SONIC ATOMIZER FOR LIQUIDS

Filed Oct. 27, 1960 4 Sheets-Sheet 1

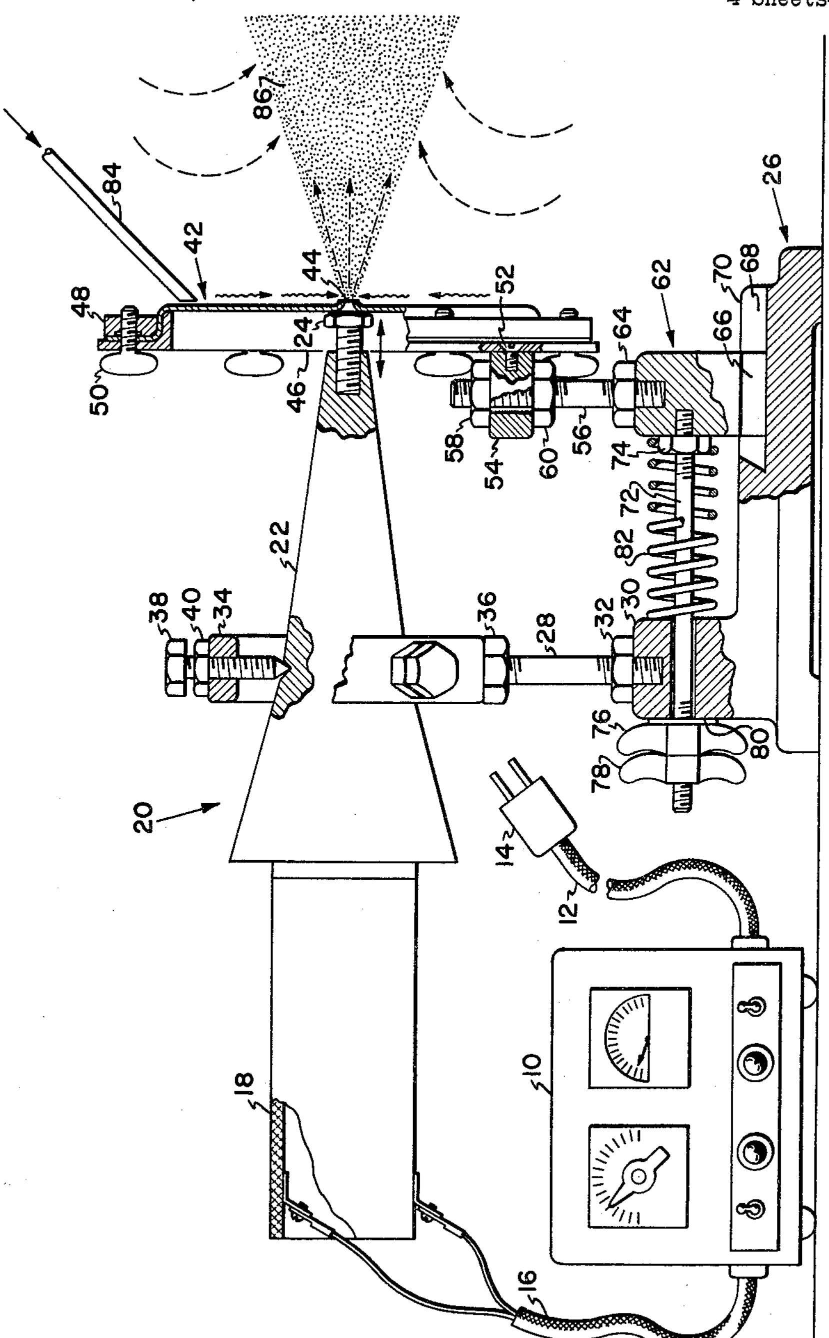

Fig. 1

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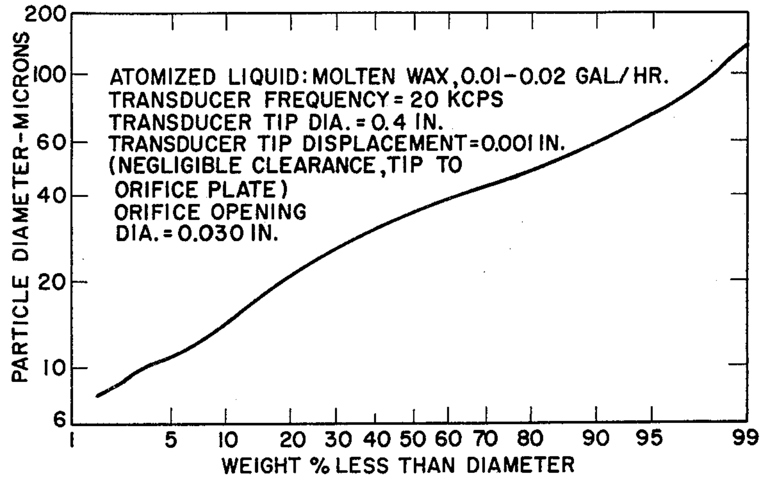

