United States Patent

Schurig et al.

[15] **3,677,525**

[45] **July 18, 1972**

[54] **PRESSURE WAVE ATOMIZING APPARATUS**

[72] Inventors: **Robert E. Schurig**, Maywood; **Joseph Korn**, Fort Lee, both of N.J.

[73] Assignee: **Sonic Development Corporation of America**, Yonkers, N.Y.

[22] Filed: **Dec. 31, 1969**

[21] Appl. No.: **889,596**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 699,109, Jan. 19, 1968, abandoned.

[52] **U.S. Cl.** **261/1,** 261/77, 261/123, 239/102, 239/DIG. 20, 259/DIG. 43

[51] **Int. Cl.** **B01f 3/04**

[58] **Field of Search**....................261/77, 123, 1, DIG. 48; 259/DIG. 43, DIG. 44; 239/102, DIG. 20

[56] **References Cited**

UNITED STATES PATENTS

1,980,171	11/1934	Amy	259/DIG. 43
2,532,554	12/1950	Joeck	259/DIG. 43
2,559,864	7/1951	Firth	259/DIG. 44
2,657,021	10/1953	Cottell et al.	259/DIG. 43
2,713,998	7/1955	Eicken	259/DIG. 43
3,176,964	4/1965	Cottell et al.	259/DIG. 44
3,282,571	11/1966	Guggenberger	261/1
1,143,162	6/1915	Armstrong	261/77
2,094,778	10/1937	Alexander	261/123
3,240,254	3/1966	Hughes	239/4 X
3,271,304	9/1966	Valdespino et al.	261/123 X
3,371,869	3/1968	Hughes	239/4 X
3,400,818	9/1968	Tarjan	261/79 A X

FOREIGN PATENTS OR APPLICATIONS

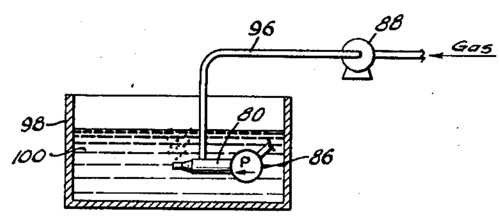
71,286	11/1946	Norway	261/1
1,139,491	2/1957	France	261/123
328,031	11/1919	Germany	261/123
458,583	12/1936	Great Britain	261/123

Primary Examiner—Tim R. Miles
Attorney—Curtis, Morris & Safford

[57] **ABSTRACT**

The liquid preferably is a body of liquid in a container. A liquid is forced through a converging-diverging nozzle towards a nearby resonator cavity, and the gas is introduced into the flowing liquid before it reaches the cavity. Preferably, the nozzle and resonator cavity both are immersed in the body of liquid. Intimate contact between the gas and liquid results from the tiny gas bubbles which are produced in the liquid body by this device and method.

