United States Patent [19]

Lambert

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[45] **May 14, 1974**

[54] **PULSATING SYRINGE**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 110,094, Jan. 27, 1971, abandoned.

[52] **U.S. Cl.** **128/66**
[51] **Int. Cl.**.. **A61h 9/00**
[58] **Field of Search** 128/66, 224, 229, 230

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[57] **ABSTRACT**

A hydraulic oscillator which produces a pulsed output from a steady flow input. The oscillator utilizes a rigid pressure chamber containing a charge of gas under pressure. A conduit passes through this chamber, and the conduit includes an inlet passage, an outlet passage and, interconnecting and extending between these passages, a flexible, resilient, collapsible-walled tubular portion. The outside of this portion is fully peripherally exposed to gas pressure in the chamber. When the impedance and resistance to liquid flow through the inlet and outlet passages, the elasticity and dimensions of the tubular portion, and the gas pressure in the chamber, are appropriately selected, then a liquid stream entering the inlet passage at a suitable pressure relative to the chamber pressure, will emerge as a pulsating flow. This pulsating flow is particularly suited to many purposes, including the cleaning, irrigating and massaging of biological living tissue, the creation of cavitation in a flowing stream, and the momentary and cyclical reversal of the direction of flow in a generally forwardly flowing system. Systems for utilizing this oscillator for these purposes are disclosed.

13 Claims, 7 Drawing Figures

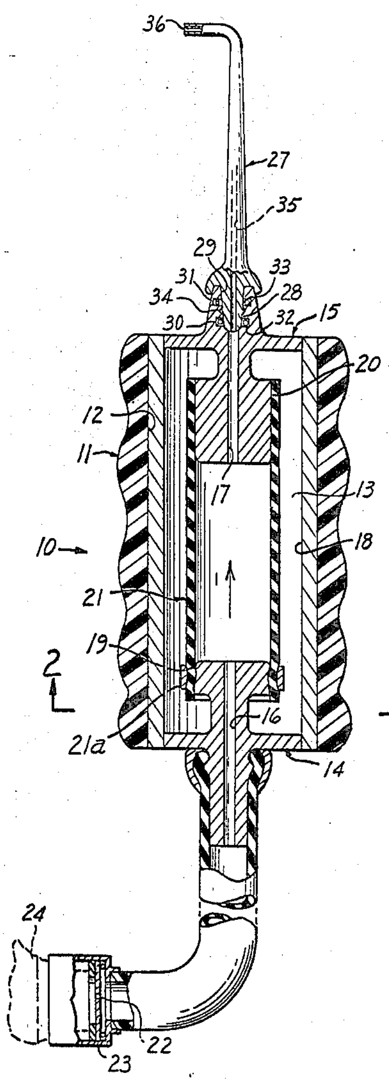


FIG. 1

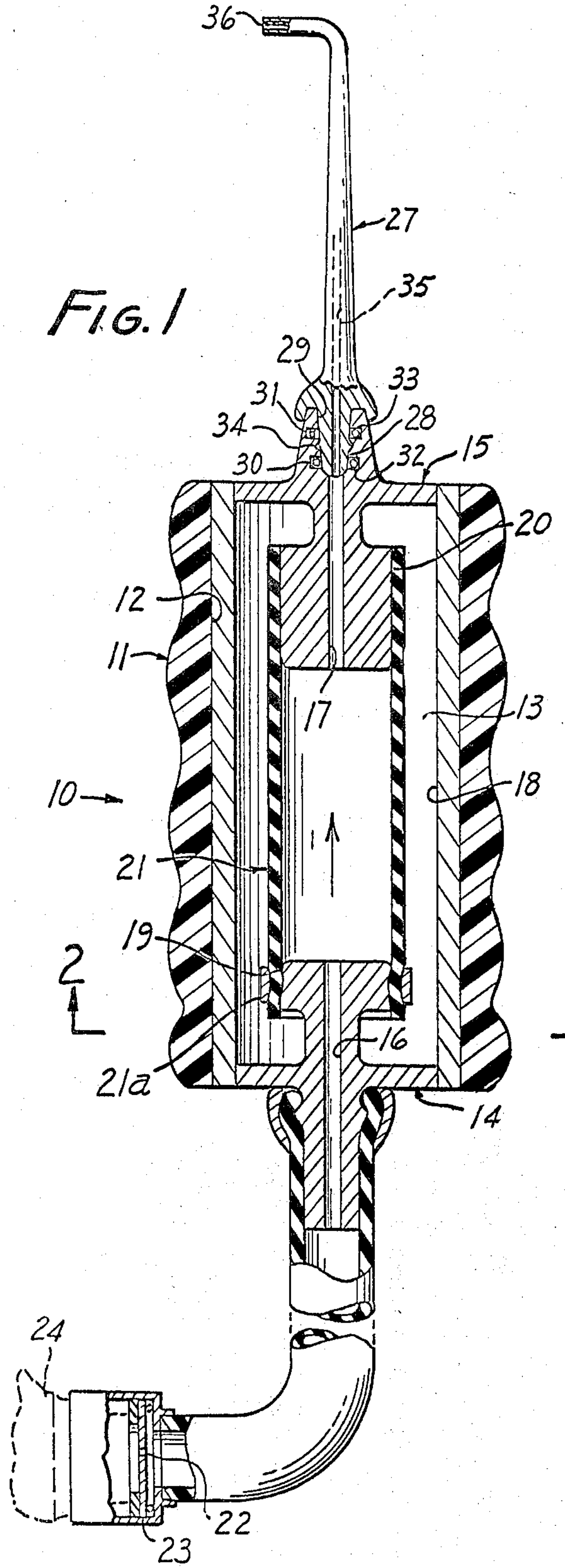
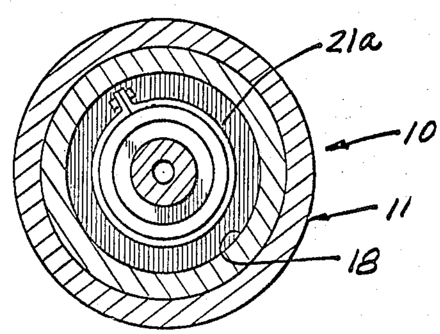