Fig. 2

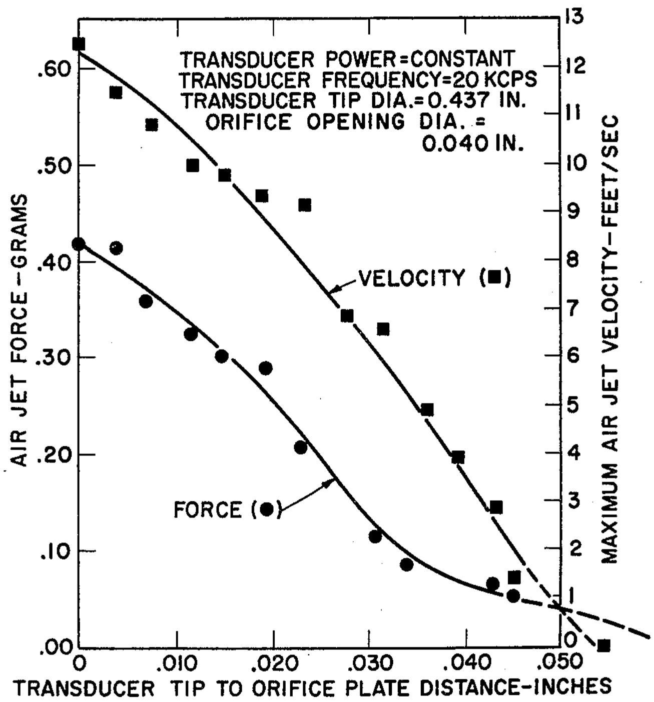

Fig. 3

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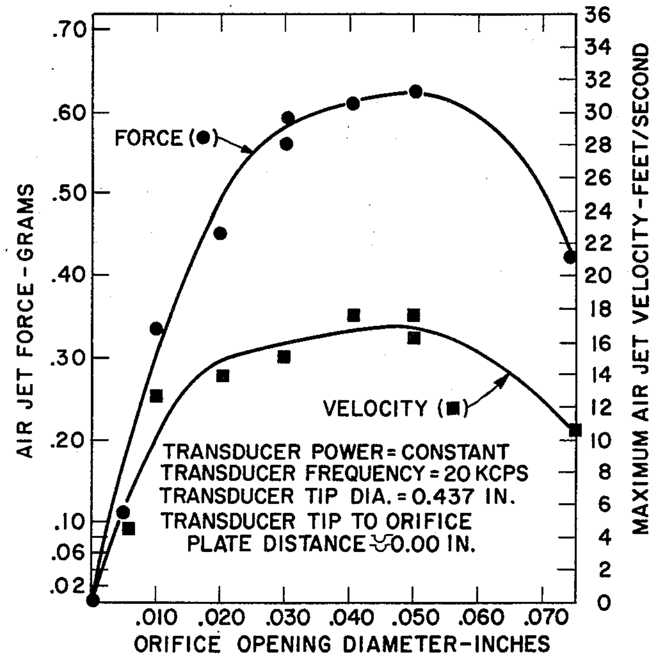