2 Claims, 7 Drawing Figures



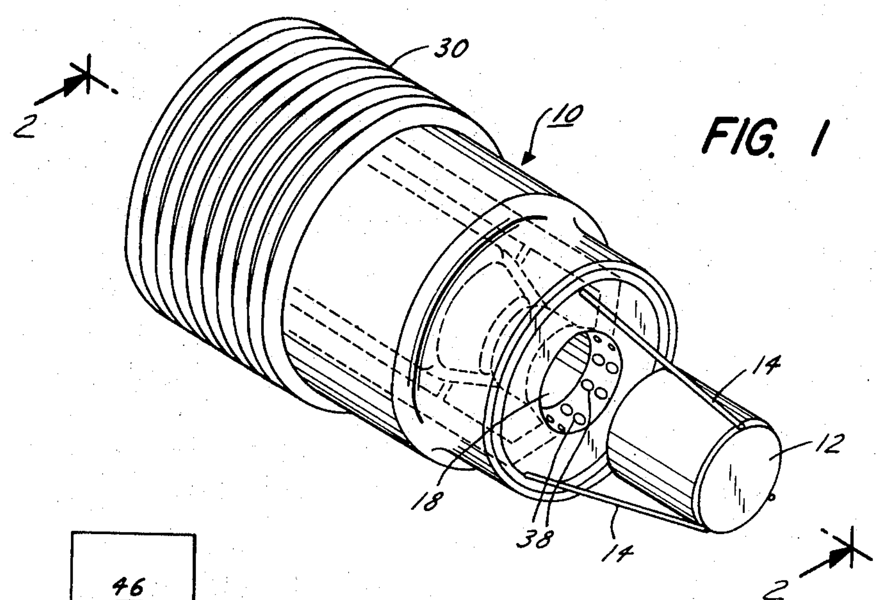


FIG. 1

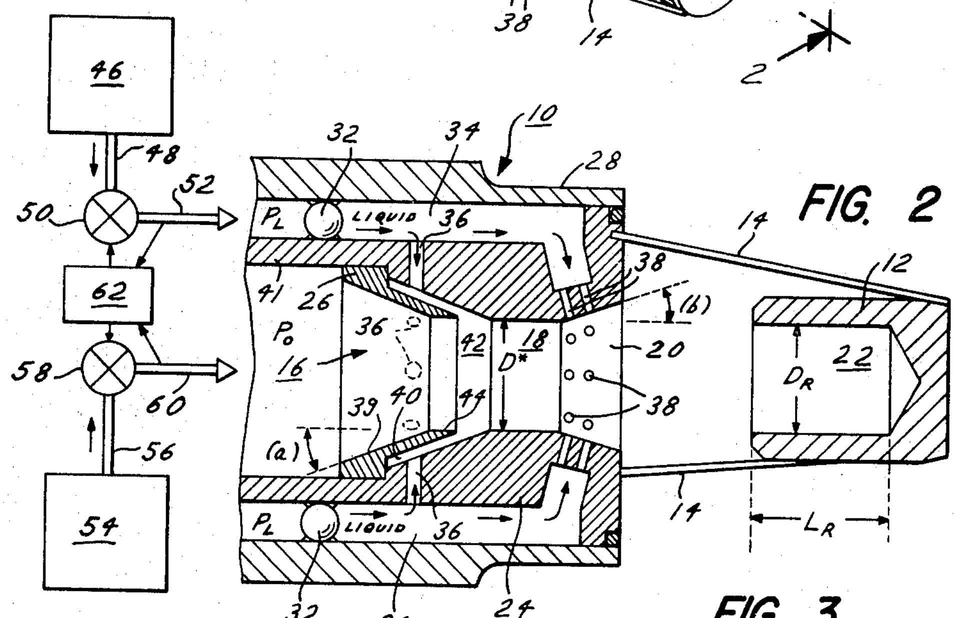


FIG. 2

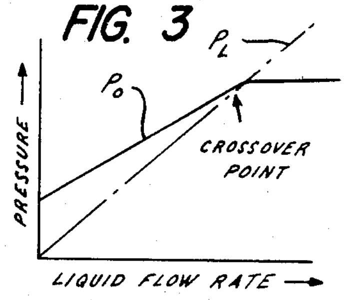


FIG. 3

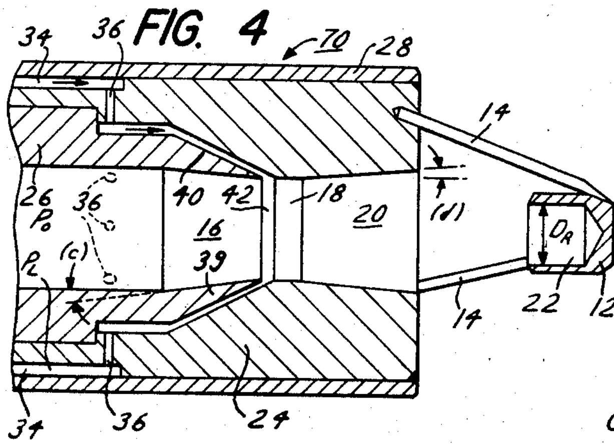


FIG. 4

INVENTOR
ROBERT E. SCHURIG
JOSEPH KORN
BY
Curtis, Morris & Safford
ATTORNEYS

Patented July 18, 1972 3,677,525

2 Sheets-Sheet 2

Fig. 5.