FIG. 2



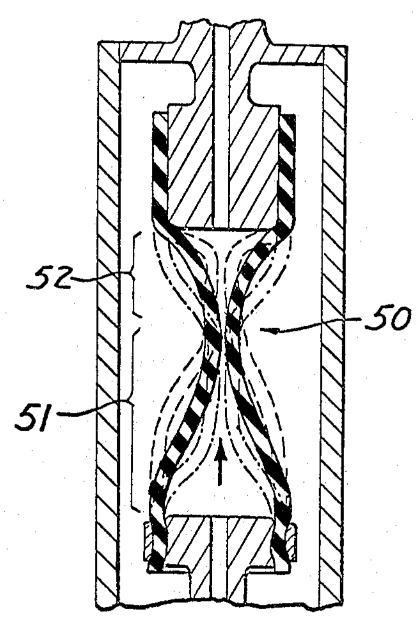


FIG. 3

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FIG. 4

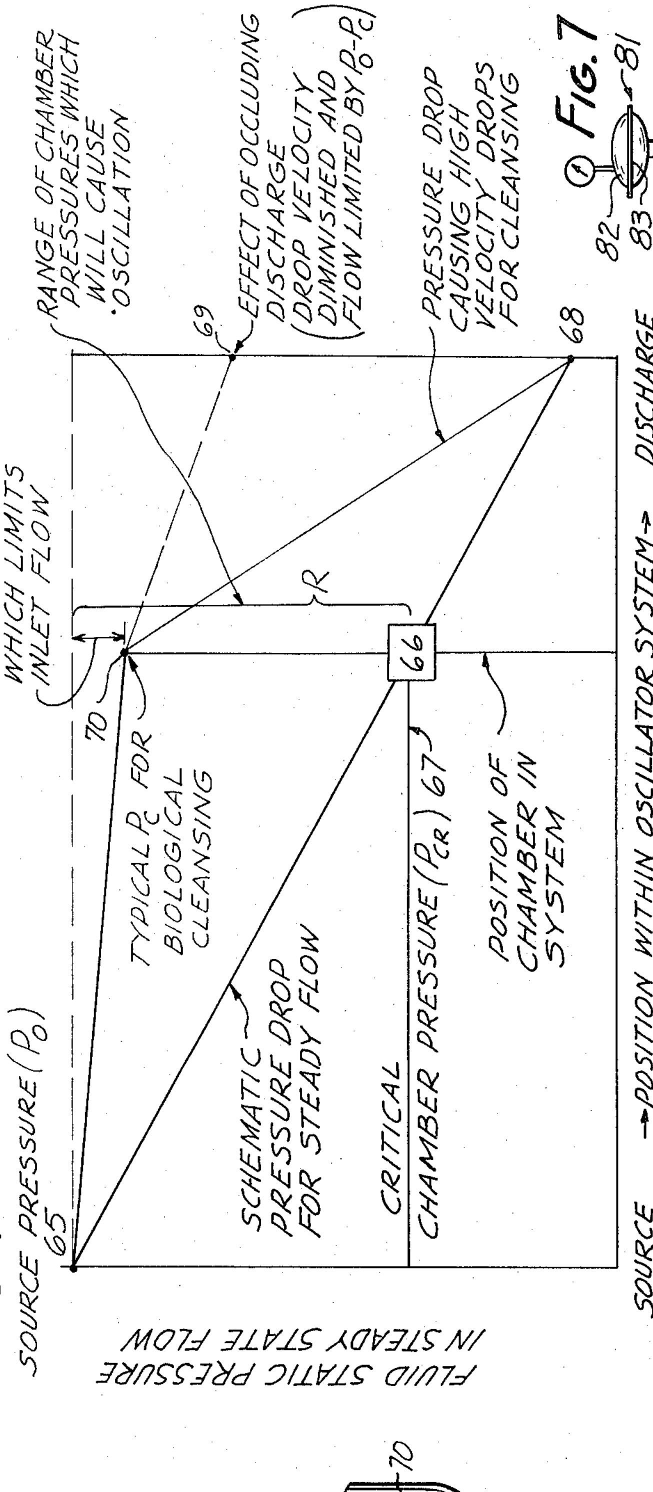
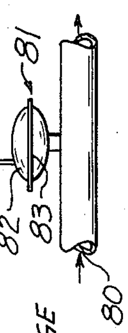


