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(54) **AIR FEED DEVICE FOR HOT WATER INSTALLATIONS**

(57) The present disclosure relates generally to hot water installations, and more specifically to air feed devices for hot water installations. Described herein is an air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising: a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream

section; a first air inlet aperture disposed at the throat section of the Venturi tube; a second air inlet aperture disposed at the downstream section of the Venturi tube and spaced from the first inlet aperture; and, wherein: the Venturi tube is configured to draw air from an air source into the flow of water via at least one of: the first air inlet aperture; and, the second air inlet aperture; and wherein the amount of air drawn from the air source via the first air inlet aperture and the second air inlet aperture varies based on the pressure of the flow of water.

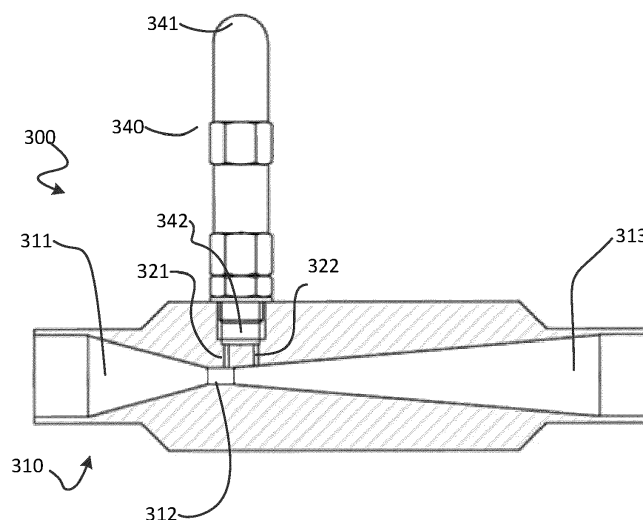


Figure 2A

Description

Technical field

[0001] The present disclosure relates generally to hot water installations, and more specifically to air feed devices for hot water installations.

Background

[0002] Hot water installations for supplying hot water for domestic or commercial purposes may incorporate a main or unvented hot water tank provided with a heating system.

[0003] In accordance with BS EN 12897:2016+A1:2020 an external expansion vessel may be coupled to an inlet pipe or outlet pipe of hot water installations to accommodate expansion of water in a tank as the water is heated. An alternative solution is to arrange for a volume of air (e.g. an air cushion) in a tank above a water level of water in the tank. The volume of air is configured to buffer expansion of the water in the tank. There is a tendency for the water in the tank to absorb air in the tank, thereby reducing its effectiveness.

[0004] Figure 1A illustrates a schematic of a water heating installation 100 connected to a water main 201 via a stop valve 202. The water heating installation 100 comprises: a pressure reducing valve 101; a check valve 102; a cold water inlet pipe 103; an expansion valve 104; a first tundish 105; an air feed device 106; a tank 108; a heater coil 109; a primary flow 110; a primary return 111; a motorized valve 112; a thermal cut-out 113; a thermostat 114; water outlet pipe 115; a hot temperature/pressure relief valve 116; a pipe 117; a second tundish 118; a water level L.

[0005] The water main 201 is connected to the stop valve 202. The stop valve 202 is connected to the pressure reducing valve 101. The pressure reducing valve 101 is connected to the check valve 102. The check valve 102 is connected to the cold water inlet pipe 103. The cold water inlet pipe 103 is connected to the expansion valve 104. The first tundish 105 is disposed beneath the expansion valve 104. The expansion valve 104 is connected to the air feed device 106. The air feed device 106 is connected to the tank 108. The heater coil 109 is disposed within the tank 108. The primary flow 110 is connected to the motorized valve 112. The motorized valve is connected to the heater coil 109. The heater coil 109 is connected to the primary return 111. The thermal cut-out 113 is connected to the tank 108. The thermal cut-out 113 is coupled to the motorized valve 112. The thermostat 114 is connected to the tank 108. The thermostat 114 is coupled to the motorized valve 112. The water outlet pipe 115 is connected to the tank 108. The tank 108 is connected to the hot temperature/pressure relief valve 116. The hot temperature/pressure relief valve 116 is connected to the pipe 117. The second tundish 118 is disposed beneath the pipe 117. Water is

disposed within the tank 108. The water fills the tank 108 to level L.

[0006] In use, water is drawn off from the tank 108 through the water outlet pipe 115 (e.g. when one or more hot water taps in fluid communication with the water outlet pipe 115 are opened).

[0007] Water flows from the water main 201 via stop valve 202 into the pressure reducing valve 101. The pressure reducing valve 101 is configured to reduce the pressure of the water received from the water main 201.

[0008] Water flows from the pressure reducing valve 101 via the check valve 102 to the cold water inlet pipe 103. Water flows from the cold water inlet pipe 103 to the expansion valve 104. The expansion valve 104 is configured to accommodate expansion of the water. Some water may leak from the expansion valve 104. The first tundish 105 is disposed beneath the expansion valve 104 and therefore is configured to collect water which leaks from the expansion valve 104.

[0009] Water flows from the expansion valve 104 to the air feed device 106. Figure 1B illustrates an example air feed device 106 (described below).

[0010] The air feed device 106 is configured to introduce air into the water flowing through the air feed device. The air which is introduced into the water flowing through the air feed device 106 enters the tank 108. Air which enters the tank 108 rises above water in the tank (e.g. due to buoyant forces) to form and/or replenish an air cushion at the top of the tank 108. The water in the tank 108 therefore has a water level L determined by the volume of the air cushion.

[0011] In the event of a problem being encountered with the air feed device 106, the stop valve 202 is configured to isolate the air feed device 106 from the mains 201 (e.g. stop valve 202 is closed) and the tank 108 is drained. Subsequently removal and replacement of the air feed device 106 is enabled.

[0012] In the example shown in Figure 1A the cold water inlet pipe 103 is connected to the water main 201. Water in the tank 108 is heated by a heater coil 109. The heater coil 109 comprises a pipe which is configured to receive hot water from the primary flow 110. The hot water from the primary flow may be supplied by a water heating means such as, for example, a boiler or an electric heater.

[0013] The thermostat 114 is configured to modify and/or maintain temperature of the water in tank 108. Thermostat 114 is connected to the tank 108 and may be configured to determine a temperature of water in the tank 108. The thermostat coupled to the motorized valve 112 to control hot water supplied to the heater coil 109 from the primary flow 110. The primary return 111 is configured to remove water from the heater coil 109.

[0014] The air inlet device 106 is connected to the cold water inlet pipe 103 so as introduce air into the tank 108.

[0015] The water outlet pipe 115 is connected to taps or appliances. Accordingly, heated water in the tank 108 is supplied to the taps or appliances.

[0016] The hot water outlet pipe 115 is positioned so as to open into the tank below the anticipated position of the water level L. The pipe 117 is positioned to open into the tank 108 at the distance from a bottom of the tank at which the hot water outlet pipe 115 opens into the tank 108 (e.g. both pipe 117 and hot water outlet pipe 115 are located at the same level in the tank).

[0017] The air cushion in the tank allows the water in the tank to expand as it is heated and the regular replenishment of the air cushion by the air feed device 106 compensates for any tendency of the water in the tank to absorb air from the air cushion.

[0018] Figure 1B illustrates an air feed device 106. The air feed device 106 comprises: a Venturi tube 150; an air inlet aperture 154; a non-return valve 155.

[0019] The Venturi tube 150 comprises: an upstream section 151; a throat section 152; a downstream section 153.

[0020] The throat section 152 is disposed between the upstream section 151 and the downstream section 153. The air inlet aperture 154 is disposed at the throat section 151 of the Venturi tube 150. The non-return valve 155 is connected to the air inlet aperture

[0021] The upstream section 151 has an upstream flow cross-sectional area. The upstream flow cross-sectional area is the axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube 150 (e.g. the largest axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube).

[0022] The throat section 152 has a throat flow cross-sectional area. The throat flow cross-sectional area is the cross-sectional area available to the flow of water at the throat section of the Venturi tube 150 (e.g. the smallest cross-sectional area available to the flow of water at the upstream section of the Venturi tube).

[0023] The downstream section 153 has an upstream flow cross-sectional area. The upstream flow cross-sectional area is the cross-sectional area available to the flow of water at the upstream section of the Venturi tube 150 (e.g. the largest cross-sectional area available to the flow of water at the upstream section of the Venturi tube).

[0024] The upstream flow cross-sectional area is greater than the throat flow cross-sectional area. The downstream flow cross-sectional area is greater than the throat flow cross-sectional area.

[0025] The air inlet aperture 154 is connected to the non-return valve 155 and the throat section 152 of the Venturi tube 150. The non-return valve 155 permits air to flow from an air source, through the non-return valve 155 to the air inlet aperture 154. The non-return valve 155 prevents water flowing from the air inlet aperture 154, through the non-return valve 155 to an exterior of the Venturi tube 150.

[0026] The Venturi tube 150 is configured to receive a flow of water from the expansion valve 104. The Venturi tube 150 is configured to receive the flow of water such that the flow of water passes sequentially through the

upstream section 151, the throat section 152 and the downstream section 153.

[0027] A notional fluid particle of water at the narrowest part of the Venturi tube 150 e.g. the throat section 152 of the Venturi tube, may typically have the lowest instantaneous pressure and greatest instantaneous speed of any other notional fluid particle of water passing through the Venturi tube.

[0028] Without being bound to a particular theory, the decrease in pressure of the water in the throat section when compared to the remainder of the Venturi tube 150 acts to draw air from an air source through the non-return valve 155 and the air inlet aperture 154 into the water passing through the throat section of the Venturi tube 150.

[0029] A problem which arises in connection with employing an air feed device for a range of hot water installations is that some hot water installations have a greater rate of flow of water to the tank than others. Factors which affect the flowrate of the flow of water to the tank include any of: the pressure of water provided by a mains water supply; the draw off rate of water from the tank. In most hot water installations, the flowrate of the flow of water through the inlet pipe and into the tank may be between 10 and 55 litres per minute.

[0030] A problem which has been found to arise with air feed devices comprising Venturi tubes is that the constriction provided by the throat section of Venturi tubes places a limit on the flowrate at which water can pass through the air feed device into the tank. This in turn limits the rate at which water can be drawn off through the hot water outlet pipe 115.

[0031] Consequently, the maximum achievable flowrate of water through the hot water installation may be substantially below that at which the system would operate in the absence of the air feed device, which is typically 55 litres per minute.

[0032] Some typical air feed devices comprise "throttle members" e.g. throttle member 18 illustrated in Figure 4 of UK Patent GB2413623B. The throttle member shown in Figure 4 of UK Patent GB2413623B is disposed centrally within a throat section of a Venturi tube and is in a rest position when no water flows through the Venturi tube. The throttle member is biased towards its rest position by compression springs bearing at one end of the throttle member and at the other end against stop discs located at the upstream section and the downstream section of the Venturi tube. The throttle member is hollow and is slidably supported on a shaft. The ends of the shaft pass through openings in the stop discs. The ends of the shaft are screw-threaded so as to receive retaining nuts bearing against the discs. The throttle member has conical upstream and downstream surfaces. When water flows through the Venturi tube the throttle member may be displaced in the downstream direction against a restoring force of the springs so as to increase the throat flow cross-sectional area of the Venturi tube. The position occupied by the throttle member, and hence the throat

flow cross sectional area, is related to the rate at which water flows through the Venturi tube.

[0033] Disadvantages with such throttle members is that impurities in water passing through the Venturi tubes may corrode and/or build-up on the throttle members or associated elements (e.g. springs; screws).

[0034] Corrosion and/or build-up of the impurities on the springs may reduce the efficacy of the springs. For example, the stiffness of the springs may be affected (e.g. stiffness increase or stiffness decrease). Correspondingly, the displacement of the throttle member from the rest position be an inadequate response to the flow of water through the Venturi tube.