Fig. 4

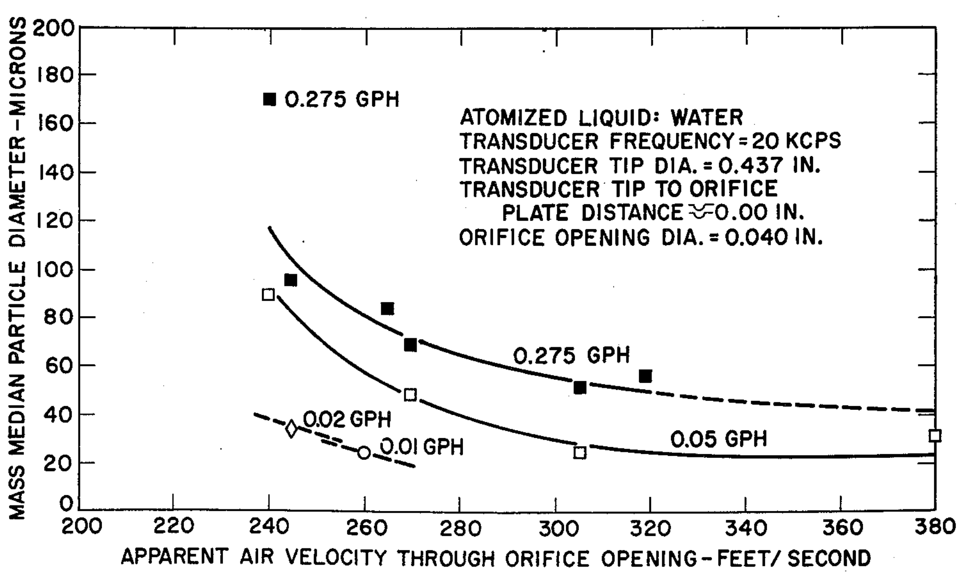

Fig. 5

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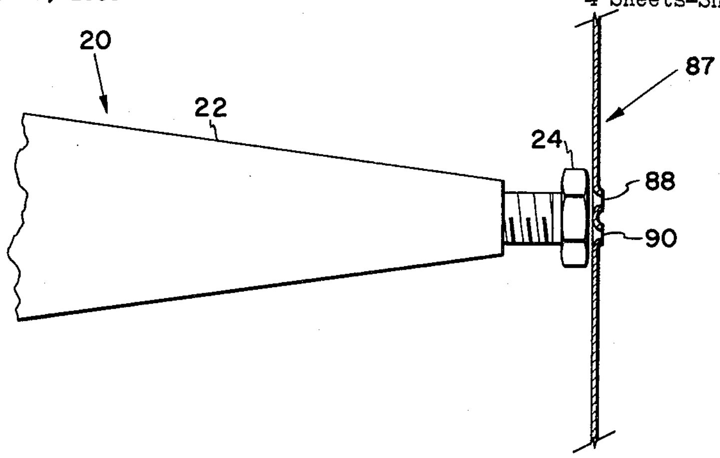

Fig. 6

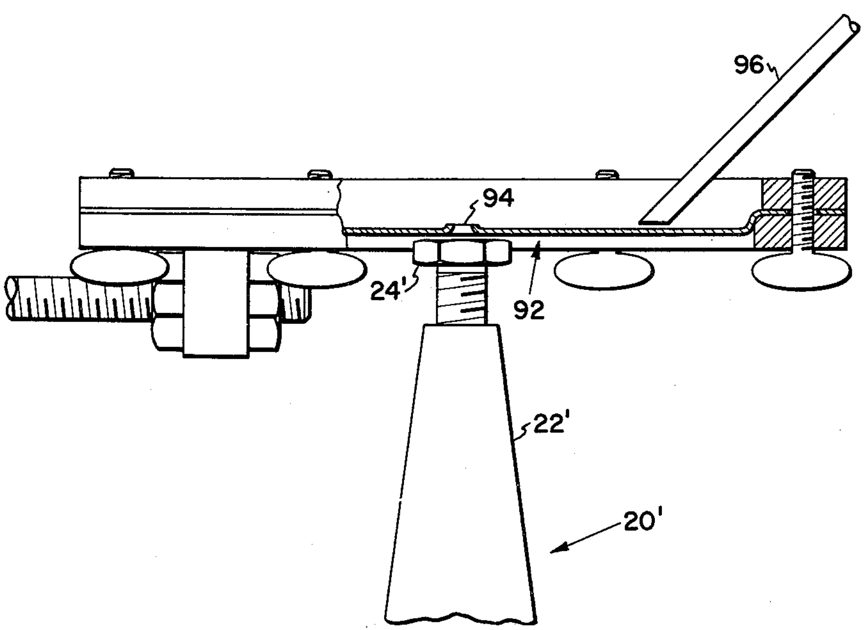

Fig. 7

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SONIC ATOMIZER FOR LIQUIDS

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6 Claims. (Cl. 239—4)

This invention relates to a method and apparatus for atomizing liquids. It relates particularly to a method and apparatus for atomizing liquids through the use of sonic energy, and it relates more particularly to such a method and apparatus wherein and whereby sonic energy is used for the production of a rapidly pulsating stream of air to impinge upon the liquid to be atomized.

It is well known in the art that atomization of liquids may be effected through the use of sonic energy. A pertinent reference is the article "Ultrasonic Atomization of Liquids" by J. N. Antonevich appearing at pp. 6–15 of Transactions on Ultrasonics, February 1959, published by the Institute of Radio Engineers. One apparatus which has been used for atomizing liquids is a transducer comprising a piece of ceramic piezo-electric material such as barium titanate bonded on a flat surface to the larger diametral surface of a truncated conical resonator of elastic and electrically conductive material such as aluminum. In a particular apparatus of the prior art, the ceramic piece is in the form of a cylinder. The length of this cylinder and the resonator to which it is bonded are respectively one-half the wavelength of sound in their particular materials at the operating frequency selected. Such apparatus is illustrated and described, for example, in U.S. Patent No. 2,514,080 to W. P. Mason, issued July 4, 1950.

When an alternating voltage of relatively high frequency is applied across the ceramic cylinder, this cylinder will be cyclically lengthened and shortened and will generate alternate compression and rarefaction waves of sonic energy. This energy, which may be characterized by a frequency above the range of normal hearing, will cause a cyclical lengthening and shortening or longitudinal vibration of the metal resonator as it flows thereinto. With decreasing cross sectional area of a cone-shaped resonator in the direction away from the ceramic cylinder, there will be a concentration of energy near the resonator tip and an increasing amplitude of motion. If a drop of liquid such as home heating oil be applied to the resonator tip while the resonator is being vibrated longitudinally, sonic energy will flow into this drop and the drop will be broken up into a fog of fine particles; that is, it will be atomized.