FIG. 7



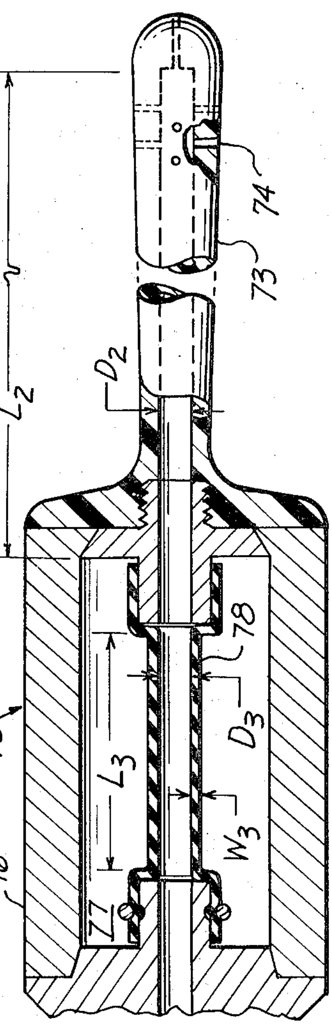
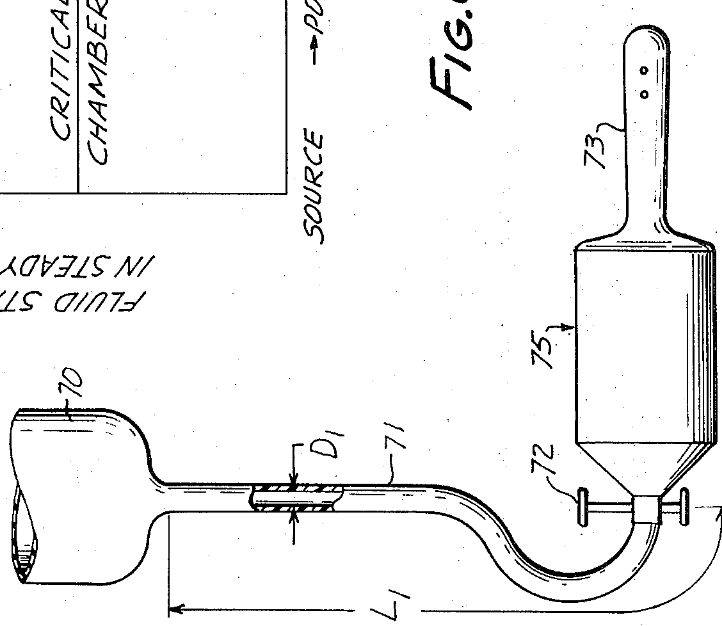


FIG. 6

FIG. 5



PULSATING SYRINGE

CROSS-REFERENCE TO OTHER PATENT APPLICATIONS

This application is a continuation-in-part of applicant's abandoned copending U.S. Pat. application, Ser. No. 110,094 filed Jan. 27, 1971, entitled Oral Hygiene Device, which was abandoned upon the filing of this instant application.

This invention relates to a hydraulic oscillator which converts a steady-flow stream of water into a pulsating stream, without the use of moving parts as that term is commonly used. It also relates to a system for providing a pulsating liquid flow of unique properties for various purposes, including the irrigation, cleansing or massaging of biological tissue.

One disadvantage of existing devices for this function resides in their usage of various classes of motors, pumps, and precision parts in order to create the pulsating flow, and in the resulting high cost and short-term functional life of the device.

Still another disadvantage of prior art devices for producing pulsed streams for cleansing biological tissues resides in what occurs if the outlet nozzle is fully or partially occluded. If the device is a constant-displacement type, as many are, then the pressure of the stream will rise as high as necessary in order to overcome the obstacle and eject the liquid (subject, of course, to stalling out or breaking first). Partial occlusion of the exhaust orifice decreases its cross-section, and causes the pressure to rise and the stream to accelerate. This would occur in the case of the partial occlusion which would result when the high pressure partially unblocked the orifice, or in which the orifice was brought close to a blocking surface. In both events, an undesirably strong, small jet of fluid results, which can severely abrade and damage the tissue.

A similar result occurs when an orifice discharging from a steady state stream carried from a water source such as a faucet is partially or totally blocked. While the pressure itself will build no higher than that of the source, the velocity of the effluent stream will increase partially, and may do damage to the tissue.

In contrast, the partial occlusion of the outlet stream of this invention actually causes the system to throttle down to a mere dribble. There is no risk of damage to the tissues, because there is no jetting stream. Accordingly, a pulsating jet stream can be directed at the most sensitive of tissues, without caution for the placement of the nozzle, in the sure and certain knowledge that no jet stream will issue except at safe velocities and pressures. Thus, the oscillator according to this invention enables to be made a new pulsating-jet system with completely different output characteristics from those which have heretofore been known.

Another disadvantage of prior art pulsating jet systems resides in the fact that they cannot "tailor" the shape and volume of the globules of the jet stream. In accordance with this invention, while still maintaining the same frequency (which itself is selectible), one can vary the liquid content (volume) and shape (length and cross-section) of the globules so as to impinge upon a surface a stream of globules of a shape which can optimally treat the surface.

Another object ot this invention is to produce, when desired a momentary and cyclical reversal of the direction of flow in generally forwardly-flowing stream. This

enables elements such as filters to be continuously backwashed. This is only one of many potential uses of this feature.

