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(12) # EUROPEAN PATENT APPLICATION

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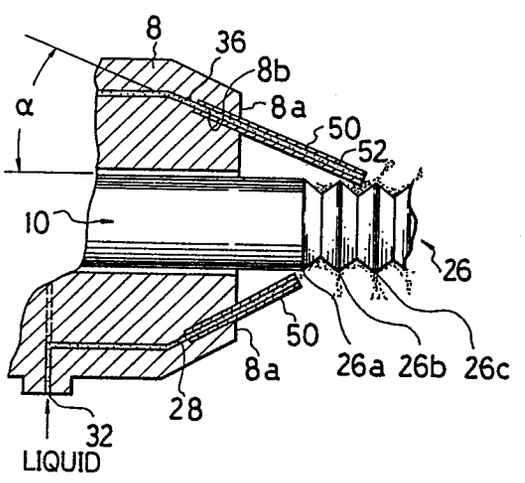
(54) **Ultrasonic atomizing apparatus.**

(57) Liquid fuel is supplied directly to different edged portions (26a) and (26c) of a liquid atomizing section (26) of a vibrating element (10) subject to ultrasonic vibrations by means of guide tubes (50). The fuel may alternatively be jetted onto these edged portions (see Fig. 6). By supplying liquid to separate locations on the vibrating element performance is improved irrespective of the flow rate of the liquid supply.

FIG. 7



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Description

ULTRASONIC ATOMIZING APPARATUS

Background of the Invention

This invention relates generally to an ultrasonic atomizer, and particularly to an ultrasonic atomizing apparatus for atomizing liquid either intermittently or continuously. Such atomizing apparatus may be effectively used as (1) automobile fuel injection means such as electronically controlled gasoline injection valves and electronically controlled diesel injection valves, (2) gas turbine fuel nozzles, (3) burners for use on industrial commercial and domestic boilers, heating furnaces and stoves, (4) industrial liquid atomizers such as drying atomizers for drying liquid materials such as foods, medicines, agricultural chemicals, fertilizers and the like, spray heads for controlling temperature and humidity, atomizers for calcining powders (pelletizing ceramics), spray coaters and reaction promoting devices, and (5) liquid atomizers for uses other than industrial ones, such as spreaders for agricultural chemicals and antiseptic solution.

Pressure atomizing burners or liquid spray heads have been heretofore used to atomize liquid in the various fields of art as mentioned above. The term "liquid" herein used is intended to mean not only liquid but also various liquid materials such as solution, suspension and the like. Conventional atomizers used as spray burners and liquid atomizers are adapted to atomize the liquid by virtue of the shearing action between the liquid discharged through the nozzles and the ambient air (atomospheric air). Accordingly, increased pressure under which the liquid was supplied was required to provide atomization of the liquid, resulting in requiring complicated and large-sized liquid supplying facility such as pumps, piping and the like.

Furthermore, regulation of the flow rate of injection was effected by varying either the pressure under which to deliver supply liquid or the area of the nozzle outlet opening. However, the former method provided poor liquid atomization at a low flow rate (under a low pressure), as a remedy for which air or steam was additionally used on medium or large-sized boilers to aid in atomization of liquid, requiring more and more complicated and enlarged apparatus. On the other hand, the latter method required an extremely intricate construction of nozzle which was troublesome to control and maintain.

In order to overcome the aforesaid drawbacks to such prior art injection nozzles, attempts have been made to apply ultrasonic waves to liquid material as it is injected out through the jet of the atomizer nozzle under pressure.

However, the conventional ultrasonic liquid atomizer had so small capacity for spraying that it was unsuitable for use as such atomizer nozzles as described above which are required to handle a large amount of atomized liquid.

In an attempt to overcome the aforesaid problem with the prior art and accomplish atomization of a large amount of liquid, the present applicant has proposed before an ultrasonic injecting method and injection nozzle (see European Patent Application No. 85 302674.8 and No. 85 308982.9) in which an ultrasonic vibrating element is provided at its end with a multi-stepped edge portion (liquid atomizing section) which is capable of atomizing a large quantity of liquid by delivering liquid along said edged portion in a film form from its base to its forward end.

This invention relates to improvements in the heretofore proposed atomizers as described above.

Thus, it is an object of the present invention to provide an ultrasonic atomizing apparatus which is capable of feeding a multi-stepped edged section generally uniformly with liquid, irrespective of the flow rate of liquid supply and providing effective liquid atomization.

Summary of the Invention

Briefly, the present invention provides an ultra sonic atomizing apparatus including an ultrasonic vibration generating means, an elongated vibrating element connected at one end to said ultrasonic vibration generating means and having a liquid atomizing section having two or more edged portions at the other end, liquid delivery means provided adjacent that other end of the vibrating element having the liquid atomizing section for feeding said edged portions with liquid, characterized by said liquid delivery means being adapted to supply liquid individually to at least two distinct ones of said edged portions.