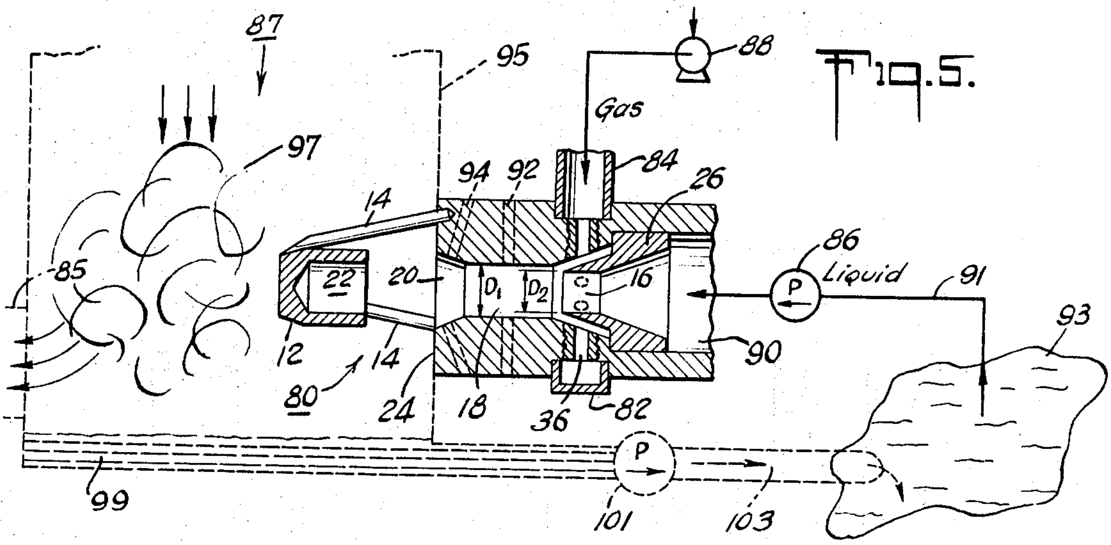


Fig. 6.

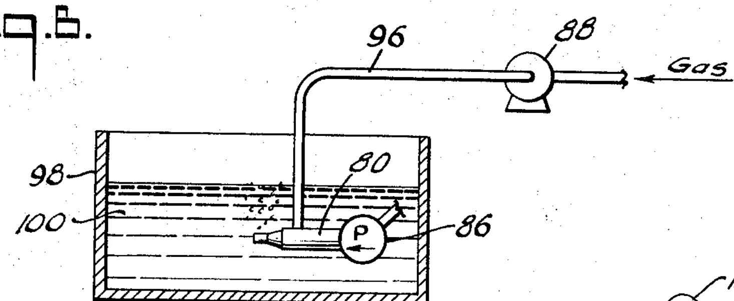
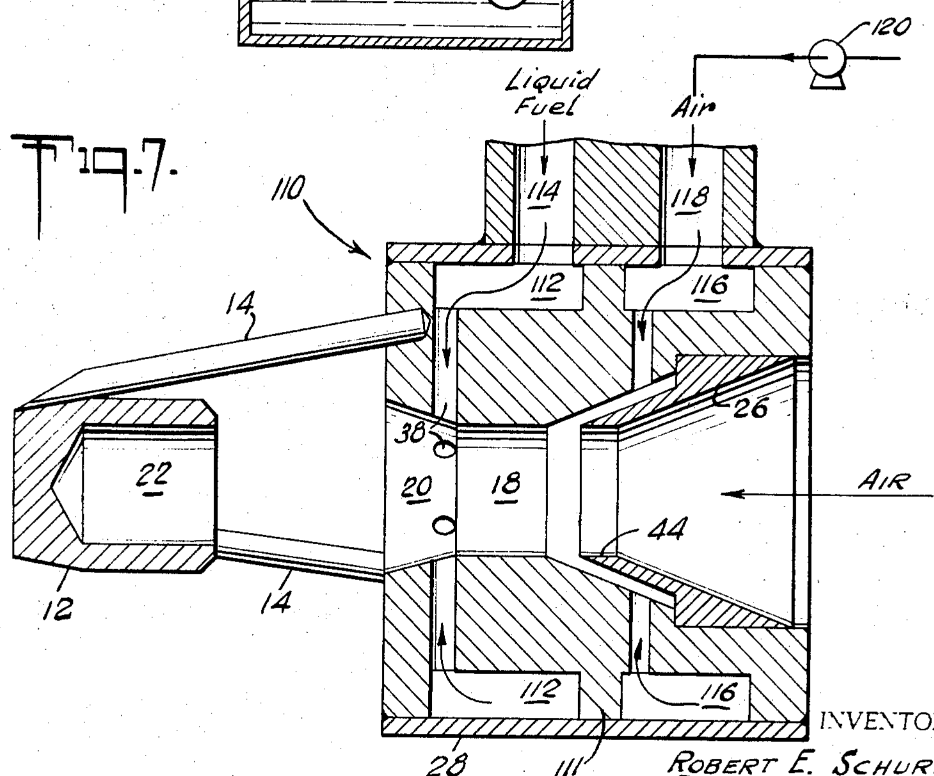


Fig. 7.



INVENTORS:
ROBERT E. SCHURIG
BY JOSEPH KORN
Curtis, Morris & Safford
ATTORNEYS.