Still another object of this invention is to produce, if desired, cavitation in the outlet stream. There are many potential uses, besides that of study of the phenomenon, of considerable value.

A hydraulic oscillator according to this invention includes a rigid pressure chamber containing a charge of gas under pressure. A conduit passing through and extending beyond the chamber has an inlet passage, an outlet passage, and between and interconnecting these two passages, and physically attached thereto, a deflectible resilient-walled-tubular portion whose outside wall is fully peripherally exposed to the said gas pressure in the pressure chamber. The pressure of the gas charge is related to the pressure of the liquid in the inlet passage, such that the liquid is driven out of the device at a velocity faster than it enters, and as a result, the fluid stream is broken up corpuscularly, resulting in a pulsating flow of timed, spaced-apart drops of water. The impedance and resistance to liquid flow through the inlet and outlet passages, the elasticity and dimensions of the tubular portion, and the gas pressure in the chamber, are selected such that a pulsating flow is created at the exit from the outlet passage.

A tissue-treating system according to this invention utilizes the foregoing oscillator in combination with a source of liquid under pressure connected to the inlet passage by a supply tube.

According to a preferred but optional feature of this invention, the properties of the source other than its pressure output, are substantially dynamically isolated from the tubular portion, whereby waves set up by the tubular portion's contortions do not deleteriously interact with the properties of the pressure source.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is an axial cross-section, partly in schematic notation, showing the presently preferred embodiment of the invention;

FIG. 2 is a cross-section taken at line 2—2 of FIG. 1;

FIG. 3 is a fragmentary axial cross-section schematically showing some facets of the operation of the device in FIG. 1;

FIG. 4 is a graph illustrating some features of the operation of the system;

FIG. 5 is a schematic elevation of another embodiment of the invention;

FIG. 6 is an enlarged portion of FIG. 5, partly in axial cross-section; and

FIG. 7 is a fragmentary schematic view of an accessory which may optionally be used with this invention.

In FIG. 1 there is shown an oral hygiene device, which cleanses, massages and irrigates the tissues around the teeth. It includes a grip **11** for the user to hold. The grip has a central opening **12** therein to receive a pressure chamber **13.** The pressure chamber is rigid-walled. It includes an upstream end plate **14** and a downstream end plate **15.** Inlet and outlet **16, 17** respectively, pass through plates **14** and **15.** The end plates are joined by means such as brazing, soldering or welding to peripheral wall member **18** to form the rigid pressure chamber.

End plates **14** and **15** include shoulders **19, 20** respectively, inside the pressure chamber. A tubular portion **21** is attached to these two shoulders inside the pressure chamber. It is spaced from the wall of the chamber, and is fully peripherally exposed to its pressure.

A band **21***a* binds the tubular portion to the shoulder on the upstream end plate. The downstream end of the tubular portion is stretched over the shoulder of the downstream end plate, but not bound thereto. The tubular portion is deflectible and resilient, and its relaxed inner diameter is smaller than the outer diameter of both of the shoulders. The springback force of the tubular portion will be sufficient to maintain a seal under normal operating conditions, but it is preferable for the upstream end to be bound, such as by band **21***a*, because the pulsating forces at the upstream end may deflect the tube enough to cause leakage under certain conditions at that end.

At the time of manufacture, gas can be forced into the tubular portion under sufficient pressure to overcome the unbound seal, thereby to stretch that end of the tubular portion and leak past it into the pressure chamber so as to charge the chamber to its desired pressure level. When this elevated pressure is relieved in the tubular portion, the seal is restored by the forces derived from the gas pressure in the pressure chamber and from the elastic springback of the material so as to keep the gas contained in the pressure chamber. Thus the downstream end of the tubular portion acts as a valve to admit and to retain chamber pressure. The approximate pressure can be determined by measuring the water pressure required to open the tubular portion to flow after it has been collapsed by the gas pressure.

The tubular portion, being flexible, and resilient, is deflectible in the sense of being collapsible. The term "collapsible" does not necessarily mean collapsed flat so as completely to close the tubular portion, although it includes this condition. It means that the tubular portion has relatively little resistance to bending, being relatively thin or relatively soft, so it can buckle, bend, pinch, and undergo like contortions. Without fluid pressure inside the tubular portion of a value somewhat above that of the chamber pressure, the gas pressure in the chamber will tend to close it. Sufficient pressure inside the tubular portion tends to open the tube, thereby to permit liquid to flow through it. The dimensional and pressure relationships discussed below will result in a cyclical increase and decrease in lateral cross-section area along the length of the tubular portion. A fluctuation in liquid flow will be generated as a consequence of the contortions of the tubular portion when liquid at a correct pressure relative to the gas pressure flows through the tubular portion, when the remainder of the system is also properly proportioned.

The tubular portion separates the gas in the chamber from the liquid in the tubular portion, thereby allowing the gas pressure to be exerted on the liquid, but without mixing them.

An upstream pressure compensating orifice **22** is formed in an orifice plate **23** adjacent to the water supply **24**, which supply might be such as a faucet, a tank or a pump. This orifice enables a given system at a given gas pressure to be used with a wide range of water system pressures, still producing the desired pulsating output.