Like this equipment and process of the prior art, the present invention provides an atomizing apparatus and method wherein and whereby a sonic energy transducer is employed. Unlike the prior art equipment and process, however, the sonic energy transducer of this invention does not have the liquid to be atomized applied directly onto it. Instead, according to this invention, the tip of the resonator element of the transducer employed is disposed in closely spaced relation to the opening in an orifice plate, and liquid to be atomized is trickled across this plate toward the opening therein on the side of the plate away from the transducer. When the transducer is energized, it acts as a pump or blower to draw air in through the orifice opening in a wide-angle pattern on the retracting or suction stroke of the resonator element tip and then discharge air from this same opening in a narrow, jet-like stream on the subsequent forward or driving stroke. Liquid running over the edge of the orifice opening is impinged upon by this stream, and consequently atomized.

The nature and substance of this invention will be more clearly perceived and fully understood by referring to the following description and claims taken in connection with the accompanying drawings in which:

FIG. 1 represents a side elevation view partly in section of a high frequency electronic generator coupled to a sonic energy transducer disposed horizontally in a suitable mounting, an orifice plate being provided closely adjacent the tip end of the resonator element of this transducer according to the present invention, and this plate having mounting means whereby its position relative to the transducer may be adjusted;

FIG. 2 represents a plot of particle size distribution obtained using an apparatus embodiment of this invention for the atomization of molten wax;

FIG. 3 represents a plot of force and velocity of an air jet generated by an apparatus embodiment of this invention measured with respect to distance from the tip of the resonator element of the sonic energy transducer to the orifice plate for given values of resonator element tip diameter and orifice diameter;

FIG. 4 represents a plot of force and velocity of an air jet generated by an apparatus embodiment of this invention measured with respect to orifice diameter for given values of resonator element tip area and distance from the tip of the resonator element to the orifice plate;

FIG. 5 represents a plot of mass median drop diameters obtained using an apparatus embodiment of this invention for the atomization of water measured with respect to apparent air velocity through the orifice for a plurality of rates of liquid feed;

FIG. 6 represents a side elevation view partly in section of the tip end of the resonator element of the sonic energy transducer of FIG. 1 and an orifice plate closely adjacent thereto, this plate being provided with a plurality of orifices, and

FIG. 7 represents a side elevation view partly in section of the tip end of the resonator element of the sonic energy transducer of FIG. 1 disposed vertically and an orifice plate closely adjacent thereto.

Referring now to the drawings in detail, especially to FIG. 1 thereof, a high frequency electronic generator or oscillator **10** having connection to a low frequency voltage source through cable **12** and plug **14** is closely coupled on its output side by means of cable **16** across the bore of a cylindrical-type piezo-electric element **18** of a sonic energy transducer **20**. This piezo-electric element is bonded to a boss on the larger diametral surface of a resonator element **22** of generally conical form. At its smaller diametral surface, the resonator element is drilled and tapped to receive the shank of a headed bolt **24**. The diameter of the head of this bolt is effectively the diameter of the tip end of the resonator element for purposes of the present invention. Accordingly by having available a plurality of bolts **24** of different head diameters, a range of tip sizes of the resonator element may be obtained by substitution of bolts one for another.

For purposes of the present invention, it is not critical that generator **10** be of the electronic variety. This generator may be of the rotary variety also, both varieties and their uses being well known in the sonic energy art. Likewise, the nature of piezo-electric element **18** is not critical. This element may comprise any one of several materials. Use in sonic energy transducers of such a piezo-electric material as the ceramic barium titanate has been mentioned already. Other ceramic materials suitable for this use include lead zirconates and lead zirconium titanates. In assembling transducer **20**, the electrical leads or lugs of piezo-electric element **18** are soldered thereto, and then this element is bonded to resonator element **22**. The bond between these two elements is critical for proper operation of the transducer, although neither its structure nor the method of making it constitutes any part of the present invention. In one suitable method of joining the piezo-electric and resonator elements, a cement such as an epoxy resin is used which sets by polymerization rather than by solvent evaporation. A suitable elastic and electrically conductive material for the resonator element is aluminum, as mentioned above. Other materials appropriate for resonator element 22 include brass and stainless steel.

In the apparatus embodiment of this invention illustrated in FIG. 1, support for transducer 20 is furnished from base element 26. An upwardly-extending post member 28 is threaded into a raised region 30 of base 26, and locked in place with nut 32. At its upper end, this vertical member has a transducer locating ring element 34 threaded thereonto and locked with a nut 36. This ring element encloses resonator element 22. The resonator is maintained in spaced relation to ring 34 by means of three point-ended screws 38 substantially equally spaced around the ring element, and having lock nuts 40. These screws directed radially inwardly through ring 34 engage notches or drill spots in the lateral surface of the resonator element. All these spots should be in a single circumferential line on this element, and this line should coincide with the node of vibrations in the resonator when transducer 20 is energized from generator 10.