PRESSURE WAVE ATOMIZING APPARATUS

This application is a continuation-in-part of U. S. Pat. application, Ser. No. 699,109, filed Jan. 19, 1968, now abandoned.

This invention relates to apparatus for atomizing and mixing fluent materials and burning combustible fluids.

U. S. Pat. No. 3,240,254, which is assigned to the same assignee as this application, describes atomizing and fuel burning structures and methods which utilize a converging-diverging gas accelerating and expansion nozzle together with a cavity resonator to produce high-intensity sonic pressure waves. Fluent materials such as liquids are introduced into the high-speed gas stream moving through and issuing from the nozzle, at various positions within or out-side of the nozzle. The resonant sonic pressure wave energy atomizes the liquids into minute droplets of a highly uniform size. When used in burners, such atomizers produce flames of excellent quality over a relatively wide range of fuel flow rates.

Although atomizers and burners constructed in accordance with the above-identified patent are superior to other prior devices and are highly satisfactory for most purposes, it is an object of the present invention to improve upon them by increasing their "turn-down ratios;" that is, by increasing the ratio of the maximum flow rate to the minimum flow rate at which fluids can be atomized satisfactorily.

In accordance with the foregoing, it is a major object of the present invention to provide atomizing,mixing and fuel burning apparatus which give relatively very high turn-down ratios while maintaining highly satisfactory atomization. A further object of the present invention is to provide such apparatus which is simple in construction and operation, has relative large fluid feed holes which do not become clogged easily, which is economical to use and requires relatively low gas flow rates, which will operate effectively in a liquid ambient medium, and which is relatively inexpensive to manufacture. A further object is to provide an improved liquid feed means for such apparatus.

Further objects, aspects and advantages of the present invention will be set forth in and will be apparent from the following description and drawings.

In the drawings:

FIG. 1 is a perspective view of an atomizing and fuel burning device constructed in accordance with the present invention;

FIG. 2 is a cross-sectional, partially schematic view taken along line 2—2 of FIG. 1;

FIG. 3 is a graph illustrating qualitatively variation of some of the operating parameters of the device shown in FIGS 1 and 2;and

Each of FIGS 4, 5, 6 and 7 is a cross-sectional view of another embodiment of the invention.

The atomizer and burner device shown in FIGS. 1 and 2 includes a nozzle assembly **10**, and a cavity resonator member **12** which is secured to one end of the nozzle assembly **10** by means of three support struts **14**.

Referring specifically to FIG. 2, the nozzle assembly **10** includes a gas accelerating and expanding nozzle comprising a converging inlet section generally indicated at **16**, a diverging outlet section **20**, with a straight-wall cylindrical "stabilizing" section **18** interconnecting the converging and diverging sections. As is disclosed in greater detail in the above-mentioned U. S. Pat. No. 3,240,254, pressurized gas, preferably air, is introduced into the converging section **16** of the nozzle, and the nozzle is believed to accelerate the gas to supersonic velocities and expand it to sub-ambient pressures at the exit opening of the diverging section **20**. The resonator member **12** has a resonator cavity **22** which resonates the pressure waves created by the nozzle, and the device thus produces high-intensity sonic or ultra-sonic pressure waves.

The nozzle assembly **10** is composed of three main components; an internal nozzle member **24**, a "baffle" member **26** within the member **24**, and an outer sleeve **28**. As is shown in FIG. 1, the sleeve **28** has a threaded portion **30** (not shown in FIG. 2) at one end which is used for coupling the nozzle to gas and liquid supply conduits. Several metal balls **32** are welded in position to permanently space the inner nozzle member **24** from the outer sleeve **28** as is shown in FIG. 2 and thus form an annularly shaped liquid flow conduit **34**.

The baffle member **26** is generally frustro-conically shaped, and has an angle of inclination (a) equal to the angle of inclination of the frustro-conically shaped walls of the converging nozzle section of the nozzle member **24**. The left end of the baffle member **26** is forced-fitted into the cylindrical inner wall **41** of the nozzle member **24**, and forms a liquid flow passageway **40** between the wall **39** of the baffle and the nozzle wall.

Several Symmetrically-positioned liquid feed holes **36** pass through the wall of the nozzle number **24** and exit into the passageway **40** formed between the baffle wall **39** and the nozzle wall. The downstream end of the baffle member **26** forms a liquid flow opening **42** through which liquid passes into the stabilizing section of the nozzle. The baffle **26** has a cylindrical end portion **44** which has the same diameter D* as the stabilizing section **18** and thus effectively forms a portion of the stabilizing section. The exit opening **42** is substantially cylindrically shaped and is continuous around the entire periphery of the nozzle.