The water supply is sometimes referred to as a "pressure source." The term "inlet passage" means the passageway extending from the source of pressure to the end of port **16** facing into the tubular portion. In FIG. **1**, this includes the bore **16** in the metal end fitting closest to the supply plus the lumen of the hose to its junction with orifice plate **23**. The term "outlet passage" means the passageway extending from end of the bore **17** in the metal end fitting farther from the supply, plus the lumen of a discharge tip **27**. Thus these terms comprehend the passageways which feed and discharge from the tubular portion. The inlet and outlet passages plus the tubular portion are sometimes referred to as a "conduit."

A discharge tip **27** bounds the downstream end of passage **20**. In order that it may readily be removed and attached, this tip has a taper **28** on one end adapted to enter a matching taper **29** in the passage. Two O-rings **30, 31** are seated in respective grooves **32, 33** in the wall of the passage, and a shoulder **34** on the tip is adapted to pass beyond O-ring **30** to aid in retention. The force generated by pressing taper **28** against the O-rings also retains the tip. The tip has a delivery tube **35** which terminates at a discharge nozzle **36**.

The fluttering tube effect utilized herein is relatively unknown at the present time. However, reference may be made to the following references for some details concerning it, even though many of these details are incorrect, misleading, and insufficient to guide one to the means for securing the objectives of this invention.

Rodbard, S. and Saiki, H.: Flow-through Collapsible Tubes, American Heart Journal 46: 715, 1953 and

Lambert, J.W.: Flutter from Steady Driving Pressures: Elementary Theory, Proceedings of the American Society of Civil Engineers, Engineering Mechanics Division Meeting, Washington, D.C., Oct. 13, 1966.

IBM Technical Disclosure Bulletin, Vol. 13 No. 5, October 1970, entitled "Sonar Sound Generator" by L.J. Andrews and J.W. Lambert.

Briefly stated, with the pressure relationships stated above, namely with chamber pressure below that of the pressure at the inlet passage, the fluttering tube accelerates the water such that its linear exit velocity is greater than it linear inlet velocity. The tendency is to empty the device faster than it can be filled, and as a result the flow becomes corpuscular, the tubular portion changing its lateral cross-section area in the process. In fact, it may even close between drops, and open to permit the flow of a drop. With some relationships of pressures and dimensions, the stream may not become a succession of separate drops, but instead one of a continuous stream with an undulating cross-section. With some other relationships the flow in the outlet passage reverses, and in others, some part of it cavitates.

FIG. **3** schematically shows the general mode of operation of the flexible tubular portion. Without liquid pressure in the tubular portion, it collapses and constricts, sometimes closing nearly completely. When sufficient liquid pressure is exerted to open the tubular portion against the gas pressure, a peculiar wave motion begins to occur in the wall of the tube. Essentially, it involves a progression of waves, which can be the alternating filling and emptying the tubular portion, with waves traveling back and forth along the tubular portion. The tubular portion is shown at one of its instantaneous positions in FIG. 3, the portion tapering inwardly from the inlet and to a point **50** where it is almost closed. Then it tapers outwardly again to the discharge end. In segment **51**, there is a breathing motion shown by the two sets of dashed lines, and in segment **52**, another similarly shown breathing motion.

It appears that there is a pulsating flow in segment **51** which forces liquid past point **50** at its peak, and is retarded at point **50** by closure or near closure of the tube at that point at lower pulse pressures. However, segment **52** accelerates the "corpuscle" of liquid which passed point **50** before it closed down, and the discrete drop appears to form in this region. The inertia of the drops, and the continuing pressure pulses cause the stream to discharge corpuscularly.

It is a feature of this oscillator system, that if the discharge orifice is partially occluded, the velocity of the output pulses of liquid is diminished. With sufficient occlusion, oscillation stops and the system reverts to a steady, very low velocity flow. This low velocity is much less than would be the velocity created by the same pressure source and conduitry without the choking effect of the tubular portion.

The basis for this safety factor will be understood from a study of FIG. 4, which is a graph which plots as the abscissa the location along the system of the elements, and as an ordinate, the static pressure measured at points along the system while the system is flowing. If the system is plugged and flow stops, then of course all points rise to the source pressure.

There is a source pressure **65** feeding through the inlet passage to the chamber, shown as element **66** in FIG. 4. There is a critical chamber pressure **67**, (Pcr). This critical pressure is ideally the fluid static pressure within the portion at steady flow. This would be measured by starting flow of liquid through the system without any pressure in the chamber, and gradually building up the chamber pressure until oscillation started. That pressure when it started is P_{cr}. Oscillation will occur at all chamber pressures higher than P_{cr} and lower than P_o. The range R above this level represents chamber pressures, P_c, at which oscillation will occur. Point **68** represents an outlet pressure such as atmosphere. It will be raised by occlusion, and point **69** shows one such level, which occurs as a consequence of partial occlusion. Now notice that the differential pressure driving liquid into the oscillator is only $P_o - P_c$ (supply pressure minus chamber pressure), and this is very small. Further the pressure difference $P_c - P_{69}$ which is much diminished from $P_d - P_{68}$ due to the occlusion is the only pressure available for acceleration (if any) and hence with occlusion, high, jetting, exit velocities cannot occur. With complete occlusion the entire system of course reverts to a steady source pressure with the occluding force limited to source pressure times the small area of the discharge orifice, but the static pressure at the opening will not abrade, because there is no flow. This is demonstrated in FIG. 4.

