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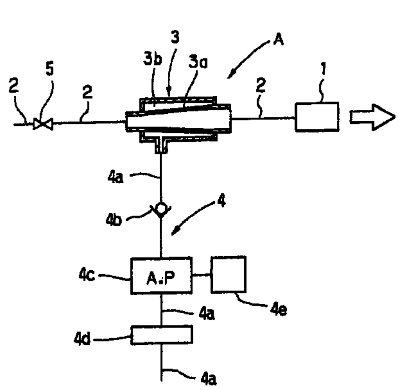
(54) **CLEANING WATER DISCHARGE APPARATUS**

(57) A wash water spouting apparatus has a wash water spouting device, a wash water supplying device for supplying the wash water spouting device with wash water and an air bubble mixing device for mixing air bubbles with the wash water passing through a wash water passage. The wash water spouting apparatus spouts a bubble flow wherein a large number of micro air bubbles are dispersed in the wash water.

Fig. 5



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Description

[TECHNICAL FIELD]

[0001] The present invention relates to a wash water spouting apparatus.

[BACKGROUND ART]

[0002] Japanese Patent Laid-Open Publications No.56-70338 and No.5-33377 disclose washing systems for regions of the human body such as the anus and private parts comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water and air bubble mixing means for mixing air bubbles with the wash water. In these washing systems, wash water containing air bubbles is spouted to increase detergency of the wash water or give a gentle stimulation to the user.

[0003] Japanese Patent Laid-Open Publications No. 10-18391 discloses a washing system for regions of the human body such as the anus and private parts wherein a large quantity of air is mixed with wash water to increase the speed of the wash water jet thereby achieving a large amount of water saving.

[0004] A wash water jet must actually contain a large number of air bubbles when it reaches a target surface in order to achieve high detergency and give a gentle stimulation to the user. However, the techniques disclosed in Japanese Patent Laid-Open Publications No. 56-70338 and No. 5-33377 do not ensure that a wash water jet actually contains a large number of air bubbles when it reaches the target surface.

[0005] A wash water must be reliably accelerated by the air bubbles mixed with the wash water in order to achieve a large amount of water saving. But, the technique disclosed in Japanese Patent Laid-Open Publication No. 10-18391 does not ensure that the wash water is reliably accelerated by the air bubbles mixed with the wash water. Thus, the technique disclosed in Japanese Patent Laid-Open Publication No.10-18391 does not ensure a large amount of water saving.

[DISCLOSURE OF INVENTION]

[0006] An object of the present invention is to provide a wash water spouting apparatus wherein a wash water jet actually contains a large number of air bubbles when it reaches a target surface and a large amount of water saving is achieved.

[0007] According to the present invention, there is provided a wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water and air bubble mixing means for mixing air bubbles with the wash water.

[0008] The inventors of the present invention conducted an extensive study and found that a wash water jet actually contains a large number of air bubbles when it reaches a target surface and wash water is reliably accelerated by air bubbles mixed with the wash water only if the flow regime of a gas-liquid two-phase flow passing through a wash water passage is optimized. The knowledge obtained by the inventors will be explained.

(1) Flow regime of a gas-liquid two-phase flow

[0009] The following phenomena are observed in a gas-liquid two-phase flow passing through a wash water passage.

① When a large quantity of air is simply mixed with wash water passing through a wash water passage, the flow regime of a gas-liquid two-phase flow passing through the wash water passage is liable to become a slug flow wherein columnar air layers and columnar liquid layers are alternately laminated as shown in Figure 1(b), or a froth flow wherein air layers and liquid layers in a slug flow get deformed as shown in Figure 1(c), or a cylindrical mist flow wherein columnar air layers containing mist of water are surrounded by cylindrical wash water layers as shown in Figure 1(d).

When a slug flow, a froth flow or a cylindrical mist flow spouts from a nozzle, columnar air layers, deformed columnar air layers or columnar air layers containing mist of water immediately disperse in the air. Thus, wash water striking against a target surface contains only a small number of air bubbles so that its detergency is low and it can not give a gentle stimulation to the user.

In a slug flow, a froth flow or a cylindrical mist flow, substantially a single columnar air layer continuously extends to the outlet of the wash water passage. Therefore, most of the air mixed with the wash water passes through the columnar air layer and spouts from the outlet of the wash water passage without mixing with the wash water. Thus, even if a large quantity of air is mixed with the wash water, the air only passes through the columnar air layer at high speed, the wash water cannot be accelerated by a large amount, and wash water cannot be saved by a large amount.

② When a large number of micro air bubbles are mixed with and dispersed in wash water, the flow regime of a gas-liquid two-phase flow passing through the wash water passage becomes a bubble flow wherein a large number of micro air bubbles disperse in the wash water as shown in Figure 1(a).

[0010] When a bubble flow spouts from a nozzle, air bubbles dispersed in the wash water do not disperse in the air. Thus, a large number of air bubbles remain in the wash water striking against a target surface to increase the detergency of the wash water and give a gentle stimulation to the user.

[0011] In a bubble flow, the air mixed with wash water disperses in the wash water to move integrally with the wash water. Thus, the flow rate of the fluid passing through the wash water passage increases by an amount of the flow rate of the air mixed with the wash water and the wash water is accelerated. Thus, if the flow regime of a gas-liquid two-phase flow passing through the wash water passage is a bubble flow, it is possible to mix a large quantity of air with the wash water to accelerate the wash water by a large amount thereby saving the wash water by a large amount.

(2) Detergency of a jet of a bubble flow

[0012] Detergency of a jet of a bubble flow will be theoretically discussed.

[0013] The average value Ps of the pressure generated on a target surface when a jet of wash water strikes against the target surface is expressed by formula 1.

$$Ps = \Delta W / S_S = \rho(S_1 / S_S)V_1^2 \qquad 1$$

[0014] In the above formula, ΔW is change in the momentum of the wash water jet when the jet strikes against the target surface. ρ is the density of the wash water. As shown in Figure 2, S_1 is the cross sectional area of the wash water jet, S_S is the area of the target surface, and V_1 is the flow velocity of the wash water jet.

[0015] In formula 1, (S_1 / S_S) can be considered to be substantially constant so far as factors such as the kind of wash water, the temperature of the wash water, S_1, etc. do not change extremely. Thus, formula 1 can be rewritten as formula 2.

$$Ps = \rho(S_1 / S_8)V_1^2 \fallingdotseq C\rho V_1^2 \qquad 2$$

[0016] In the above formula, $C = S_1 / S_S$, and C is substantially a constant value.

[0017] When the wash water jet is a bubble flow jet, the density of the wash water ρ is expressed by formula 3.

$$\rho = (\rho_G Q_G + \rho_L Q_L) / (Q_G + Q_L) = (\rho_G \eta + \rho_L) / (1 + \eta) \fallingdotseq \rho_L / (1 + \eta) \qquad 3$$

[0018] In the above formula, ρ_G is the density of the gas forming the air bubbles, ρ_L is the density of the wash water without air bubbles, Q_G is the volume flow rate of the gas forming the air bubbles, Q_L is the volume flow rate of the wash water without air bubbles, and η is Q_G / Q_L . η is gas-liquid ratio. Gas-liquid ratio means the ratio of the volume flow rate of the gas forming the air bubbles to the volume flow rate of the wash water without air bubbles. In the above formula, $\rho_G \ll \rho_L$. When spherical air bubbles of the same diameter are packed in the wash water to form the most closely packed cubic lattice, the theoretical maximum of the gas-liquid ratio η is about 2.85 : 1. If the shape of the air bubbles is polyhedron, the gas-liquid ratio η becomes still larger because polyhedron-shaped air bubbles can be packed more closely than spherical air bubbles. However, when the gas-liquid ratio becomes too large, air bubbles are liable to merge with one another and become too large to remain in the wash water jet. The gas-liquid ratio η should therefore not become too large. Considering the above, $\rho_G \eta$ in the second formula of the above formulae seems to be negligible relative to ρ_L . Thus, the third formula 3 is derived from the second formula of the above formulae.

[0019] The average pressure Ps generated when a bubble flow jet strikes against a target surface can be derived from the formulae 2 and 3.

[0020] Formula 3 is substituted into formula 2.

$$Ps = C \rho V_1^2 \fallingdotseq C \rho_L V_1^2 / (1 + \eta) \qquad 2$$

[0021] The following formula is substituted into the above formula.

$$V_1 = (Q_G + Q_L)/S_1 = (\eta Q_L + Q_L) / S_1 = (\eta + 1)Q_L / S_1 \qquad 4$$

[0022] Then,

$$Ps \fallingdotseq C \rho_L V_1^2 / (1 + \eta) \fallingdotseq C \rho_L (1 + \eta)(Q L / S_1)^2 \qquad 5$$

[0023] It can be seen from formula 5 that, if the volume flow rate Q_L of the wash water without air bubbles is constant, the average pressure Ps generated on the target surface when the bubble flow jet strikes against the target surface increases and the detergency of the bubble flow jet increases as the gas-liquid ratio η increases or the volume of the air mixed with the wash water increases.

[0024] ζ = Ps(η)/Ps(η =0) obtained from formula 5 on condition that Q_L is constant is shown in Figure 3. The correlation between ζ and η obtained by measurements carried out using city water on condition that Q_L is constant is also shown in Figure 3. It can be seen from Figure 3 that the correlation between ζ and η derived from formula 5 and the correlation between ζ and η obtained by the measurements are in good agreement. As is clear from Figure 3, the measurements confirm that the detergency of the bubble flow jet increases as the gas-liquid ratio increases.

[0025] It can be seen from Figure 3 that, if Ps is kept constant, the volume flow rate Q_L of the wash water without air bubbles can be decreased or the wash water can be saved by increasing the gas-liquid ratio η . As can be seen from Figure 3, flow velocity V_1 of the wash water jet increases as the gas-liquid ratio η increases or the volume of the air mixed with the wash water increases. Therefore, even if the flow rate Q_L of the wash water without air bubbles decreases, the momentum of wash water jet remains constant, the change of the momentum of the wash water jet when the jet strikes against the target surface remains constant, and Ps remains constant.

[0026] $\phi = Q_L(\eta)/Q_L(\eta = 0)$ obtained from formula 5 on condition that Ps is constant is shown in Figure 4. The correlation between ϕ and η obtained by measurements carried out using city water on condition that Ps is constant is also shown in Figure 4. It can be seen from Figure 4 that the correlation between ϕ and η derived from formula 5 and the correlation between ϕ and η obtained by the measurements are in good agreement. As is clear from Figure 4, the measurements confirm that, when Ps is kept constant, Q_L of the wash water without air bubbles can be decreased by increasing the gas-liquid ratio η.

[0027] The present invention is based on the above knowledge. In the present invention, the flow regime of a gas-liquid two-phase flow passing through the wash water passage is made a bubble flow to make a wash water jet containing a large number of air bubbles strike against the target surface thereby saving the wash water by a large amount.

[0028] According to the present invention, there is provided a wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water, air bubble mixing means for generating a large number of micro air bubbles, while preventing merging of the air bubbles, and mixing the air bubbles with and dispersing the air bubbles in the wash water flowing in a wash water passage.

[0029] According to the present invention, there is provided a wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed substantially uniformly in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water, air bubble mixing means for generating a large number of micro air bubbles, while preventing merging of the air bubbles, and mixing the air bubbles with and dispersing the air bubbles substantially uniformly in the wash water flowing in a wash water passage.

[0030] A large number of micro air bubbles must be mixed with wash water passing through a wash water passage in order to make the flow regime of a gas-liquid two-phase flow passing through the wash water passage a bubble flow. A large number of micro air bubbles must be generated in order to mix a large number of micro air bubbles with the wash water passing through the wash water passage. If a large number of micro air bubbles are generated in a limited region, the micro air bubbles merge with one another when they are generated and become large air bubbles. Thus, large air bubbles are mixed with the wash water. Large air bubbles are liable to merge with one another because their rigidity is low and they are easily deformed and cause the flow regime of a gas-liquid two-phase flow to become a slug flow , a froth flow or a cylindrical mist flow. Accordingly, micro air bubbles must be prevented from merging when they are generated in order to obtain a bubble flow wherein a large number of micro air bubbles are dispersed in wash water. Moreover, the generated micro air bubbles must be mixed with and dispersed in, more preferably dispersed substantially uniformly in, the wash water passing through a wash water passage. If the air bubbles are dispersed in the wash water, more preferably dispersed substantially uniformly in the wash water, the air bubbles are prevented from merging and generation of a slug flow, a froth flow or a cylindrical mist flow is prevented.

[0031] According to the present invention, there is provided a wash water spouting apparatus comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water, air bubble mixing means for generating a large number of micro air bubbles and mixing the air bubbles with the wash water flowing in a wash water passage, wherein the relation between E_w and E_t is $E_w < E_t$, where E_w is the energy of the wash water passing through the part of the wash water passage just upstream of the air mixing means and E_t is the energy of the wash water passing through the part of the wash water passage just downstream of the air mixing means.

[0032] When a large number of micro air bubbles are generated and simultaneously mixed with and dispersed in wash water passing through a wash water passage, the wash water is accelerated just after the mixing of the air bubbles and the energy of the wash water is increased. That is, if a large number of micro air bubbles are generated and mixed with and dispersed in the wash water simultaneously, the mixed micro air bubbles perform as an air bubble pump. Thus, the relation between E_w and E_t becomes $E_w < E_t$.

[0033] According to the present invention, there is provided a wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water, air bubble mixing means for mixing air bubbles with the wash water flowing in a wash water passage and air bubble breaking means for breaking air bubbles mixed with the wash water into micro air bubbles.

[0034] The effect of making a gas-liquid two-phase flow into a bubble flow and thereby enabling spouting of a bubble flow can also be achieved by breaking air bubbles mixed with wash water into micro air bubbles instead of by mixing micro air bubbles with the wash water.

[0035] According to a preferred embodiment of the present invention, the spouting apparatus further comprises forced air supplying means for force supplying the air mixing means with air.

[0036] If the air mixing means is force supplied with air, a large number of air bubbles can be mixed with the wash water.

[0037] According to a preferred embodiment of the present invention, the mean diameter of the air bubbles mixed with the wash water is 100 μm to 1000 μm.

[0038] Because of their high rigidity, micro air bubbles of 100 μm to 100 μm mean diameter do not merge with one another easily . Thus, a stable bubble flow can be obtained by mixing micro air bubbles of 100μm to 1000μm mean diameter with the wash water.

[0039] The wash water spouting apparatus in accordance with the present invention can be incorporated in a washing system for regions of the human body such as the anus and private parts. In such case, the mean diameter of the air bubbles in a bubble flow is preferably less than or equal to 1000μm because the bubble flow must be passed without difficulty through pipes or nozzles of sizes suitable for the washing system. On the other hand, generation of extremely fine micro air bubbles is technologically difficult. Considering these facts, the mean diameter of the air bubbles dispersed in the bubble flow spouted from the wash water spouting apparatus incorporated in a washing system is preferably 100 μm to 1000 μm.

[0040] According to a preferred embodiment of the present invention, the ratio of the volume flow rate of the air mixed with the wash water to the volume flow rate of the wash water is 0.5 : 1 to 4.0 : 1.

[0041] Forced supply of air to the air bubble mixing means will now be considered. When spherical air bubbles of the same diameter are packed in the wash water to form the most closely packed cubic lattice, the theoretical maximum of the gas-liquid ratio is about 2.85 : 1. If the shape of the air bubbles is polyhedron, the gas-liquid ratio becomes still larger because polyhedron-shaped air bubbles can be paeked more closely than spherical air bubbles. However, when the gas-liquid ratio becomes too large, air bubbles are liable to merge with one another to make the flow regime of the gas-liquid two-phase flow a slug flow, a froth flow or a cylindrical mist flow. On the other hand, when the gas-liquid ratio is too small, detergency of the jet flow cannot be increased. Considering the above, the ratio of the volume flow rate of the air mixed with the wash water to the volume flow rate of the wash water is preferably between 0.5 and 4.0.

[0042] According to a preferred embodiment of the present invention, the sectional area of the wash water passage at the air bubble mixing means and downstream of the air bubble mixing means is set larger than the projected area of a sphere of a diameter equal to the mean diameter of the mixed air bubbles and the sectional area of the wash water passage downstream of the air bubble mixing means is set larger than or equal to that at the air bubble mixing means.

[0043] The inventors conducted an extensive study and found that the wash water passage should satisfy the following conditions in order to spout the wash water and cause it to strike against the target surface while maintaining a large number of micro air bubbles dispersed in the wash water.