Additional liquid feed holes **38** are positioned symmetrically in the nozzle member so as to exit into the diverging section **20** of the nozzle. The total cross-sectional area of the holes **36** preferably is approximately equal to the total cross-sectional area of the holes **38**. In one specific embodiment of the invention which has been built and tested, there are eight of the upstream holes **36** and sixteen of the holes **38**.

In prior art fuel burning methods using atomizers such as those shown in the above-identified patent, the liquid to be atomized, such as fuel oil, is fed from a reservoir **46** (see FIG 2) through a pipe **48**, a pump **50** and another conduit **52** into the liquid flow conduit of the atomizer. Compressed air, steam, or the like is supplied to the converging nozzle inlet by means of any convenient, well-known pressure source **54** through a pipe **56**, a valve **58** and another pipe **60**. In the usual prior fuel burning installation of relatively high heat-producing capacity, a known linkage control device **62** is provided which senses the pressure P_L at which the liquid fuel is supplied, and simultaneously measures the pressure P_0 at which gas is supplied to the atomizer. The control device **62** automatically varies the liquid pressure P_L and the gas pressure P_0 to change the heat output in response to changing heat demands on the system, and maintains a differential between the liquid and gas pressures throughout the entire range of variation of the burner output. One pressure always is greater than the other pressure.

In the above-described prior art atomizers, ordinarily only one set of liquid feed holes is used. The inventors have discovered that the turn-down ratios of such atomizers is limited by the liquid feed characteristics of the atomizer at very low liquid flow rates. The total cross-sectional area of the feed holes must be large enough to pass up to several hundred gallons per hour. When a single set of feed holes large enough to pass such quantities of liquids is used to feed liquids at very low flow rates, the liquid flows through only some of the holes and not others, with the result that the flame pattern sometimes is asymmetrical. Furthermore, the liquid pressure P_L drops virtually to zero. The result of this is that the pressure sensed by the control system **62** is zero, and the system cannot control the flow rate at lower liquid pressures. Thus, the minimum flow rate and, hence, the turn-down ratio, is limited by the inability of the control system to function at lower flow rates.

The present invention solves the foregoing problems by providing, in addition to the usual holes **38**, another set of holes **36** at a position in the nozzle where the gas stream pressure working against the flow of liquid through the holes **36** varies from a positive value which exceeds the liquid pressure, to a value which is lower than the liquid pressure. When the gas pressure is lower than the liquid pressure, as it is at very high liquid flow rates, liquid flows not only through the passages 38 but also through the holes 36 so that, in effect, the total feed passage cross-sectional area is the sum of the areas of the holes 36 and 38. However, when the gas pressure is greater than the liquid pressure, as it is at low flow rates, the higher gas pressure substantially prevents liquid from flowing through the holes 36 and forces substantially the entire quantity of liquid to flow only through the holes 38. The holes 38 are positioned so that the gas pressures at their exit openings always are considerably lower than the fluid feed pressure so that there is always a flow of liquid through the holes 38 as long as any liquid is being supplied. At such low flow rates, the effective cross-sectional area of the liquid flow passages is reduced to half of the value at high flow rates, with the result that a liquid pressure P_L greater than zero is developed and liquid flows through all of the holes 38 around the periphery of the nozzle. Thus, the atomizer produces a symmetrical spray or flame pattern. Since a pressure P_L is developed which is large enough to be sensed by the control system 62, it is possible for the control system to vary the flow rate to far lower levels than in previous devices. Thus, the effective turn-down ratio of the device is greatly increased. For example, in devices of the present invention which have been tested using water as the liquid and air as the input gas, turn-down ratios of 30 to 1 have been achieved.

It is believed that in a nozzle with the relative dimensions shown in the drawings, substantially no liquid flows through the holes 36 until the inlet pressure P_o approximately equals the liquid supply pressure P_L, and then liquid flows at all pressures at which P_L is greater than P_o. The point at which liquid first starts feeding in substantial quantities through the holes 36 is termed herein as the "cross-over point." In accordance with one aspect of the present invention, the control system 62 is made to vary the gas pressure, P_O so that the liquid pressure P_L exceeds the input gas pressure P_O by a certain amount at the high flow rates and is less than the gas pressure at the low flow rates. This has been found to insure that the "cross-over" point will occur at some point in the range of maximum to minimum flow rates, and that the turn-down ratio will be maximized.

