured with stroboscopic equipment at 0.855 feet.

When the working liquid is water, the spinning sheet is crystal clear and very much like glass in appearance. Consequently, very interesting and decorative refraction and reflection effects can be achieved with appropriately directed colored lighting.

A particularly interesting feature of the present invention is that the inflow rate to chamber **15** remains substantially constant, regardless of the switching states of the various diverter elements. This is because all of the inflow to a given diverter is diverted to chamber **15**, regardless of the switching state of that diverter; the only effect the switching state has is on flow direction in chamber **15**. Since the flow rate through chamber **15** can be maintained constant, the above-described conditions for bubble integrity can be readily achieved for all of patterns **43, 45, 47** and **49**.

It is to be understood that for some applications tubing **35** can be dispensed with and the right control ports **30** of the various diverters can be sequentially blocked by externally controlled devices; the preferred embodiment, however, is the embodiment illustrated in the drawings because the sequential control mechanism is effectively self-contained.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. A element for producing decorative liquid flow patterns, comprising:

a plurality of fluidic diverter elements, each having a first operative state in which pressurized fluid is issued from a first outlet passage, a second operative state in which fluid is issued from a second outlet passage, and control means for selectively and individually determining the operative states of said diverter elements; and

a chamber having inlets for receiving pressurized fluid from the first outlet passage of each of said diverter elements and having at least one outlet for issuing fluid so received in a predetermined flow pattern having a configuration dependent upon the number of said diverters which are in said first operative state, said at least one outlet being larger than each of said inlets.

2. The combination according to claim **1** wherein said chamber is of generally cylindrical configuration having a closed end and an open end, and wherein said first outlet passage of each diverter element is arranged to issue pressurized fluid tangentially into said chamber proximate said closed end.

3. The combination according to claim **1** further comprising means responsive to all of said diverter elements in said second operative state for supplying a predetermined region with liquid, and means responsive to the liquid in said predetermined region achieving a specified level for sequentially switching said diverter elements to said first operative state.

4. A display element for producing a variety of decorative liquid flow patterns, said element comprising:

a chamber of generally cylindrical configuration having a longitudinal axis and including a wall of circular cross section, one entirely open end for issuing said liquid flow, and a closed end, and

control means having first and second operative states for issuing liquid into said chamber generally transversely of said longitudinal axis, said liquid being directed radially into said chamber in said first operative state and tangentially into said chamber in said second operative state.

5. The display element according to claim **4** further comprising means for sequentially switching said control means between said first and second operative states.

6. The combination according to claim **4** wherein said control means comprises a plurality of fluidic diverter elements, each having first and second operative states, an inlet port responsive to application of pressurized liquid thereto for issuing a power stream of liquid, a first outlet passage for issuing said power stream radially into said chamber in said first operative state, a second outlet passage for issuing said power stream tangentially into said chamber in said second operative state, and means for selectively effecting said first and second operative states.

7. The combination according to claim **6** further comprising means for cyclically switching said fluidic diverter elements in a predetermined sequence from their respective first to second operative states.

8. The combination according to claim **7** wherein said means for selectively effecting said first and second operative states includes first and second control ports arranged on opposite sides of said power stream for inflowing ambient air to said diverter in response to aspiration by said power stream, said second control port being larger than said first control port such that when unblocked said second control port inflows ambient air at a greater rate than said second control port and thereby deflects said power stream to said first outlet passage, said combination further comprising:

container means for receiving overflow liquid from said chamber when all of said diverter elements are in said first operative state; and

switching means for sequentially switching said diverter elements to said second state when the liquid level in said container means is above a predetermined level.

9. The combination according to claim 8 wherein said switching means comprises a tube having one end disposed in said container means at said predetermined level and exposed to ambient air when the liquid level in said container means is below said predetermined level, and connected sequentially to the second control port of each of said fluidic diverter elements.

10. The combination according to claim 9 wherein said container means includes means for slowly draining liquid therefrom at a slower rate than liquid is supplied thereto when all of said diverter elements are in said first operative state.

11. The combination according to claim 4 further comprising a liquid supply passage disposed concentrically about said chamber for receiving liquid under pressure, and wherein said control means comprises a plurality of fluidic diverter elements each having respective first and second operative states, a power nozzle arranged to receive pressurized liquid from said supply passage and issue a power stream of liquid, a first outlet passage arranged to issue said power stream radially into said chamber near said closed end when said diverter element is in said first operative state, a second outlet passage arranged to issue said power stream tangentially into said chamber near said closed end when said diverter element is in said second operative state, and control means for selectively effecting said first and second operative states.

12. The combination according to claim 11 further comprising a region between said supply passage and said chamber for receiving liquid overflowing the open end of said chamber when all of said diverter elements are in said first operative state, and means responsive to the liquid in said region achieving a predetermined level for sequentially switching said diverter elements from said first to said second operative states.