The liquid delivery means may comprise a plurality of liquid supply passages, at least one of which opens at each of said edged portions. The liquid supply passages may have nozzle orifices for discharging liquid to the respective edged portions at locations close to the edged portions.

Alternatively, the liquid delivery means may comprise at least one nozzle orifice for discharging liquid to said edged portions and a groove radially inwardly extending from said nozzle orifice adjacent the outlet portion of the nozzle orifice, said groove having a predetermined depth and width greater than the diameter of the nozzle orifice.

Some ways of carrying out the present invention will hereinafter be described in detail by way of example with reference to drawings some of which show prior art constructions.

Brief Description of the Drawings

FIG. 1 is a sectional view of a prior art ultrasonic atomizing apparatus;

FIGS. 2 and 3 are enlarged sectional views of the forward portion of an ultrasonic atomizing apparatus outside the scope of the present invention;

FIGS. 4 and 5 are a sectional view and front view, respectively of an embodiment of the ultrasonic atomizing apparatus according to the present invention;

FIGS. 6, 7 and 8 are sectional views of alternate embodiments of the ultrasonic atomizing apparatus according to this invention;

FIG. 9 is a sectional view of the apparatus taken along the line IX-IX in Figure 8;

FIGS. 10 and 11 are side views of different embodiments of the liquid feeding means; and

FIGS. 12 and 13 are a sectional view and front view, respectively of the forward portion of still another embodiment of the ultrasonic atomizing apparatus according to the invention.

With reference now to the drawings, Fig. 1 shows a prior art atomizer in the form of a fuel injection nozzle 1 for a gas turbine. The atomizer comprises a generally cylindrical elongated valve body 4 having a central bore 2 extending therethrough. Connected with or formed integrally with the valve body adjacent one end thereof is a liquid fuel delivery means 8 having a through bore 6 in coaxial alignment with the bore 2 of the valve body.

A vibrating element (vibrator horn) 10 is disposed extending through the central bore 2 of the valve body and through bore 6 of the fuel delivery means 8. The vibrating element 10 comprises a body portion 14, an elongated cylindrical vibrator shank 16 having a diameter smaller than that of the body portion, and a transition portion 18 connecting the body portion and the shank. The body portion 14 has an enlarged diameter flange 20 which is attached to the valve body 4 by a shoulder 22 formed in the other end of the valve body and an annular vibrator retainer 24 which is fastened to the end face of the valve body by bolts (not shown).

The shank portion 16 of the vibrating element 10 extends outwardly beyond the liquid delivery means 8. The forward end of the vibrating element, that is, the forward end of the shank 16 is formed with a liquid atomizing section 26 comprising two or more steps or edged portions, five concentric and equal diameter V-shaped edged portions 26a to 26e in the illustrated example.

The fuel delivery means 8 has one or more supply passages 28 arrayed in a ring for supplying the edged portions 26a to 26e with fuel. The fuel outlets 30 of the supply passages 28 open in the proximity of the edged portion 26a which is the most proximal of the portions 26a to 26e. The inlets 32 of the passages 28 are connected with a source of fuel supply (not shown) to be fed with liquid fuel.

With the construction described above, the vibrating element 10 is continuously vibrated by an ultrasonic generator 100 operatively connected to the body portion 14. Liquid fuel is thus supplied through the passages 28 to the edged portions 26a to 26e where the fuel is atomized and discharged out.

In the atomizing apparatus so constructed, liquid is usually supplied to the liquid atomizing section 26 adjacent its base, that is, the most proximal edged portion 26a in the shown example. The liquid is atomized as it flows down the atomizing section 26 from the proximal edged portion 26a to the distal or forward end of the section, i.e. to the edged portion 26e in the shown example.

However, researches and experiments by the present inventors have revealed that at a given flow rate of liquid supply the atomization takes place on the upstream edged portions such as the edged portions 26a, 26b, 26c alone while the downstream edged portions 26d, 26e are starved of liquid and remain idle, not contributing to atomization. On the other hand, at an increased flow rate of liquid supply the upstream edged portions such as the edged portions 26a, 26b, 26c are excessively loaded with liquid. In other words, liquid is deposited on the upstream edged portions in an excessively thick film, so that spray droplets are increased in their particle size, exhibiting an expanded distribution of particle size. As the flow rate of liquid is further increased, no atomization will ultimately take place on the edged portions, all of which become overloaded with liquid.