Closely adjacent the head end of bolt 24 there is an orifice plate 42. While this plate may actually be in contact with the bolt head at least intermittently during operation of transducer 20, no physical bond exists between the plate and the bolt. Plate 42 may conveniently be of circular form, but it is not required to be so configured. In its center it is provided with a lipped orifice opening 44 in substantially axial alignment with transducer 20, the lip or rim of this opening extending away from the transducer. At its outer edge region, plate 42 is slightly upset to fit closely over and extend outwardly along a shaped annular surface of frame member 46. The plate is held tightly on and against frame 46 by means of a clamping ring 48, whereinto are threaded a plurality of thumb screws 50 which pass through clear holes in frame 46. There are likewise holes or slots in the outer edge region of orifice plate 42 for accommodation of the thumb screws.

Extending across the lower region of frame 46 and fixedly secured thereto by a plurality of screws 52 is a rigid yoke member 54. This yoke is bored vertically to have at least one clear hole through which passes the upper threaded end of a post member 56. Yoke 54 is secured on post 56 by means of nuts 58 and 60. The lower end of post 56 is threaded into a sliding block member 62, and is locked therein by means of nut 64. Block 62 is characterized by a guide element 66 formed on or fitted onto its lower surface. This guide element, which may be wedge-shaped in transverse section, fits closely into a groove region 68 formed in base 26. Block 62, guided by element 66 running in groove 68, may slide on surface 70 of base 26. This surface will preferably be smoothly finished as will be the surface of block 62 sliding upon it, and also the bearing surfaces of guide element 66 and groove region 68.

At least one position-adjusting rod 72 is threaded into block 62, and secured therein by means of nut 74. This rod, threaded at both ends, extends horizontally through a clear hole in raised region 30 of base 26. On its threaded end extending to the left beyond raised base region 30, rod 72 is provided with two wing nuts 76 and 78, the first of these being intended to bear against a lateral, preferably finished surface 80 of raised base region 30, and the second being intended to bear and lock against the first. A compression spring 82 encloses adjusting rod 72, and is contained between sliding block 62 and raised base region 30. The force of spring 82

acting against block 62 tends to move this block in a direction carrying orifice plate 42 away from the tip end of transducer 20.

The remaining structural item appearing in FIG. 1 is feed tube 84 through which liquid to be atomized is flowed onto plate 42. This tube has connections not shown leading to a source of liquid, a tank of home heating oil for example, these connections including appropriate pumping and metering devices. The mounting of feed tube 84 will be capable of movement so that this tube may be moved not only simultaneously with the orifice plate as sliding block 62 is shifted, but also, desirably, independently of plate 42 to allow adjustment of the position of the tube outlet end with respect to orifice opening 44. In general, this outlet end should be so positioned that liquid will flow from it across the plate to the lipped region thereof surrounding the orifice opening.

Although the machine elements which would be involved are not specifically illustrated, it is obviously within the scope of well known art that means for recovering liquid material flowed onto but not atomized from plate 42 could be provided. Such means might include, for example, a drip pan located below the plate and a scraper operating across the face of the plate removed from transducer 20.

Adjustment and operation of the apparatus shown in FIG. 1 will now be considered. Locking wing nut 78 is backed off from adjusting wing nut 76, and the latter nut is manipulated to shift sliding block 62 as necessary to offset plate 42 from the head of bolt 24 by a distance substantially equal to half of the total displacement of the tip of the resonator element, that is, effectively, the displacement from static position of the bolt on its forward stroke upon transducer 20 being energized from generator 10 to vibrate longitudinally. Wing nut 78 is then tightened against wing nut 76. Nuts 58 and 60 may be manipulated to shift yoke 54 up or down on post 56, and so adjust the position of plate 42 to center orifice opening 44 vertically with respect to transducer 20. Although no means of making transverse adjustment of the orifice plate position are particularly illustrated, it is obvious that such means could be provided easily if desired. However, if no such means are provided, satisfactory results will be achieved within the scope of other adjustments if the illustrated parts are so designed that orifice opening 44 is centered transversely with respect to the head of bolt 24. Such centering is indeed practically required.

Orifice plate 42 having been positioned with respect to transducer 20, liquid feed tube 84 is positioned with respect to this plate. The next step is to start generator 10 according to procedures appropriate to that piece of equipment. Such procedures do not constitute any part of the present invention. With generator 10 imposing a high frequency alternating voltage, about 20 kc. p.s., for example, across opposite side walls of piezo-electric element 18 there will be a cyclical increase and decrease in diameter of this element. Due to well known elastic effects, this variation in diameter will cause a cyclical change in length of the piezo-electric element. This high frequency lengthening and shortening of piezo-electric element 18 will cause a flow of sonic energy into resonator element 22. Physically, this flow will be evidenced by a high frequency lengthening and shortening of the resonator element. Actual movement of any region of this element or part effectively a portion thereof will be greatest at the head of bolt 24 adjacent orifice plate 42.