For biological cleansing purposes the chamber pressure will be set relatively close to inlet pressure, thereby:

1. Causing a relatively low rate of inlet flow to the oscillator;
2. Causing a relatively large pressure drop for acceleration of cleansing drops; and
3. Limiting the flow in case of partial occlusion of the discharge.

One of the problems inherent in previous attempts to make hydraulic oscillators of this type has been that oscillation has either been impeded, totally frustrated, or the output rendered unstable and impure in wave-form by inter-reaction between the pressure source and the tubular portion. Some efforts have been made to overcome this problem, but without significant success, and definitely without a solution to the problem which would enable an oscillator to be made which does have a pure output of desired wave-form characteristics and which will continue to oscillate steadily. Similarly, other design characteristics were unknown which could have assisted in the design.

Primarily, a pure output in the sense of a steady-state ocillation of pulses of uniform shape, is derived from a substantially steady flow rate to the tubular portion. This requires much more than just a non-pulsing source, because the pressure pulsations of the tubular portion can, unless isolation is provided for the supply from the tubular portion, so effect the input stream that it has fluctuations in its flow rate, and these interfere with the frequency of the tubular portion, and the behavior of the system becomes variable from cycle to cycle, a situation which is both unmanageable and unpredictable.

It has been found that the problems derived from the source are solved by providing a sufficiently high impedance to flow upstream of the tubular portion. The dimensions of impedance are:

length/cross-section area = L/A of the supply tube.

It has been found that by providing the inlet passage with an impedance at least 5 times as great as that of the discharge passage, the inlet stream entering the tubular portion will be relatively free of such wave-forms from the tubular portion as will frustrate the proper oscillation of the system. Greater ratios may of course be used, and in systems where priority of output is of no importance, but other features are, the ratio might even be less than one. There are pressure variations in the tubular portion at its end adjacent to the inlet passage. If the impedance of the inlet passage is great enough, these downstream fluctuations will have no significant effect on the steady rate of flow of the liquid into the tubular portion.

The resistance of the inlet passage is of importance because, over a wide range of supply pressures, it limits the range of stream velocities, and thereby reduces frequency range with varying supply pressures. Orifice plate **22** performs that function. Similarly, the resistance of the inlet passage inter-acts with the pressure difference $P_o - P_c$ to establish the average flow rate, which in turn affects the times t_2 and t_3 in the equations below.

Some additional design considerations of this system are as follows:

OUTPUT FREQUENCY

The frequency, f, is more easily discussed in terms of the period T of one cycle which is $1 \div f$. The period of one cycle is the sum of at least three individual times t_1, t_2 and t_3, thus:

$$f = 1/t_1 + t_2 + t_3$$

t_1 is the time required to accelerate the liquid in the discharge line a certain amount. This time is a function of the pressure difference between the chamber and the outlet, and the impedance (L/A) of the outlet passage. The actual formula for t_1 is the solution of a complex nonlinear differential equation, and also involves the elastic properties of the flexible tube.

Times t_2 and t_3 are associated with the times required for two different waves to traverse the flexible tube. One of these waves is an accelerating velocity wave in the collapsed portion of the tube, and the other is a decelerating velocity wave in the collapsed portion of the tube. The time of propagation of each of these waves is related to the local fluid velocity within the flexible tube. Thus the design parameters controlling t_2 and t_3 are the inlet pressure difference ($P_{65} - P_c$) the inlet passage resistance, and indirectly the outlet passage resistance.

Thus in selecting frequencies, if t_1 is large compared to t_2 and t_3, frequency can be selectibly controlled by chamber pressure and by the length of the discharge pipe. On the other hand if t_2 and t_3 are larger compared to t_1 frequency can be selectibly controlled by varying inlet pipe length, source pressure and/or chamber pressure.

As general statements, the following pertain for a given set up:

a. An increase in P_c increases the frequency if t_1 is large compared to both of t_2 and t_3

b. An increase in length of the outlet passage decreases the frequency;

c. An increase in inlet passage length decreases the frequency;

d. An increase in P_o (source pressure) increases the frequency; and

e. An increase in chamber pressure decreases the frequency if t_2 and t_3 are both large compared to t_1

DROP SHAPE AND VOLUME

The gross size of each drop is primarily determined by the general plumbing, and by the frequency generated.

The shape of the drops can be varied by changing either the chamber pressure or the inlet pressure to the tubular portion.

One example of dimensions for an oral hygiene device, which, at a supply pressure upstream of orifice **22** between about 75 psig to 120 psig will produce a pulsating stream pulsating at about 20 cycles per second, is as follows:

Gas pressure (nitrogen or other inert gas) in the chamber 58 psig.

Upstream passage 16: 3 inches in length, inner diameter: 0.06 inches.

Downstream passage **17** plus conduit **35** in tip 27: 4 inches in length, inner diameter: 0.06 inches.

Orifice **22**: 0.040 inches diameter.

Tubular portion **21**: Unsupported length: 15/16 inches; wall thickness about 1/16 inches; relaxed inner diameter: 3/16 inches; preferred material; neoprene rubber or silastic (silicone) rubber. Further as to the material for tubular portion **21**, it appears that an elastomeric property is to be sought. The elasticity of the portion appears to affect the frequency, and of course the material must be flexible, and the neoprene and silastic rubbers would be selected from those of these types which have the extensibility and return to original length typical of elastomers.