Furthermore, in the course of the researches and experiments the present inventors found that with the construction shown in Fig. 2 in which liquid is jetted from the liquid delivery passages 28 formed through the delivery means 8 to the atomizing section 26 to feed the edged portions 26a to 26e, the liquid jets (D) from the passages 28 are adversely affected by air eddies (B) caused by air streams (A) flowing around the atomizer axially thereof, and/or air streams (C) flowing radially along the front end face 8a of the delivery means 8, and are prevented from reaching the appropriate positions on the atomizing section 26, resulting in failure to provide effective liquid atomization. Such adverse effects are noticeable especially at a low flow rate of liquid supply at which the liquid issued from the outlets 30 of the passages 28 is not propelled into and through the air due to the decreased jet velocity but flows down the end face 8a of the delivery means 8 as shown in Fig. 3. Consequently, the liquid falls in drops from the end face without arriving at the atomizing section 26 of the vibrating element. Additionally, liquid particles once atomized can be caused to impinge against and adhere to the end face 8a at the outlets of the delivery passages 28 due to the air swirls (B), causing liquid drops along the end face 8a and/or fouling the end face with deposits (such as coke in the case of liquid fuel).

Turning now to Figs. 4 et. seq. of the drawings, ultrasonic atomizing apparatus according to the present invention will now be described in detail.

While the atomizing apparatus of the present invention may be effectively used for the various applications as mentioned hereinbefore, the embodiment illustrated in Figs. 4 and 5 will be described as being used as a fuel nozzle for a gas turbine as described with reference to Fig. 1. The nozzle 1A in this embodiment is of a construction similar to that of the nozzle 1 shown in Fig. 1, and those parts of this embodiment which have the same functions as the parts of the nozzle 1 are designated by like reference numerals and will not be described in detail.

According to the present invention, the fuel delivery means 8 is provided with second fuel supply passage means 36 in addition to the fuel supply passage means 28. The second supply passage means 36 is arranged to discharge fuel directly to an

edged portion, the edged portion 26c in the illustrated embodiment, other than an edged portion, the portion 26a in the shown embodiment fed by the first supply passage means 28. The first and second supply passage means 28 and 36 are not to be limited to the arrangement shown, but may be arranged to feed any of the different edged portions such as edged portion 26a and 26d, edged portions 26b and 26d and so on, or even three or more different edged portions 26a to 26d. Preferably, each of the passage means 28 and 36 may comprise a plurality of passages, as seen in Fig. 5.

In another arrangement according to the invention shown in Fig. 6, both of the liquid supply passage means 28 and 36 in the delivery means 8 are arranged to jet liquid to their respective edged portions, the edged portions 26a and 26c respectively, in the embodiment shown in Fig. 6. Preferably, the liquid supply passage means 28 and 36 to jet liquid to these edges may be inclined at an angle α in the range of 10° to 60°, for example, the liquid supply passage means 28 and 36 intersecting and opening into the outer end face 8a of the liquid delivery means 8. The injection angles α of the supply passage means 28 and 36 with respect to the selected edged portions 26a to 26d may be selected to be either the same or different from each other.

In a still further arrangement according to the invention shown in Fig. 7, liquid flow guide tubes 50 are disposed in communication with the outlet portions of the supply passages 28, 36 of the delivery means 8. These guide tubes 50 open in the proximity of the atomizing section 26 and have nozzle orifices 52 through which liquid is discharged directly to the corresponding edges. The guide tubes 50 may be affixed to the liquid delivery means 8 in any suitable manner. In the illustrated embodiment, counterbores 8b are formed in the outlet portions of the supply passages 28 and 36 so that the guide tubes 50 may be press fitted into the respective couterbores 8b or alternatively inserted into the counterbores and secured thereto by welding or the like.

As is apparent from the foregoing, since the supply passages 28, 36 do not serve as nozzle orifices to jet liquid to the edged portions 26a to 26e in this embodiment, the passages 28, 36 may have a large bore diameter compared to that of liquid supply passages of the prior art atomizer of Fig. 1. Furthermore, it is to be understood that the passages 28, 36 need not be formed at an inclination angle α of 10° to 60° as in the embodiment shown in Fig. 7.

A plurality of the liquid flow guide tubes 50 are provided, each corresponding to one of the liquid supply passages 28, 36 , and are inclined at an angle of 10° to 60°.

As described above, according to this invention, liquid is supplied to the multi-stepped edged portion or liquid atomizing section 26 at two or more of the edged portions 26a to 26e, so that all of the edged portions are generally evenly fed with liquid, irrespective of the flow rate of liquid supply. Consequently, a substantially uniform thickness of liquid film is maintained over all of the edged portions and provides liquid spray having a small liquid particle size as well as accomplishing liquid atomization with a narrow distribution of particle size.

In addition, owing to the provision of the liquid flow guide tubes 50 the liquid from the liquid delivery means 8 is directed through the supply passages 28, 36 and the nozzle orifices 52 of the guide tubes 50 to be spouted directly onto two or more of the edged portions 26a to 26e, so that the liquid jets (D) from the nozzle orifices 52 will not be adversely affected by any axial air stream (A), air eddies (B) and/or radial air streams (C) flowing around the atomizer as described with reference to Fig. 2. The liquid jets (D) will thus be applied to the edged portions 26a to 26e of the vibrating element at appropriate locations as designed, whereby effective liquid atomization may be consistently achieved. In addition, with the construction according to this invention as described above, particularly with reference to Figs. 7 and 8, spray droplets or liquid particles are prevented from adhering to the end face 8a and thereabouts to cause various troubles such as liquid dropping and fouling the end face with coke.