As the head of bolt 24 advances toward and withdraws from orifice plate 42 it acts, in effect, like the piston of an air pump. Without specific limitation to any particular theory, the pumping action which is obtained is considered to be substantially the same as that described in U.S. Patent No. 2,787,444 of April 2, 1957, issued to C. W. Skarstrom for "Heat Exchanger and Means for Circulating Fluids". In summary, as the head of bolt **24** withdraws from orifice plate **42** there is inward or leftward flow of air through orifice opening **44** from an extensive area over the outer or right hand surface of the orifice plate with the flow lines widely dispersed in a large solid angle. This is indicated in FIG. 1 by sinuous arrows. Thereafter, as the head of bolt **24** advances toward the orifice plate, air is discharged to the right through the orifice opening in the form of a jet or stream of small solid angle. This is indicated in FIG. 1 by straight dashed arrows. The jet of discharged air in turn induces flow of air from the surrounding atmosphere as indicated by curved dashed arrows.

After transducer **20** has been energized to start the pumping action just described, flow of liquid to be atomized may be started through feed tube **84**. This liquid will run down the orifice plate and onto the lipped region thereof surrounding and defining the orifice opening. As the liquid feed goes over the edge of the lipped region of orifice plate **42** it will be struck by the pulsating jet of air issuing from orifice opening **44**, and will be broken up into fine particles or atomized thereby. The air jet will not only atomize the liquid feed, but will also give it an appreciable displacement to the right away from the orifice plate. Said in other words, a jet of air and atomized liquid will issue from orifice opening **44**. This stream is indicated in part by the particle fog **86**. Air flowing according to the curved arrows in FIG. 1 will tend to be drawn into this mixture stream, and may be helpful in forming a combustible mixture when the atomized liquid is heating oil fed at a relatively high rate.

Referring next to FIG. 2, experimental measurements have been made of the diametral size distribution of liquid particles generated by an apparatus embodiment of this invention generally similar to that shown in FIG. 1. In this embodiment the transducer had a tip diameter of about 0.4 in., a tip displacement of about 0.001 in., and an operating frequency of about 20 kc. p.s. The opening in the orifice plate had a diameter of about 0.030 in., and liquid to be atomized was fed at a rate of about 0.01 to 0.02 gal./hr. This liquid was molten "Acrawax C" made by Glyco Products Co., Inc., New York, N.Y. Acrawax C is a synthetic material having an unusually high and well defined melting range of 284–290° F. The specific gravity of this wax in the temperature range of 310–350° F. referred to water at 60° F., and its surface tension in this same temperature range are quite close to those of a typical home heating oil at 100° F., the approximate temperature at which an oil of this kind is frequently atomized by traditional means such as a pressure nozzle for mixing with air and subsequent combustion.

In the carrying out of the experiments, molten wax particles discharged from the orifice opening with the pulsating air jet were cooled and condensed, and the solidified particles collected and thereafter analyzed in a Sharples Micromerograph for distribution of size in terms of weight percentage of the whole less than any particular diameter. The results of this analysis are plotted in FIG. 2. Mass median particle size was determined to be 34 microns. The pulsating nature of the air jet whereby the molten wax was atomized was found to be definitely advantageous for the generation of fine particles. This was shown by a second experiment in which liquid was atomized by an air stream from a steady source of compressed air, this stream issuing through the opening in the same orifice plate used with the transducer in the first experiment, and having axial momentum essentially the same as that of the air stream generated by the transducer. In this second experiment, large droplets were observed to form and fall quickly out of the spray or particle fog designated **86** in FIG. 1. The superior results, that is, the finer particles, obtained using the transducer were probably due either to increased turbulence in the pulsating transducer-generated air jet or to the high peak velocities associated with this cyclical air flow.

Referring next to FIGS. 3 and 4, experimental measurements have been made of the force and velocity of an air jet generated by an apparatus embodiment of this invention generally similar to that shown in FIG. 1. In each case the transducer had a tip diameter of about 0.437 in., an operating frequency of about 20 kc. p.s., and an essentially constant power input. For the experiments providing the data of FIG. 4, however, the power level was somewhat higher than for those providing the data of FIG. 3. Force of the jet was measured by orienting the transducer vertically and causing the pulsating air stream issuing through the orifice opening to impinge upon one pan of a laboratory balance. The weight needed to be applied to the balance to maintain it in an equilibrium position gave a direct reading of jet force. Velocity of the air jet was measured with a hot wire anemometer. The velocity values indicated in FIGS. 3 and 4 represent profile maxima or peaks measured transversely across the air stream at a determined distance out from the orifice opening. They are essentially steady values, no significant cyclical variation of jet velocity on account of transducer tip movement having been detectable with the instrument system used.