Shoulders **19, 20**: Diameter: 3/8 inches.

Discharge nozzle **36**: Diameter: 0.040 inches; length: 1/4 inches.

FIG. **5** shows another system for washing biological tissue. This system is a douche. It has a tank **70** which drains into a hose (inlet passage) **71.** An off-on valve **72** of any desired type is located in the hose. A nozzle (outlet passage) **73** has ports **74** to discharge a pulsating stream.

An oscillator **75** is connected to the inlet passage and outlet passage. It includes a rigid case **76** with a pressure chamber **77** in which a collapsible tubular portion **78** of flexible material is enclosed. It interconnects the inlet and outlet passages. The tubular portion and passages are together sometimes referred to as a "conduit." In the illustrated embodiments, and generally with the usage of this invention, the conduit will be cylindrical, sometimes with steps between adjacent different diameters.

This system, properly proportioned and charged with gas, will produce a pulsating output of water. The maximum inlet pressure is limited by the length of the hose, because this limits the elevation of the water bag relative to the oscillator. The system will oscillate when there is a pressure head above the oscillator of at least eleven inches of water.

As an example of a workable system, the following details are given:

L_1 (length of inlet passage) — 4 feet

D_1 ¼ inch inside diameter

L_2 (length of outlet passage) — about 4-½ inches, eight or nine outlet ports, totaling area of ¼ inch diameter circle

D_2 ¼ inch inside diameter

L_3 unsupported length of tubular portion, 1-¼ inches

D_3 — ¼ inches inside diameter

W_3 — relaxed wall thickness **0.012** inch.

Total length of tubular portion in relaxed state — about 2 inches.

Chamber pressure, about 0.37 psig.

The hose forming the inlet passage is semi-rigid plastic hose. The outlet tip is a hard plastic.

The material of the tubular portion is latex rubber with a modulus of elasticity of about 100 psi.

A two quart tank will empty in about 90 seconds, the frequency of oscillation being about twenty cycles (pulses) per second.

There will be applications wherein it is desirable to have a pulsating flow somewhere in a system, but it will be necessary to remove the pulsations and return the stream to an unpulsed flow, without going through a sump. For this purpose, and as shown in FIG. **7**, the outlet passage **80** from any of the aforementioned system may be passed by a Helmholtz resonator **81.** A typical example is a pressure dome having a chamber **82** with a flexible diaphragm **83** extending across it. Gas under pressure is charged into the top of the chamber, and fluctuations in the stream are absorbed by this device.

As to the interdependence of the various proportions, dimensions, and properties of materials, some experimentation must be anticipated, because knowledge of this phenomenon is at present very incomplete. However, by starting with the considerations, materials and dimensions given above, one can, without undue experimentation, scale the device to other sizes and frequencies.

In summary, by appropriate selection of the impedances and resistances of the inlet an outlet passages, of the dimensions and modulus of elasticity of the tubular portion, and of the supply and chamber pressures, one can arrange for various kinds of pulsed outputs. The impedances of the inlet and outlet passages are of importance because of their effects on the capacity of the tubular portion to receive and expel liquid from the system. The impedance of the inlet passage serves dynamically to isolate the tubular portion from the supply so they do not affect each other.

The dynamic impedance of the outlet passage is important as to frequency, drop shape, drop volume, and the phase relationships between pressure levels within a single cycle. With appropriate relative selection of outlet impedance, there can even be a reversal of flow in the outlet passage between drops. This is an ideal relationship for an oral hygiene device, because the drops are so sharply separated, and also is ideal for backwash systems wherein cyclical reverse flow in a generally forwardly moving stream is desirable. This reversal of flow will be found to occur principally when the unstressed diameter of the tubular portion is larger than the diameter of both the inlet passage and the outlet passage.

Similarly, cavitation can be induced, which will in these systems provide a laboratory tool for the study of the effects of cavitation in a traveling stream, and can provide for mixing and vaporization of vaporizable mixtures such as liquid fuels.

Further, this oscillator can be used as a ditherer to keep a stream "live," and to exert mechanical forces which can overcome stick-slip tendencies in associated mechanical systems.

This oscillator will function with any liquid, and while its principal usage is expected to be with water, it can also be used for milk, oils, fuels, solvents, and other liquids in general, wherever an oscillating flow is desired.

This invention thereby provides a basic oscillator, the properties of whose output can readily be selectibly varied. The systems using it have safety features useful when biological tissues are being irrigated, cleansed or massaged. Also, the characteristics of the output can be rendered pure in wave-form, and made independent of the dynamic peculiarities of the pressure source.

This invention is not to be limited by the embodiment shown in the drawings and described in the description, which is given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. A hydraulic oscillator for discharging fluid onto living biological tissue, said oscillator producing a pulsating fluid output stream from a steady inlet flow, said oscillator having the property of producing only a relatively sluggish output stream when its outlet is partially occluded, said oscillator comprising: a rigid pressure chamber; a charge of gas contained in said chamber; a conduit passing through and beyond said chamber, said conduit comprising an inlet passage, an outlet passage, said passages having the properties of impedance and resistance to liquid flow, and a flexible, collapsible-walled tubular portion extending between and interconnecting said passages, that part of the tubular portion which extends between the passages having an outside wall which is fully peripherally exposed to the gas in the chamber, the inlet passage being adapted for connection to a source of liquid under supply pressure, the pressure of the chamber being above that critical level at and above which oscillation will always occur, and less than the pressure of the source, and the resistance and dynamic impedance of the outlet passage being such as to secure a cyclical output.