In the embodiment shown in Fig. 7, the guide tubes 50 may preferably be of stainless steel tube having an outer diameter of 1.2 mm and an inner diameter of 0.85 mm. Preferably, the nozzle orifice 52 of the tube 50 opens loosely adjacent to or at a distance of the order of about 1.0 mm to the corresponding edged portion 26a to 26e, although not in a limiting sense.

While the edged portions 26a to 26e of the vibrating element 10 are shown as concentric V-shaped ridges having the same diameter in the illustrated embodiments so far described, they may be in the form of two or more annular steps having progressively decreasing or increasing diameters, or progressively decreasing and then progressively increasing diameters. What is important is that liquid be applied separately at two or more different edged portions (including the vicinity of the edges of the edged portions), regardless of what configuration of edged portion of vibrating element may be employed.

Figs. 8 and 9 illustrate a further embodiment of the invention in which the atomizing section 26 of the vibrating element 10 is provided with one or more axially extending channels 54. Liquid guide tubes 50 are arranged to feed the respective channels 54 which in turn distribute the liquid to all of the edged portions.

Figs. 10 and 11 illustrate still other embodiments of the liquid delivery means 8 adapted to feed two or more different edged portions of the atomizing section 26 with liquid independently.

In Fig. 10, the liquid delivery means 8 comprises a plurality of ring nozzles 8a, 8b axially spaced apart from each other, said ring nozzles surrounding the multi-stepped edged portion 26 to feed different edges of the edged portion 26 generally evenly with liquid. Each of the nozzles 8a, 8b is provided with a plurality of small orifices circumferentially generally equally spaced apart to jet the liquid onto its selected edge.

In the embodiment of Fig. 11, the vibrating

element 10 is formed in its forward end with a recess 10a having a multi-stepped edged portion 26 in its peripheral wall. Mounted in facing relation with the edged portion 26 is a semi-spherical nozzle 8 having a plurality of equally spaced small apertures formed through its semi-spherical wall to jet the liquid onto two or more of the steps of the edged portion.

In the various embodiments of the invention described, the flow rates of supply liquid passing through the liquid supply passages 28 and 36 may be equal to or different from one another. Further, simultaneous application of liquid to the respective edged portions may be effected by making the timings of supplying liquid to the supply passages 28, 36 individually adjustable, as desired. Alternatively, supply of liquid to any of the supply passages may be selectively terminated so that liquid may be applied only to a desired edged portion or portions.

Figs. 12 and 13 illustrate a still further embodiment of the invention which is designed to avoid causing liquid drops along the end face at the outlet of the liquid supply passages as well as fouling the end face with coke particularly at a low flow rate of supply liquid.

According to this embodiment, the end face 8a of the liquid delivery means 8 which is intersected by the outlets 40 of the supply passages 36 is formed with a groove 42 extending from each of the outlets 40 for jetting liquid onto one of the edged portions, radially inwardly toward the central vibrating element 10, said groove having a predetermined depth (h) and width (w) greater than the diameter (d) of the supply passages or nozzle orifices 36. The depth (h) and width (w) of the grooves 42 may vary depending upon the viscosity and surface tension of the supply liquid and the material of which the supply passages are made, but may generally be one and half times to three times the diameter (d) of the nozzle orifice. When the supply liquid is kerosene and the diameter (d) of the nozzle bore is 0.3 mm, the width (w) and depth (h) of the groove 42 may be 0.5 mm and 0.6 mm, respectively, and the clearance (G) between the inner diameter of the delivery means 8 and the outer diameter of the vibrating element 10 may be 0.5 mm.

The end face or wall 8a of the delivery means 8 is usually inclined at a predetermined angle Θ ($10° \leqq \Theta \leqq 60°$) (although it may be perpendicular to the axis of the vibrating element as shown in Fig. 6), and the grooves 42 are formed in parallelism to the plane of the end face 8a. Preferably, the angle Θ of inclination is 35°, and the angle α of the nozzle bore 36 with respect to the axis of the vibrating element may be in the range of 10° to 60°.

Whatever may be the geometry of the grooves 42, it is preferable that the length of the grooves be minimized. When the feed liquid is kerosene, the length of the grooves is preferably 5 mm or less.

When the flow rate of supply liquid is decreased, the liquid from the nozzle bore 36 flows along the grooves 42 and is delivered toward the edged portion 26 due to the surface tension, but does not drip off the end face 8a as is the case with a conventional atomizer.