For the particular experiments providing the data of FIG. 3, the diameter of the orifice opening was kept at a single value of about 0.040 in. Force and velocity measurements were taken for a range of static distances from the transducer tip, that is, the effective tip of the resonator element, to the orifice plate. The word "static" here relates to distances determined when the transducer was in a deenergized or non-vibrating condition. All distance values indicated in FIG. 3 are static, except for the zero value which represents the dynamic condition of the transducer vibrating and so positioned that the effective tip of its resonator element just barely touches the orifice plate on its forward stroke. Such a zero value for dynamic conditions corresponds to a distance on the order of less than 0.001 in. for static conditions, a value so small as to be not easily distinguishable from an actual zero distance position on the abscissa axis of FIG. 3. The two curves of this figure show clearly that it is desirable to have the transducer tip positioned as close to the orifice plate as possible short of having this tip pound or impact on the plate when the transducer is energized. In essence, it is desirable to create a piston pump having no head end clearance.

For the particular experiments providing the data of FIG. 4, the distance from the transducer tip to the orifice plate was kept at a single value of about 0.00 in., that is, the value determined according to the data of FIG. 3 as that providing the greatest force and velocity of the air jet for a given orifice opening diameter. Force and velocity measurements were taken for a range of diameters of the orifice opening, and the two curves of FIG. 4 show clearly that there is a mid-range optimum value of this diameter of about 0.050 in. Expressed as a range of ratios, it is desirable that the diameter of the transducer tip be six to fifteen times as great as the diameter of the orifice opening. More desirably, the former diameter will be about nine times as great as the latter.

Further experiments using an apparatus embodiment of this invention generally similar to that shown in FIG. 1 were conducted to determine the effect on air jet force and velocity of changes in tip diameter of the transducer, that is, the use with resonator element **22** of a series of bolts **24** with a range of head sizes. For these experiments the transducer had an operating frequency of about 20 kc. p.s., and a constant power input at about the level of power at which the data plotted in FIG. 4 were gathered. The diameter of the orifice opening was kept at a single value of about 0.040 in., and the distance from the transducer tip to the orifice plate was kept at a single value of about 0.00 in. Data gathered in these experiments are given in Table I as follows:

Table I

Transducer Tip Diameter (in.)	Air Jet Force (gms.)	Max. Air Jet Velocity (ft./sec.)
0.250	0.030	3.3
0.437	0.610	17.5
0.562	0.615	17.1

These data show clearly that once a certain diameter of the transducer tip has been reached, at least about 0.437 or 7/16 in. for the experiments described, no particular increase of either force or velocity of the air jet will result from the use of a larger tip. On the other hand, if the tip diameter be reduced significantly below its lower limiting value for essentially constant air jet force and velocity there will be a marked decrease in each of these two quantities.

Referring next to FIG. 5, experimental measurements have been made of the mass median drop diameters of water fed at various rates to an apparatus embodiment of this invention generally similar to that shown in FIG. 1, and atomized thereby. For these experiments the transducer had a tip diameter of about 0.437 in., an operating frequency of about 20 kc. p.s., and a variable power input. The diameter of the orifice opening was kept at a single value of about 0.040 in., and the distance from the transducer tip to the orifice plate was kept at a single value of about 0.00 in.

For the atomized water, mass median particle sizes or drop diameters were determined according to the method given in the article "A Technique for the Investigation of Spray Characteristics of Constant Flow Nozzles" by J. H. Rupe appearing at pp. 680–694 of Third Symposium on Combustion, Flame and Explosion Phenomena, The Williams & Wilkins Co., 1949, Baltimore, Md. Essentially this method calls for atomized water to be collected in a series of cells filled with a material such as kerosene or Stoddard Solvent. These materials are less dense than and immiscible with water. Therefore the water particles falling into the collection cells sink to the bottom thereof while retaining their discrete identities, and may later be viewed optically or photomicrographed for counting and sizing.

Velocities through the orifice opening of the air jets generated by the transducer were not measured directly. Instead a force measurement of the transducer-generated air stream was made according to the method hereinbefore described for each power level of transducer operation. After that an air stream from a steady source of compressed air was directed through the same orifice opening used for the water atomization experiments, and force measurements were made of this stream, the effective supply pressure at the stream source being adjusted through a series of values to give such a measurement equal to each of those of the transducer-generated air stream. For each of these values of steady-source stream pressure, the volumetric flow rate of air issuing through the orifice opening was determined by means of a rotameter. With knowledge of air flow rates and also of the diameter of the orifice opening, air velocity through this opening was calculated for each steady-source stream pressure value. These calculated values are indicated on the abscissa axis of FIG. 5 as "apparent" air velocities. They represent, in effect, root means square velocity values of the air jets generated by the transducer.