[0035] Corrosion and/or build-up of impurities on the screws may make maintenance (e.g. replacement of the throttle member) more difficult and/or impossible. For example, the screws may become stuck on the shaft. If the screws become stuck on the shaft, the whole air feed device may need to be replaced as opposed to replacement of a defective part.

Summary

[0036] An aspect of the disclosure provides an air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising: a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream section; a first air inlet aperture disposed at the throat section of the Venturi tube; a second air inlet aperture disposed at the downstream section of the Venturi tube and spaced from the first inlet aperture; and, wherein: the Venturi tube is configured to draw air from an air source into the flow of water via at least one of: the first air inlet aperture; and, the second air inlet aperture; and wherein the amount of air drawn from the air source via the first air inlet aperture and the second air inlet aperture varies based on the pressure of the flow of water.

[0037] The amount of air drawn from the air source via the first air inlet aperture and the second air inlet aperture may vary based on: the pressure of the flow of water at the throat section of the Venturi tube; and/or the pressure of the flow of water at the downstream section of the Venturi tube. For example, the pressure of the flow of water at the throat section of the Venturi tube and/or the downstream section of the Venturi tube may be lower than the pressure of the flow of water at other positions in the Venturi tube e.g. the pressure of the flow of water at the upstream portion of the Venturi tube.

[0038] The pressure of the flow of water which passes through the Venturi tube depends on: the flowrate of the flow of water through the Venturi tube; and, the position of a notional fluid particle of the flow of water.

[0039] A notional fluid particle at the narrowest part of the Venturi tube e.g. the throat section of the Venturi tube

may typically have the lowest instantaneous pressure and greatest instantaneous speed of any other notional fluid particle in the Venturi tube.

[0040] As the flowrate increases the instantaneous speed of all notional fluid particles in the Venturi tube. As the flowrate increases the position of the notional fluid particle with the lowest instantaneous pressure and greatest instantaneous speed drifts downstream of the narrowest part of the Venturi tube (e.g. drifts into the downstream section of the Venturi tube).

[0041] In typical air feed devices the air inlet aperture is disposed at the narrowest part of the Venturi tube e.g. the throat section of the Venturi tube. The efficacy of the air feed device may be improved by providing an air inlet aperture at the position of the notional fluid particle with the lowest instantaneous pressure. This may be adequate for air feed devices wherein the flowrate of water through the Venturi tube is small because the notional fluid particle of lowest instantaneous pressure is located at or very close to the air inlet aperture.

[0042] However, at higher flowrates, the notional fluid particle having the lowest instantaneous pressure drifts a non-negligible distance (more than a few millimetres) from the narrowest part of the Venturi tube and the efficacy of these typical air feed device (e.g. the rate at which air is drawn into the air feed device) is reduced.

[0043] Typical air feed devices do not comprise a second air inlet aperture. Therefore, when typical air feed devices receive a flow of water at a high flowrate such that the notional fluid particle having the lowest instantaneous pressure drifts a non-negligible distance (more than a few millimetres) from the narrowest part of the Venturi tube and first air inlet into the downstream section of the Venturi tube, this notional fluid particle is spaced from the first air inlet aperture. As described above, the efficacy of the typical air feed device may be reduced given that the notional fluid particle is spaced from the first air inlet aperture.

[0044] A first pressure difference may be defined as the magnitude of the pressure difference between: air at the air source; and, the pressure of the flow of water at the first air inlet aperture when the notional fluid particle having the lowest instantaneous pressure is at the first air inlet aperture (e.g. when the flowrate of the flow of water is low).

[0045] A second pressure difference may be defined as the magnitude of the pressure difference between: air at the air source; and, the pressure of the flow of water at the first air inlet aperture when the notional fluid particle having the lowest instantaneous pressure is spaced from the first air inlet aperture (e.g. when the flowrate of the flow of water is high).

[0046] Accordingly, the first pressure difference may be greater than the second pressure difference.

[0047] The amount of air drawn from the air source via the first air inlet aperture into the Venturi tube may be proportional to the pressure difference between: air at the air source; and, the pressure of the flow of water at

the first air inlet aperture. Therefore, the amount of air drawn from the air source via the first air inlet aperture into the Venturi tube when the notional fluid particle having the lowest instantaneous pressure is spaced from the first air inlet aperture may be less than, the amount of air drawn from the air source via the first air inlet aperture into the Venturi tube when the notional fluid particle having the lowest instantaneous pressure is at the first air inlet aperture.

[0048] Accordingly, there may be a relationship between the amount of air drawn into the Venturi tube via the first air inlet aperture and the distance (e.g. axial distance along the Venturi tube) between: the notional fluid particle having the lowest instantaneous pressure; and, the first air inlet aperture.

[0049] The amount of air drawn from the air source via the first air inlet aperture into the Venturi tube may depend upon (e.g. may be proportional to), a distance (e.g. axial distance along the Venturi tube) between: the notional fluid particle having the lowest instantaneous pressure; and, the first air inlet aperture.

[0050] Therefore, in typical air feed devices which do not comprise a second air inlet aperture, the amount of air drawn from the air source via the first air inlet aperture into the Venturi tube may decrease when the flowrate of the flow of water through the Venturi tube increases due to an increased distance between: the notional fluid particle having the lowest instantaneous pressure; and, the first air inlet aperture. The decrease in the amount of air drawn into the Venturi tube when the flowrate increases is disadvantageous because, for example, at higher flowrates an insufficient amount of air may be drawn into the flow of water. Therefore, an air cushion in the tank may not be replenished at a sufficient rate and the hot water installation may not function efficiently and/or correctly. Aspects of the disclosure address may avoid and/or mitigate this disadvantage and/or other disadvantages with typical air feed devices described herein.

[0051] The disclosure provides an air feed device comprising a first air inlet aperture and a second air inlet aperture in a downstream portion of the Venturi tube.

[0052] The second air inlet aperture disposed at the downstream section of the Venturi tube may be spaced from the first inlet aperture by a selected spacing parameter.

[0053] The spacing parameter may be a measurement of physical spacing between the first air inlet aperture and the second air inlet aperture e.g. the shortest distance between a centre of the first air inlet aperture and a centre of the second air inlet aperture.

[0054] In examples, the spacing parameter may preferably be 5 mm.

[0055] Aspects of the disclosure provide air feed devices comprising a first air inlet aperture and a second air inlet aperture. When an air feed device receives a flow of water at a high flowrate, the notional fluid particle having the lowest instantaneous pressure drifts a non-negligible distance (more than a few millimetres) from the

narrowest part of the Venturi tube and first air inlet into the downstream section of the Venturi tube and towards the second air inlet aperture. The distance between this notional fluid particle and the first air inlet aperture is increased. The distance between this notional fluid particle and the second air inlet aperture is decreased.

[0056] The amount of air drawn from the air source via the first air inlet aperture into the Venturi tube may depend on (e.g. may be proportional to) a pressure difference between: air at the air source; and, the pressure of the flow of water at the first air inlet aperture.

[0057] The amount of air drawn from the air source via the first air inlet aperture into the Venturi tube may depend upon (e.g. may be proportional to), a distance (e.g. axial distance along the Venturi tube) between: the notional fluid particle having the lowest instantaneous pressure; and, the first air inlet aperture.

[0058] The amount of air drawn from the air source via the second air inlet aperture into the Venturi tube may depend on (e.g. may be proportional to) a pressure difference between: air at the air source; and, the pressure of the flow of water at the second air inlet aperture.

[0059] The amount of air drawn from the air source via the second air inlet aperture into the Venturi tube may depend upon (e.g. may be proportional to), a distance (e.g. axial distance along the Venturi tube) between: the notional fluid particle having the lowest instantaneous pressure; and, the first air inlet aperture.

[0060] The spacing parameter may be selected so that an increase in the distance between the notional fluid particle having the lowest instantaneous pressure and the first air inlet aperture results in a corresponding decrease in the distance between the notional fluid particle having the lowest instantaneous pressure and the second air inlet aperture. Therefore, the spacing parameter may be selected so that a reduction in the amount of air drawn into the Venturi tube via the first air inlet aperture which may occur when the distance between notional fluid particle having the lowest instantaneous pressure and the first air inlet aperture is increased may be offset (at least partially) by a corresponding reduce in the amount of air drawn into the Venturi tube via the second air inlet aperture which may occur when the distance between notional fluid particle having the lowest instantaneous pressure and the second air inlet aperture is decreased (e.g. at high flowrates).

[0061] Therefore, in air feed devices provided by aspects of the disclosure may provide an increase amount of air drawn from the air source into the Venturi tube over a spectrum of operational flowrates (e.g. between 10 Litres per minute to 55 Litres per minute).

[0062] A preferred spacing parameter may be configured such that the amount of air drawn into the flow of water is constant between flowrates of 10 Litres per minute to 30 Litres per minute.

[0063] Air may be drawn through the first air inlet aperture into the Venturi tube. Air may be drawn through the first air inlet aperture into the Venturi tube at a first

air flow rate. Air may simultaneously be drawn through both the first air inlet aperture and the second air inlet aperture into the Venturi tube at a second air flow rate.

[0064] If air is drawn through both the first air inlet aperture and the second air inlet aperture into the Venturi tube, the first air flow rate through the first air inlet aperture may be different to the rate second air flow through the second air inlet aperture.

[0065] When the notional fluid particle of the lowest instantaneous pressure in the Venturi tube is located closer to the first air inlet aperture than to the second air inlet aperture, the first air flow rate through the first air inlet aperture may be greater than the second air flow rate through the second air inlet aperture.

[0066] When the notional fluid particle of the lowest instantaneous pressure in the Venturi tube is located closer to the second air inlet aperture than to the first air inlet aperture, the first air flow rate through the first air inlet aperture may be less than the second air flow rate through the second air inlet aperture.

[0067] The selected threshold value may be preferably 30 litres per minute.

[0068] The spacing parameter may be selected so that the second air inlet aperture may be located at a position in the Venturi tube wherein the notional fluid particle of the lowest instantaneous pressure is located when the flow of water through the Venturi tube is at a maximum flowrate of water which the air feed device is configured to receive.

[0069] The spacing parameter may be selected so that the second air inlet aperture may be located at a position in the Venturi tube wherein the notional fluid particle of the lowest instantaneous pressure is located when the flow of water through the Venturi tube is at a mean flowrate of water which the air feed device is configured to receive.

[0070] In examples, a third air inlet aperture may be provided.

[0071] In examples wherein a first air inlet aperture is provided in the throat section of the Venturi tube and a second air inlet aperture is provided in the downstream section of the Venturi tube, the third air inlet aperture may be provided in the downstream section of the Venturi tube. The shortest distance from the third air inlet aperture to the throat section of the Venturi tube may be greater than the shortest distance from the second air inlet aperture and the throat section of the Venturi tube.

[0072] In examples wherein a first and a second air inlet aperture are provided in the throat section of the Venturi tube, the third air inlet aperture may be provided in the throat section of the Venturi tube. The shortest distance from the third air inlet aperture to the downstream section of the Venturi tube may be smaller than the shortest distance from the first air inlet aperture and the downstream section of the Venturi tube. The shortest distance from the third air inlet aperture to the downstream section of the Venturi tube may be smaller than the shortest distance from the second air inlet aperture

and the downstream section of the Venturi tube.

[0073] In examples wherein a first and a second air inlet aperture are provided in the throat section of the Venturi tube, the third air inlet aperture may be provided in the downstream section of the Venturi tube. The shortest distance from the third air inlet aperture to the second air inlet aperture may be smaller than the shortest distance from the third air inlet aperture and the first air inlet aperture.

[0074] In examples, the first air inlet aperture may be proximate to a boundary between the throat section and the upstream section of the Venturi tube (e.g. the first air inlet aperture is proximate an upstream end of the throat section).

[0075] In examples, the second air inlet aperture may be proximate to a boundary between the throat section and the downstream section of the Venturi tube (e.g. the second air inlet aperture is proximate a downstream end of the throat section).

[0076] The third air inlet aperture may be spaced from the second air inlet aperture by a second spacing parameter.

[0077] The second spacing parameter may be a measurement of physical spacing between the second air inlet aperture and the third air inlet aperture e.g. the shortest distance between a centre of the second air inlet aperture and a centre of the third air inlet aperture.

[0078] The second spacing parameter may preferably be 5 mm,

[0079] The second spacing parameter may be selected so that the third air inlet aperture may be located at a position in the Venturi tube wherein the notional fluid particle of the lowest instantaneous pressure is located when the flow of water through the Venturi tube is at a maximum flowrate of water which the air feed device is configured to receive.

[0080] The air feed device may comprise: a non-return valve having a non-return valve inlet and a non-return valve outlet, wherein: the non-return valve is configured to permit fluid to pass from the non-return valve inlet to the non-return valve outlet and, the non-return valve inlet is in fluid communication with an air source; wherein, the first air inlet aperture and the second air inlet aperture are in fluid communication with the non-return valve outlet.

[0081] The air source may be atmosphere.

[0082] The non-return valve may prevent leakage of water from the air feed device to the environment. Conveniently, the water pressure of water flowing through the air feed device may be maintained.

[0083] An aspect of the disclosure provides an air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising: a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream

section; a deformable member disposed in the throat section; wherein the deformable member is configured to: deform when a flowrate value of the flow of water through the Venturi tube is above a selected threshold deformation flowrate value; and, deform by a deformation magnitude, wherein the deformation magnitude is based on the flowrate value of the flow of water in the Venturi tube; and; a first air inlet aperture disposed, in the Venturi tube at a downstream side of the deformable member; and, wherein: the Venturi tube is configured to draw air from an air source into the flow of water via the first air inlet aperture due to the pressure of the flow of water at a region at the first air inlet aperture.

[0084] The air feed device provides a variable throat flow cross section. Conveniently, the throat cross section may be varied to an appropriate size to provide an adequate flowrate of water through the Venturi tube. Conveniently, the throat cross section may be varied to an appropriate size to provide an adequate water pressure at the first air inlet aperture of the Venturi tube.

[0085] The air feed device provides a variable throat flow cross section with fewer parts which require maintenance. Advantageously, at least some of the disadvantages associated with throttle members of typical air feed devices may be avoided. For example, the usable lifetime of air feed devices according to the disclosure may be improved relative to typical air feed devices.

[0086] To avoid the need to make available a range of air feed devices having different throat flow cross sections for a variety of hot water installations with a variety of different flow characteristics, the disclosure provides a means for adjusting the throat flow cross-sectional area based on the flowrate of water passing through the air feed device.

[0087] The deformable member is provided at the throat section of the Venturi tube. The deformable member deforms when the flowrate of the flow of water through the Venturi tube exceeds a selected threshold flowrate value. The deformation magnitude may be based on the flowrate of the flow of water passing through the Venturi tube. Advantageously, the available throat area may remain proportional to the rate at which water flows through the Venturi tube. In consequence, the rate at which air is drawn into the inlet pipe is substantially independent of the rate of flow of water during normal operation.

[0088] The deformable member may comprise silicone e.g. a silicon gasket.

[0089] For example, the throat flow cross section may be circular. For example, the deformable member may comprise an annular shape wherein the deformable member is configured to permit the flow of water to pass through a hole of the annular shape.

[0090] In examples, the selected threshold deformation flowrate value may a flowrate of 5 litres per minute, or more preferably 10 litres per minute.

[0091] A deformation magnitude of zero may correspond to no deformation of the deformable member. The deformation magnitude of the deformable member may

be zero when the flowrate value of the flow of water in the Venturi tube is below the selected threshold deformation flowrate value.

[0092] A maximum deformation magnitude may correspond to deformation of the deformable member when a maximum flowrate of water passes through the Venturi tube. The term "maximum flowrate" may refer to the maximum flowrate of water an air feed device is configured to receive.

[0093] A continuous range of deformation magnitudes may be achievable by the deformable member between, a lower limit of a deformation magnitude of zero, and an upper limit of a maximum deformation magnitude.

[0094] The deformation magnitude above a selected threshold deformation flowrate value may be based on the flowrate of the flow of water passing through the Venturi tube. For example, the deformation magnitude above a selected threshold deformation flowrate value may be proportional to the flowrate of the flow of water through the Venturi tube.

[0095] A flow cross-sectional area of the throat section may be based on the deformation magnitude of the deformable member.

[0096] The deformable member is configured to deform towards the downstream section of the Venturi tube.

[0097] The deformable member may be disposed between the upstream portion and the first air inlet aperture.

[0098] An aspect of the disclosure provides an air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising: a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream section; a first air inlet aperture disposed at the throat section of the Venturi tube; and, wherein the Venturi tube is configured to draw air from an air source into the flow of water via the first air inlet aperture due to the pressure of the flow of water at a region at the first air inlet aperture; and, a bypass pipe configured to permit a portion of the flow of water from the upstream section to bypass the throat section, the bypass pipe comprising: a variable impedance member configured to permit water to flow through the bypass pipe when a flowrate value of the flow of water in the Venturi tube is above a selected threshold bypass flowrate value.

[0099] To avoid the need to make available a range of air feed devices having different throat flow cross sections for a variety of hot water installations with a variety of different flow characteristics, the disclosure provides a means for adjusting the amount of water which flows from the upstream section of the air feed device to a tank of a hot water installation.

[0100] The variable impedance member may be further configured to permit water to flow through the bypass pipe at rate based on the flowrate value of the flow of water entering the air feed device.

[0101] Aspects of the disclosure may comprise: a non-return valve having an inlet and an outlet, wherein: the non-return valve is configured to permit fluid to pass from the inlet to the outlet and, the inlet of the non-return valve is in fluid communication with an air source; and, wherein, the first air inlet aperture is in fluid communication with the outlet of the non-return valve.

[0102] Aspects of the disclosure may comprise: a second air inlet aperture disposed at the downstream section of the Venturi tube and spaced from the first inlet aperture by a selected spacing parameter.

[0103] For aspects comprising a deformable member, the air feed device provides a variable throat flow cross section. Conveniently, the throat cross section may be varied to an appropriate size to provide an adequate water pressure at the second air inlet aperture of the Venturi tube.

[0104] Aspects of the disclosure comprising a Venturi tube wherein the Venturi tube may be configured to draw air from an air source into the flow of water via at least one of: the first air inlet aperture; and, the second air inlet aperture; due to the pressure of the flow of water at a region at and between the first air inlet aperture and the second air inlet aperture.

[0105] Aspects of the disclosure may comprise: a non-return valve having an inlet and an outlet, wherein: the non-return valve is configured to permit fluid to pass from the inlet to the outlet and, the inlet of the non-return valve is in fluid communication with an air source; wherein, the first air inlet aperture and the second fluid inlet aperture are in fluid communication with the outlet of the non-return valve.

[0106] Aspects of the disclosure may comprise: an air duct having a first air duct opening and a second air duct opening, wherein the first air duct opening is connected to the inlet of the non-return valve and the second air duct opening is in fluid communication with an air source; a receptacle disposed below the second air duct opening, the fluid receptacle configured to collect leakage of water through the non-return valve.

[0107] An aspect of the disclosure provides a hot water installation comprising: an unvented hot water tank; a water inlet pipe; configured to supply a flow of water to the unvented hot water tank; and, an air feed device according to an aspect of the disclosure; the air feed device connected to the water inlet pipe; the air feed device configured to provide air to the flow of water to the unvented hot water tank to replenish an air cushion in the unvented hot water tank.

[0108] Any non-return valve described herein may have an open configuration wherein the non-return valve permits air to pass from the non-return valve inlet to the non-return valve outlet. The non-return valve may have a closed configuration wherein the non-return valve prevents air to pass from the non-return valve inlet to the non-return valve outlet.

[0109] The non-return valve may be configured to open (e.g. transition to an open configuration) with a snap ac-

tion when pressure across the non-return valve is at or above a selected differential pressure across the non-return valve.

[0110] The non-return valve may be configured to close (e.g. transition to a closed configuration) with a snap action when pressure across the non-return valve is below a selected differential pressure across the non-return valve.

[0111] When there is no flow of water through the air feed device, the pressure across the non-return valve may be below the selected differential pressure across the non-return valve and accordingly the non-return valve is in a closed configuration.

[0112] For example, the selected differential pressure may be equal to the magnitude of the difference between standard atmospheric pressure (e.g. 101.325 KPa) and a selected water pressure of the flow of water at the first air inlet aperture.

[0113] In use, a flow of water is provided through the Venturi tube of the air feed device. As the flowrate of water through the air feed device increases, the pressure of a notional fluid particle of water at (or close to) the first air inlet aperture may decrease. When the flowrate is increased to a point wherein the selected differential pressure across the non-return valve is reached (e.g. the water pressure at (or close to) the first air inlet aperture is less than atmospheric pressure), the non-return valve may snap open and air enters the inlet pipe.

[0114] While the non-return valve is in the open configuration, the rate of air flow from the non-return valve inlet to the non-return valve outlet may be proportional to the differential pressure across the non-return valve. Factors which may affect the rate at which air is drawn into the air feed device may include any of: changes in atmospheric pressure (e.g. deviations in atmospheric pressure from standard atmospheric pressure); and/or the flowrate of water through the Venturi tube of the air feed device; and/or the humidity of the air.

[0115] When water ceases to flow through the air feed device (e.g. water is no longer drawn off from the tank and the inlet valve to the tank begins to close) the flowrate of the flow water through the Venturi tube may fall. Correspondingly, the pressure of a notional fluid particle of water at the first air inlet aperture (or, for example, the second air inlet aperture, if present) may increase. Accordingly, the differential pressure across the non-return valve may decrease to the selected differential pressure, and the non-return valve may snap shut. The pressure of the water may continue to increase until it exceeds atmospheric pressure.

[0116] The selected differential pressure of the non-return valve may be as low as possible. For example, successful results have been achieved with non-return valves having a selected differential in the region of approximately 0.03 bar. Water pressures of up to 10 bar present in typical hot water installations do not lead to any risk of water escaping when the non-return valve is open. Although under normal operating conditions no wa-

ter may be expected to escape from non-return valves when closed, in order to allow for the possibility that the non-return valve may be faulty when installed, or may develop a fault later, the non-return valve may be connected through a pipe to a tundish normally provided for the expansion relief valve and the pressure/temperature relief valve conventionally associated with unvented tanks.

[0117] In examples, the non-return valve is directly mounted to the air feed device. For example, the air feed device may comprise a threaded boss and the non-return valve may comprise a corresponding threaded portion configured to connect with the threaded boss. In examples, the non-return valve may be indirectly mounted to the air feed device, for example, the non-return valve and the air feed device may be connected to the air feed device by a length of pipe.

[0118] The Venturi tubes described herein may be used in any given hot water installation. The Venturi tubes may have throat flow cross-sectional area. The throat cross-sectional area may be the axial cross-sectional area available to the flow of water at the throat section of the Venturi tube (e.g. the smallest axial cross-sectional area available to the flow of water at the throat section of the Venturi tube).

[0119] The throat flow cross-sectional area may be chosen based upon the expected flowrate of water through the water inlet pipe for the hot water installation. The expected flowrate of water through the air feed device depends upon the rate at which hot water is drawn off from the tank via the hot water outlet. A typical flowrate of water through the water inlet pipe may be in the range of 10 to 55 litres per minute. A standard inlet pipe may have a circular flow cross section and an internal diameter of 20 mm. The throat flow cross section may be in the range of approximately 7 mm² and 64 mm² for example, corresponding to a circular throat flow cross section with a diameter within the range of approximately 3 mm to approximately 9 mm.

Drawings

[0120]

Figure 1A illustrates a schematic of a water heating installation;

Figure 1B illustrates an air feed device;

Figure 2A illustrates a longitudinal cross-sectional view of an example air feed device;

Figure 2B illustrates a longitudinal cross-sectional view of a central portion of the air feed device of Figure 2A;

Figure 2C illustrates a perspective view of the example air feed device of Figure 2A along a longitudinal axis of the device;

Figure 3A illustrates a longitudinal cross-sectional view of an example air feed device;

Figure 3B illustrates a longitudinal cross-sectional

view of a central portion of the air feed device of Figure 3A wherein the deformable member is not deformed;

Figure 3B illustrates a longitudinal cross-sectional view of a central portion of the air feed device of Figure 3A wherein the deformable member is deformed;

Figure 4A illustrates a longitudinal cross-sectional view of an example air feed device comprising a bypass pipe having a variable impedance member;

Figure 4B illustrates a longitudinal perspective view of the example air feed device of Figure 4A;

Figure 4C illustrates a longitudinal cross-sectional view of an example air feed device wherein the variable impedance member is positioned to prevent water to pass through the bypass pipe;

Figure 4D illustrates a longitudinal cross-sectional view of an example air feed device wherein the variable impedance member is positioned to permit water to pass through the bypass pipe.

Specific description

[0121] Figure 2A illustrates a longitudinal cross-sectional view of an example air feed device; Figure 2B illustrates a longitudinal cross-sectional view of a central portion of the air feed device of Figure 2A; Figure 2C illustrates a perspective view of the example air feed device of Figure 2A along a longitudinal axis of the device;

[0122] The air feed device 300 comprises: a Venturi tube 310; a first air inlet aperture 321; a second air inlet aperture 322; a spacing parameter 323; a non-return valve 340.

[0123] The Venturi tube 310 comprises: an upstream section 311; a throat section 312; a downstream section 313.

[0124] The non-return valve 340 comprises: a non-return valve inlet 341; a non-return valve outlet 342.

[0125] The throat section 312 is disposed between the upstream section 311 and the downstream section 313. The first air inlet aperture 321 is disposed at the throat section 311 of the Venturi tube 310. The second air inlet aperture 322 is disposed at the downstream section of the Venturi tube. The second air inlet aperture 322 is spaced from the first air inlet aperture 321. The second air inlet aperture 322 is spaced from the first air inlet aperture 321 by the spacing parameter 323. For example, the spacing parameter is the shortest distance between a centre of the first air inlet aperture and the centre of the second air inlet aperture. The non-return valve inlet 341 is connected to the first air inlet aperture 321. The non-return valve outlet 342 is connected to the second air inlet aperture 322.

[0126] The upstream section 311 has an upstream flow cross-sectional area. The upstream flow cross-sectional area is the axial cross-sectional area available to a flow of water at the upstream section 311 of the Venturi tube 310 (e.g. the largest axial cross-sectional area available

to the flow of water at the upstream section of the Venturi tube 310). In the example shown in Figure 2C, the upstream flow cross-sectional area has a circular shape. The upstream section 311 of the Venturi tube 310 converges to the throat section 312 e.g. the upstream section 311 has a truncated conical shape.

[0127] The upstream section 311 of the Venturi tube 310 converges at a constant angle throughout its length, preferably in the range of a swept angle of 1 degree to a swept angle of 30 degrees, and more preferably 10 degrees swept. Experiments have shown that a 10 degrees swept angle is adequate for achieving a water pressure drop from 3 bar to 0 bar in order to draw air into the throat section.

[0128] The throat section 312 has a throat flow cross-sectional area. The throat flow cross-sectional area is the axial cross-sectional area available to the flow of water at the throat section 312 of the Venturi tube 310 (e.g. the smallest axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube). In the example shown in Figure 2C, the throat flow cross-sectional area has a circular shape.

[0129] The downstream section 313 has a downstream flow cross-sectional area. The downstream flow cross-sectional area is the axial cross-sectional area available to the flow of water at the downstream section 313 of the Venturi tube 310 (e.g. the largest axial cross-sectional area available to the flow of water at the downstream section of the Venturi tube). In the example shown in Figure 2C, the downstream flow cross-sectional area has a circular shape. The downstream section 313 of the Venturi tube diverges from the throat section e.g. the downstream section has a truncated conical shape.

[0130] In examples, the downstream section 313 of the Venturi tube 310 diverges at a constant angle throughout its length, preferably in the range of a swept angle of 1 degree to a swept angle of 30 degrees, and more preferably 10 degrees swept. Experiments have shown that a 10 degrees swept angle is adequate for achieving a pressure increase from 0 bar to 3 bar in order to draw air into the throat section.

[0131] The upstream flow cross-sectional area is greater than the throat flow cross-sectional area. The downstream flow cross-sectional area is greater than the throat flow cross-sectional area.

[0132] In examples any of: the upstream flow cross-sectional area; throat flow cross-sectional area; downstream flow cross-sectional area; may have a non-circular shape such as an elliptical shape and/or a square shape.

[0133] In examples, the first air inlet aperture may be disposed at the throat section of the Venturi tube and a second air inlet aperture may be disposed at the throat section of the tube. The shortest distance between the first air inlet aperture and the upstream section may be less than the shortest distance between the second air inlet aperture and the upstream section. The second air inlet aperture may be spaced from the first air inlet aper-

ture, for example, by a spacing parameter as defined herein.

[0134] The Venturi tube 310 is configured to receive a flow of water. The Venturi tube 310 is configured to receive the flow of water such that the flow of water passes sequentially through the upstream section 311, the throat section 312 and the downstream section 313.

[0135] The non-return valve inlet 341 is connectable to an air source. For example, the air source may be atmosphere.

[0136] The air feed device 300 is connectable to a hot water installation. For example, the air feed device 300 may be connectable to a hot water installation as set out in Figure 1A, e.g. air feed device 300 may replace air feed device 106.

[0137] The upstream section 311 is configured to receive a flow of water. The upstream section may be configured to receive the flow of water from: a water main; or, a header tank.

[0138] In the example illustrated in Figures 2A to 2C, the upstream section 311 is connectable to a water main. The upstream section 311 may be connected to the water main indirectly e.g. connected via intermediate components. One or more components may connect the upstream section to the water main.

[0139] In examples, the upstream section 311 may be connectable to a header tank (which may be pumped).

[0140] The throat section 312 is configured to receive the flow of water from the upstream section 311.

[0141] The downstream section 313 is configured to receive the flow of water from the throat section 312.

[0142] The downstream section 313 is connectable to a tank. The downstream section 313 may be connected to the tank indirectly e.g. connected via intermediate components.

[0143] The Venturi tube 310 is configured to reduce the pressure of water passing therethrough. More specifically, the Venturi tube 310 is configured to reduce the pressure of water at the throat section of the Venturi tube 310.

[0144] A notional fluid particle at the narrowest part of the Venturi tube e.g. the throat section of the Venturi tube may typically have the lowest instantaneous pressure and greatest instantaneous speed of any other notional fluid particle in the Venturi tube (e.g. due to the Venturi effect).

[0145] The non-return valve 340 is configured to permit air to move from the non-return valve inlet 341 to the non-return valve outlet 342.

[0146] The non-return valve 340 is configured to prevent water to move from the non-return valve outlet 342 to the non-return valve inlet 341.

[0147] The Venturi tube 310 is configured to draw air from an air source into the flow of water via at least one of: the first air inlet aperture 321; and, the second air inlet aperture 322; due to the pressure of the flow of water at a region at and between the first air inlet aperture and the second air inlet aperture.

[0148] The non-return valve outlet 342 is configured to provide air to the first air inlet aperture 321. The first air inlet aperture 321 is configured to permit air to pass there-through into the throat section 312 of the Venturi tube 310.

[0149] The non-return valve outlet 342 is configured to provide air to the second air inlet aperture 322. The second air inlet aperture 322 is configured to permit air to pass therethrough into the downstream section 313 of the Venturi tube 310.

[0150] In examples wherein the second air inlet aperture is disposed within the throat section of the Venturi tube, the second air inlet aperture may be configured to permit air to pass therethrough into the throat section 312 of the Venturi tube 310.

[0151] In use the air feed device illustrated in Figures 2A to 2C is connected to a water main (e.g. the upstream section 311 is directly or indirectly connected to a water main) and to a tank (e.g. the downstream section 313 is directly or indirectly connected to a tank).

[0152] The water main provides a flow of water to the air feed device 300. The flow of water passes sequentially through the Venturi tube 310 from the upstream section 311 to the throat section 312, and from the throat section 312 to the downstream section 313. The pressure of the flow of water decreases as the flow cross-sectional area of the Venturi tube decreases from the upstream portion 311 to the throat portion 312. The decrease in water pressure acts to draw air through the non-return valve 340 from the air source to the Venturi tube 310 via, sequentially, the non-return valve inlet 341, the non-return valve outlet 342, the first air inlet aperture 321 and/or the second air inlet aperture 322.

[0153] As the flowrate of water through the Venturi tube 310 is increased the instantaneous speed of all notional fluid particles in the Venturi tube is increased. Therefore, the position of the notional fluid particle with the lowest instantaneous pressure and greatest instantaneous speed drifts downstream of the narrowest part of the Venturi tube (e.g. drifts into the downstream section of the Venturi tube).

[0154] At high flowrates, the notional fluid particle having the lowest instantaneous pressure drifts a non-negligible distance towards the second air inlet aperture.

[0155] At low flowrates (e.g. a flowrate around 1 litre per minute) the position of the lowest pressure of the flow of water in the Venturi tube is at or proximal to (e.g. within a few millimetres of) to the first air inlet aperture.

[0156] At a flowrate of the flow of water at a threshold value of the flow of water (e.g. a threshold value of 30 litres per minute) the position of the lowest pressure of the flow of water in the Venturi tube is equidistant between the second air inlet aperture and the first air inlet aperture.

[0157] At a flowrate of the flow of water greater than a threshold value of the flow of water (e.g. a threshold value of 30 litres per minute) the position of the lowest pressure of the flow of water in the Venturi tube is closer to the

second air inlet aperture than to the first air inlet aperture.

[0158] At high flowrates of the flow of water (e.g. a flow-rate above 55 litres per minute) the position of the lowest pressure of the flow of water in the Venturi tube is at or proximal to (e.g. within a few millimetres of) to the second air inlet aperture.

[0159] The flow of water which exits the Venturi tube 310 via the downstream section 313 provides the flow of water to the tank.

[0160] Figure 3A illustrates a longitudinal cross-sectional view of an example air feed device; Figure 3B illustrates a longitudinal cross-sectional view of a central portion of the air feed device of Figure 3A wherein the deformable member is not deformed; Figure 3B illustrates a longitudinal cross-sectional view of a central portion of the air feed device of Figure 3A wherein the deformable member is deformed.

[0161] The air feed device 400 comprises: a Venturi tube 410; a first air inlet aperture 421; a deformable member 430; a non-return valve 440.

[0162] The Venturi tube 410 comprises: an upstream section 411; a throat section 412; a downstream section 413.

[0163] The non-return valve 440 comprises: a non-return valve inlet 441; a non-return valve outlet 442.

[0164] The throat section 412 is disposed between the upstream section 411 and the downstream section 413. The deformable member 430 is disposed in the throat section 412. The first air inlet aperture 421 is disposed in the Venturi tube and at a downstream side of the deformable member 430 e.g. the shortest distance between the first air inlet aperture and the upstream section may be greater than, the shortest distance between the first air inlet aperture and the upstream section. The non-return valve inlet 441 is connected to the first air inlet aperture 421.

[0165] The upstream section 411 has an upstream flow cross-sectional area. The upstream flow cross-sectional area is the axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube 410 (e.g. the largest axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube). In the example shown in Figures 3A-3C, the upstream flow cross-sectional area has a circular shape. The upstream section of the Venturi tube converges to the throat section e.g. the upstream section has a truncated conical shape.

[0166] The upstream section 411 of the Venturi tube 410 converges at a constant angle throughout its length, preferably in the range of a swept angle of 1 degree to a swept angle of 30 degrees, and more preferably 10 degrees swept. Experiments have shown that a 10 degrees swept angle is adequate for achieving a water pressure drop from 3 bar to 0 bar in order to draw air into the throat section.

[0167] The throat section 412 has a throat flow cross-sectional area. The throat flow cross-sectional area is the axial cross-sectional area available to the flow of wa-

ter at the throat section of the Venturi tube 410 (e.g. the smallest axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube). The throat cross-sectional area is delimited by the deformable member. In the example shown in Figures 3A-3C the deformable member has an annular shape. In the example shown in Figures 3A-3C, the throat flow cross-sectional area has a circular shape.

[0168] The downstream section 413 has a downstream flow cross-sectional area. The downstream flow cross-sectional area is the axial cross-sectional area available to the flow of water at the downstream section of the Venturi tube 410 (e.g. the largest axial cross-sectional area available to the flow of water at the downstream section of the Venturi tube). In the example shown in Figures 3A-3C, the downstream flow cross-sectional area has a circular shape. In the example shown the downstream section of the Venturi tube has a cylindrical shape which extends from the throat section.

[0169] The downstream section of the Venturi tube may diverge from the throat section e.g. the downstream section has a truncated conical shape. In examples, the downstream section of the Venturi tube may diverge at a constant angle throughout its length, preferably in the range of a swept angle of 1 degree to a swept angle of 30 degrees, and more preferably 10 degrees swept. Experiments have shown that a 10 degrees swept angle is adequate for achieving a pressure drop from 3 bar to 0 bar in order to draw air into the throat (e.g. a pressure drop should be between 3 bar to just below atmospheric pressure).

[0170] The upstream flow cross-sectional area is greater than the throat flow cross-sectional area. The downstream flow cross-sectional area is greater than the throat flow cross-sectional area.

[0171] In examples any of: the upstream flow cross-sectional area; throat flow cross-sectional area; downstream flow cross-sectional area; may have a non-circular shape such as an elliptical shape and/or a square shape.

[0172] In examples, a second air inlet aperture may be provided. The second air inlet aperture may be disposed at the downstream portion of the Venturi tube. For example, the shortest distance between the first air inlet aperture and the upstream section may be less than, the shortest distance between the second air inlet aperture and the upstream section. In examples, the first air inlet aperture may be disposed at the throat section of the Venturi tube and the second air inlet aperture may be disposed at the throat section of the tube. The shortest distance between the first air inlet aperture and the upstream section may be less than, the shortest distance between the second air inlet aperture and the upstream section. The second air inlet aperture may be spaced from the first air inlet aperture, for example, by a spacing parameter as defined herein.

[0173] The Venturi tube 410 is configured to receive a flow of water. The Venturi tube 410 is configured to re-

ceive the flow of water such that the flow of water passes sequentially through the upstream section 411, the throat section 412 and the downstream section 413.

[0174] The non-return valve inlet 441 is connectable to an air source. For example, the air source may be atmosphere.

[0175] The air feed device 400 is connectable to a hot water installation. For example, the air feed device 400 may be connectable to a hot water installation as set out in Figure 1A, e.g. air feed device 400 may replace air feed device 106.

[0176] The upstream section 411 is configured to receive a flow of water. The upstream section may be configured to receive the flow of water from: a water main; or, a header tank.

[0177] In the example illustrated in Figures 3A to 3C, the upstream section 411 is connectable to a water main. The upstream section 411 may be connected to the water main indirectly e.g. connected via intermediate components. One or more components may connect the upstream section to the water main.

[0178] In examples, the upstream section 411 may be connectable to a header tank (which may be pumped).

[0179] The throat section 412 is configured to receive the flow of water from the upstream section 411.

[0180] The downstream section 413 is configured to receive the flow of water from the throat section 412. The downstream section 413 may be connected to the tank indirectly e.g. connected via intermediate components.

[0181] The Venturi tube 410 is configured to reduce the pressure of water passing therethrough. More specifically, the Venturi tube 410 is configured to reduce the pressure of water at the throat section of the Venturi tube 410.

[0182] A notional fluid particle at the narrowest part of the Venturi tube e.g. the throat section of the Venturi tube may typically have the lowest instantaneous pressure and greatest instantaneous speed of any other notional fluid particle in the Venturi tube (e.g. due to the Venturi effect).

[0183] The non-return valve 440 is configured to permit air to move from the non-return valve inlet 441 to the non-return valve outlet 442.

[0184] The non-return valve 440 is configured to prevent water to move from the non-return valve outlet 442 to the non-return valve inlet 441.

[0185] The Venturi tube is configured to draw air from an air source into the flow of water via at the first air inlet aperture 421.

[0186] The non-return valve outlet 442 is configured to provide air to the first air inlet aperture 421. The first air inlet aperture 421 is configured to permit air to pass there-through into the throat section 412 of the Venturi tube 410.

[0187] In use the air feed device illustrated in Figures 3A to 3C is connected to a water main (e.g. the upstream section 411 is directly or indirectly connected to a water main) and to a tank (e.g. the downstream section 413 is

directly or indirectly connected to a tank).

[0188] The water main provides a flow of water to the air feed device 400. The flow of water passes sequentially through the Venturi tube 410 from the upstream section 411 to the throat section 412, and from the throat section 412 to the downstream section 413. The pressure of the flow of water decreases as the flow cross-sectional area of the Venturi tube decreases from the upstream portion 411 to the throat portion 412. The decrease in water pressure acts to draw air through the non-return valve 440 from the air source to the Venturi tube 410 via, sequentially, the non-return valve inlet 441, the non-return valve outlet 442, the first air inlet aperture 421.

[0189] The deformable member is configured to deform when the flowrate value of the flow of water in the Venturi tube is above a selected deformation flowrate value. The deformable member is configured to deform by a deformation magnitude.

[0190] In examples, the selected threshold deformation flowrate value may a flowrate of 10 litres per minute.

[0191] Figure 3B illustrates a deformable member 430 with a deformation magnitude of zero 450. The deformation magnitude of zero 450 corresponds to no deformation of the deformable member 430. The deformation magnitude of the deformable member is zero when the flowrate value of the flow of water in the Venturi tube 410 is below the selected threshold deformation flowrate value.

[0192] The deformable member 430 illustrated in Figure 3B and 3C has an annular shape wherein the deformable member is configured to permit the flow of water to pass through a circular hole of the annular shape. The circular hole of the deformable member may have a diameter of 4 millimetres when the deformation magnitude is zero 450.

[0193] Figure 3C illustrates a maximum deformation magnitude 451. The maximum deformation magnitude 451 corresponds to a deformation of the deformable member when a maximum flowrate of water passes through the Venturi tube 410. The term "maximum flowrate" may refer to the maximum flowrate of water an air feed device is configured to receive.

[0194] The circular hole of the deformable member may have a diameter of 6 millimetres when the deformation magnitude is a maximum 451.

[0195] A continuous range of deformation magnitudes are achievable by the deformable member between a lower limit of zero 450, and a maximum deformation magnitude 451.

[0196] The deformation magnitude is based on the flowrate of the flow of water passing through the Venturi tube. Therefore, the throat flow cross-sectional area may remain proportional to the rate at which water flows through the Venturi tube. In consequence, the rate at which air is drawn into the inlet pipe is substantially independent of the rate of flow of water during normal operation.

[0197] The deformable member is configured to de-

form towards the downstream portion of the air inlet device. In use, the flow of water passing and/or impacting the deformable member may cause the deformable member to deform, e.g. to bend from an equilibrium position thereby enlarging the aperture.

[0198] The Venturi tube is configured to draw air from an air source into the flow of water via the first air inlet aperture 421 by the processes described herein, for example, due to the Venturi effect.

[0199] The flow of water which exits the Venturi tube 310 via the downstream section 313 provides the flow of water to the tank.

[0200] Figure 4A illustrates a longitudinal cross-sectional view of an example air feed device comprising a bypass pipe having a variable impedance member; Figure 4B illustrates a longitudinal perspective view of the example air feed device of Figure 4A; Figure 4C illustrates a longitudinal cross-sectional view of an example air feed device wherein the variable impedance member is positioned to prevent water to pass through the bypass pipe; Figure 4D illustrates a longitudinal cross-sectional view of an example air feed device wherein the variable impedance member is positioned to permit water to pass through the bypass pipe.

[0201] The air feed device 500 comprises: a Venturi tube 510; a first air inlet aperture 521; a bypass pipe 530; a variable impedance member 535; a non-return valve 540.

[0202] The Venturi tube 510 comprises: an upstream section 511; a throat section 512; a downstream section 513.

[0203] The non-return valve 540 comprises: a non-return valve inlet 541; a non-return valve outlet 542.

[0204] The throat section 512 is disposed between the upstream section 511 and the downstream section 513. The first air inlet aperture 521 is disposed at the throat section 511 of the Venturi tube 510. The non-return valve inlet 541 is connected to the first air inlet aperture 521. The bypass pipe 530 is connected to the upstream section 511. The bypass pipe 530 is connected to the downstream section 513. The variable impedance member 535 is disposed within the bypass pipe 530.

[0205] The upstream section 511 has an upstream flow cross-sectional area. The upstream flow cross-sectional area is the axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube 510 (e.g. the largest axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube). In the example shown in Figures 4A-4D, the upstream flow cross-sectional area has a circular shape. The upstream section of the Venturi tube converges to the throat section e.g. the upstream section has a truncated conical shape.

[0206] The upstream section 511 of the Venturi tube 510 converges at a constant angle throughout its length, preferably in the range of a swept angle of 1 degree to a swept angle of 30 degrees, and more preferably 10 degrees swept. Experiments have shown that a 10 degrees

swept angle is adequate for achieving a pressure drop from 3 bar to 0 bar in order to draw air into the throat section.

[0207] The throat section 512 has a throat flow cross-sectional area. The throat flow cross-sectional area is the axial cross-sectional area available to the flow of water at the throat section of the Venturi tube 510 (e.g. the smallest axial cross-sectional area available to the flow of water at the upstream section of the Venturi tube). In the example shown in Figures 4A-4D, the throat flow cross-sectional area has a circular shape.

[0208] The downstream section 513 has a downstream flow cross-sectional area. The downstream flow cross-sectional area is the axial cross-sectional area available to the flow of water at the downstream section of the Venturi tube 510 (e.g. the largest axial cross-sectional area available to the flow of water at the downstream section of the Venturi tube). In the example shown in Figures 4A-4D, the downstream flow cross-sectional area has a circular shape. The downstream section of the Venturi tube diverges to the throat section e.g. the downstream section has a truncated conical shape.

[0209] In examples, the downstream section 513 of the Venturi tube 510 diverges at a constant angle throughout its length, preferably in the range of a swept angle of 1 degree to a swept angle of 30 degrees, and more preferably 10 degrees swept. Experiments have shown that a 10 degrees swept angle is adequate for achieving a pressure drop from 3 bar to 0 bar in order to draw air into the throat section.

[0210] The upstream flow cross-sectional area is greater than the throat flow cross-sectional area. The downstream flow cross-sectional area is greater than the throat flow cross-sectional area.

[0211] In examples any of: the upstream flow cross-sectional area; throat flow cross-sectional area; downstream flow cross-sectional area; may have a non-circular shape such as an elliptical shape and/or a square shape.

[0212] The Venturi tube 510 is configured to receive a flow of water. The Venturi tube 510 is configured to receive the flow of water such that the flow of water passes sequentially through the upstream section 511, the throat section 512 and the downstream section 513.

[0213] The non-return valve inlet 541 is connectable to an air source. For example, the air source may be atmosphere.

[0214] The air feed device 500 is connectable to a hot water installation. For example, the air feed device 500 may be connectable to a hot water installation as set out in Figure 1A, e.g. air feed device 500 may replace air feed device 106.

[0215] The upstream section 511 is configured to receive a flow of water. The upstream section may be configured to receive the flow of water from: a water main; or, a header tank.

[0216] In the example illustrated in Figures 4A to 4D, the upstream section 511 is connectable to a water main.

The upstream section 511 may be connected to the water main indirectly e.g. connected via intermediate components. One or more components may connect the upstream section to the water main.

[0217] In examples, the upstream section 511 may be connectable to a header tank (which may be pumped).

[0218] The throat section 512 is configured to receive the flow of water from the upstream section 511.

[0219] The downstream section 513 is configured to receive the flow of water from the throat section 512. The downstream section 513 may be connected to the tank indirectly e.g. connected via intermediate components.

[0220] The Venturi tube 510 is configured to reduce the pressure of water passing therethrough. More specifically, the Venturi tube 510 is configured to reduce the pressure of water at the throat section of the Venturi tube 510.

[0221] A notional fluid particle at the narrowest part of the Venturi tube e.g. the throat section of the Venturi tube may typically have the lowest instantaneous pressure and greatest instantaneous speed of any other notional fluid particle in the Venturi tube (e.g. due to the Venturi effect).

[0222] The non-return valve 540 is configured to permit air to move from the non-return valve inlet 541 to the non-return valve outlet 542.

[0223] The non-return valve 540 is configured to prevent water to move from the non-return valve outlet 542 to the non-return valve inlet 541.

[0224] The Venturi tube is configured to draw air from an air source into the flow of water via at the first air inlet aperture 521.

[0225] The non-return valve outlet 542 is configured to provide air to the first air inlet aperture 521. The first air inlet aperture 521 is configured to permit air to pass there-through into the throat section 512 of the Venturi tube 510.

[0226] The bypass pipe 530 is configured to receive a portion of the flow of water from the upstream section 511 of the Venturi tube 510.

[0227] The variable impedance member 535 is configured to permit water to flow through the bypass pipe 530 when the flowrate value of the flow of water in the Venturi tube is above a selected threshold flowrate value. The variable impedance member is configured to prevent water to flow through the bypass pipe when the flowrate value of the flow of water in the Venturi tube is below the selected threshold flowrate value.

[0228] The variable impedance member 535 is displaceable by a displacement magnitude when the flowrate value of the flow of water in the Venturi tube 510 is above a selected threshold flowrate value.

[0229] The variable impedance member 535 is displaceable by a displacement magnitude of zero when the flowrate value of the flow of water in the Venturi tube 510 is below a selected threshold flowrate value. When the variable impedance member 535 has a displacement magnitude of zero, the variable impedance member 535

is configured to prevent water flowing through the bypass pipe 530.

[0230] In examples, the bypass pipe may directly link the upstream portion of the Venturi tube with the tank.

[0231] In use the air feed device illustrated in Figures 4A to 4D is connected to a water main (e.g. the upstream section 511 is directly or indirectly connected to a water main) and to a tank (e.g. the downstream section 513 is directly or indirectly connected to a tank).

[0232] The water main provides a flow of water to the air feed device 500. The flow of water passes sequentially through the Venturi tube 510 from the upstream section 511 to the throat section 512, and from the throat section 512 to the downstream section 513. The pressure of the flow of water decreases as the flow cross-sectional area of the Venturi tube decreases from the upstream portion 511 to the throat portion 512. The decrease in water pressure acts to draw air through the non-return valve 540 from the air source to the Venturi tube 510 via, sequentially, the non-return valve inlet 541, the non-return valve outlet 542, the first air inlet aperture 521.

[0233] As illustrated in Figure 4C, when the flow of water has a flowrate below a selected threshold value (e.g. the threshold value may be around 30 litres per minute) the variable impedance member blocks the bypass pipe.

[0234] The variable impedance member is biased to block the bypass pipe in the absence of an external force (e.g. absence of water flow through the air feed device). In the Figures 4A to 4D the variable impedance member comprises a spring to bias the variable impedance member to block the bypass pipe.

[0235] As illustrated in Figure 4D, when the flow of water has a flowrate above a selected threshold value (e.g. the threshold value may be around 30 litres per minute) the variable impedance member is forced out of the bypass pipe by the water, thereby unblocking the bypass pipe.

[0236] The selected threshold value may be the flowrate above which the variable displacement member may be displaced. For example, flowrates of the flow of water below the selected threshold value may not displace the variable displacement member. For example, flowrates of the flow of water above the selected threshold value may displace the variable displacement member.

[0237] The flow of water which exits the Venturi tube 310 via the downstream section 313 provides the flow of water to the tank.

[0238] When the variable impedance member 535 has a non-zero displacement magnitude the variable impedance member 535 is configured to permit water to flow through the bypass pipe 530, the bypass pipe 530 is configured to permit the portion of the flow of water from the upstream section 511 of the Venturi tube 510 to bypass the throat section 512 of the Venturi tube.

[0239] When the variable impedance member 535 has a non-zero displacement magnitude the variable impedance member 535 is configured to permit water to pass from the upstream portion of the Venturi tube to the down-

stream portion 513 of the Venturi tube 510 without passing through the throat section 512.

[0240] A maximum displacement magnitude corresponds to a maximum displacement of the variable impedance member e.g. wherein no further displacement of the variable impedance member is possible.

[0241] A continuous range of deformation magnitudes is achievable by the deformable member between a lower limit of zero displacement (shown in Figure 4C), and a maximum displacement (shown in Figure 4D).

[0242] The displacement magnitude is based on the flowrate of the flow of water passing through the Venturi tube. For example, the displacement magnitude is proportional to the flowrate of the flow of water through the Venturi tube.

Claims

1. An air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising:

a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream section;

a first air inlet aperture disposed at the throat section of the Venturi tube;

a second air inlet aperture disposed at the downstream section of the Venturi tube and spaced from the first inlet aperture; and,

wherein:

the Venturi tube is configured to draw air from an air source into the flow of water via at least one of:

the first air inlet aperture; and,

the second air inlet aperture;

and wherein the amount of air drawn from the air source via the first air inlet aperture and the second air inlet aperture varies based on the pressure of the flow of water.

2. The air feed device of claim 1, wherein:

the second air inlet aperture disposed at the downstream section of the Venturi tube is spaced from the first inlet aperture by a selected spacing parameter.

3. The air feed device of any preceding claim, wherein:

the lowest pressure of the flow of water in the Venturi tube is closer to the second air inlet aperture than to the first air inlet aperture when the flowrate of the flow of water through the Venturi tube is above a selected threshold value; and optionally comprising:

a non-return valve having a non-return valve inlet and a non-return valve outlet, wherein:

the non-return valve is configured to permit fluid to pass from the non-return valve inlet to the non-return valve outlet and, the non-return valve inlet is in fluid communication with an air source;

wherein, the first air inlet aperture and the second air inlet aperture are in fluid communication with the non-return valve outlet.

4. An air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising:

a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream section;

a deformable member disposed in the throat section; wherein the deformable member is configured to:

deform when a flowrate value of the flow of water in the Venturi tube is above a selected threshold deformation flowrate value; and, deform by a deformation magnitude, wherein the deformation magnitude is based on the flowrate value of the flow of water through the Venturi tube;

and;

a first air inlet aperture disposed, in the Venturi tube at a downstream side of the deformable member; and,

wherein:

the Venturi tube is configured to draw air from an air source into the flow of water via the first air inlet aperture due to the pressure of the flow of water at a region at the first air inlet aperture.

5. The air feed device of claim 4, wherein: a flow cross-sectional area of the throat section is based on the deformation magnitude of the deformable member.

6. The air feed device of any of claims 4 to 5, wherein: the deformable member is configured to deform towards the downstream section of the Venturi tube.

7. The air feed device of any of claims 4 to 6, wherein: the deformable member is disposed between the upstream portion and the first air inlet aperture.

8. An air feed device, for a hot water installation comprising an unvented hot water tank, the air feed device comprising:

a Venturi tube having a throat section disposed between an upstream section and a downstream section, wherein the Venturi tube is configured to receive a flow of water, the flow of water passing sequentially through the upstream section, the throat section and the downstream section;

a first air inlet aperture disposed at the throat section of the Venturi tube; and, wherein the Venturi tube is configured to draw air from an air source into the flow of water via the first air inlet aperture due to the pressure of the flow of water at a region at the first air inlet aperture; and, a bypass pipe configured to permit a portion of the flow of water from the upstream section to bypass the throat section, the bypass pipe comprising:

a variable impedance member configured to permit water to flow through the bypass pipe when a flowrate value of the flow of water in the Venturi tube is above a selected threshold bypass flowrate value.

9. The air feed device of claim 8 wherein: the variable impedance member is further configured to permit water to flow through the bypass pipe at rate based on the flowrate value of the flow of water entering the air feed device.

10. The air feed device of any of claims 4 to 9, comprising: a non-return valve having an inlet and an outlet, wherein:

the non-return valve is configured to permit fluid to pass from the inlet to the outlet and, the inlet of the non-return valve is in fluid communication with an air source; and,

wherein, the first air inlet aperture is in fluid communication with the outlet of the non-return valve.

11. The air feed device of claim 4 to 9, comprising:

a second air inlet aperture disposed at the downstream section of the Venturi tube and

spaced from the first inlet aperture by a selected spacing parameter wherein optionally:
the Venturi tube is configured to draw air from an air source into the flow of water via at least one of:

the first air inlet aperture; and,
the second air inlet aperture;

due to the pressure of the flow of water at a region at and between the first air inlet aperture and the second air inlet aperture; and, optionally comprising:

a non-return valve having an inlet and an outlet, wherein:

the non-return valve is configured to permit fluid to pass from the inlet to the outlet and, the inlet of the non-return valve is in fluid communication with an air source;

wherein, the first air inlet aperture and the second fluid inlet aperture are in fluid communication with the outlet of the non-return valve.

- 12.** The air feed device of claims 1 to 3 or claim 11, comprising:

a third air inlet aperture disposed at the downstream section of the Venturi tube and spaced from the second inlet aperture by a selected second spacing parameter.

- 13.** The air feed device of claim 12, wherein:
the Venturi tube is configured to draw air from an air source into the flow of water via at least one of:

the first air inlet aperture;
the second air inlet aperture; and,
the third air inlet aperture;

due to the pressure of the flow of water at a region at and between the first air inlet aperture and the third air inlet aperture; and, optionally comprising:

a non-return valve having an inlet and an outlet, wherein:

the non-return valve is configured to permit fluid to pass from the inlet to the outlet and,
the inlet of the non-return valve is in fluid communication with an air source;

wherein, the first air inlet aperture, the second fluid inlet aperture and the third fluid inlet aperture are in fluid communication with the outlet of the non-return valve.

- 14.** The air feed device of any of claims 3 or 10 or 11 or 13, comprising:

an air duct having a first air duct opening and a second air duct opening, wherein the first air duct opening is connected to the inlet of the non-return valve and the second air duct opening is in fluid communication with an air source;
a receptacle disposed below the second air duct opening, the fluid receptacle configured to collect leakage of water through the non-return valve.