With the constructions according to this invention as herein described, an atomizing apparatus is capable of supplying liquid to the vibrating element at its predetermined locations in a uniform and stable manner even at a low flow rate of liquid supply, not to mention a high flow rate, irrespective of the properties of the liquid and accomplishing effective liquid atomization with a small liquid particle size and narrow distribution of particle size, hence providing a very wide range of turn-down ratio.

Thus, ultrasonic atomizing apparatus is provided which is capable of accomplishing consistent liquid atomization in that there is no substantial change in the conditions of atomization (flow rate and particle size) depending upon the properties, particularly the viscosity of the supply liquid.

Further, according to this invention, where liquid flow guide tubes such as 50 are employed, these may be in the form of a syringe needle having a predetermined constant inner diameter and may be connected with the liquid supply passage means to discharge liquid through the tube, whereby the liquid supply passage means may have any relatively large bore or may be in the form of an annular groove. This greatly facilitates the manufacture of the liquid delivery means and hence eliminates the disadvantage that the liquid jet is disturbed by rough wall surfaces of the supply passage means or burrs formed on the inner wall due to difficulty in the manufacture, as is the case with a conventional atomizer.

In addition, according to the present invention, it is possible to prevent the liquid from dropping from the end wall of the liquid delivery means at the outlet end of the supply passage means and from fouling the end wall with coke.

Claims

1. An ultrasonic atomizing apparatus including an ultrasonic vibration generating means, an elongated vibrating element connected at one end to said ultrasonic vibration generating means and having a liquid atomizing section having two or more edged portions at the other end, liquid delivery means provided adjacent that other end of the vibrating element having the liquid atomizing section for feeding said edged portions with liquid, characterized by said liquid delivery means being adapted to supply liquid separately to at least two of said two or more different edged portions.

2. An ultrasonic atomizing apparatus according to claim 1, wherein said liquid delivery means is adapted to supply liquid concurrently to two or more of said different edged portions.

3. An ultrasonic atomizing apparatus according to claim 1, wherein said liquid delivery means is adjustable with respect to the timings at which liquid is supplied individually to two or more of said different edged portions.

4. An ultrasonic atomizing apparatus according to claim 1, wherein said liquid delivery means is provided with a plurality of liquid supply passages to which liquid flow guide

tubes are conencted, each of said liquid flow guide tubes having a nozzle orifice which opens at said liquid atomizing section and discharges liquid to one of the edged portions at a location close to the edged portion.

5. An ultrasonic atomizing apparatus according to claim 4, wherein said liquid flow guide tubes are disposed at an inclination angle of 10° to 60° with respect to the axis of said vibrating element.

6. An ultrasonic atomizing apparatus according to claim 1, wherein said liquid delivery means is provided with at least one nozzle orifice in an end face thereof for jetting liquid onto at least one of said edged portions, said liquid delivery means having a groove in said end face radially inwardly extending from said nozzle orifice adjacent the outlet portion of the nozzle orifice, said groove having a predetermined depth and width greater than the diameter of the nozzle orifice.

7. An ultrasonic atomizing apparatus according to claim 6, wherein the depth and width of said groove is one and half to three times the diameter of said nozzle orifice.

8. An ultrasonic atomizing apparatus according to claim 6 or 7, wherein the outlet portion of the nozzle orifice extends at an angle α of inclination with respect to the axis of said vibrating element and said groove extends at the same angle as the inclination angle Θ of the end face of the liquid delivery means.

9. An ultrasonic atomizing apparatus according to claim 6, wherein said inclination angle Θ is in the range of 10° to 60°.

10. An ultrasonic atomizing apparatus according to claim 1, wherein said liquid delivery means comprises a plurality of axially spaced ring nozzles surrounding said liquid atomizing section.

11. An ultrasonic atomizing apparatus according to claim 10, wherein each of said ring nozzles has a plurality of equally spaced small apertures.

12. An ultrasonic atomizing apparatus according to claim 1, wherein said edged portions are formed in a recess provided in said vibrating element adjacent the other end thereof, and said liquid delivery means comprises a semi-spherical nozzle disposed in facing relation to said recess.

13. An ultrasonic atomizing apparatus according to claim 12, wherein the semi-spherical nozzle has a plurality of generally equally spaced small apertures formed through its semi-spherical portion.