Water to be atomized was supplied or fed to the apparatus at four different rates, 0.01, 0.02, 0.05, and 0.275 gal./hr. At each of the two lower rates of water feed, atomization was effected at a single transducer power level only. At each of the two higher rates, atomization was effected over a range of power levels. The plotted results show that for a given level of transducer power, this corresponding to a particular apparent air velocity through the orifice opening, mass median drop diameter or particle size of the atomized water decreased steadily with decreasing rate of water feed. The plotted results show also that for a given rate of water feed the mass median drop diameter decreased with increasing transducer power level or apparent air velocity.

Referring next to FIG. 6, an orifice plate **87** has been substituted in the apparatus of FIG. 1 for orifice plate **42** originally shown therein. Plate **87** is provided with a plurality of orifice openings in alignment with the head of bolt **24** on resonator element **22**, that is, a plurality of orifice openings closely adjacent the effective tip of transducer **20**. Specifically, two orifice openings **88** and **90** are shown. It is within the contemplation of this invention, however, that more than two openings may be provided in the orifice plate, and that they may be grouped in any suitable pattern such as a circle, a square, a diamond, etc.

The advantage which accrues from using a plurality of orifice openings rather than a single opening only is that of obtaining a better breaking up of the liquid feed stream trickling down the orifice plate from tube **84**. For a given total orifice area, a plurality of openings will have greater total lip or edge length and surface than a single opening in way of the down-coming liquid for atomization. This additional length and surface will aid in distributing the liquid in the condition of a thin, easily atomized film prior to going into the pulsating air jets through the openings, and at least tend to increase the atomizing capacity of the apparatus.

Although not illustrated specifically in any figure, it is within the contemplation of this invention that orifice plate **42**, orifice plate **87**, or any other orifice plate be provided with a collar on its side adjacent the transducer, this collar in fact enclosing the head of bolt **24** or the tip of the transducer of whatever particular configuration. As so disposed, the collar will act as the cylinder of a reciprocating air pump, and in some cases will tend to reduce side leakage of air drawn in through the orifice opening or openings on the suction stroke of the transducer tip. This in turn will tend to allow the use of a tip of smaller diameter than if no collar were present for a given pumping effect. It is to be understood clearly, however, that the use of a collar or cylinder as described is not critical for successful operation of any apparatus embodiment of this invention.

Referring finally to FIG. 7, an orifice plate **92** is held horizontally by suitable structural support means above a vertically oriented transducer **20'** comprising a resonator element **22'** having a headed bolt **24'** in its upper or tip end. Plate **92** has an upwardly lipped orifice opening **94**. A liquid feed tube **96** is disposed with its outlet end close to the upper side of the plate. When liquid material to be atomized is admitted onto plate **92** it will tend to form a little pool bounded by the lip of opening **94** and the vertical portion of the outer rim or edge region of the orifice plate. Continued feeding of liquid through tube **96** will cause overflow in thin film form of the material to be atomized around the entire lip of the orifice opening, a desirable condition of operation.

Although this invention has been described with a certain degre of particularity, it is to be understood that the present disclosure has been made only by way of example, especially with respect to numerical values given therein, and that numerous changes in the details of elements and assemblies may be resorted to without departing from the spirit and scope of this invention as set forth in the following claims which are to be construed as broadly as the state of the relevant art allows.

What is claimed is:

1. An apparatus for atomizing liquids comprising (1) a transducer capable of receiving inputs of alternating voltage and providing outputs of vibratory mechanical displacement at a localized surface region of its structure,

and (2) an orifice-containing plate element disposed opposite said region, said plate and said region defining a very small clearance space therebetween such that at maximum displacement the area available for air flow between said region and said plate element is much less than the area of said orifice, whereby said vibratory displacement of said region produces a pulsating air jet through said orifice capable of finely atomizing liquid at said orifice.

2. Apparatus according to claim 1 wherein the localized surface region and the plate are essentially planar and parallel.

3. Apparatus according to claim 1 wherein the orifice is of diameter between about one-sixth and one-fifteenth that of the localized surface region.

4. Apparatus according to claim 1 wherein the localized surface region essentially is the flat end of a piston which is vibrated in a direction substantially perpendicular to said flat end.

5. Apparatus according to claim 1 wherein the transducer is operable at about 20 kilocycles per second.

6. A method of atomizing liquids which comprises (1) vibrating at high frequency a substantially plane surface region to displace said region along an axis substantially perpendicular thereto and towards and away from an orifice in a plate element disposed closely adjacent to said region, the area of said orifice being much larger than the lateral clearance area between said region and said element at maximum displacement of said region from said plate, whereby the vibration of said region causes a jet-like pulsating air flow out of said orifice with relatively very little lateral air flow between said region and said plate element, and (2) flowing a liquid to be atomized to said orifice whereby said pulsating flow atomizes said liquid.

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