FIG. 3 is a graph showing the qualitative relationship between the pressures P_L and P_O as the liquid flow rate through the device is varied in the manner described above. The curves describing the variations in P_O and P_L need not be linear as shown in FIG. 3, but can be of different shapes determined in accordance with the particular control function desired. The offset in the P_O curve is observed when the two pressures are approximately equal. The rise in P_O is believed to be attributable to the start of liquid flow through the stabilizer section. The liquid is believed to partially occlude the stabilizer, thus changing its effective diameter and creating a greater back-pressure.

The baffle member 26 is provided in order to prevent gas from flowing from the gas stream into the liquid in conduit 34, and thus to prevent the pulsating, uneven atomization that would result. This is done, it is believed, by providing the relatively long liquid feed passageway 40 extending generally in the same direction as the flow of gas through the nozzle. It is believed that this arrangement makes it difficult for the high-speed gas flowing past the exit opening 42 to flow back into the passageway 40 and through the holes 36, even when P_O is substantially greater than P_L.

Although it is not absolutely necessary to set the point at which liquid starts flowing through the holes 36 as the one at which P_O equals P_L, it is extremely convenient to do so since these parameters can be measured and controlled readily. In order to attain this end, it is believed that the liquid pressure at the exit opening 42 should be approximately equal to the gas pressure at that position when P_L equals P_O. The gas pressure, of course, decreases as it moves to the right through the converging nozzle section 16 provided by the baffle 26. With typical input pressures P_O of 10 to 60 p.s.i.g., the gas pressure is believed to be still greater than atmospheric pressure at the opening 42. At a position further downstream, in the stabilizing section 18, a plane is reached at which the gas pressure equals atmospheric pressure, and at all points downstream from that plane, the pressure is below atmospheric. In the diverging section 20, the gas pressure can be very much below atmospheric pressure and can be so very low that it is negligible compared to the liquid feed pressure P_L.

It is believed that the reduction in gas pressure experienced at the exit opening 42 is offset by a reduction in the liquid pressure at that point of approximately the same amount. The liquid pressure reduction is accomplished simply by making the total cross-sectional area of the conduit 40 greater than the total cross-sectional area of the holes 36 by an amount sufficient to reduce the liquid pressure to the approximate value of the gas pressure at point 42. Keeping these principles in mind, the length and shape of the baffle 26 and the spacing of the converging wall section 39 from the wall of the nozzle member 24 can be varied as desired, as long as the length of passage 30 is not made so short that gas at its maximum pressure differential over the liquid flows back through the holes 36. It is believed that the baffle 26 enhances the symmetry of the spray pattern by spreading the fuel flow evenly around the nozzle periphery.

The structure shown in the drawing can be modified by providing additional sets of feed holes at different points along the length of the nozzle structure in order to give further variability in the control of flow through the nozzle. The position, size and shape of the holes can be selected so that the pressure variations at the outlets of the holes will be such as to allow liquid to flow through the holes when the liquid pressure at the outlets is greater than the gas pressure, and to prevent such flow when the gas pressure is greater than the liquid pressure.

The location of the holes 38 can be varied, but it is preferred to have the hole exits located where the gas pressure is sub-ambient so that liquids always will be drawn through the holes. The exits can be located, for example, from the downstream end of section 18 to and even beyond the downstream end of the diverging section 20.

The atomizer 70 shown in FIG. 4 has substantially the same construction as the atomizer 10 shown in FIGS 1 and 2, except that the downstream feed holes 38 have been omitted from the atomizer 70, and the dimensions of the nozzle and resonator are different. The atomizer 70 is particularly desirable for use where extremely high turn-down ratios are not needed, but where it is desired to use very high inlet gas pressure P_O. The use of the baffle 26 directs the liquid into the gas generally in the direction of the gas flow and prevents the gas from flowing back into the liquid feed conduit. Also, the annular shape of the opening 42 spreads the liquid around the nozzle and produces a symmetrical spray pattern.

The atomizer 70 has the further advantage that it produces an elongated spray or flame pattern which is highly desirable for many purposes. The use of the baffled liquid feed arrangement into the upstream portion of the nozzle rather than the downstream portion makes the elongated spray pattern possible by enabling the resonator diameter D_R to be considerably less than the metal throat diameter D^* without any noticeable effect upon the atomization quality produced by the device. It is believed that this is true because the evenly distributed sheet of liquid flowing through the stabilizing section 18 restricts the section and makes its effective diameter approximately the same as that of the resonator. The reduced cavity diameter allows the resonator member itself to be reduced in size, with the resultant narrowing and longitudinal extension of the spray pattern.

Most of the parameters of the nozzle and resonator structures disclosed above are described in the prior art. However, for the sake of completeness, some of the more important parameters will be discussed next.