> ① The sectional area of the wash water passage at the air bubble mixing means and downstream of the air bubble mixing means should be larger than the projected area of a sphere of a diameter equal to the mean diameter of the mixed air bubbles.
>
> If the sectional area of the wash water passage at the air bubble mixing means and downstream of the air bubble mixing means is smaller than or equal to the projected area of a sphere of a diameter equal to the mean diameter of the mixed air bubbles, the flow regime of a gas-liquid two-phase flow passing through the wash water passage becomes a slug flow or a froth flow. On the other hand, if the sectional area of the wash water passage at the air bubble mixing means and downstream of the air bubble mixing means is larger than the projected area of a sphere of a diameter equal to the mean diameter of the mixed air bubbles, the flow regime of the gas-liquid two-phase flow passing through the wash water passage becomes a bubble flow.
>
> ② The sectional area of the wash water passage downstream of the air bubble mixing means should be larger than or equal to that at the air bubble mixing means.

[0044] If the sectional area of the wash water passage becomes smaller than that at the air bubble mixing means at a point downstream of the air bubble mixing means, the flow regime of the gas-liquid two-phase flow passing through the the part of the wash water passage downstream of the point becomes a cylindrical mist flow. It is thought that the air bubbles dispersed in the wash water gather about the center of the flow at the point where the sectional area of the wash water passage becomes smaller than that at the air bubble mixing means, so that a large number of air bubbles merge with one another to form a columnar air layer about the center of the flow. If the sectional area of the wash water passage downstream of the air bubble mixing means is set larger than or equal to that at the air bubble mixing means, the flow regime of the gas-liquid two-phase flow passing through the wash water passage is maintained as a bubble flow.

[0045] According to a preferred embodiment of the present invention, the wash water passage downstream of the air bubble mixing means extends substantially straight.

[0046] If the wash water passage downstream of the air bubble mixing is curved, centrifugal force acting on the micro air bubbles dispersed in the wash water is liable to merge them with one another when the bubble flow passes through the curved portion. Thus, the bubble flow is liable to become a slug flow or a froth flow. If the wash water passage downstream of the air bubble mixing means extends substantially straight, merging of the micro air bubbles by centrifugal force is prevented and the bubble flow is maintained.

[0047] According to a preferred embodiment of the present invention, the air bubble mixing means is disposed in the wash water spouting means.

[0048] According to a preferred embodiment of the present invention, the air bubble mixing means is disposed in the wash water spouting means and in the vicinity of the outlet port of the wash water spouting means.

[0049] If the air bubble mixing means is disposed in the wash water spouting means, preferably in the vicinity of the outlet port of the wash water spouting means, the residence time of the bubble flow in the wash water passage decreases, the probability of merging of the micro air bubbles decreases, and the probability of the maintenance of the bubble flow increases.

[0050] According to a preferred embodiment of the present invention, the air bubble mixing means is disposed in the wash water spouting means and in the vicinity of the outlet port of the wash water spouting means, and the part of the wash water spouting means in the vicinity of the outlet port is detachably connected to the remaining part of the wash water spouting means.

[0051] When the air bubble mixing means is disposed in the wash water spouting means and in the vicinity of the outlet port of the wash water spouting means, maintenance of the air bubble mixing means becomes easy if the part of the wash water spouting means in the vicinity of the outlet port is detachably connected to the remaining part of the wash water spouting means.

[0052] According to a preferred embodiment of the present invention, the air bubble mixing means has an air bubble generating member provided with a large number of independent pores at its surface contacting the wash water passing through the wash water passage.

[0053] An independent air bubble is generated at each of the large number of independent pores formed in the surface of the air bubble generating member contacting the wash water. If the large number of pores are continuous pores made of a plurality of pores connected to one another, a plurality of air bubbles are liable to be generated at each of the continuous pores. These air bubbles generated at each of the continuous pores are liable to merge to form large air bubbles. If the large number of pores formed in the surface of the bubble generating member contacting the wash water are independent pores, merging of the air bubbles at the stage of the generation of the air bubbles is prevented and the formation of large air bubbles is prevented. The independent bubble generated at each of a large number of independent pores grows to a certain size, leaves the independent pore entrained by the wash water passing through the wash water passage, and is dispersed in the wash water. A large number of micro air bubbles are generated at a large number of independent pores formed in the surface spreading over a certain area and released into the wash water. Thus, the micro air bubbles are mixed with and dispersed in the wash water. As a result, a bubble flow is reliably generated.

[0054] According to a preferred embodiment of the present invention, the independent pores are disposed regularly and in a lattice.

[0055] If the independent pores are disposed regularly and in a lattice, the density of the pores can be increased and the size of the air bubble mixing means reduced. Moreover, the space between the air bubbles can be kept constant and merging of the air bubbles at the stage of the generation of the air bubbles can be prevented.

[0056] According to a preferred embodiment of the present invention, the air mixing means has an air bubble generating member of mesh construction at its surface contacting the wash water passing through the wash water passage.

[0057] If the air bubble generating member is of mesh construction at its surface contacting the wash water passing through the wash water passage, the mesh construction forms independent pores. The mesh construction can be achieved easily by stacking or weaving fibers. The shape of the pores and the space between the pores can be adjusted easily by selecting the diameter of the fibers, the space between the fibers or the orientation of the fibers.

[0058] According to a preferred embodiment of the present invention, the air bubble generating member is made of an aggregate of substantially spherical particles.

[0059] Substantially spherical particles can be packed close to make the shape of the pores uniform. Thus, the generation of continuous pores made of a plurality of pores connected to one another is suppressed and the generation of independent pores is promoted.

[0060] According to a preferred embodiment of the present invention, the mean diameter of the substantially spherical particles forming the aggregate is 50 μm to 300 μm.

[0061] According to a preferred embodiment of the present invention, the space between the substantially spherical particles forming the aggregate is 50 µm to 300 µm.

[0062] When substantially spherical particles of 50 µm to 300 µm mean diameter are packed to form the most closely packed cubic lattice, the mean diameter of the independent pores formed by the spaces between the particles becomes 50 µm to 300µm. The mean diameter of the air bubbles generated by the independent pores of 50 µm to 300 µm mean diameter is 100 µm to 1000 µm.

[0063] According to a preferred embodiment of the present invention, the filling factor of the substantially spherical particles forming the aggregate is larger than or equal to 70 %.

[0064] When spherical particles of the same diameter are packed to form the most closely packed cubic lattice, the theoretical maximum of the filling factor is 74%. It is hard to pack spherical particles to form the most closely packed cubic lattice because of the generation of static electricity, etc. However, the filling factor of the substantially spherical particles forming the aggregate is preferably larger than or equal to 70% in order to obtain independent pores.

[0065] According to a preferred embodiment of the present invention, the air bubble generating member is made of a hot formed compact of heat fusible powder.

[0066] When heat fusible powder is hot formed, abutting surfaces between the adjacent particles are fused and bonded, thereby forming independent pores. A hot formed compact of heat fusible powder can endure the water pressure and the air pressure when it is used.

[0067] According to a preferred embodiment of the present invention, the surface of the air bubble generating member contacting the wash water extends flush with the inner surface of the wash water passage.

[0068] When the surface of the air bubble generating member contacting the wash water extends flush with the inner surface of the wash water passage, turbulence or stagnation is not generated in the wash water by the air bubble generating member. Thus, the probability of merging of the air bubbles by turbulence in the wash water or by increase of the residence time of the air bubbles caused by stagnation in the wash water is reduced.

[0069] According to a preferred embodiment of the present invention, the air bubble generating member is a cylindrical porous member forming the wash water passage.

[0070] It is possible to mix a large number of air bubbles with the wash water passing through the wash water passage by supplying the cylindrical porous member forming the wash water passage with air.

[0071] According to a preferred embodiment of the present invention, an air passage is formed around the cylindrical porous member.

[0072] When an air passage is formed around the cylindrical porous member, a large number of air bubbles can be mixed easily with the wash water passing through the wash water passage through the cylindrical porous member.

[0073] According to a preferred embodiment of the present invention, the sectional area of the wash water passage in the cylindrical porous member is constant or gradually increases from the upstream end toward the downstream end.

[0074] It is possible to prevent the two-phase flow passing through the wash water passage in the cylindrical porous member from becoming a cylindrical mist flow if the sectional area of the wash water passage in the cylindrical porous member is constant or gradually increases from the upstream end toward the downstream end.

[0075] According to a preferred embodiment of the present invention, the cylindrical porous member is fixed to the wash water spouting means by press fitting.

[0076] If the cylindrical porous member is fixed to the wash water spouting means by press fitting, the air is prevented from mixing with the wash water through a gap formed at the fixed part. Thus, large air bubbles are prevented from mixing with the wash water unexpectedly.

[0077] According to a preferred embodiment of the present invention, the inner diameter of the cylindrical porous member is made larger at the press fitting part than at the remaining part.

[0078] If the inner diameter of the cylindrical porous member is made larger at the press fitting part than at the other part, the inner diameter of the press fitting part becomes equal to that of the remaining part after the press fitting. Thus, the generation of turbulence in the wash water is prevented.

[0079] According to a preferred embodiment of the present invention, the cylindrical porous member is press fitted at both ends. The inner diameter of the cylindrical porous member is made larger at one of the press fitting parts than at the remaining part.

[0080] If the cylindrical porous member is press fitted at both ends, it can be firmly fixed to the wash water spouting means. The cylindrical porous member is generally made by powder molding. If the inner diameter of the cylindrical porous member is larger at both ends than at the other part, burrs are formed at one end of the cylindrical porous member because of the arrangement of the molds. Therefore, it is preferable to make the inner diameter of the cylindrical porous member larger at its one end than at the remaining part.

[0081] According to a preferred embodiment of the present invention, all or part of the air bubble generating member is made of water repellent material, or a water repellent finish is applied to the surface of the wash water passage in the air bubble generating member.

[0082] When city water is used as the wash water, calcium ions often contained in the city water in large quantities are liable to deposit to form calcium carbonate, etc. in the pores of the air bubble generating member, whereby the performance of the air bubble generating member is liable to be degraded by clogging of the pores. Moreover, the performance of the air bubble generating member is liable to be degraded by osmotic pressure caused by capillarity in the pores. If the air bubble generating member is made of water repellent material such as PTFE, ETEF, etc., in whole or in part, or a water repellent finish using paraffin, carnauba wax, etc. is applied to the surface of the wash water passage in the air bubble generating member, the entry of the water into the pores can be prevented and osmotic pressure caused by the capillarity in the pores can be decreased. Thus, deterioration of the air bubble generating member and decrease in the performance of the air bubble generating member can be prevented.

[0083] According to a preferred embodiment of the present invention, all or part of the air bubble generating member is made of hydrophilic material, or a hydrophilic finish is applied to the surface of the wash water passage in the air bubble generating member.

[0084] Wettability of the surface of the air bubble generating member affects the size of the air bubbles. When the air bubble generating member is not wettable (water repellent), the air discharged from the pores is liable to reside on the surface of the air bubble generating member, whereby the diameter of the air bubbles is liable to become large. When the air bubble generating member is wettable (hydrophilic), the air discharged from the pores is unlikely to reside on the surface of the air bubble generating member and, therefore, the diameter of the air bubbles is unlikely to become large. If the air bubble generating member is made of hydrophilic material such as HDPE, LDPE, PP, PA, PET, MMA, glass, polyolefine, cellulose, etc., in whole or in part, or the surface of the wash water passage in the air bubble generating member is subjected to hydrophilic finish with acrylic acid, plasma surface treatment, chromic acid surface treatment, silica coating, etc., the size of the air bubbles decreases and the generation of slug flow or froth flow is prevented.

[0085] According to a preferred embodiment of the present invention, the surface of the wash water passage in the air bubble generating member is coated with a surface finishing agent preventing the deposit of calcium.

[0086] If the surface of the wash water passage in the air bubble generating member is coated with a surface finishing agent preventing the deposit of calcium, pores in the surface of the wash water passage in the air bubble generating member are prevented from clogging and the air bubble generating member is protected from performance degradation.

[0087] According to a preferred embodiment of the present invention, the surface finishing agent contains siloxane linkage.

[0088] If the surface finishing agent contains siloxane linkage, deposition of calcium on the surface of the wash water passage in the air bubble generating member made of acrylic material or polyethylene material is effectively prevented.

[0089] According to a preferred embodiment of the present invention, the surface finishing agent contains acrylic agent and silicon agent.

[0090] If the surface finishing agent contains acrylic agent and silicon agent, deposition of calcium on the surface of the wash water passage in the air bubble generating member made of acrylic material or polyethylene material is effectively prevented.

[0091] According to a preferred embodiment of the present invention, the air bubble generating member is made of porous polyethylene material and the surface finishing agent contains alkylpolysiloxane.

[0092] If the surface finishing agent contains alkylpolysiloxane, deposition of calcium on the surface of the wash water passage in the air bubble generating member made of porous polyethylene material is effectively prevented.

[0093] According to a preferred embodiment of the present invention, the air bubble generating member is made of porous acrylic material and the surface finishing agent contains cold setting glass.

[0094] If the surface finishing agent contains cold setting glass, deposition of calcium on the surface of the wash water passage in the air bubble generating member made of porous acrylic material is effectively prevented.

[0095] According to a preferred embodiment of the present invention, the wash water spouting apparatus further comprises solute concentration controlling means for solving a solute in the wash water to a predetermined concentration.

[0096] It is preferable to solve a solute such as chemicals, surface active agent, etc. in the wash water to a predetermined concentration. If the flow rate of the wash water is kept at a predetermined value, the control of the solution of the solute in the wash water becomes easy.

[0097] According to a preferred embodiment of the present invention, the wash water spouting apparatus further comprises wash water supply controlling means for intermittently stopping the supply of the wash water to the wash water passage when the forced air supplying means operates.

[0098] If the supply of the wash water to the wash water passage is intermittently stopped when the forced air supplying means operates, deposition of calcium on the surface of the wash water passage in the air bubble generating member is effectively suppressed.

[0099] According to a preferred embodiment of the present invention, the water supplying means comprises a wash water storage tank, the forced air supplying means force supplies the air to the air bubble mixing means and the wash water storage tank to pressurize the wash water thereby discharging the wash water from the wash water storage tank.

[0100] If the wash water spouting apparatus has a wash water storage tank, the apparatus can be incorporated in various kinds of portable washing devices. When the forced air supplying means is used for force feeding of the wash water as well as force feeding of the air, the number of the components decreases and the manufacturing cost of the wash water spouting apparatus decreases compared with the case of providing wash water force feeding means separately. If the air bubbles are mixed with flowing wash water, a large number of micro air bubbles can be mixed with the wash water and the washing effect of the wash water can be increased.

[0101] According to a preferred embodiment of the present invention, the pipe connecting the forced air supplying means with the wash water storage tank and/or the pipe connecting the forced air supplying means with the air bubble mixing means are provided with pressure control valves.

[0102] If the pipe connecting the forced air supplying means with the wash water storage tank and/or the pipe connecting the forced air supplying means with the air bubble mixing means are provided with pressure control valves, flow rate of-the air bubbles mixed with the wash water can be controlled.

[0103] According to a preferred embodiment of the present invention, the size, weight and electric power consumption of the wash water spouting apparatus are determined to be convenient for portable use.

[0104] If the size, weight and electric power consumption of the wash water spouting apparatus are determined to be convenient for portable use, various kinds of washing devices having the wash water spouting apparatus can be made portable.

[0105] According to the present invention, there is provided a washing system for regions of the human body such as the anus and private parts comprising one of the wash water spouting apparatus described above.

[0106] In the present washing system for the human body, a bubble flow is spouted to achieve high detergency and large amount of water saving.

[0107] According to a preferred embodiment of the present invention, the wash water spouting apparatus of the washing system for the human body comprises forced air supplying means for force supplying air to the air bubble generating means and the washing system for the human body further comprises a controller for driving the wash water supplying means and the forced air supplying means for a predetermined period of time.

[0108] If the wash water supplying means and the forced air supplying means are driven for a predetermined period of time, the washing system for the human body is automatically maintained and the function of the washing system for the human body can be maintained for a long time.

[0109] According to a preferred embodiment of the present invention, the air bubble mixing means in the wash water spouting apparatus of the washing system for the human body has an air bubble generating member wherein a large number of independent pores are formed in the surface contacting the wash water passing through a wash water passage, the air bubble generating member is made of a porous cylindrical body forming the wash water passage, the porous cylindrical body is disposed in the wash water spouting means and in the vicinity of the outlet port of the wash water spouting means, and the downstream end of the porous cylindrical body is directed upward.

[0110] If the porous cylindrical body is disposed in the wash water spouting means and in the vicinity of the outlet port of the wash water spouting means, and the downstream end of the porous cylindrical body is directed upward, the wash water passage downstream of the porous cylindrical body can extend substantially straight to prevent merging of the air bubbles.

[0111] According to a preferred embodiment of the present invention, the washing system for the human body further comprises volatile constituent mixing means for mixing a volatile constituent with the air to be supplied to the air mixing means.

[0112] If a volatile constituent such as odor removing agent, aromatic agent, etc. is mixed with the air to be mixed with the wash water, the washing system for the human body becomes even more convenient.

[0113] According to a preferred embodiment of the present invention, the wash water spouting means of the wash water spouting apparatus in the washing system for the human body has a plurality of outlet ports and the bubble flow is selectively fed to one of the plurality of outlet ports through a passage selection means.

[0114] If the bubble flow is red to one of the plurality of outlet ports through a passage selection means to be discharged according to the regions to be washed, the washing system for the human body becomes even more convenient.

[0115] According to the present invention, there is provided a showering apparatus, a hair washing apparatus, a face washing apparatus, an eye washing apparatus, a palate washing apparatus, a hand washing apparatus, a water faucet apparatus and a bath tub comprising one of the wash water spouting apparatuses as described above.

[0116] If one of the wash water spouting apparatuses as described above is incorporated in a showering apparatus, a hair washing apparatus, a face washing apparatus, an eye washing apparatus, a palate washing apparatus, a hand washing apparatus, a water faucet apparatus or a bath tub, the detergency of the apparatus increases and wash water is saved.

[0117] According to the present invention, there is provided an ultrasonic washing apparatus comprising one of the wash water spouting apparatuses as described above.

[0118] When the bubble flow spouting from the wash water spouting apparatus in accordance with the present invention strikes against a target surface, an ultrasonic vibration is generated on the target surface because of the difference between the kinetic energy of the air in the air bubbles and the kinetic energy of wash water between the adjacent air bubbles. Thus, the detergency of the wash water increases.

[0119] According to the present invention, there is provided a hot-water supplying apparatus comprising one of the wash water spouting apparatuses as described above.

[0120] If one of the wash water spouting apparatuses as described above is incorporated in a hot-water supplying apparatus, the hot water is saved, the size of the heating apparatus in the hot-water supplying apparatus is reduced, the size of the hot-water supplying apparatus is reduced, and energy is saved.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0121] In the drawings:

Figures 1(a) to 1(d) are schematic views of the flow regime of a gas-liquid two-phase flow. Figure 1(a) shows a bubble flow, Figure 1(b) shows a slug flow, Figure 1(c) shows a froth flow and Figure 1(d) shows a cylindrical mist flow.

Figure 2 is a plan view of a jet flow striking against a target surface.

Figure 3 is a diagram showing the relation between the generated pressure and the gas-liquid ratio when a bubble flow strikes against a target surface.

Figure 4 is a diagram showing the relation between the flow rate of the wash water and the gas-liquid ratio under a condition that the pressure generated when a bubble flow strikes against a target surface is kept constant.

Figure 5 is a layout diagram of a wash water spouting apparatus in accordance with a first embodiment of the present invention.

Figure 6 is a side view of a bubble flow spouting from a nozzle.

Figure 7 is an electron microscope enlarged view of the surface of a hot formed compact of substantially spherical particles of ultrahigh molecular weight polyethylene.

Figure 8 is an electron microscope enlarged view of the surface of a hot formed compact of acrylic resin.

Figure 9 is a layout diagram of a wash water spouting apparatus in accordance with a second embodiment of the present invention.

Figures 10(a) to 10(c) are schematic sectional views of an example of an automatic cleaning apparatus for the internal surface of a bubble generating member. Figure 10(a) is a general view, and Figures 10(b) and 10(c) are enlarged views of the part in Figure 10(a) surrounded by a broken line.

Figure 11 is a layout diagram of a washing system for regions of the human body such as the anus and private parts comprising a wash water spouting apparatus in accordance with a third embodiment of the present invention.

Figure 12 is a plan view of a discharging nozzle of a wash water spouting apparatus in accordance with a third embodiment of the present invention.

Figure 13 is a sectional view of Figure 12 along line A-A' .

Figure 14 is a diagram showing the relation between the diameter of just generated air bubbles and the flow velocity or water.

Figure 15 is a diagram showing the relation between the degree of the growth of air bubbles and the residence time of the air bubbles.

Figure 16 is a sectional view of a discharging nozzle of a wash water spouting apparatus in accordance with a fourth embodiment of the present invention.

Figure 17 is a sectional view of a passage selecting apparatus of a wash water spouting apparatus in accordance with the fourth embodiment of the present invention.

Figures 18 is a diagram showing the relation between the mixing rate of air and the amplification factor of energy and the relation between the mixing rate of air and the combined efficiency.

Figure 19 is a schematic view of a variation of the air bubble generating member.

Figure 20 is a table showing the result of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 21 is a layout diagram of the test equipment used in the confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 22 is a diagram showing the results of confirmation tests of the suppression effect of flow program against calcium carbonate deposition.

Figure 23 is a diagram showing the results of confirmation tests of the suppression effect of flow program against calcium carbonate deposition.

Figure 24 is a diagram showing the results of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 25 is a diagram showing the results of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 26 is a diagram showing the results of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 27 is a diagram showing the results of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 28 is a diagram showing the results of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 29 is a diagram showing the results of confirmation tests of the suppression effect of surface finishing agents against calcium carbonate deposition.

Figure 30 is a layout diagram of a hot-water supplying apparatus comprising a wash water spouting apparatus in accordance with the first embodiment of the present invention.

Figure 31(a) is a layout diagram of a showering apparatus comprising a wash water spouting apparatus in accordance with the first embodiment of the present invention and Figure 31(b) is a sectional view of the air bubble generating member.

Figure 32 is a plan view of a hair washing apparatus comprising a wash water spouting apparatus in accordance with the first embodiment of the present invention.

Figure 33 is a sectional view of Figure 32 along line A-A.

Figure 34 is a sectional view of Figure 32 along line B-B.

Figure 35 is a layout diagram of a water faucet comprising a wash water spouting apparatus in accordance with the first embodiment of the present invention.

Figure 36 is a plan view of the water faucet of Figure 35.

Figure 37 is a side view of the water faucet of Figure 35.

Figure 38 is a layout diagram of a wash water spouting apparatus comprising an air bubble breaking apparatus.

Figure 39(a), Figure 39(b), Figure 39(c) are sectional views of the air bubble breaking apparatus incorporated in the wash water spouting apparatus of Figure 38.

[THE BEST MODE FOR CARRYING OUT THE INVENTION]

A. First Embodiment

A-1 Structure of a wash water spouting apparatus

[0122] A wash water spouting apparatus in accordance with the first embodiment of the present invention will be described.

[0123] As shown in Figure 5, a wash water spouting apparatus A in accordance with the first embodiment of the present invention comprises a wash water discharging nozzle 1, a pipe 2 forming a wash water passage extending to the wash water discharging nozzle 1, an air bubble mixing apparatus 3 disposed in the course of the pipe 2, a forced air supplying apparatus 4 for force supplying air to the air bubble mixing apparatus 3, and a continuous flow valve 5 disposed in the course of the pipe 2 and upstream of the air bubble mixing apparatus 3. The pipe 2 is connected to a water faucet not shown in Figure 5 at its upstream end.

[0124] The air mixing apparatus 3 has a cylindrical air bubble generating member 3a made of porous material. The cylindrical air bubble generating member 3a forms a part of the wash water passage. The inner surface of the cylindrical air bubble generating member 3a extends flush with the inner surface of the wash water passages adjacent to the cylindrical air bubble generating member 3a in the front and in the rear. The cylindrical air bubble generating member 3a is provided with a large number of independent pores at its inner surface. The sectional area of the wash water passage formed in the cylindrical air bubble generating member 3a gradually increases from the upstream end to the downstream end. A pressure chamber 3b is formed around the cylindrical air bubble generating member 3a.

[0125] The forced air supplying apparatus 4 has a pipe 4a connected to the pressure chamber 3b of the air bubble mixing apparatus 3. A check valve 4b, an air pump 4c and an air cleaning filter 4d are disposed in the course of the pipe 4a. They are disposed in series in the order of the check valve 4b, the air pump 4c and the air cleaning filter 4d from downstream to upstream relative to the air flow in the pipe 4a. The pipe 4a upstream of the air cleaning filter 4d is open to the atmosphere. A controller 4e is disposed to control the operation of the air pump 4c.

[0126] The sectional area of the wash water passage formed by the air bubble generating member 3a, the pipe 2 downstream of the air bubble generating member 3a and the wash water discharging nozzle 1 is set larger than the projected area of a sphere of a diameter equal to the mean diameter of the air bubbles mixed with the wash water passing through the wash water passage by the air bubble generating member 3a. The mean diameter is calculated from the mean volume of the air bubbles. The sectional area of the wash water passage downstream of the air bubble generating member 3a is set larger than or equal to the sectional area of the wash water passage at the downstream end of the air bubble generating member 3a.

[0127] In the wash water spouting apparatus A, when the water faucet not shown in Figure 5 is opened, city water flows into the pipe 2 to pass through the continuous flow valve 5 and have its flow rate restricted to a predetermined value. The city water of the predetermined flow rate passes through the pipe 2 into the air bubble generating member 3a of the air bubble mixing apparatus 3.

[0128] The electric power source of the controller 4e is turned on and the air pump 4c starts under the control of the controller 4e. Air is drawn into the pipe 4a and passed through the air cleaning filter 4d to be cleaned of dust. The air cleaned of dust is force fed to the pressure chamber 3b through the pump 4c and the check valve 4b. The pressurized air flowing in the pressure chamber 3b passes through the pores in the air bubble generating member 3a made of porous material to form an independent air bubble at each of a large number of independent pores formed in the inner surface of the air bubble generating member 3a. The air bubbles grow to a predetermined size, leave the independent pores entrained by the city water passing through the wash water passage formed by the inner surface of the air bubble generating member 3a. Thus, micro air bubbles are mixed with and dispersed in the water.

[0129] A large number of micro air bubbles are mixed with and dispersed in the water. Thus, the flow of the water becomes a bubble flow. The bubble flow passes through the pipe 2 and spouts from the wash water discharging nozzle 1 to become a jet flow. The jet flow of the bubble flow having high detergency strikes against a target surface to wash the surface thoroughly. The jet flow of the bubble flow achieves a high water saving effect.

[0130] Figure 6 shows an example of the jet flow of the bubble flow spouting from a wash water spouting apparatus like the wash water spouting apparatus A. It is clear from Figure 6 that a large number of micro air bubbles are contained in the wash water. The air bubbles do not interact with the atmosphere after they are discharged from the wash water spouting apparatus because they are enclosed by the wash water. Thus, the air bubbles can reliably reach the target surface.

[0131] In the wash water spouting apparatus A, an independent air bubble is generated at each of a large number of independent pores formed in the inner surface of the air bubble generating member 3a. If the large number of pores formed in the inner surface of the air bubble generating member 3a should be continuous pores made of a plurality of pores connected to one another, a plurality of air bubbles might be generated at each of the continuous pores. These air bubbles would be likely to merge to form large air bubbles. In the wash water spouting apparatus A, however, the large number of pores formed in the inner surface of the air bubble generating member 3a are independent pores. Merging of the air bubbles at the stage of the generation of the air bubble is therefore prevented so that formation of large air bubbles does not occur. The inner surface of the air bubble generating member 3a forms the surrounding wall of the wash water passage. The air bubbles generated at the pores formed in the inner surface of the air bubble generating member 3a therefore grow at right angles to the flow of the wash water. As a result, shear force is applied to the growing air bubbles by the flowing wash water, the air bubbles leave the pores entrained by the wash water at the first stage of growth and the air bubbles are mixed with the wash water. Thus, micro air bubbles are mixed with and dispersed in the wash water.

[0132] In the wash water spouting apparatus A, the air bubbles are discharged from the whole inner surface of the air bubble generating member 3a in the flowing water substantially uniformly. Thus, micro air bubbles are mixed with and dispersed in the flowing water substantially uniformly .

[0133] Thus, in the wash water spouting apparatus A, a large number of micro air bubbles are mixed with and dispersed in the water passing through the wash water passage substantially uniformly to form a bubble flow.

[0134] In the wash water spouting apparatus A, the sectional area of the wash water passage formed by the air bubble generating member 3a, the pipe 2 downstream of the air bubble generating member 3a and the wash water discharging nozzle 1 is set larger than the projected area of a sphere of a diameter equal to the mean diameter of the air bubbles, the mean diameter being calculated from the mean volume of the air bubbles, mixed with the city water passing through the wash water passage by the air bubble generating member 3a. The above described structure can be realized by controlling the diameter of the pores in the porous material forming the air bubble generating member 3a thereby controlling the diameter of the independent pores formed in the inner surface of air bubble generating member 3a, controlling the apparent flow velocity of the city water (volume flow rate of water without air bubbles divided by the sectional area of the wash water passage), or controlling the wettability of the porous material as described later thereby controlling the mean volume of the air bubbles mixed with the water.

[0135] In the wash water spouting apparatus A, the sectional area of the wash water passage formed by the inner surface of the air bubble generating member 3a gradually increases from the upstream end toward the downstream end. The sectional area of the wash water passage downstream of the air bubble generating member 3a is set larger than or equal to the sectional area of the wash water passage at the downstream end of the air bubble generating member 3a.

[0136] As a result, in the wash water spouting apparatus A, the city water with which a large number of micro air bubbles are mixed and in which a large number of micro air bubbles are dispersed can discharge from the wash water discharging nozzle 1 to reach the target surface while keeping the large number of micro air bubbles dispersed in the water.

[0137] As is clear from the above description, the wash water spouting apparatus A can spout a jet flow at a bubble flow of city water wherein a large number of micro air bubbles are dispersed.

[0138] In the wash water spouting apparatus A, the controller 4e controls the voltage applied to the air pump 4c to make the gas-liquid ratio η fall in the range of 0.5 to 4.0. When the air pressurized by a pump is mixed with city water, the gas-liquid ratio η can be increased to or greater than 2.85, 2.85 being the maximum value of the gas-liquid ratio obtained when spherical air bubbles are packed in the most closely packed cubic lattice. However, when the gas-liquid ratio η becomes too large, air bubbles are liable to merge to cause the flow regime of the gas-liquid two-phase flow to become a slug flow or a froth flow. In the wash water spouting apparatus A therefore, the maximum value of the gas-liquid ratio η was set at 4.0 to prevent generation of a slug flow or a froth flow. On the other hand, when the gas-liquid ratio η is too small, detergency of the jet flow cannot be increased and high water saving effect cannot be obtained. Thus, the minimum value of the gas-liquid ratio was set at 0.5.

[0139] The gas-liquid ratio will be explained in more detail.

[0140] The stimulation produced by a bubble flow of wash water striking a target surface increases as the gas-liquid ratio η increases. In a washing mode wherein wash water of small flow rate washes off a small amount of fouling matter, the gas-liquid ratio η is preferably set at 1.0 or less to decrease the stimulation because the necessity of strong detergency or water saving is low.

[0141] In a washing mode wherein wash water of large flow rate washes off a large amount of fouling matter, the gas-liquid ratio η is preferably set at 1.6 or more to achieve strong detergency and water saving. However, if the flow rate of the wash water is too large, the turbulence in the wash water is liable to become large because of the increase in the velocity of the wash water, the air bubbles are liable to marge and become large, the stability of the bubble flow is liable to be degraded, and a slug flow or a froth flow is liable to be generated. Thus, the gas-liquid ratio η is preferably set at 2.3 or less to maintain the stability of the bubble flow.

[0142] The theoretical maximum value 2.85 of the gas-liquid ratio η in the bubble flow is obtained when spherical air bubbles are packed in the most closely packed cubic lattice. Theoretically, therefore, if the gas-liquid ratio η becomes larger than 2.85, the air bubbles contact and merge to form large air bubbles that degrade the stability of the bubble flow. In fact, however, because of the flexibility of the air bubbles, the air bubbles can deform if they contact to one another. Thus, merging of air bubbles is suppressed and the stability of the bubble flow is maintained. The air bubbles contained in the bubble flow have fairly broad diameter distribution. Air bubbles of relatively small diameter can therefore be forced between air bubbles of relatively large diameter. Thus, in fact, the gas-liquid ratio η can be increased to 4.0 while maintaining the stability of the bubble flow. In a washing mode wherein the flow rate of the wash water is set at a moderate value and the stability of the bubble flow can be obtained easily, the gas-liquid ratio η is preferably increased to 4.0 or so to achieve strong detergency and high water saving effect.

[0143] In the wash water spouting apparatus A, the flow rate of the city water passing through the wash water passage in the air bubble generating member 3a is controlled to be constant by the continuous flow valve 5. The gas-liquid ratio η can therefore be controlled easily and the detergency of the jet flow of the bubble flow spouting from the wash water discharging nozzle 1 can be controlled easily only by controlling the voltage applied to the air pump 4c.