- 15.** A hot water installation comprising:

an unvented hot water tank;
a water inlet pipe; configured to supply a flow of water to the unvented hot water tank; and,
an air feed device of any of the preceding claims;
the air feed device connected to the water inlet pipe; the air feed device configured to provide air to the flow of water to the unvented hot water tank to replenish an air cushion in the unvented hot water tank.

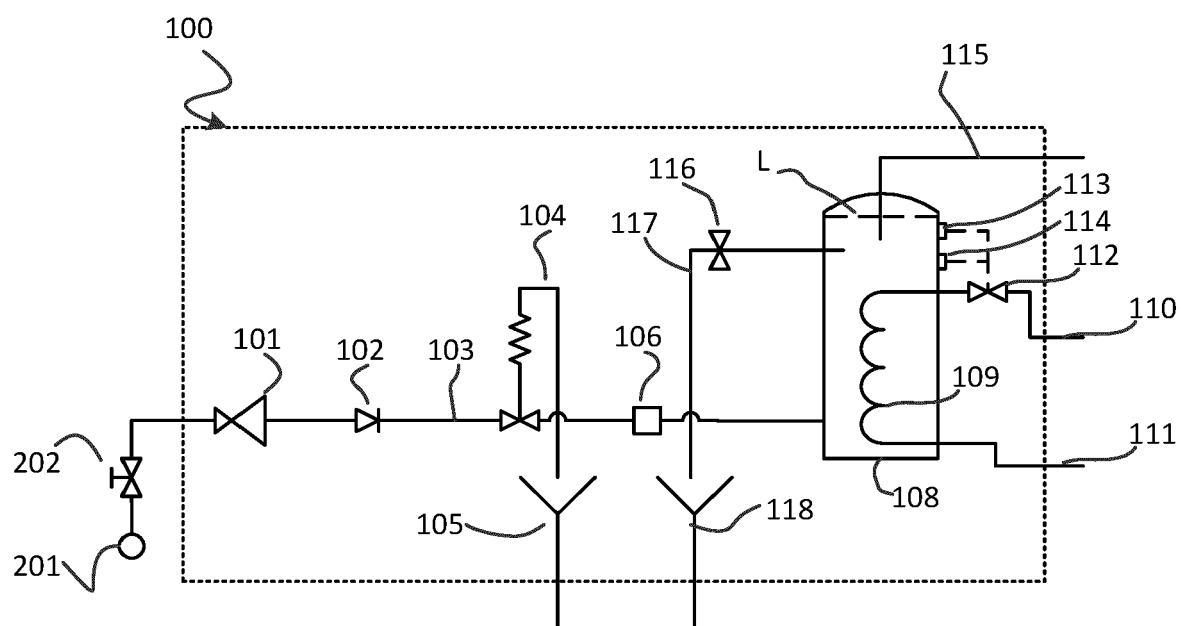


Figure 1A

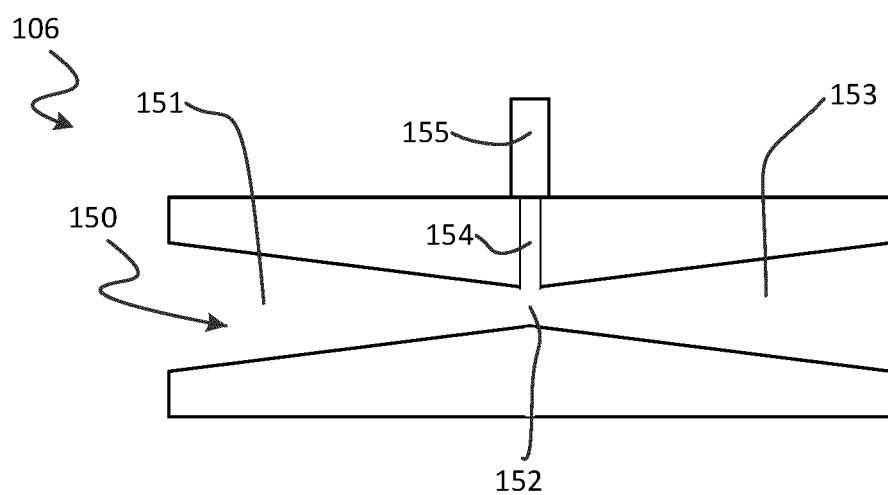


Figure 1B

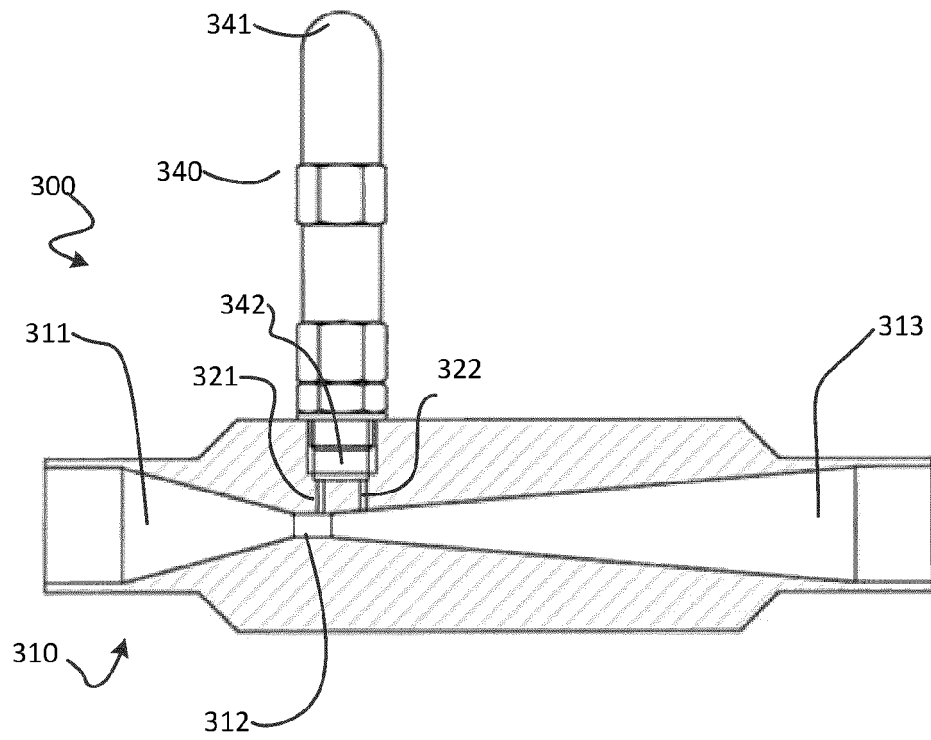


Figure 2A

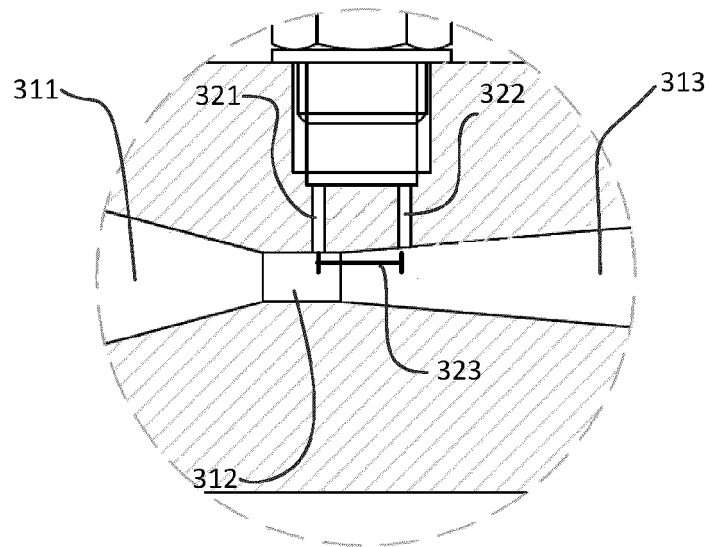


Figure 2B

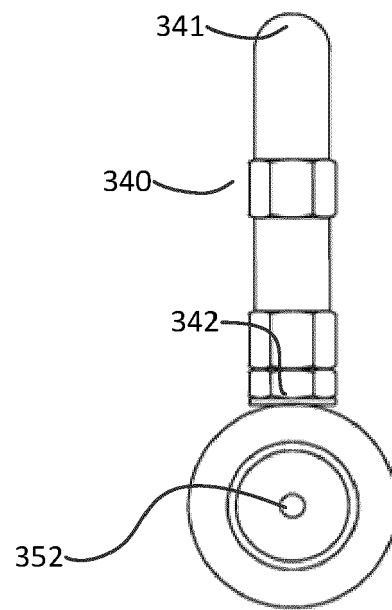


Figure 2C

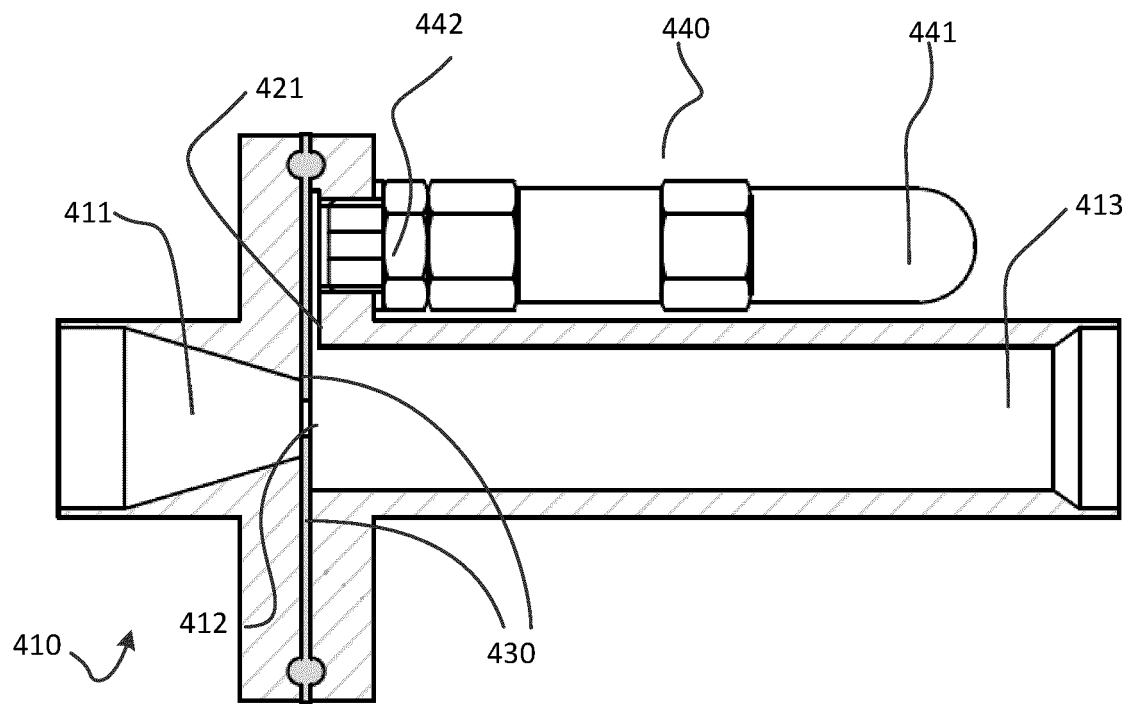
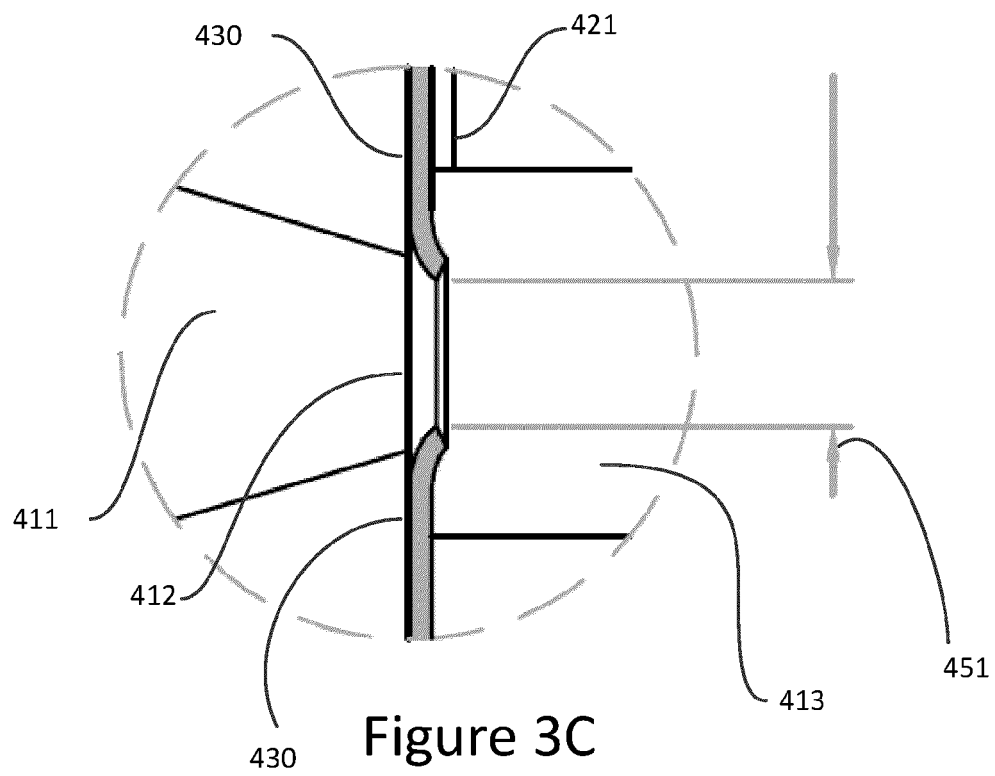
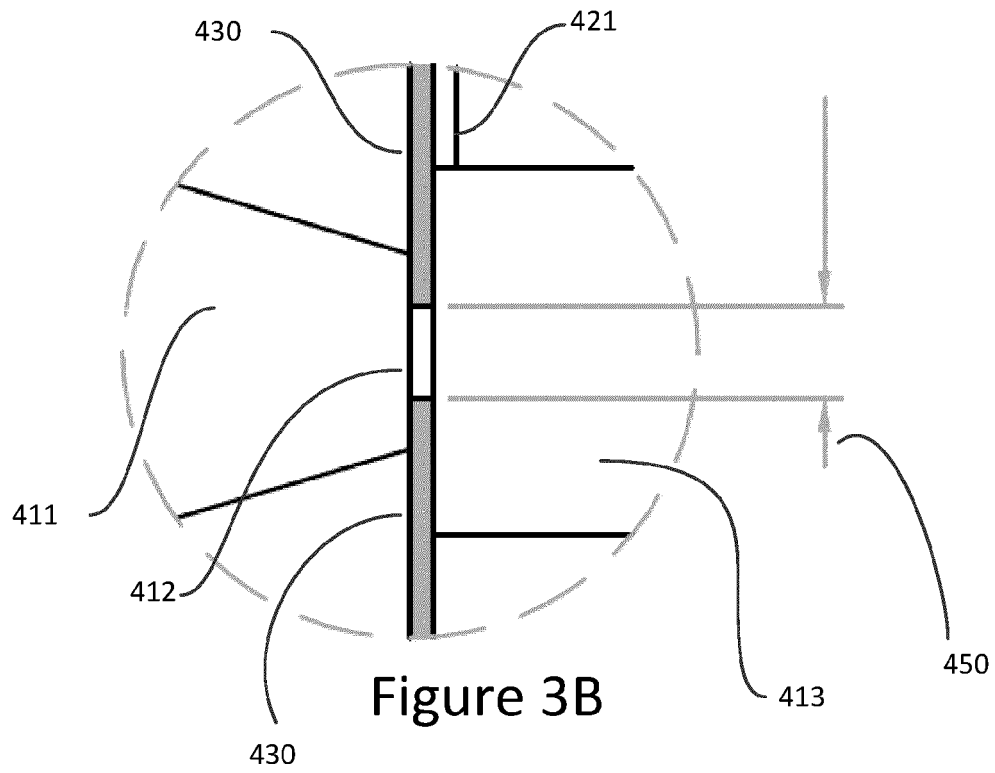


Figure 3A



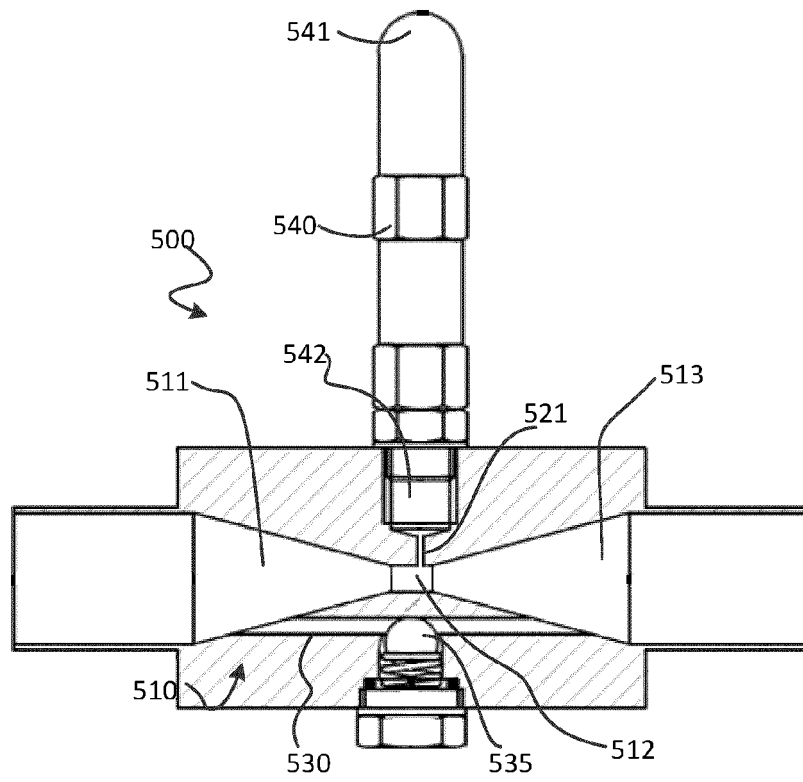


Figure 4A

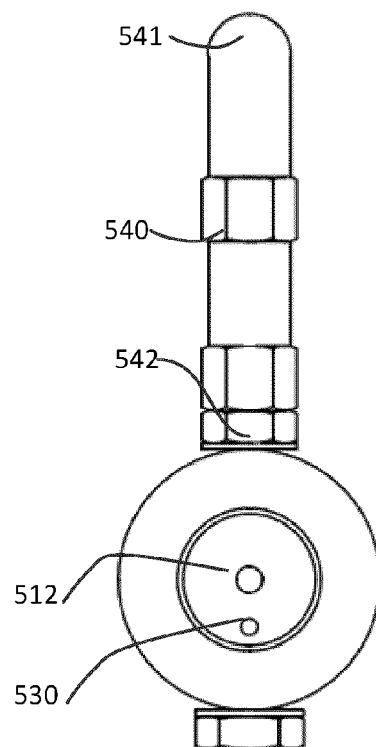


Figure 4B

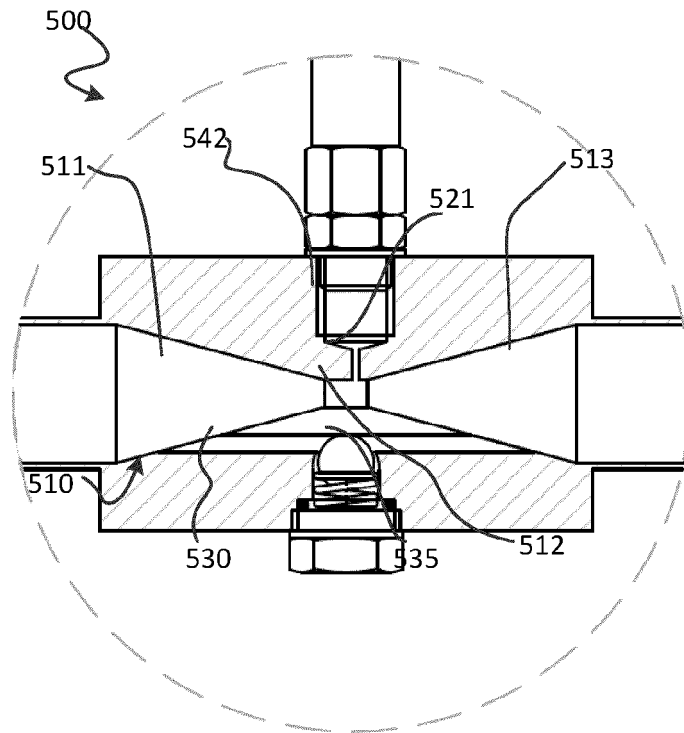


Figure 4C

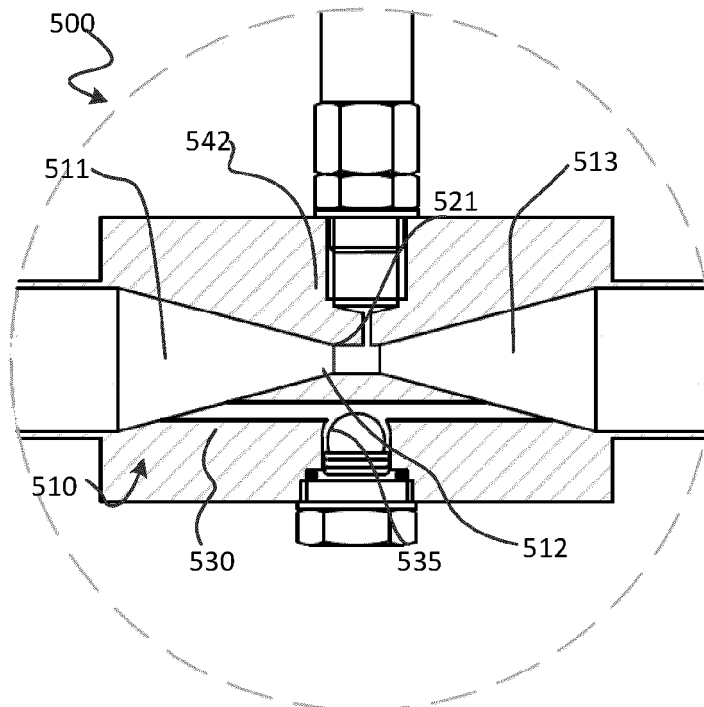


Figure 4D



PARTIAL EUROPEAN SEARCH REPORT

Application Number

under Rule 62a and/or 63 of the European Patent Convention.
This report shall be considered, for the purposes of
subsequent proceedings, as the European search report

EP 21 16 6350

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 103 307 748 A (WUHU MIDEA KITCHEN APPLIANCES MFG CO LTD) 18 September 2013 (2013-09-18) * abstract *; figures *	1-3, 12-14	INV. F04F5/04 F24D3/10 F04F5/44 F04F5/46 F04F5/54
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A	GB 2 413 623 A (FABDEC LTD [GB]) 2 November 2005 (2005-11-02) * abstract *; figures *	15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F04F F24H F24D

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

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Place of search	Date of completion of the search	Examiner
Munich	29 November 2021	Pinna, Stefano
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		

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**INCOMPLETE SEARCH
SHEET C**

Application Number
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Claim(s) completely searchable:
1-3, 12-15

Claim(s) not searched:
4-11

Reason for the limitation of the search:

Rule 62A

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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29-11-2021

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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