In order to attain maximum atomizing power, the diameter D_R of the resonator cavity 22 should be approximately equal to the effective diameter D^* of stabilizing section 18. The depth L_R of the resonator cavity 22 preferably is equal to either $\lambda/2$ or $\lambda/4$, where λ is given approximately by the following equation:

$$\lambda = 1.307 \quad D^*\sqrt{M_E^2 - 1}$$

which M_E is the Mach number of the gas flowing at the exit of the diverging section **20** of the nozzle, and D* is the nozzle throat diameter.

The half-angle of the diverging section should be maintained within the range of from about 3° or 4° to about 25°. The angle (*b*) shown in FIG. **2** is around 15°, and the angle (*d*) in FIG. **4** is around 4°. The value of the half-angle of convergence of the converging section **16** ordinarily is not particularly critical and can vary widely, as is well known in the art. However, in order to align the passageway **40** approximately in the direction of the flow of gas through the nozzle, it is desired to keep the convergence angle relatively small. The angle (*a*) shown in FIG. **2** of the drawings is approximately 20°, and the angle (*c*) shown in FIG. **4** is approximately 5°.

The resonator support members **14** can have any shape desired, but preferably they consist of three relatively thin, symmetrically positioned stainless steel wires.

It has been found that the atomizers constructed and operated in accordance with the present invention will produce very high turn-down ratios with high quality atomization throughout the range of flow rate variation. What is more, the control of the liquid flow rate is simple and positive, and the flame pattern produced by the device when used as a burner nozzle is quite symmetrical.

Applicants have discovered that atomizers with a structure quite similar to that shown in FIGS. **1** through **4**, but with different fluid feed arrangements offer distinct advantages in many uses. One such atomizer **80** is shown in FIG. **5**, in which corresponding parts are given the same reference numerals as before. The main difference between the atomizer **80** and the atomizers shown in FIGS **2** and **4** is that liquid is fed through the center of the nozzle instead of at the periphery of the nozzle, and gas is fed through the holes **36** through which liquid is fed in the embodiments shown in FIGS. **2** and **4**. Gas is pumped by a compressor **88** and is fed through an inlet tube **84** to an annular manifold **82**, through the holes **36**, along the baffle **26**, and into the liquid at the entrance to the throat section **18**. The liquid is pumped by a pump **86** through a conduit **90**, through the throat section **18** and the diverging section **20**, to form a jet which impinges upon the cavity-bearing resonator member **12**.

The gas is pumped into the atomizer under relatively high pressures, e.g., 30 to 100 p.s.i.g., and mixes intimately with the liquid in the nozzle before the liquid-gas mixture emerges from the nozzle and strikes the cavity **22** in member **12**.

The convergence and divergence angles of the nozzle of atomizer **80** are the same as those of the nozzle shown in FIG. **2**. However, the throat section **18** is considerably longer than the corresponding throat section in the FIG. **2** structure. Another difference is that the diameter D_1 of the throat section **18** is larger than the diameter D_2 of the opening **16** of the baffle member. For example, the diameter D_1 in a typical nozzle which has been tested successfully is 0.344 inch, whereas the diameter D_2 is 0.312 inch. The spacing between the inner wall of the baffle **26** and the converging wall of the nozzle is 0.022 inch.

The atomizer **80** has several advantages. One significant advantage is that, because of its relatively large liquid feed passages, very badly contaminated liquids can be atomized without clogging the nozzle. This advantage is exemplified by the schematic showing, in FIG. **5**, of a gas scrubber **87**. In the scrubber **87**, one or more atomizer **80** is used to atomize and spray water into an enclosure **95**, which is, for example, a chamber receiving smoke-laden air from a furnace, in order to "scrub" smoke or dust **97** out of the air. The smoke flows downwardly into the enclosure **95**, and out through an opening **85**. The smoke-and-debris-laden water **99** falls and collects at the bottom of the enclosure **95**, and is pumped to a settling pond **93** by a pump **101** through a conduit **103**. The debris-laden water enters the pond at one end, and is re-used by pumping it out through a conduit **91** at the other end of the pond, presumably after the debris has settled out in the pond. However, such water, when used, for example, to clean air from smoke in an asphalt-making plant, invariably has debris in it when it is re-used. Such debris includes pebble-sized cinders which will clog the feed holes of most atomizers. However, not so with the atomizer **80**. Thus, the atomizer **80** is an extremely clog-free atomizer.