2. A hydraulic oscillator according to claim 1 in which the chamber pressure and the supply pressure are selected to be sufficiently close to each other in magnitude that, when the outlet passage is partially occluded, flowthrough the system occurs at a relatively small rate as a consequence of the relatively small difference between the said two pressures.

3. In a system for discharging fluid onto living biological tissue, said system having a supply of fluid under steady supply pressure, and an outlet tip to direct an output stream, a hydraulic oscillator causing said output stream to pulsate, and having the property of producing only a relatively sluggish output stream when its outlet is partially occluded, said oscillator comprising: a rigid pressure chamber; a charge of gas contained in said chamber; a conduit passing through and beyond said chamber, said conduit comprising an inlet passage, an outlet passage, said passages having the properties of impedance and resistance to liquid flow, and a flexible, collapsible-walled tubular portion extending between and interconnecting said passages, that part of the tubular portion which extends between the passages having an outside wall which is fully peripherally exposed to the gas in the chamber, the inlet passage being adapted for connection to a source of liquid under supply pressure, the pressure of the chamber being above that critical level at and above which oscillation will always occur, and less than the pressure of the source, and the resistance and dynamic impedance of the outlet passage being such as to secure a cyclical output.

4. Apparatus according to claim 3 in which the chamber pressure and the supply pressure are selected to be sufficiently close to each other in magnitude that, when the outlet passage is partially occluded, flowthrough the system occurs at a relatively small rate as a consequence of the relatively small difference between the said two pressures.

5. A system for generating and discharging a pulsing flow of liquid upon living biological tissue comprising: a supply source of liquid under pressure; an outlet tip for directing the flow to a selected location; and a hydraulic oscillator comprising: a rigid pressure chamber; a charge of gas contained in said chamber; a conduit passing through and beyond said chamber, said conduit comprising an inlet passage, an outlet passage, said passages having the properties of impedance and resistance to liquid flow, and a flexible, collapsible-walled tubular portion extending between and interconnecting said passages, that part of the tubular portion which extends between the passages having an outside wall which is fully peripherally exposed to the gas in the chamber, the inlet passage being adapted for connection to a source of liquid under supply pressure, being sufficiently large so as substantially to isolate the tubular portion dynamically from the pressure source, the pressure of the chamber being above that critical level at and above which oscillation will always occur, and less than the pressure of the source, and the resistance and dynamic impedance of the outlet passage being such as to secure a cyclical output, the inlet passage

being connected to the supply source, and the outlet passage discharging through the tip.

6. A system according to claim **5** in which the chamber pressure and the supply pressure are selected to be sufficiently close to each other in magnitude that, when the outlet passage is partially occluded, flowthrough the system occurs at a relatively small rate as a consequence of the relatively small difference between the said two pressures.

7. A system according to claim **5** in which the tip is adapted for use as an oral hygiene device.

8. A system according to claim **5** in which the tubular portion is made of an elastomeric material.

9. A system according to claim **5** in which the inlet and outlet passages terminate at shoulders located inside the pressure chamber, over which shoulders the tubular portion is stretched, at least one end of the tubular portion being held to the respective shoulder only by the springback force of the material of the tubular portion, whereby gas may be injected into the pressure chamber by exerting sufficient force inside the tubular portion to cause the gas to leak past that shoulder.

10. A system according to claim **9** in which the tubular portion is made of an elastomeric material.

11. A system according to claim **5** in which the inner diameters of the passages are smaller than the inner diameter of the tubular portion in its relaxed condition.

12. A system according to claim **11** in which the inlet and outlet passages terminate at shoulders located inside the pressure chamber, over which shoulder the tubular portion is stretched, at least one end of the tubular portion being held to the respective shoulder only by the springback force of the material of the tubular portion, whereby gas may be injected into the pressure chamber by exerting sufficient force inside the tubular portion to cause the gas to leak past the shoulder.

13. A system according to claim **11** in which an orifice is placed in the flow of the liquid stream upstream of the inlet passage.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,810,465 Dated May 14, 1974

Inventor(s) JOHN W. LAMBERT

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[76], line 2	"91714" should read --91740--
Abstract, line 6	after "sage" first occurrence, insert a comma
Col. 4, line 2	'source."' should read --source".--
Col. 4, line 14	'conduit."' should read --"conduit".--
Col. 4, line 45	"it" should read --its--
Col. 5, line 28	"while the system is flowing" should be underlined
Col. 5, line 50	"P_d" should read --P_c--
Col. 6, line 15	"ocillation" should read --oscillation--
Col. 8, line 15	'duit."' should read --duit".--
Col. 8, line 54	"tem" should read --tems--
Col. 9, line 31	'"live,"' should read --"live",--
Col. 10, line 11 (Cl. 2, line 5)	"flowthrough" should read --flow through--
Col. 10, line 41, (Cl. 4, line 4)	"flowthrough" should read --flow through--
Col. 11, line 6 (Cl. 6, line 4)	"flowthrough" should read --flow through--

Signed and Sealed this

Eighth Day of March 1977

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks