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(54) **FOAMING SOAP DISPENSERS AND METHODS**

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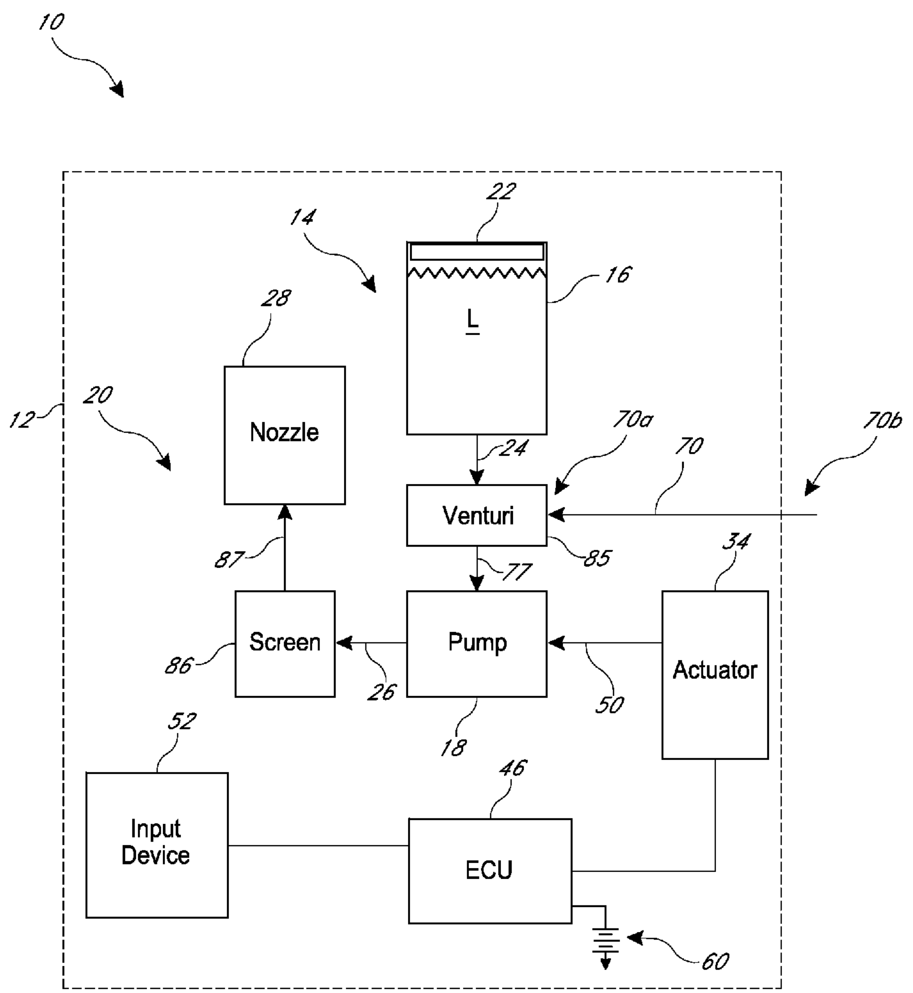
(57) **ABSTRACT**

A soap dispenser can be configured to dispense an amount of foam soap. In some embodiments, the dispenser can include a venturi device with an air inlet and a soap inlet. In certain implementations, the dispenser can include a flexible impeller pump. In some such embodiments, the pump can be configured to draw liquid soap through the soap inlet of the venturi device and air through the air inlet of the venturi device. The soap and air can mix to form foam, which can be drawn into the pump and dispensed via a nozzle in communication with the pump. In some embodiments, the dispenser includes a screen, which can modify the texture of the foam.



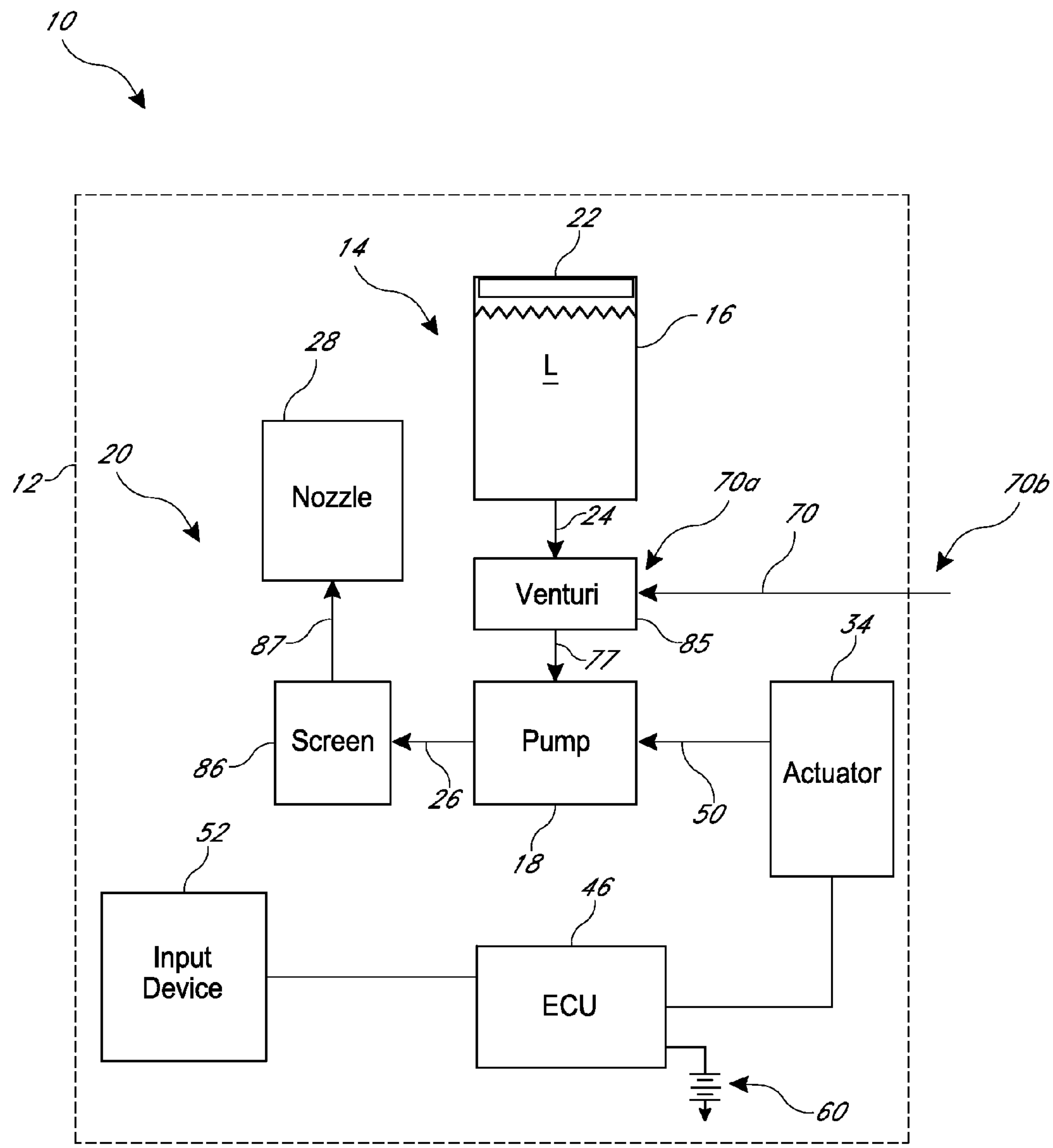

10
14
22
16
L
28
Nozzle
20
12
70a
70
70b
24
Venturi
85
77
87
34
Screen
Pump
Actuator
86
26
50
18
52
46
Input
Device
ECU
60

FIG. 1

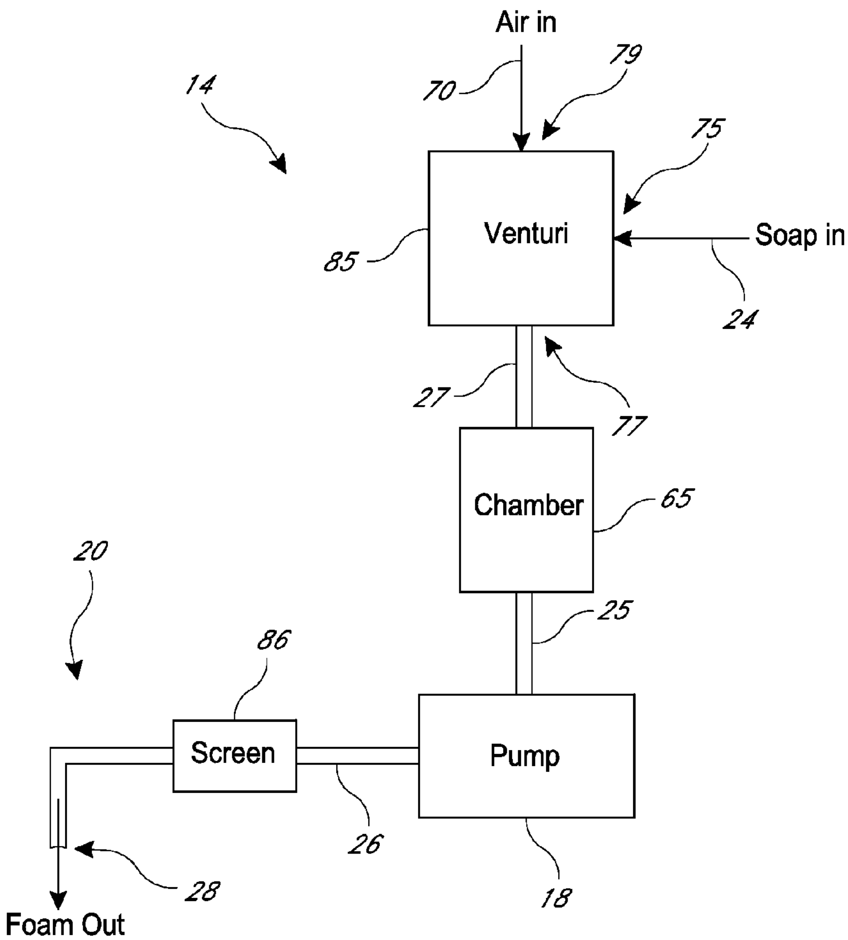

Air in
70
79
14
75
Venturi
85
Soap in
24
27
77
Chamber
65
20
25
86
Screen
Pump
26
28
18
Foam Out

FIG. 2A

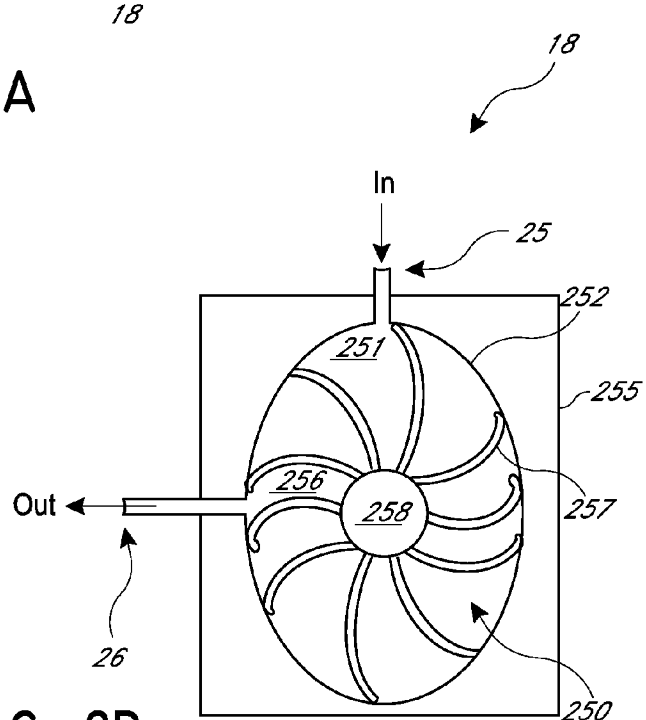

18
In
25
252
251
255
256
257
Out
258
26
250

FIG. 2B

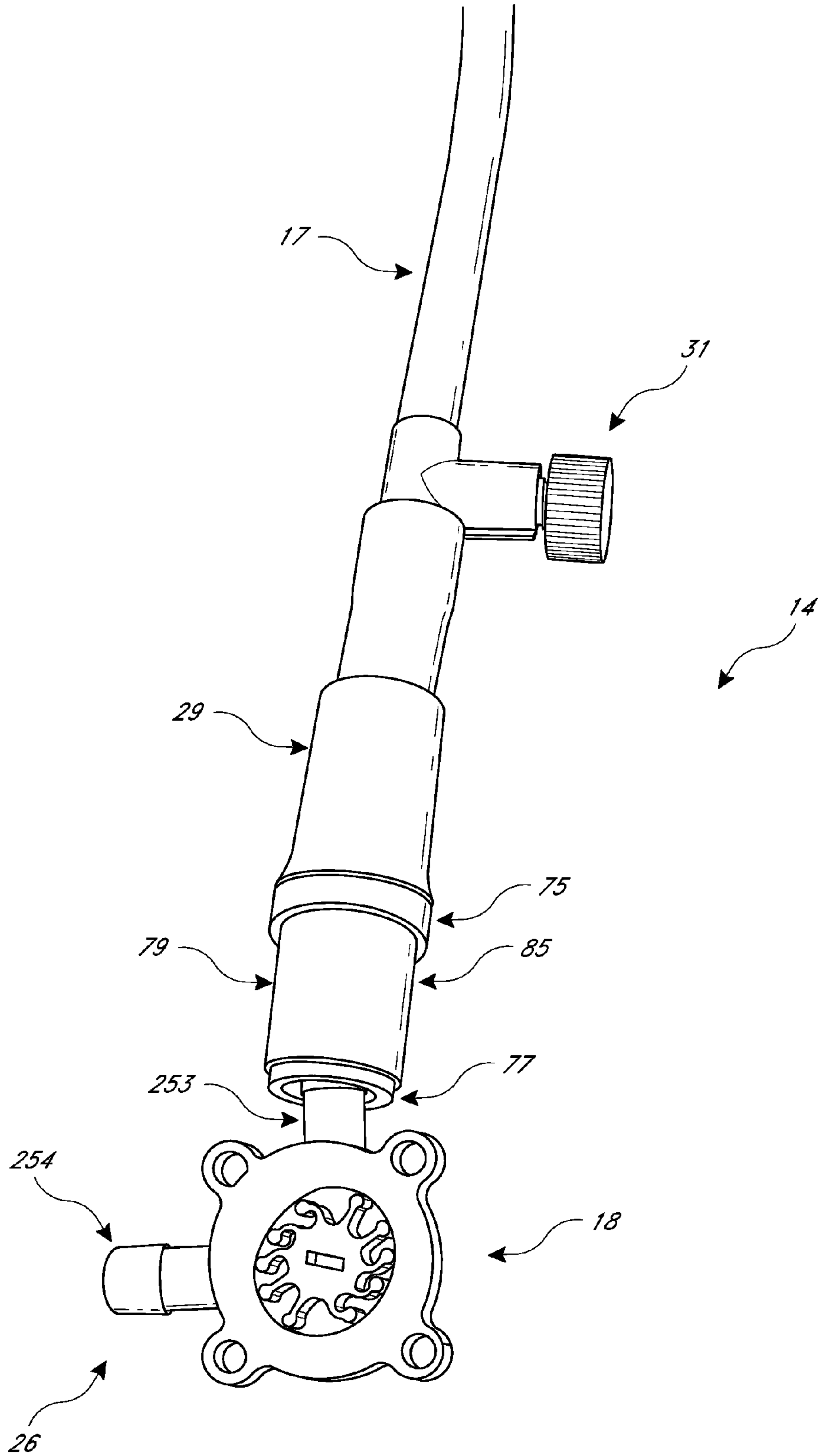


FIG.3

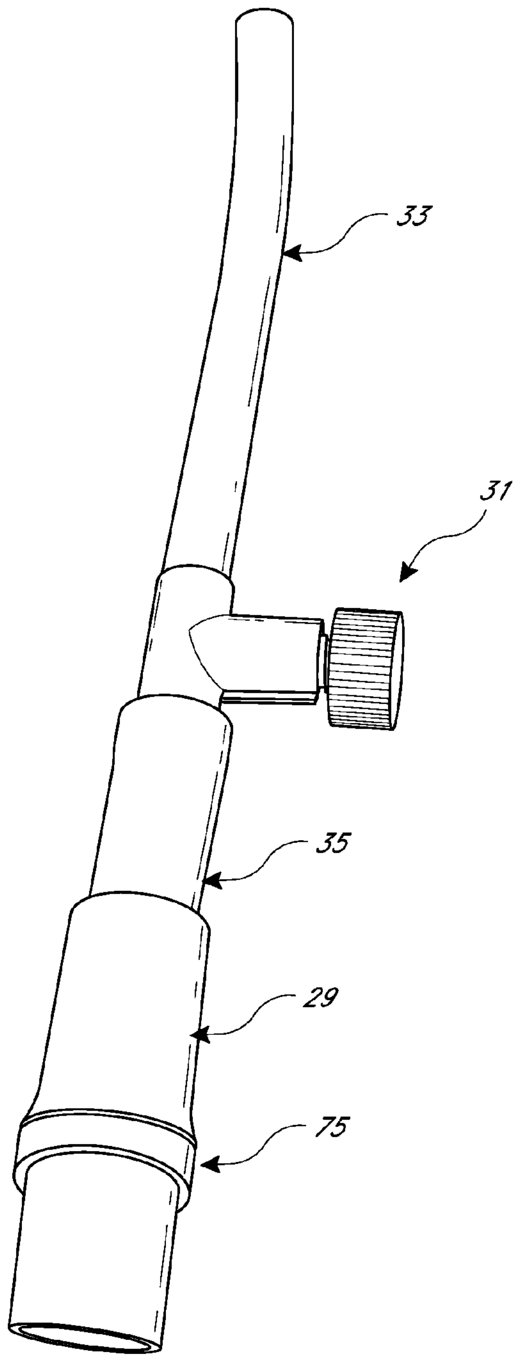


FIG.4

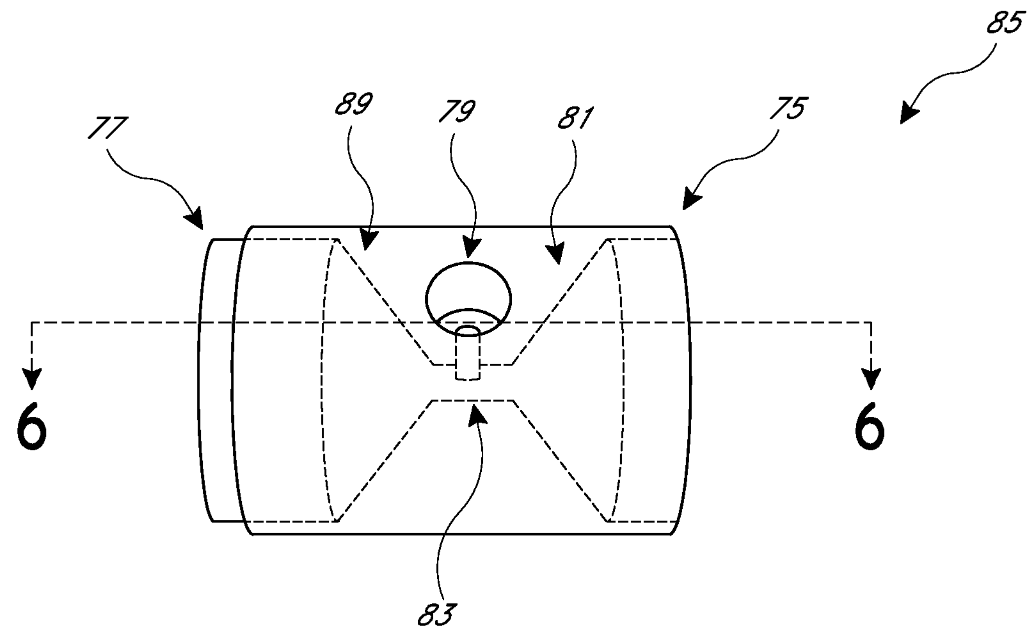


FIG. 5

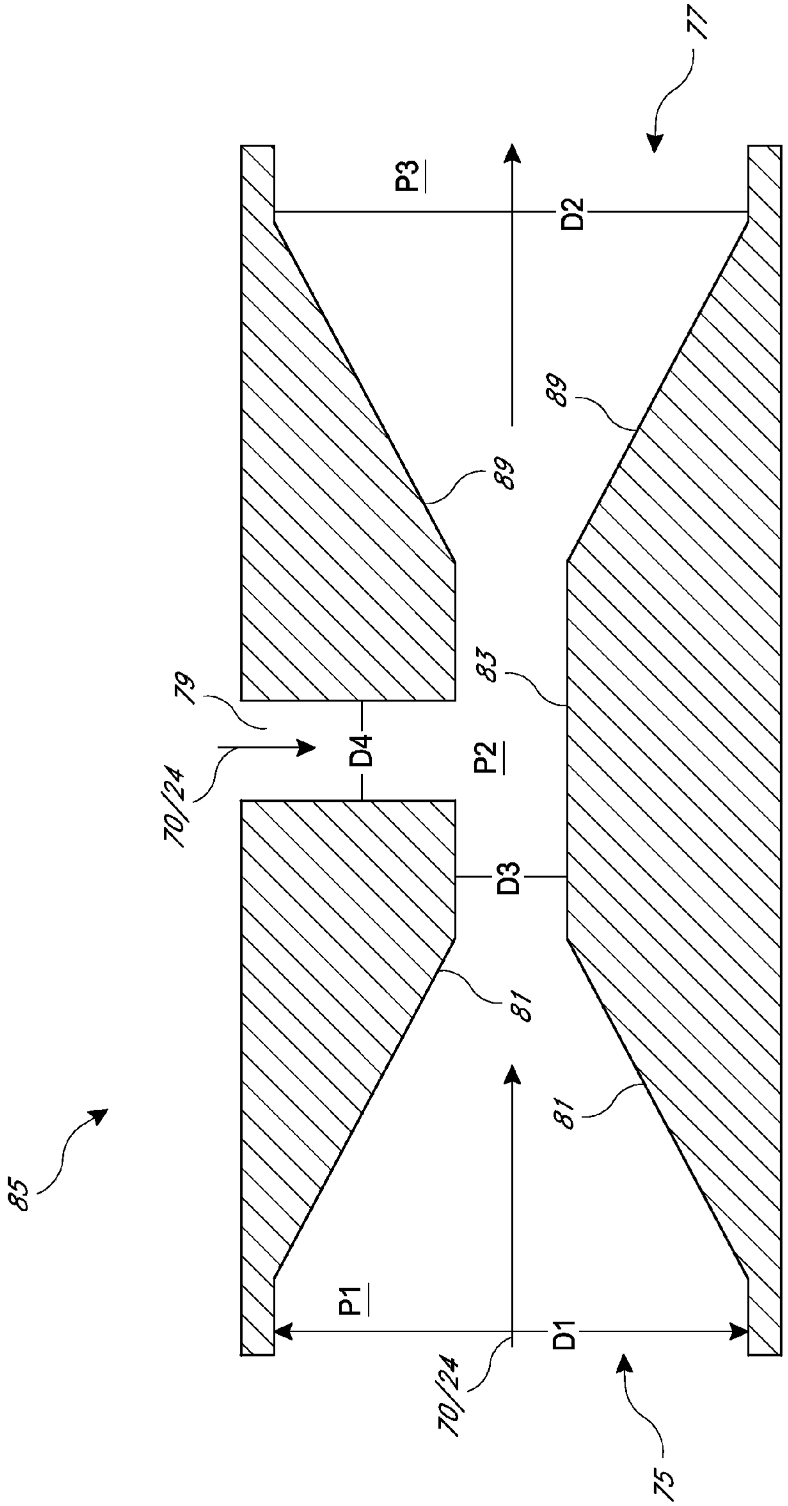


FIG. 6

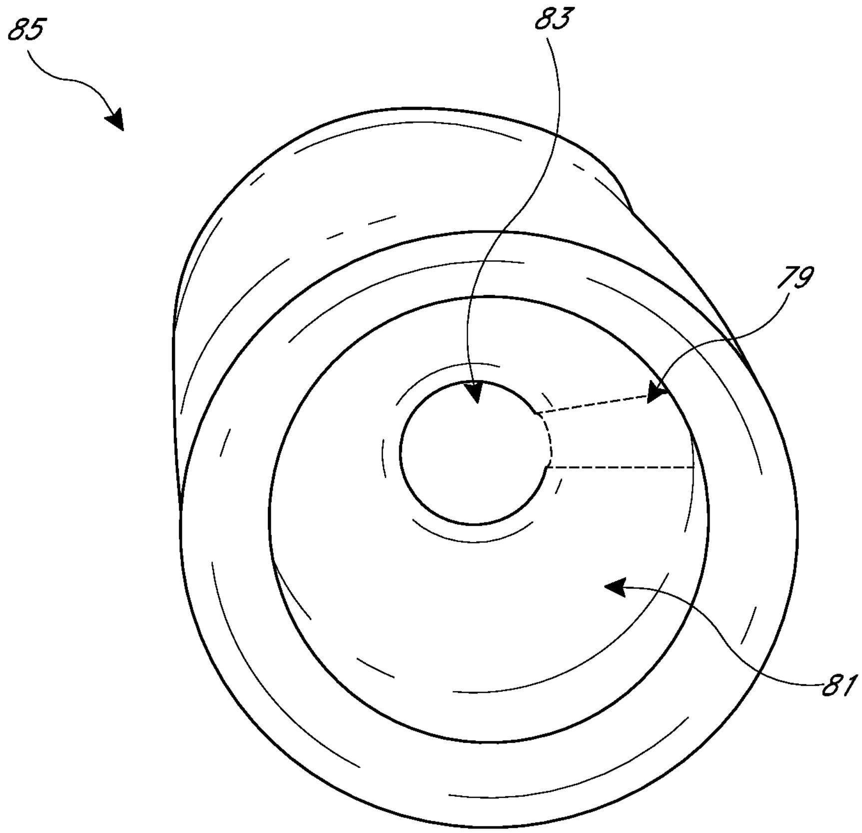


FIG. 7

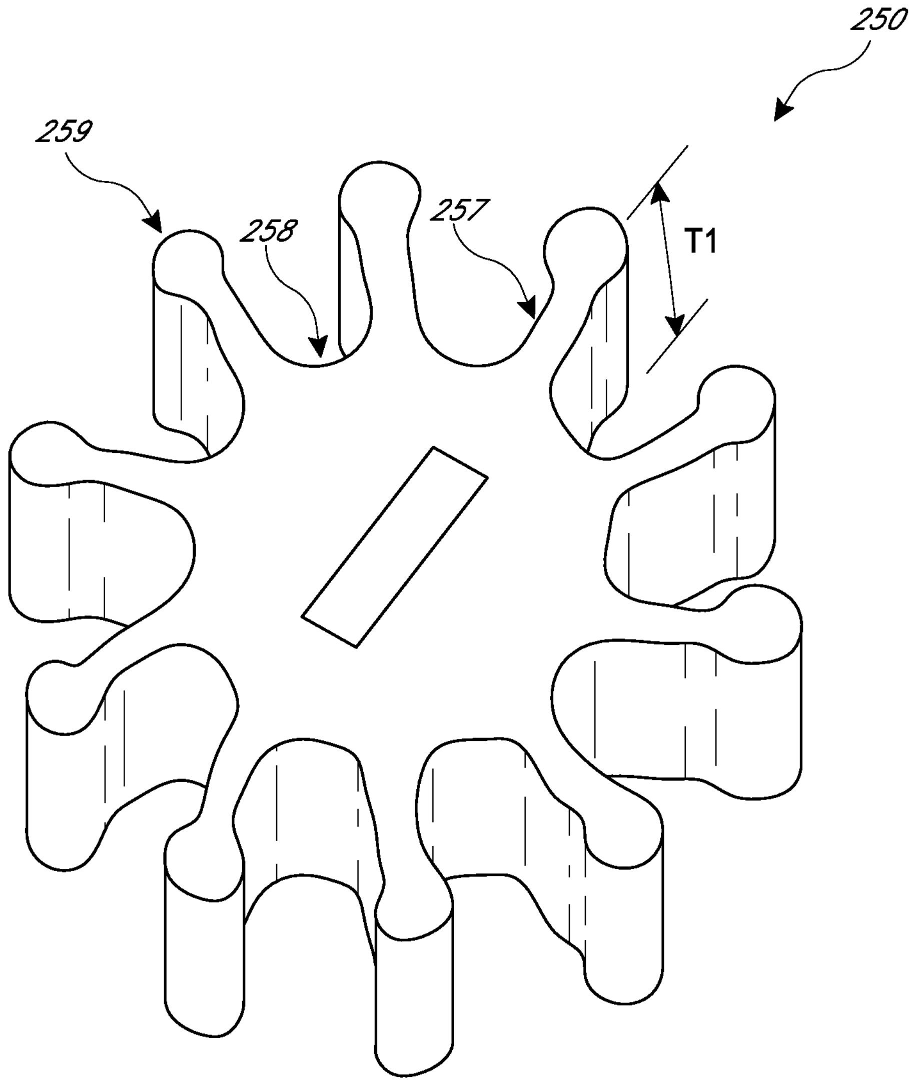


FIG. 8

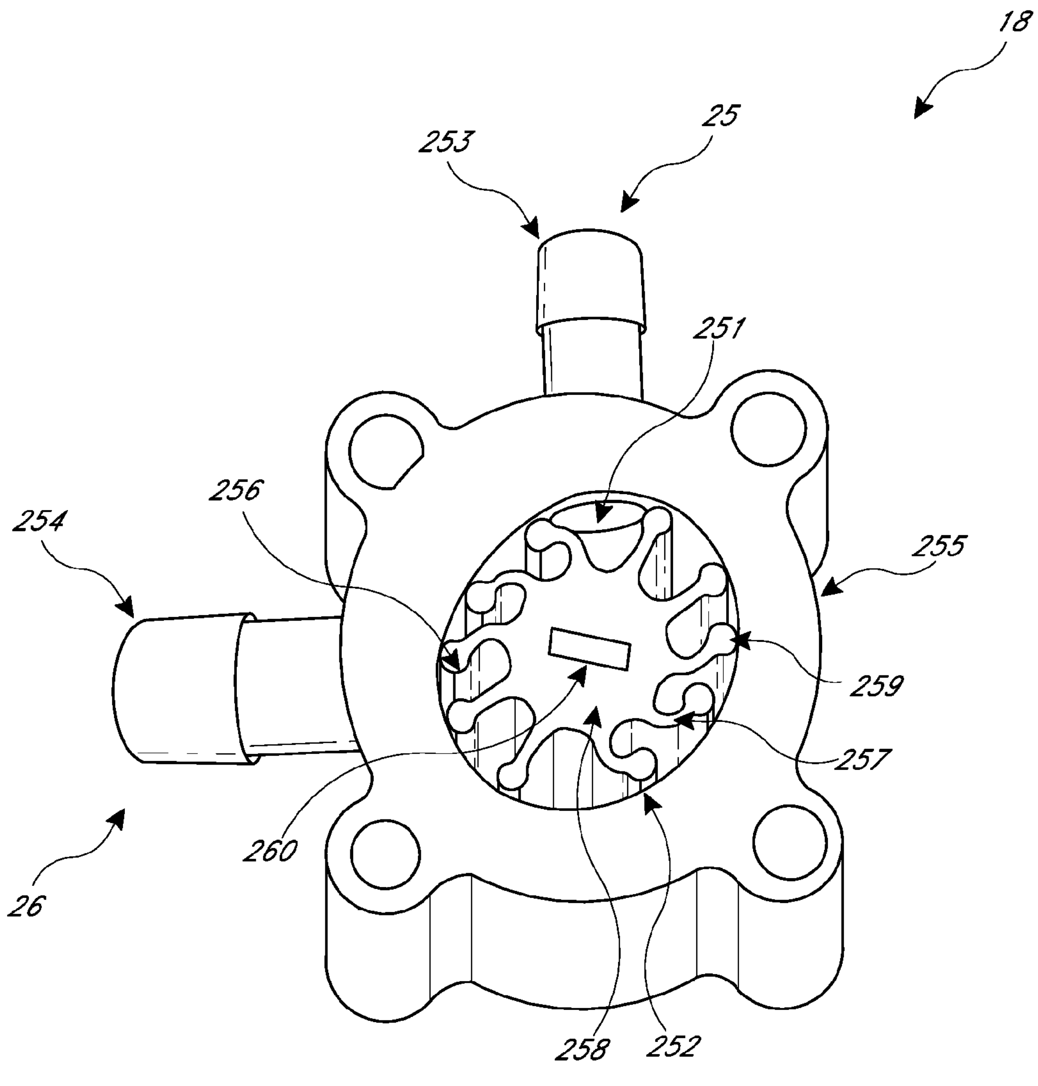


FIG. 9

FOAMING SOAP DISPENSERS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This present application claims priority benefit under 35 U.S.C. §119(e) to U.S. Provisional Application No. 61/595,629, filed Feb. 6, 2012, entitled "FOAMING SOAP DISPENSERS AND METHODS," which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Field

[0003] The present disclosure relates to dispensing devices, and some embodiments are particularly related to dispensers configured to dispense foam soap.

[0004] 2. Description of the Related Art

[0005] Users of modern public washroom facilities increasingly desire that each of the fixtures in the washroom operate automatically without being touched by the user's hand. This is important in view of increased user awareness of the degree to which germs and bacteria may be transmitted from one person to another in a public washroom environment. Today, it is not uncommon to find public washrooms with automatic, hands-free operated toilet and urinal units, hand washing faucets, soap dispensers, hand dryers, and door opening mechanisms. This automation allows the user to avoid touching any of the fixtures in the facility, and therefore lessens the opportunity for the transmission of disease-carrying germs or bacteria resulting from manual contact with the fixtures in the washroom.

SUMMARY

[0006] Certain aspects of this disclosure are directed toward a soap dispenser including a housing, a reservoir, an aspirator, a pump, and a discharge nozzle. The reservoir can be at least partly contained in the housing and configured to store liquid soap. The aspirator can include a first inlet, a second inlet, and an outlet. The first inlet can be in fluid communication with the reservoir, and the second inlet can be in fluid communication with the ambient environment. The outlet can be in fluid communication with the first and second inlets via a channel. The pump can be disposed in the housing and can include a body and an impeller. The impeller can be disposed in an inner cavity of the body, and the inner cavity can be in fluid communication with the aspirator outlet. The pump can be configured to encourage a flow of liquid soap from the reservoir through the first inlet and to encourage a flow of air from the ambient environment through the second inlet. The channel of the aspirator can be configured to encourage mixing of the flows of liquid soap and air to generate soap foam. The discharge nozzle can be configured to discharge a portion of the soap foam. The discharge nozzle can be in fluid communication with the inner cavity of the pump body.

[0007] The features disclosed in this specification can be included in any embodiments. The soap dispenser can include a valve disposed along a flow path between the reservoir and the aspirator. The aspirator can include a first tapered portion in fluid communication with the channel and a second tapered portion in fluid communication with the channel. The first inlet and the outlet can be generally axially aligned. A first inlet diameter can be larger than a second inlet diameter. A first inlet diameter can be larger than a channel diameter. The second inlet can be generally centered on an axis that is substantially perpendicular to the longitudinal axis of the channel. The impeller can include a central body portion and a plurality of flexible arms. The impeller can include a bore. In certain aspects, the soap dispenser can include an actuation mechanism connected to the impeller bore. The impeller can include a central body portion and a plurality of flexible arms. In certain aspects, each of the flexible arms can include a rounded protrusion. The impeller can include a central body portion and a plurality of flexible arms. The inner cavity can be configured to bend at least one of the flexible arms more than another one of the flexible arms. The inner cavity can have a generally eccentric-circular shape. The pump can be configured to generate a negative pressure that is less than a pressure at the aspirator outlet. The pump can include an inlet pocket near a pump inlet and an outlet pocket near a pump outlet. The inlet pocket can be larger than the outlet pocket. The pump can include a pocket configured to transition between a first configuration and a second configuration. The pocket can be larger in the first configuration than in the second configuration. The soap dispenser can include a flow-enhancing member in fluid communication with the inner cavity of the pump body and disposed downstream from the pump. The flow-enhancing member can be a screen. The flow-enhancing member can be configured to provide a back pressure. The discharge nozzle can be a duckbill valve. The soap dispenser can include a holding chamber disposed downstream of the aspirator. The holding chamber can be configured to store the soap foam for a period of time.

[0008] Certain aspects of this disclosure are directed toward methods of dispensing foaming liquid soap from a soap dispenser. Some embodiments of the methods can include drawing a flow of liquid soap from a reservoir and through a first inlet of an aspirator. Certain embodiments include drawing a flow of ambient air through a second inlet of the aspirator. Some variants of the methods can include generating soap foam in a channel of the aspirator. According to some variants, the methods can include drawing the soap foam from an aspirator outlet and through an inlet of a pump. The pump can include a body and an impeller, and the impeller can be disposed in an inner cavity of the body. In some embodiments, the methods can include discharging a portion of the soap foam from a nozzle.

[0009] The method steps disclosed in this specification can be used in any embodiments of the methods. The methods can include drawing the soap foam through an outlet of the aspirator and into a holding chamber. Some embodiments of the methods can include storing the soap foam in the holding chamber for a period of time. Drawing the flow of liquid soap from the reservoir and through the first inlet can include drawing the flow of liquid soap through a valve. The methods can also include driving the impeller. In certain aspects, driving the impeller can include moving a pocket between a first configuration and a second configuration. The pocket can be larger in the first configuration than in the second configuration. In certain aspects, driving the impeller can include moving each of the flexible arms between a first configuration and a second configuration. Each of the flexible arms can be more bent in the first configuration than in the second configuration. The methods can include generating a negative pressure within the aspirator channel relative to ambient. The methods can include generating a region of pressure near the second inlet that is less than a region of pressure near the first inlet.

The methods can also include generating a negative pressure within the inner cavity relative to ambient. The methods can include generating a pressure within the inner cavity that is less than the pressure at the aspirator outlet. The methods can include discharging the soap foam from an outlet of the pump and through a flow-enhancing member. Discharging the soap foam through the flow-enhancing member can include generating a back pressure.

[0010] For purposes of summarizing the disclosure, certain aspects, advantages and features of the inventions have been described herein. It is to be understood that not necessarily any or all such advantages can be achieved in accordance with any particular embodiment of the inventions disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Certain features, aspects, and advantages of the subject matter disclosed herein are described below with reference to the drawings, which are intended to illustrate and not to limit the scope of the disclosure. Various features of different disclosed embodiments can be combined to form additional embodiments, which are part of this disclosure. No structures, features, steps, or processes are essential or critical; any can be omitted in certain embodiments. The drawings comprise the following figures:

[0012] FIG. **1** is a schematic diagram illustrating an embodiment of a foam soap dispenser;

[0013] FIG. **2**A is a schematic diagram illustrating another embodiment of a foam soap dispenser including a venturi device, pump, mesh, and dispensing assemblies;

[0014] FIG. **2**B is a cut-away top view of an embodiment of the pump of FIG. **2**A;

[0015] FIG. **3** is a perspective view of a venturi device and an impeller pump;

[0016] FIG. **4** is a perspective view of the venturi device of FIG. **3**;

[0017] FIG. **5** is a perspective view of the venturi device of FIGS. **3** and **4**;

[0018] FIG. **6** is a cross-sectional view of the venturi device of FIG. **5** taken along line **6-6**;

[0019] FIG. **7** is an end view of the venturi device of FIGS. **3** and **4**;

[0020] FIG. **8** is a perspective view of a flexible impeller mechanism; and

[0021] FIG. **9** is a perspective view of a flexible impeller pump.

DETAILED DESCRIPTION

[0022] FIG. **1** schematically illustrates an embodiment of a foaming soap dispenser **10** that can include various features and embodiments of the subject matter disclosed herein. Certain features and embodiments of the subject matter are disclosed in the context of a foam soap dispenser **10** because they have particular utility in this context. However, the subject matter disclosed herein can be used in many other diverse contexts and environments of use. For example, some or all of the subject matter disclosed herein can be used in other types of pumps, dispensers, battery-powered devices, or even any other electric devices. Those of ordinary skill in the art will recognize, from the description set forth below, many of the other environments of use in which the subject matter can be used, although all of those environments are not described herein.

[0023] The soap dispenser **10** includes a housing **12**. The housing **12** can be configured to support a liquid handling system **14**. The liquid handling system **14** can include a reservoir **16**, a pump **18**, and a discharge assembly **20**. Some embodiments of the liquid handling system **14** include an air inlet conduit **70** and an aspirator, such as a venturi device **85**. In some embodiments, the inlet conduit **70** is configured to intake air directly from the ambient environment. In some embodiments, the inlet conduit **70** is configured to intake air indirectly from the ambient environment, such as by intaking air within the housing **12**.

[0024] The reservoir **16** can be any type of container, such as a vessel, bag, balloon, or otherwise. In the illustrated embodiment, the reservoir **16** is configured to contain a volume of liquid soap, such as liquid soap for hand washing. In some embodiments, the reservoir **16** can include a lid **22** configured to form a seal at the top of the reservoir **16** for maintaining the liquid soap L within the reservoir **16**. In some embodiments, the lid **22** can include an air vent (not shown), so as to allow air to enter the reservoir **16** as the level of liquid soap L falls within the reservoir **16**.

[0025] The reservoir **16** can include an outlet **24**. In certain embodiments, the outlet **24** can comprise a conduit extending from the reservoir **16**. In some embodiments, the outlet **24** can comprise an opening in the lower portion of the reservoir **16**. In certain implementations, the outlet **24** can place the reservoir **16** in fluid communication with an aspirator.

[0026] In some embodiments, the aspirator can be an eductor-jet pump or a filter pump, or a venturi device **85** as illustrated, which can include an air inlet conduit **70** and an outlet **77**. The air inlet conduit **70** can be any type or diameter of conduit, so as to allow air to enter the venturi device **85**. The air inlet conduit **70** can include a first end **70***a* and a second end **70***b*. The first end **70***a* can be connected with the venturi device **85**. In some embodiments, the second end **70***b* of the air inlet conduit **70** is disposed outside the reservoir **16** (e.g., in communication with the ambient environment). In some embodiments, the second end **70***b* of the air inlet conduit **70** is positioned in the reservoir **16** (e.g., above the fill level of liquid soap). In some variants, the air inlet conduit **70** includes a one-way valve (e.g., a flapper valve, duckbill valve, or otherwise) that is configured to inhibit air and/or soap from exiting the venturi device **75** via the air inlet conduit **70**. As shown, the venturi device **85** can be connected to the pump **18** via the outlet **77**.

[0027] The pump **18** can be configured to draw a flow of soap from the outlet **77** and encourage the soap to flow through the conduit **26**. In some embodiments, the pump **18** can be disposed in the reservoir **16**. In certain such embodiments, the pump **18** can be automatically primed due to the force of gravity drawing soap into the pump **18**. In some implementations, the pump **18** is positioned elsewhere within the housing **12**. For example, in some configurations, the pump **18** is positioned above at least part of the reservoir. In certain cases, a fluid conveyor, such as a worm-screw or an auger, or the like, is configured to deliver liquid soap to the pump **18**.

[0028] As illustrated, the pump **18** can be connected to the discharge assembly **20** via the conduit **26**. The discharge assembly **20** can include a flow-enhancing member (e.g., a screen **86**), and tubing **87**, and a discharge nozzle **28**. In some embodiments, the screen **86** is disposed in the flow path of the soap between the pump **18** and the nozzle **28**. In some embodiments, the screen **86** is disposed elsewhere, such as downstream of the discharge nozzle **28**.

[0029] In certain implementations, the discharge nozzle **28** is configured to dispense foam and inhibit undesired dripping of soap (liquid or foamed) after a dispensing cycle ends. For example, the discharge nozzle **28** can include a one-way valve, such as a duckbill or pin valve, that is configured to close after an amount of foam has been dispensed. The size of the discharge nozzle **28** can be determined to provide the appropriate flow rate and/or resistance against flow of foam soap from the pump **18**.

[0030] In some embodiments, the nozzle **28** can be disposed at a location spaced above the lower portion of the housing **12** (e.g., at or near the top of the housing) so as to make it more convenient for a user to place a hand or other body part under the nozzle **28**. For example, in some embodiments, the nozzle **28** can be disposed on a vertical portion of the housing **12**, so that the force of gravity encourages the foam soap to shear from the nozzle **28** after dispensation. However, other configurations can also be used.

[0031] The pump **18** can be driven or otherwise operated by an actuator **34**. In certain embodiments, the actuator **34** is an AC or DC electric motor, stepper motor, server motor, solenoid, stepper solenoid, or any other type of actuator. In some implementations, the actuator **34** is connected to the pump **18** with a transmitter device **50**. For example, the transmitter device **50** can include any type of gear train or any type of flexible transmitter assembly (e.g., belt, chain, or otherwise).

[0032] In certain embodiments, the pump **18** is controlled by an electronic control unit **46**. The ECU **46** can include one or a plurality of circuit boards providing a hard wired feedback control circuit, a processor and memory devices for storing and performing control routines, or any other type of controller. In some embodiments, the ECU **46** can include an H-bridge transistor/MOSFET hardware configuration which allows for bidirectional drive of an electric motor, and a microcontroller such as Model No. PIC16F685 commercially available from the Microchip Technology Inc., and/or other devices.

[0033] Some embodiments of the dispenser **10** can include a power supply **60**. Typically, the power supply **60** is configured to power the ECU **46** and/or the actuator **34**. The power supply **60** can be, for example, a battery or can include electronics for accepting AC or DC power.

[0034] The dispenser **10** can also include a user input device **52**. The user input device **52** can be any type of device allowing a user to input a command into the ECU **46**. For example, the input device **52** can be a button that a user can depress to transmit a command to the ECU **46**. In some embodiments, the ECU **46** can be configured to actuate the actuator **34** to drive the pump **18** any time the input device **52** is activated by a user. The ECU **46** can also be configured to provide other functions upon the activation of the input device **52**, such as signaling the dispenser to dispense a predetermined amount (e.g., an amount suitable for washing cookware) or a continuous flow of foam soap.

[0035] FIG. 2A provides a schematic illustration of the liquid handling system **14**, discharge assembly **20**, and pump **18**. As previously described, the liquid handling system **14** can include the venturi device **85**. The venturi device **85** can have a first inlet **75**, a second inlet **79**, and an outlet **77**. The outlet **77** can be in fluid communication with the first and second inlets **75**, **77**. According to some embodiments, the venturi device **85** can be configured such that the first inlet **75** and the second inlet **79** each receive an inflow of liquid soap, air, or any combination of liquid soap and air.

[0036] In some embodiments, the pump **18** can draw liquid soap into the venturi device **85** via the first inlet **75**. For example, in some embodiments, the pump **18** can create a negative pressure of the venturi device **85**, compared to ambient. In certain variants, compared to ambient, a negative pressure of at least about 0.3 psi is created within the venturi device **85**. In some embodiments, the pump **18** generates a negative pressure of less than or equal to about 0.5 psi inside of the venturi device **85**, compared to ambient. In some embodiments, the pump **18** generates a negative pressure of at least about 0.5 psi inside of the venturi device **85**, compared to ambient.

[0037] In some embodiments, the negative pressure within the venturi device **85** can result in air being drawn in through the second inlet **79**. As discussed in further detail below, the venturi device **85** can include a necked portion, or a region in which a cross-sectional width is less than the cross-sectional widths of nearby regions, which can further encourage the drawing of air into the venturi device **85** via the second inlet **79**. In some embodiments, the pump **18** can encourage both liquid soap and air to be pulled through the venturi device **85** toward the outlet **77**, such as via the first and second inlets **75**, **77**, respectively. In certain implementations, the liquid soap and the air mix as they pass through the venturi device **85**, thereby forming soap foam. For example, the flow of liquid soap and the flow of air can turbulently engage to produce soap foam.

[0038] Some embodiments of the dispenser **10** include a chamber **65** disposed between the venturi device **85** and the pump **18**. The dispenser **10** can include a conduit **27** which provides fluid communication between the venturi device **85** and the chamber **65**. In some implementations, the chamber **65** can be configured to store foam produced by the venturi device **85**. For example, some variants of the chamber **65** can receive and/or store an overflow of foam (e.g., more foam than the venturi device can contain) from the outlet **77** of the venturi device **85**. In certain embodiments, the volume of the chamber **65** can be equal to or greater than the volume of the venturi device **85** and/or the pump **18**. In some embodiments, the chamber **65** and the venturi device **85** are separate components. In other embodiments, the chamber **65** can be incorporated into, and/or monolithically formed with, the venturi device **85** so that the chamber **65** and venturi device **85** form a unitary component. Certain implementations of the chamber **65** can allow for further mixing of soap and air after the above-described initial mixing occurs within the venturi device **85**. In some embodiments, the flow of the soap foam pauses in the chamber **65** for a period of time (e.g., greater than or equal to about 1 second). For example, in some variants, the flow of the soap foam is generally stationary in the chamber **65** before proceeding toward inlet **25** of the pump **18**. In some implementations, the volume of soap foam entering the chamber **65** (e.g., the volume of soap foam exiting the venturi device **85**) is greater than or approximately equal to the volume of soap foam exiting the chamber **65** (e.g., the volume of soap foam entering the pump **18**).

[0039] According to some embodiments, an outlet **25** provides fluid communication between the venturi device **85** and/or chamber **65** and the pump **18**. Various types of pumps can be employed. For example, in certain embodiments, the pump **18** is a gear pump. In some embodiments, the pump **18** can comprise a flexible impeller pump, such as is illustrated in

FIG. 2B. Certain embodiments of a flexible impeller pump generally include a pump body **255** with an inner cavity **252** that houses a flexible impeller **250**. In some embodiments, the flexible impeller **250** can comprise a central body portion **258** and a plurality of flexible arms **257** extending from the central body portion **258**. Typically, the flexible arms **257** are made of a resilient material, such as rubber, plastic, or silicone. As discussed in further detail below, in certain orientations, the flexible arms **257** are bent, compressed, or otherwise moved or changed in shape, by the body **255**, thereby drawing the soap in through a pump inlet **253** and discharging the soap out through a pump outlet **254**. The pump **18** can be configured to engage with the conduit **26** via the pump outlet **254**.

[0040] As discussed above, the conduit **26** can include one or more flow-enhancing members, such as mesh screens **86**. The one or more screens **86** can be made of any material, such as a material that resists corrosion in the presence of water, such as plastic, rubber, stainless steel, or any other similar material. The mesh-size of the screen **86** (e.g., the size of the holes defined by the structure of the screen) can be chosen so as to provide a desired flow characteristic of foam discharged through the nozzle **28**, in the downstream direction. For example, a screen **86** can be used to provide a back pressure sufficient to briefly hold back an initial flow of foam as it is discharged from the nozzle **28** such that the foam that is first discharged has a shape that matches the shape of the nozzle **28**. In some embodiments, without such a screen or backpressure-creating device, a pump can occasionally discharge an initial amount of foam that has an outer diameter or shape that does not match the nozzle **28**. In some embodiments, the nozzle **28** can comprise a duckbill valve or some other low-pressure valve.

[0041] FIGS. **3** and **4** show a partial embodiment of the liquid-handling system **14**. In the embodiment shown, the reservoir **16** and outlet **24** are illustrated as a liquid soap supply **17** and a tube adaptor **29**. Of course, in other implementations, the dispenser **10** includes the reservoir **16** and outlet **24**, as discussed above. The liquid soap supply **17** can include a first tube **33** and a second tube **35** with a disconnection-resistant valve **31** connected therebetween (e.g., with barbed fittings). The valve **31** can be configured to control the flow of liquid soap passing through the liquid soap supply **17**. The tube adaptor **29** can be configured to connect with the second tube **35** and the venturi device **85**. For example, one end of the adaptor **29** can be configured to receive the second tube **35** and a second end of the adaptor **29** can flare radially outward to receive a portion of the venturi device **85**.

[0042] With regard to FIGS. **5-7**, an embodiment of the venturi device **85** is shown. As previously noted, the venturi device **85** can comprise the first inlet **75**, second inlet **79**, and outlet **77**. The first inlet **75** can be configured to engage with a source of liquid soap (e.g., the reservoir **16**), an air source, or both. The second inlet **79** can be configured to engage with an air source, a source of liquid soap, or both. The outlet **77** can be configured to discharge the flow of the inlets **75**, **79**. In some embodiments, the first inlet **75** has a first inner diameter D**1** and the outlet **77** has a second inner diameter D**2**. In some embodiments, D**1** is approximately equal to D**2**. In certain implementations, D**1** and/or D**2** are at least about 1.0 mm and/or equal to or less than about 20 mm. In some versions, D**1** and/or D**2** are at least about 2.0 mm and/or equal to or less than about 10 mm. In certain embodiments, D**1** and/or D**2** are at least about 2.5 mm and/or equal to or less than about 5.0 mm. Further, in some embodiments, D**1** and/or D**2** is approximately 3.0 mm. In some arrangements, D**2** is greater than D**1**. For example, D**2** can be at least about 1.1, about 1.7, or about 2.0 or otherwise, times the size of D**1**. Such a configuration can, for example, provide additional through-put for foam via the outlet **77**. In certain embodiments, the outlet **77** of the venturi device **85** can be configured to engage with an inlet **253** of the pump **18**.

[0043] In some embodiments, the first inlet **75** communicates with a first tapered portion **81** and the outlet **77** communicates with a second tapered portion **89**. A channel **83** can fluidly connect the first and second tapered portions **81**, **89**. The channel **83** can have an inner diameter D3. Typically, the inner diameter D3 is less than each of the inner diameters D**1** and D**2**. For example, D**3** can be less than or equal to about ⅛, about ½, about ⅞ or otherwise, the size of D**1** and/or D**2**. The venturi device **85** can have a generally hour-glass shape in cross-section. In some embodiments, the interior shape can facilitate a change in pressure as fluid flows through the venturi device **85**, as discussed in further detail below. In some embodiments, the first tapered portion **81** tapers from D**1** to D**3** and the second tapered portion tapers from D**2** to D**3**. In some versions, D**3** is at least about 0.5 mm and/or equal to or less than about 10 mm. In certain embodiments, D**3** is at least about 0.75 mm and/or equal to or less than about 2.5 mm. According to some configurations, D**3** is approximately 1.0 mm. The first tapered portion **81** and/or the second tapered portion **89** can each taper generally linearly or generally non-linearly (e.g., can be generally curved). In some embodiments, generally one of the portions **81**, **89** tapers generally linearly, and the other of the tapered portions **81**, **89** tapers non-linearly.

[0044] In certain implementations, the channel **83** is also fluidly connected with the second inlet **79**. For example, as shown, the second inlet **79** can be positioned on a side of the venturi device **85**. In some embodiments, the second inlet **79** is disposed substantially perpendicular to a longitudinal axis of the channel **83**. In some instances, the second inlet **79** is spaced apart from the first and second tapered portions **79**. In certain implementations, the second inlet **79** is generally non-tapered.

[0045] The second inlet can have an inner diameter D**4**. In certain versions, D**4** is at least about 0.5 mm and/or less than or equal to about 5.0 mm. In some instances, D**4** is about 2.0 mm. In some embodiments, D**4** is less than D**1** and/or D**2**. For example, D**4** can be less than or equal to about ⅛, about ½, or about ⅞ or otherwise, the size of D**1** and/or D**2**. In certain implementations, D**4** is at least about 0.8 times and/or less than or equal to about 1.3 times the size of D**3**. In some embodiments, D**4** is about equal to D**3**.

[0046] Generally, when fluid (e.g., liquid soap) is flowing though the venturi device **85** from the first inlet **75** to the outlet **77**, the first inlet has a pressure of P**1** and the outlet **77** has a pressure of P**3**. As the fluid flows through the first tapered portion **81** toward the reduced diameter of the channel **83**, the fluid generally increases in velocity. Such an increase in velocity generally results in a reduction of pressure, thereby forming a region of low pressure P**2** in the vicinity of the second inlet **79**. This low pressure P**2** can cause fluid (e.g., air) to be pulled into the venturi device **85** via the second inlet **79**, which can result in a mixing of the fluid entering through the first inlet **75** and the fluid entering the second inlet **79**.

[0047] For example, in some embodiments, the pump **18** will create a pressure differential that can pull liquid soap through the first inlet **75**, through the venturi device **85**, and out of the outlet **77**. As the liquid soap passes through the first tapered portion **81** and the channel **83** the velocity of the liquid soap increases due to the decreased diameter, thereby generating the low pressure P**2** is created in the channel **83**. The low pressure P**2** can cause air to be drawn in through the second inlet **79**. The air and liquid soap can then mix in the venturi device **85** and the mixture can exit the venturi device **85** via the outlet **77**, generally in the form of soap foam. In some embodiments, air enters the venturi device **85** via the inlet **75** and liquid soap enters the venturi device **85** through the second inlet **79**.

[0048] Various foams can be produced with the venturi device **85**. According to some configurations, the ratio of soap to air can be at least approximately 3:1 and/or less than or equal to approximately 8:1, depending on, for example, the type of soap used and the desired qualities of the foam. In some embodiments, the ratio of soap to air can be less than about 3:1. In other embodiments, the ratio of soap to air could be greater than about 8:1.

[0049] FIGS. **8** and **9** show an embodiment of the flexible impeller pump **18**. As previously noted, the flexible impeller pump **18** can include the pump body **255** that is configured to receive the flexible impeller **250**, which in turn can comprise the central hub **258** with a plurality of flexible arms **257** extending therefrom. In some embodiments, the outside diameter of the flexible impeller **250** (including the arms **257**) can be at least about: 8.0 mm, 12.0 mm, 14.0 mm, or otherwise. In some embodiments, the length of the flexible arms **257** can be at least about: 1.5 mm, 3.5 mm, 5.0 mm, or otherwise.

[0050] In some implementations, the flexible arms **257** have ends **259** that are functionally shaped to enhance the sealing contact between the flexible arms **257** and the pump body **255**. For example, in the embodiment shown, the ends **259** have rounded protrusions. The shape of the flexible arms **257** can facilitate the movement of the pump, such as by reducing the likelihood of the arms becoming caught or snagged on the pump body **255**.

[0051] The pump body **255** can include an inner cavity **252**. In some embodiments, the inner cavity **252** has a generally elliptical, generally eccentric-circular, or other non-circular shape. In certain such instances, some portions of the inner cavity **252** are nearer to the central hub **258** than other portions of the inner cavity **252**. For example, in some embodiments, the inner cavity can have an elliptical shape having a major axis (e.g., of at least approximately: 10 mm, 14 mm, 17 mm, or otherwise) and a minor axis (e.g., of about: 8 mm, 10 mm, or 13 mm, or otherwise). In some instances, the portions of the pump body **255** that form the minor axis are closer to the central hub **258** of the flexible impeller **250** than the portions of the pump body **255** that form the major axis.

[0052] In some embodiments, the flexible impeller **250** can be housed within the inner cavity **252** of the pump body **255**. The impeller **250** can be operably connected with the actuator **34**, such that the actuator **34** can rotate the impeller **250** relative to the pump body **255**. For example, the impeller **250** can include a bore **260** that is configured to couple with the transmitter device **50** (e.g., a shaft), which in turn connects with the actuator **34**. In some embodiments, the actuator **34** can rotate the impeller **250**. For example, the actuator **34** can be configured to rotate the impeller at a speed of at least about 2,000 RPM and/or equal to or less than about 3,000 RPM. According to some configurations, the thickness T**1** of the flexible impeller **250** can be such that the top surface of the flexible impeller **250** can be substantially flush with the top surface of the pump body **255**. In some implementations, the top surface of the flexible impeller **250** is recessed from top surface of the pump body **255** so as to allow space for another component, such as a gasket.

[0053] In some embodiments, the inner cavity **252** can be shaped or otherwise configured to cause bending in the flexible arms **257** as the central body portion **258** rotates relative to the pump body **255**. For example, when the flexible arms **257** contact the portions of the inner cavity **252** that are nearer to the central hub **258** of the flexible impeller **250**, the flexible arms **257** deflect, move, compress, other otherwise change in shape, more than when the arms contact the portions of the inner cavity **252** that are farther from the central hub **258** of the flexible impeller **250**. For example, in a generally elliptical inner cavity **252**, the arms **257** in contact with the portion of the inner cavity at the minor axis of the ellipse can be bent more than the arms in contact with the portion of the inner cavity at the major axis of the ellipse.

[0054] Typically, the flexible arms **257** of the impeller **250** are configured to contact the inner cavity **252** of the pump body **250**. In various configurations, a plurality of pockets can be formed between the impeller **250** and the inner cavity **252**. In some implementations, each of the pockets can be formed between two of the arms **257**, the central body **258**, and the inner cavity **252**. In certain embodiments, at least one of the pockets can be variably-sized, such as during the movement (e.g., rotation) of the pump. For example, as illustrated in FIGS. **2A** and **8**, an inlet pocket **251** can be formed in the vicinity of the pump inlet **253** and an outlet pocket can be formed in the vicinity of the pump outlet **254**. In some embodiments, the inlet pocket **251** can be larger than the outlet pocket **256**.

[0055] In some embodiments, the size of at least one pocket will vary as the impeller **250** spins. As the impeller **250** spins, the pocket moves around the periphery of the inner cavity **252**. According to some embodiments, as illustrated in FIGS. **2** and **9**, a pocket that starts as an inlet pocket **251** will gradually change in size as it moves about the inner cavity **252**. For example, the size of the pocket can remain relatively constant until the pocket approaches the outlet **254**. As the pocket approaches the outlet **254**, the radius of the interior walls of the inner cavity **252** can decrease which can cause the flexible arms **257** defining the pocket to bend and reduce the size of the pocket. This reduction in size of the pocket can increase the pressure within the pocket, which in turn can eject the foam within the pocket into the pump outlet **254** as the pocket passes the outlet **254**.

[0056] As the pocket continues to move about the inner cavity **252**, an increase in the radius of the inner cavity **252** can cause the arms **257** to unbend or to otherwise return to an initial state or condition in the vicinity of the inlet **253** and thereby increase the size of the pocket. As the pocket expands and passes the inlet **253**, a decrease in pressure (e.g., a vacuum) can be created within the pocket, which can pull foam into the pocket from the inlet **253**. In some embodiments, the pump **18** generates a negative pressure that is less than the pressure at the outlet **77** of the venturi device **85** (e.g., ambient). In various embodiments, foam from the venturi device **85** is draw into the pocket in the pump **18**. In certain implementations, the pump **18** generates a negative pressure (relative to the pressure in at the outlet **77**) of at least about 0.2 psi and/or less than or equal to about 2.0 psi. In some instances, the pump **18** generates a negative pressure of at least about 0.4 psi and/or less than or equal to about 1.0 psi. In some embodiments, the pump **18** generates a negative pressure of about 0.5 psi.

[0057] Accordingly, as the impeller **250** spins within the pump body **255**, foam can be drawn from the venturi device **85** into the pump body **255**. Further, the foam can be discharged from the pump body **255** into the conduit **26** for dispensation via the nozzle **28** as desired.

[0058] Although the dispenser has been disclosed in the context of a certain embodiments and examples, it will be understood by those skilled in the art that the dispenser extends beyond the specifically disclosed embodiment to other alternative embodiments and/or uses of the dispenser and obvious modifications and equivalents thereof. In addition, while several variations of the dispenser have been shown and described in detail, other modifications, which are within the scope of this disclosure, will be readily apparent to those of skill in the art. For example, some embodiments of the dispenser are configured to draw air through the first inlet of the venturi device and soap through the second inlet of the venturi device. Further, some embodiments of the dispenser are configured to dispense foam other than soap foam, such as lotion foam, fire-suppressant foam, insulation foam, and otherwise. Moreover, in certain embodiments, the air inlet of the venturi device can be selectively closed (e.g., by a valve, movable door, other otherwise), thereby permitting the dispenser to selectively dispense either liquid soap or foam soap based on whether liquid soap and air or only liquid soap are allowed to enter the venturi device. It is also contemplated that various combination or sub-combinations of the specific features and aspects of the embodiments or variations may be made and still fall within the scope of this disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with or substituted for one another in order to form varying modes of the dispenser. Thus, it is intended that the scope of the dispenser herein-disclosed should not be limited by the particular disclosed embodiments described above, but should be determined only by a fair reading of the claims that follow.

1. A soap dispenser comprising:

a housing;

a reservoir configured to store liquid soap;

an aspirator comprising a first inlet, a second inlet, and an outlet, the first inlet in fluid communication with the reservoir, the second inlet in fluid communication with the ambient environment, the outlet in fluid communication with the first and second inlets via a channel;

a pump disposed in the housing and comprising a body and an impeller, the impeller disposed in an inner cavity of the body, the inner cavity in fluid communication with the aspirator outlet, the pump configured to encourage a flow of liquid soap from the reservoir through the first inlet and to encourage a flow of air from the ambient environment through the second inlet, the channel of the aspirator configured to encourage mixing of the flows of liquid soap and air to generate soap foam; and

a discharge nozzle configured to discharge a portion of the soap foam, the discharge nozzle in fluid communication with the inner cavity of the pump body.

2. The soap dispenser of claim **1**, further comprising a valve disposed along a flow path between the reservoir and the aspirator.

3. The soap dispenser of claim **1**, wherein the aspirator further comprises a first tapered portion in fluid communication with the channel and a second tapered portion in fluid communication with the channel.

4. The soap dispenser of claim **1**, wherein the first inlet and the outlet are generally axially aligned.

5. The soap dispenser of claim **1**, wherein a first inlet diameter is larger than a second inlet diameter.

6. The soap dispenser of claim **1**, wherein a first inlet diameter is larger than a channel diameter.

7. The soap dispenser of claim **1**, wherein the second inlet is generally centered on an axis that is substantially perpendicular to the longitudinal axis of the channel.

8. The soap dispenser of claim **1**, wherein the impeller comprises a central body portion and a plurality of flexible arms.

9. The soap dispenser of claim **8**, wherein each of the flexible arms comprises a rounded protrusion.

10. The soap dispenser of claim **8**, wherein the inner cavity is configured to bend at least one of the flexible arms more than another one of the flexible arms.

11. The soap dispenser of claim **1**, wherein the inner cavity comprises a generally eccentric-circular shape.

12. The soap dispenser of claim **1**, wherein the impeller comprises a bore.

13. The soap dispenser of claim **12**, further comprising an actuation mechanism connected to the impeller bore.

14. The soap dispenser of claim **1**, wherein the pump is configured to generate a negative pressure that is less than a pressure at the aspirator outlet.

15. The soap dispenser of claim **1**, wherein the pump further comprises an inlet pocket near a pump inlet and an outlet pocket near a pump outlet, the inlet pocket being larger than the outlet pocket.

16. The soap dispenser of claim **1**, wherein the pump further comprises a pocket configured to transition between a first configuration and a second configuration, the pocket being larger in the first configuration than in the second configuration.

17. The soap dispenser of claim **1**, further comprising a flow-enhancing member in fluid communication with the inner cavity of the pump body, the flow-enhancing member disposed downstream from the pump.

18. The soap dispenser of claim **17**, wherein the flow-enhancing member is a screen.

19. The soap dispenser of claim **17**, wherein the flow-enhancing member is configured to provide a back pressure.

20. The soap dispenser of claim **1**, wherein the discharge nozzle is a duckbill valve.

21. The soap dispenser of claim **1**, further comprising a holding chamber disposed downstream of the aspirator, the holding chamber configured to store the soap foam for a period of time.

22. A method of dispensing foaming liquid soap from a soap dispenser, the method comprising:

drawing a flow of liquid soap from a reservoir and through a first inlet of an aspirator;

drawing a flow of ambient air through a second inlet of the aspirator;

generating soap foam in a channel of the aspirator;

drawing the soap foam from an aspirator outlet and through an inlet of a pump, the pump comprising a body and an impeller, the impeller disposed in an inner cavity of the body; and

discharging a portion of the soap foam from a nozzle.

23. The method of claim **22**, further comprising drawing the soap foam into a holding chamber, the holding chamber disposed downstream from the aspirator.

24. The method of claim **23**, further comprising storing the soap foam in the holding chamber for a period of time.

25. The method of claim **22**, wherein drawing the flow of liquid soap from the reservoir and through the first inlet comprises drawing the flow of liquid soap through a valve.

26. The method of claim **22**, further comprising generating a negative pressure within the aspirator channel relative to ambient.

27. The method of claim **22**, further comprising generating a region of pressure near the second inlet that is less than a region of pressure near the first inlet.

28. The method of claim **22**, further comprising driving the impeller, the impeller including a central body portion and a plurality of flexible arms.

29. The method of claim **28**, wherein driving the impeller comprises moving a pocket between a first configuration and a second configuration, the pocket being larger in the first configuration than in the second configuration.

30. The method of claim **28**, wherein driving the impeller comprises moving each of the flexible arms between a first configuration and a second configuration, wherein each of the flexible arms is more bent in the first configuration than in the second configuration.

31. The method of claim **22**, further comprising generating a negative pressure within the inner cavity relative to ambient.

32. The method of claim **21**, further comprising generating a pressure within the inner cavity that is less than the pressure at the aspirator outlet.

33. The method of claim **22**, further comprising discharging the soap foam from an outlet of the pump and through a flow-enhancing member.

34. The method of claim **33**, wherein discharging the soap foam through the flow-enhancing member further comprises generating a back pressure.

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