The baffle **26** and the inclined gas feed passageway it provides also help to prevent inoperativeness due to clogging. The inclination of the gas feed passageway towards the direction of gas flow minimizes the likelihood of objects becoming lodged in the passageway. Furthermore, the enlargement of the central passageway due to the change from diameter D_2 to diameter D_1 is believed to create suction on the gas passageway which tends to keep it open and clean.

Another advantage of the atomizer **80** is that it produces good atomization, quite sufficient to produce excellent gas scrubbing, and yet requires a relatively low gas flow rate for satisfactory operation. This can result in considerable savings in compressor equipment costs. The even spread of the gas when it is injected into the water at the edge of the baffle **26** is believed to assist in obtaining good atomization.

Alternative forms of the invention can be made by using gas feed holes **92** in the throat section **18**, or inclined holes **94** in the diverging section, instead of the baffle **26** and feed holes **36**.

The atomizer **80** also has been found to be particularly advantageous in aeration of liquids, or the dissolving of gases in liquids. Such a use of the atomizer **80** is illustrated in FIG. **6** of the drawings.

FIG. **6** shows a tank **98** with a body of liquid **100** in the tank. Submerged in the liquid is the atomizer **80**. Gas is pumped to the atomizer **80** through a pipe **96**. The pump **86** pumps liquid in the tank through the atomizer **80**, in the manner illustrated in FIG. **5**. The atomizer **80** intimately mixes the gas with the liquid, and issues the gas in tiny bubbles which thus come into intimate contact with the liquid. If the gas is soluble in the liquid, it often dissolves before reaching the surface of the liquid.

It is well known in the prior art that a gas can be drawn into a liquid stream flowing through a converging-diverging conduit by aspiration through one or more holes in the nozzle. Similarly, aspiration can be used to draw gases through one or more of the holes **94** (see FIG. **5**) in the nozzle of the atomizer **80**, thus avoiding the need for a gas pump such as the pump **88** shown in FIG. **6**.

The gas which is dissolved in the liquid can vary considerably. For example, in the ozonization of water, ozone is fed into the atomizer **80** and dissolved in the water in the tank to kill algae, etc., in the water. Air, of course, chlorine, etc., are other examples of gases which it is useful to percolate through the liquid.

FIG. **7** illustrates another atomizer **110** which is essentially the same as the atomizer shown in FIGS **1** and **2**, except that only one row of diverge-section feed holes **38** is provided, and a barrier **111** is provided to separate the annular feed passageways and provide separate chambers **112** and **116** to feed the holes **38** and **36**, respectively.

The atomizer **110** is used in a gas turbine engine, in the manner shown in U.S. Pat. No. 3,320,144, in which the main gas flow through the center of the nozzle is created by the pressure difference between the combustion chamber interior and the compressor of the turbine. Since, during starting of the engine, the pressure on the gas fed to the atomizer is relatively low, higher pressure air is fed through a conduit **118** from a compressor **120** into the nozzle through the chamber **116** and holes **36**. Pressurized liquid fuel is fed to the holes through the conduit **114**. Then, when the rotational speed of the compressor of the turbine increases to a sufficient level, the separate air source **120** is removed, and the only air flow is through the center of the nozzle.

A significant advantage of both of the nozzles **80** and **110** shown in FIGS. **5** and **7** is that the cross-sectional area provided by the holes **36** is substantially less than the area of the central passageway through the nozzle, with the result that atomization is accomplished with a considerably reduced air flow volume. Thus, the compressors **88** and **120** can have a lower flow capacity and can be less expensive than higher capacity compressors which otherwise might be required.

We claim:

1. Apparatus for intimately contacting a gas with a liquid in a liquid body, said apparatus comprising, in combination, a liquid body, a nozzle having a converging inlet portion and a diverging outlet portion with a substantially cylindrical central portion of substantially constant cross-sectional area joining said converging and diverging portions, a member having a substantially cylindrical resonator cavity closely adjacent and opposite the outlet of said nozzle, said cavity having a diameter approximately equal to the minimum internal diameter of said nozzle, the depth of said cavity being selected from the group of lengths consisting of $\lambda/2$ and $\lambda/4$, where λ is defined hereinabove when a gas rather than a liquid is flowing through the nozzle, means for pumping a liquid through said nozzle towards said cavity, said nozzle having a lateral entrance hole, and conduit means for introducing said gas through said entrance hole and into the liquid flowing through said nozzle, said nozzle and said member being immersed in said liquid body.

2. Apparatus as in claim **1** in which said lateral entrance hole is annular and is formed by a baffle extending at an angle to the longitudinal axis of said nozzle adjacent said central portion of said nozzle.

* * * * *