FIG. 1

PRIOR ART

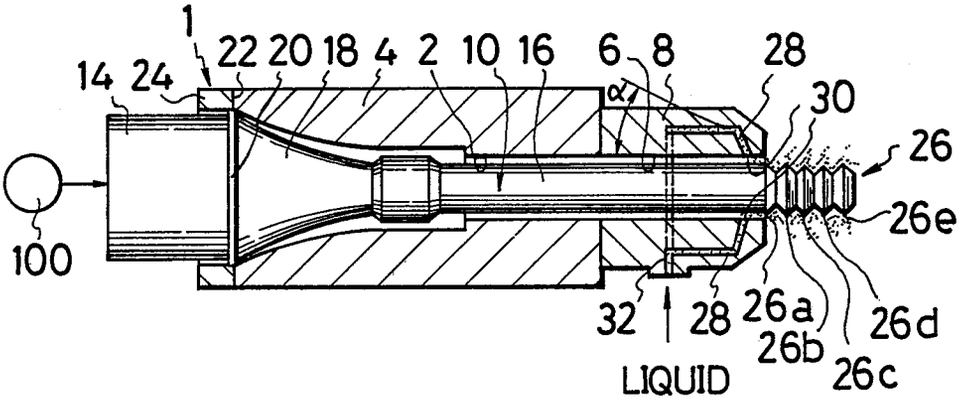

FIG. 2

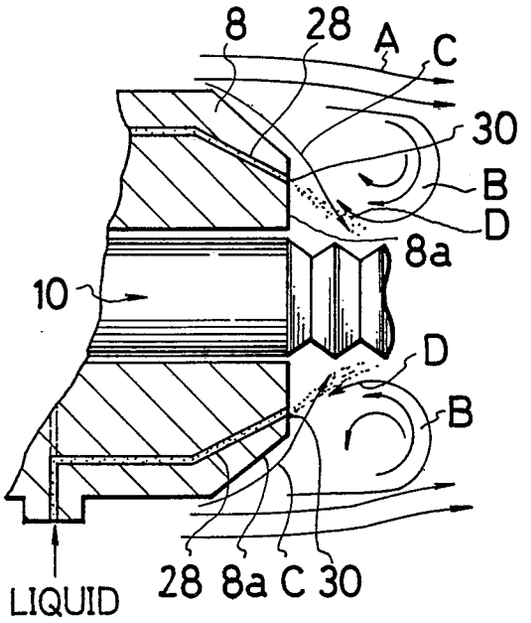

FIG. 3

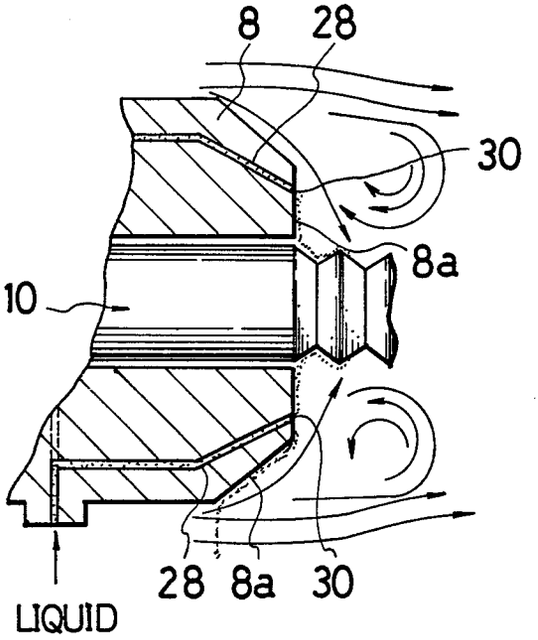
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FIG. 4

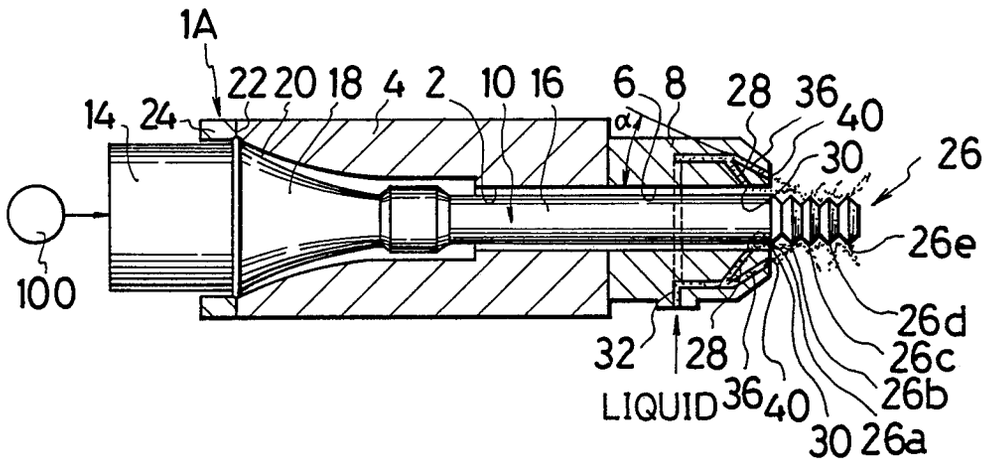
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FIG. 5