[0144] In the wash water spouting apparatus A, the air is force supplied to the cylindrical air generating member 3a made of porous material and forming the wash water passage. Thus, a large number of micro air bubbles can be mixed easily with the water passing through the wash water passage.

[0145] In the wash water spouting apparatus A, the pressure chamber 3b is formed around the cylindrical air bubble generating member 3a. The air bubbles can therefore be mixed easily with the water passing through the wash water passage through the air bubble generating member 3a by force supplying the air to the pressure chamber 3b.

[0146] In the wash water spouting apparatus A, the inner surface of the cylindrical air bubble generating member 3a extends flush with the inner surfaces of the wash water passages in front and in rear. Therefore, no turbulence or stagnation is generated in the flow of the water by the air bubble generating member 3a. If the flow of the water becomes turbulent, the air bubbles are liable to merge with one another, and if the flow of the water becomes stagnant, the air bubbles are liable to merge owing to long residence in the wash water passage. In the wash water spouting apparatus A, however, the possibility of air bubble merging is small and a bubble flow of good quality can be spouted because no turbulence or stagnation is generated in the flow of the water.

[0147] In the wash water spouting apparatus A, the function of-the pump 4c is protected by providing the check valve 4b to prevent the city water from flowing from the cylindrical air generating member 3a to the air pump 4c.

[0148] In the wash water spouting apparatus A, the function of the air bubble generating member 3a is protected by providing the air cleaning filter 4d upstream of the air pump 4c to prevent clogging of the air bubble generating member 3a.

A-2 Specific measures for forming independent pores.

[0149] Specific measures for forming independent pores in the inner surface of the air bubble generating member 3a will be described.

(1) Hot forming of particles of heat fusible material.

[0150] Figure 7 shows an electron microscope enlarged view of the surface of a hot formed compact made by a process wherein substantially spherical particles of ultrahigh molecular weight polyethylene are packed in a mold to be hot formed. As is clear from Figure 7, a large number of independent pores are formed in the surface of the hot formed compact. In an aggregate of substantially spherical particles, the substantially spherical particles can be packed close to generate pores of uniform shape. Thus, the generation of continuous pores made of a plurality of pores connected to one another is suppressed and the generation of independent pores is promoted. If the particles have the same diameter, the pores can be disposed regularly and in a lattice, and the spaces between the air bubbles generated at-the pores become constant. Thus, merging of the air bubbles at the stage of generation of the air bubbles can be prevented. If the pores are disposed regularly and in a lattice, the density of the pores can be increased, the size of the air bubble generating member 3a can be reduced, and the size of the wash water spouting apparatus can be reduced.

[0151] Ultrahigh molecular weight polyethylene has a low melt index (MI) and its properties in molten condition are similar to those of rubber. Thus, ultrahigh molecular weight polyethylene hardly runs in molten condition. When spherical particles of ultrahigh molecular weight polyethylene are packed in a mold and hot formed at a temperature slightly higher than the melting point, the particles are fused together at contact points without deformation. Therefore, if substantially spherical particles made of ultrahigh molecular weight polyethylene are used and the diameter and filling factor of the particles are controlled, the diameter of the independent pores formed in the inner surface of the air bubble generating member 3a can be controlled freely. Ultrahigh molecular weight polyethylene is suitable for a detergent containing hydrochloric acid, hydrochloric acid radical, organic solvent, etc. because it is stable chemically. Ultrahigh molecular weight polyethylene is suitable for a detergent comprising water because it hardly absorbs water.

[0152] Figure 8 shows an electron microscope enlarged view of the surface of a hot formed compact made by a process wherein substantially spherical particles of acrylic resin are packed in a mold to be hot formed. As is clear from Figure 8, a large number of independent pores are formed substantially in a lattice in the surface of the hot formed compact. Acrylic resin has low surface tension and is hydrophilic. Acrylic resin is therefore suitable for generating micro air bubbles as described later.

[0153] Particles of heat fusible material including metallic materials such as bronze, stainless steel, etc., glass, various kinds of ceramics, etc. can be hot formed to make the air bubble generating member 3a.

[0154] When the particles or powder of heat fusible material are hot formed, the particles are fused together. An air bubble generating member 3a having adequate strength against water pressure and air pressure can therefore be obtained.

[0155] The mean diameter of the substantially spherical particles of heat fusible material is preferably 50 μm to 300 μm. When substantially spherical particles of 50 μm to 300 μm mean diameter are packed to form the most closely packed cubic lattice, the mean diameter of the independent pores formed by the spaces between the particles becomes 50 μm to 300μm. The mean diameter of the air bubbles generated and dispersed by the independent pores of 50 μm to 300 μm mean diameter is 100 μm to 1000 μm. Micro air bubbles of 100 μm to 1000 μm mean diameter resist merging with one another because of their high rigidity. A stable bubble flow can be obtained by mixing micro air bubbles of 100 μm to 1000 μm mean diameter with the wash water. When the wash water spouting apparatus A is incorporated in a washing system for regions of the human body such as the anus and private parts, the mean diameter of the air bubbles in the bubble flow is preferably less than or equal to 1000 μm because the bubble flow must be passed without difficulty through pipes or nozzles of sizes suited for the washing system. On the other hand, generation of extremely small micro air bubbles is technologically difficult. Considering the above mentioned facts, the mean diameter of the air bubbles dispersed in the bubble flow spouted from the wash water spouting apparatus incorporated in a washing system is preferably 100 μm to 1000 μm.

[0156] The filling factor of the substantially spherical particles made of heat fusible material is preferably larger than or equal to 70%. When spherical particles of the same diameter are packed to form the most closely packed cubic lattice, the theoretical maximum of the filling factor is 74%. It is hard to pack spherical particles to form the most closely packed cubic lattice because of the generation of static electricity, etc. However, the filling factor of the substantially spherical particles forming the aggregate is preferably larger than or equal to 70% in order to obtain independent pores.

(2) Woven cloth, unwoven cloth

[0157] Fibers such as nylon etc. can be woven, knitted or stacked to become woven cloth or unwoven cloth thereby forming a mesh construction. The mesh construction forms independent pores. If the diameters of the fibers and the spaces between the fibers are made substantially the same, the pores can be disposed regularly and substantially in a lattice arrangement. Shape of the pores and the space between the pores can be adjusted easily by selecting the diameter of the fibers, the space between the fibers or the orientation of the fibers. Woven cloth and unwoven cloth are preferably fixed to a supporting member because they lack adequate strength. If a plurality of woven cloths or unwoven cloths are stacked, the vibration of the cloths is suppressed and the air bubble mixing operation of the cloths becomes stable.

(3) Others

[0158] Phase inversion glass may be used to form continuous pores.

A-3 Water repellent finishing, hydrophilic finishing

[0159] In the wash water spouting apparatus A, the cylindrical air bubble generating member 3a made of porous material may be completely or partly made of water repellent material such as PTFE, ETEF, etc., or water repellent finish with paraffin, carnauba wax, etc. may be applied to the surface of the cylindrical air bubble generating member 3a made of porous material. When city water is used as the wash water, calcium ions contained in the-city water in large quantities are liable to deposit to form calcium carbonate, etc. in the pores of the porous material to clog the pores thereby degrading the air bubble generating member 3a. Moreover, the performance of the air bubble generating member 3a is liable to be degraded by the osmotic pressure caused by the capillarity in the surface of the porous material. If the air bubble generating member 3a is completely or partly made of water repellent material such as PTFE, ETEF, etc., or water repellent finish with paraffin, carnauba wax, etc. is applied to the surface of the wash water passage in the air bubble generating member 3a, the entry of the water into the pores can be prevented and the osmotic pressure caused by the capillarity in the surface of the porous material can be decreased. Thus, degradation of the air bubble generating member 3a and degradation of the performance of the air bubble generating member 3a can be prevented.

[0160] In the wash water spouting apparatus A, the air bubble generating member 3a may be completely or partly made of hydrophilic material such as HDPE, LDPE, PP, PA, PET, MMA, glass, polyolefine, cellulose, etc., or hydrophilic finish with acrylic acid, plasma surface treatment, chromic acid surface treatment, silica coat, etc. may be applied to the surface of the wash water passage in the air bubble generating member 3a.