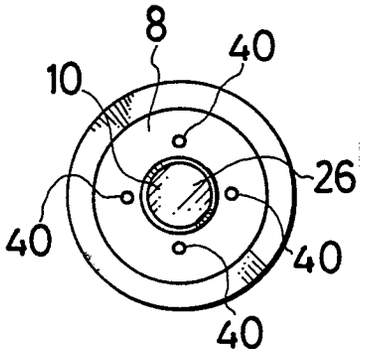

FIG. 6

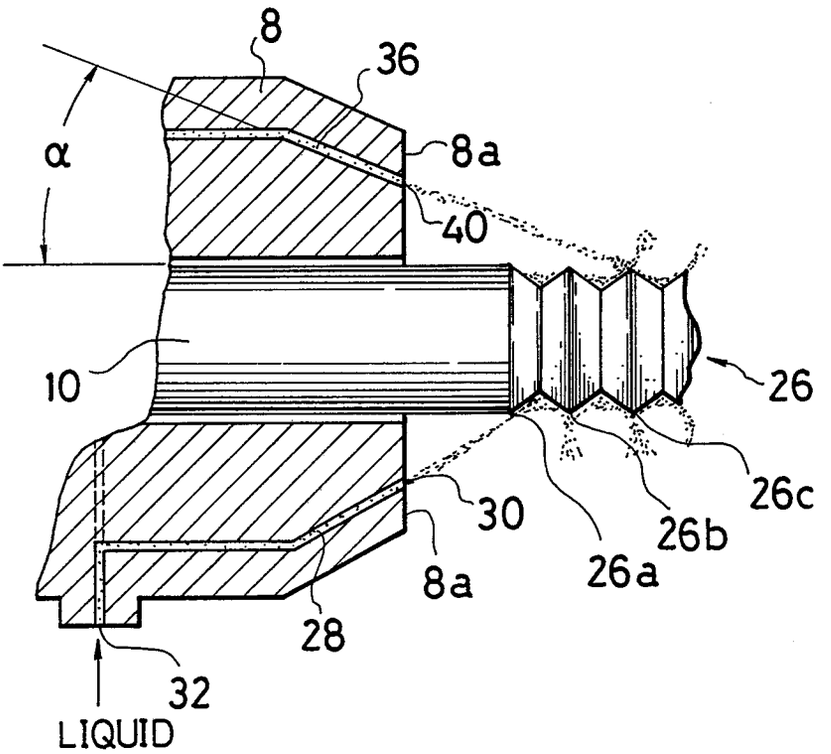

FIG. 7

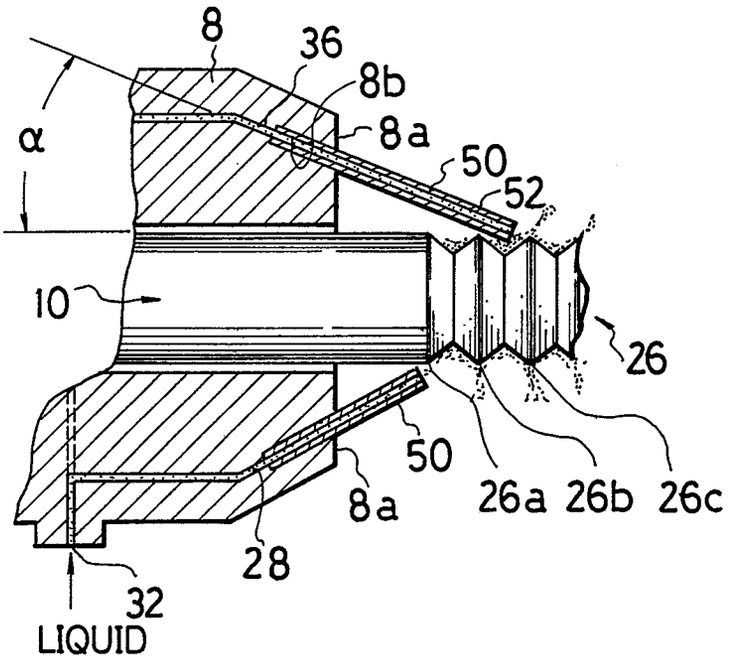
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FIG. 8

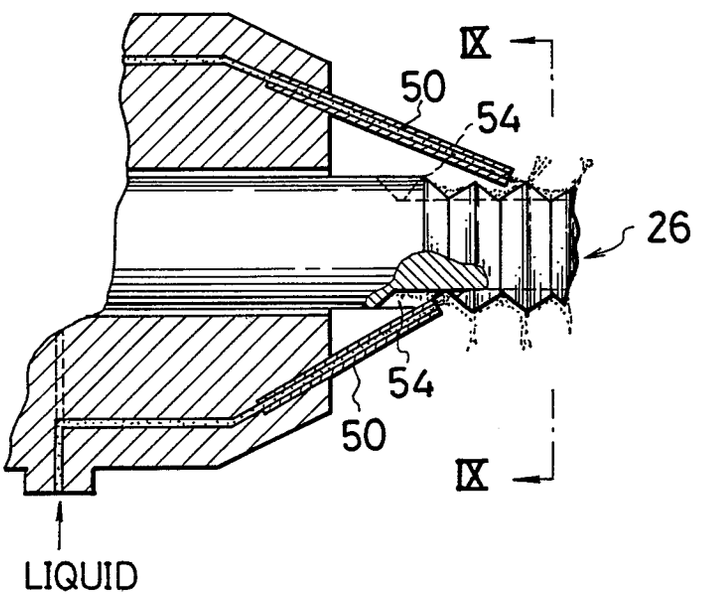
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FIG. 9

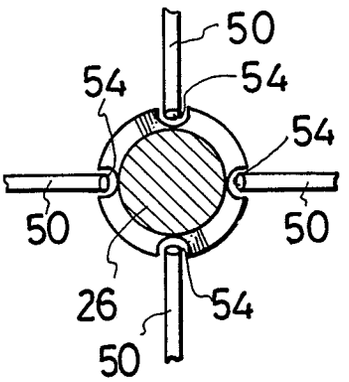

FIG. 10

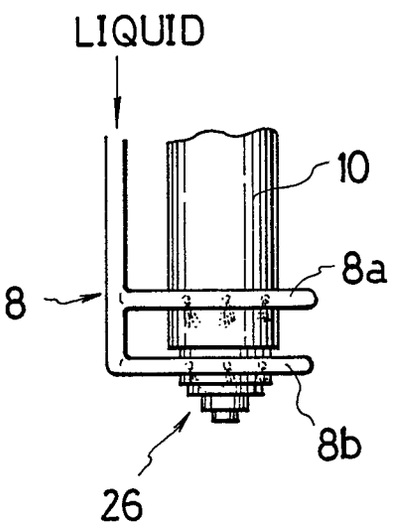

FIG. 11

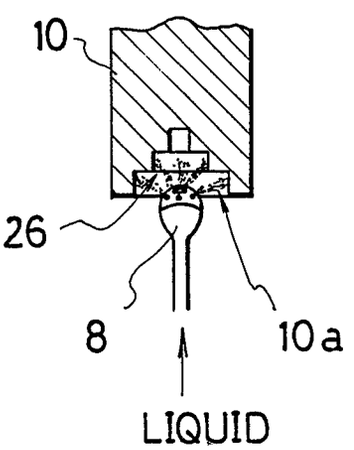

FIG. 12

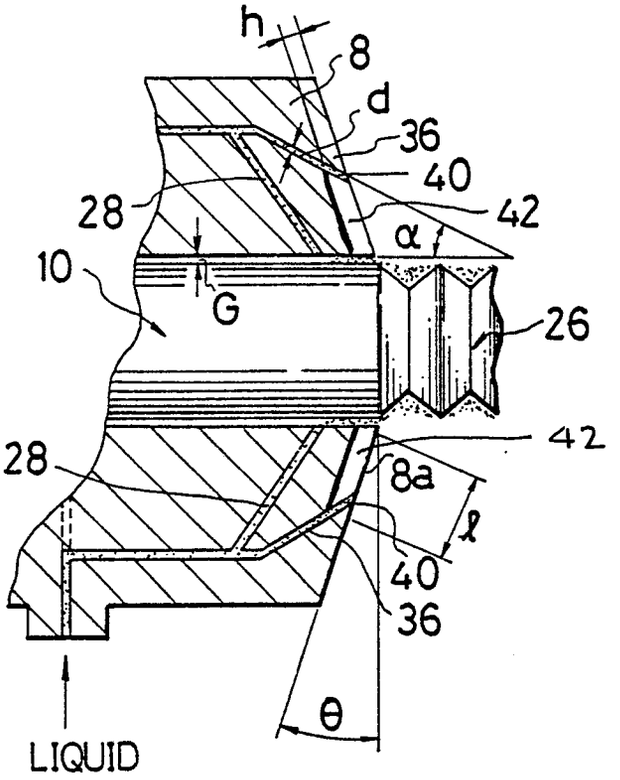
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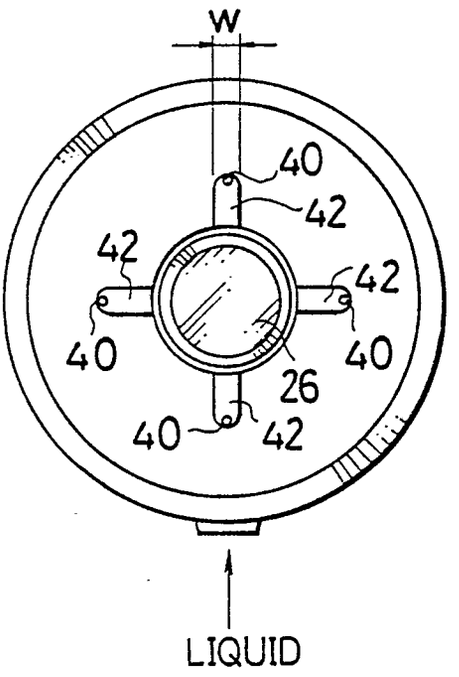
FIG. 13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