[0161] The wettability of the surface of the porous material affects the size of the air bubbles. When the porous material is not wettable (water repellent), the air discharged from the pores is liable to reside on the surface of the porous material and the diameter of the air bubbles is liable to become large. When the porous material is wettable (hydrophilic), the air discharged from the pores cannot easily reside on the surface of the porous material and the diameter of the air bubbles is unlikely to become large. If the air bubble generating member 3a is made of hydrophilic material such as HDPE, LDPE, PP, PA, PET, MMA, glass, polyolefine, cellulose, etc., in whole or in part, or hydrophilic finish with acrylic acid, plasma surface treatment, chromic acid surface treatment, silica coat, etc. is applied to the surface of the wash water passage in the air bubble generating member 3a, the size of the air bubbles can be decreased and the generation of slug flow or froth flow can be prevented.

A-4 Addition of various functions

[0162] In the wash water spouting apparatus A, the pipe 2 may be provided between the continuous flow valve 5 and the air bubble mixing apparatus 3 with a temperature controller for heating the city water to a predetermined temperature or a solute concentration controller for solving a solute such as a chemical, surface active agent, etc. in the wash water to a predetermined concentration. It is preferable to heat the wash water to a predetermined temperature or solve a solute such as a chemical, surface active agent, etc. in the wash water to a predetermined concentration according to the-nature of the object to be washed. In the wash water spouting apparatus A, the control of the solution of the solute in the wash water is easy, because the flow rate of the wash water passing through the wash water passage in the air bubble generating member 3a is kept at a predetermined value by the continuous flow valve 5.

[0163] In the wash water spouting apparatus A, the air pump 4c and the controller 4e may be eliminated. In this case, the air is absorbed into the air bubble generating member 3a by the negative pressure generated in the water passing through the air bubble generating member 3a. In this case, the gas-liquid ratio becomes about 0.5.

[0164] In the wash water spouting apparatus A, the sectional area of the wash water passage in the cylindrical air bubble generating member 3a may be constant from the upstream end to the downstream end. Even if the sectional area of the wash water passage in the air bubble generating member 3a is constant from the upstream end to the downstream end, the flow regime of the gas-liquid two-phase flow passing through the wash water passage in the air bubble generating member 3a does not become a cylindrical mist flow. Thus, the sectional area of the wash water passage in the cylindrical air bubble generating member 3a may be constant from the upstream end to the downstream end.

[0165] The air bubble generating member 3a forms all of the wall surrounding the wash water passage. However, only a part of the wall surrounding the wash water passage need be formed by a bubble generating member made of porous material. Also in this case, micro air bubbles can be mixed with and dispersed in the wash water.

B. Second Embodiment

[0166] A wash water spouting apparatus in accordance with the second embodiment of the present invention will be described.

[0167] As shown in Figure 9, a wash water spouting apparatus B in accordance with the second embodiment of the present invention comprises a wash water discharging nozzle 11, a pipe 12 forming a wash water passage extending to the wash water discharging nozzle 11, an air bubble mixing apparatus 13 disposed in the course of the pipe 12, a forced air supplying apparatus 14 for force supplying air to the air bubble mixing apparatus 13 and a wash water storage tank 15 disposed upstream of the pipe 12.

[0168] The air mixing apparatus 13 has a cylindrical air bubble generating member 13a made of porous material. The cylindrical air bubble generating member 13a forms a part of the wash water passage. The cylindrical air bubble generating member 13a is provided with a large number of independent pores at its inner surface. The sectional area of the wash water passage formed in the cylindrical air bubble generating member 13a gradually increases from the upstream end to the downstream end. A pressure chamber 13b is formed around the air bubble generating member 13a.

[0169] The forced air supplying apparatus 14 has a pipe 14a connected to the pressure chamber 13b of the air bubble mixing apparatus 13. A pressure control valve 14b, an air pump 14c and an air cleaning filter 14d are disposed in the course of the pipe 14a. They are disposed in series in the order of the pressure control valve 14b, the air pump 14c and the air cleaning filter 14d from downstream to upstream relative to the air flow in the pipe 14a. The pipe 14a upstream of the air cleaning filter 14d is open to the atmosphere. A controller 14e is disposed to control the operation of the air pump 14c. A pipe 14a' extending from the air pump 14c is connected to the upper part of the wash water storage tank 15 through a pressure control valve 14b'.

[0170] The sectional area of the wash water passage formed by the air bubble generating member 13a, the pipe 12 downstream of the air bubble generating member 13a and the wash water discharging nozzle 11 is set larger than the projected area of a sphere of a diameter equal to the mean diameter of the air bubbles, the mean diameter being calculated from the mean volume of the air bubbles, mixed with the wash water passing through the wash water passage by the air bubble generating member 13a. The sectional area of the wash water passage downstream of the air bubble generating member 13a is set larger than or equal to the sectional area of the wash water passage at the downstream end of the air bubble generating member 13a.

[0171] The size, weight and electric power consumption of the wash water spouting apparatus B are determined to be convenient for portable use.

[0172] In the wash water spouting apparatus B, the electric power source of the controller 14e is turned on and the air pump 14c starts under the control of the controller 14e. Air is drawn into the pipe 14a and passed through the air cleaning filter 14d to be cleaned of dust. The air cleaned of dust is force fed the wash water storage tank 15 through the air pump 14c and the pressure control valve 14b'. The wash water in the wash water storage tank 15 is pressurized to discharge from the wash water storage tank 15 and flows into the air bubble generating member 13a of the air mixing apparatus 13 through the pipe 12.

[0173] The air passing through the air pump 14c is also force fed to the pressure chamber 13b through the pressure control valve 14b. The pressurized air flowing into the pressure chamber 13b passes through pores in the air bubble generating member 13a made of porous material and the large number of independent pores formed in the inner surface of the air bubble generating member 13a to form micro air bubbles. The micro air bubbles are mixed with and substantially uniformly dispersed in the wash water passing through the wash water passage in the air bubble generating member 13a.

[0174] A large number of micro air bubbles are mixed with and dispersed in the wash water. Thus, the flow of the wash water becomes a bubble flow. The bubble flow passes through the pipe 12 and spouts from the wash water discharging nozzle 11 to become a jet flow. The jet flow of the bubble flow having high detergency strikes against a target surface to wash the surface thoroughly. The jet flow of the bubble flow achieves a high water saving effect.

[0175] The wash water spouting apparatus B can be incorporated in various kinds of portable washing apparatuses because it has a wash water storage tank. The air pump 14c of the forced air supplying apparatus 14 is used for force feeding of the wash water as well as force feeding of the air. Thus, the number of the components decreases and the manufacturing cost at the wash water spouting apparatus B decreases as compared with the case where a separate pump is disposed for force feeding of the wash water. If the air bubbles are mixed with stagnant wash water through the air bubble generating member 13a, the air bubbles need to grow to a certain size before they leave the air bubble generating member 13a to be mixed with the wash water. If the air bubbles are mixed with flowing wash water through the air bubble generating member 13a, the air bubbles can leave the air bubble generating member 13a entrained by the flowing wash water when they are still small in size to be mixed with the wash water. In the wash water spouting apparatus B, the air bubbles are mixed not with stagnant wash water but with flowing wash water. Thus, a large number of micro air bubbles can be mixed with the wash water and the washing effect of the wash water can be increased.

[0176] The pressure control valve 14b installed in the pipe 14a controls the pressure of the air flowing into the pressure chamber 13b to control the rate of the air bubble generation by the air bubble generating apparatus 13a. The pressure control valve 14b' installed in the pipe 14a' controls the pressure of the air flowing into the wash water storage tank 15 to control the flow rate of the wash water passing through the wash water passage. Thus, the rate of the mixing of the air bubbles with the wash water can be controlled. The pressure control valve 14b or 14b' alone can control the rate of the mixing of the air bubbles with the wash water.

[0177] The size, weight and electric power consumption of the wash water spouting apparatus B are set at values convenient for portable use. Thus, various kinds of washing devices such as a shower, a washing system for regions of the human body such as the anus and private parts, a hand washing apparatus, a palate washing apparatus, etc. having the wash water spouting apparatus B can be made portable.

C. Cleaning device for the air bubble generating member.

[0178] Figures 10(a) to 10(c) show an example of an automatic cleaning device for the internal surface of the air bubble generating member.

[0179] An air bubble generating member 23a and a pressure chamber 23b of an air bubble mixing apparatus similar to the air bubble mixing apparatus 3 in the first embodiment or the air bubble mixing apparatus 13 in the second embodiment are disposed in the course of a pipe 22 supplying wash water to a wash water discharging nozzle 21. The pipe 22 is bent at right angles upstream of the air bubble generating member 23a. The above described members are made integral with on another and can be driven transversely in Figures 10(a) to 10(c) by a driving apparatus which is not shown in Figures 10(a) to 10(c) .

[0180] The pipe 22 is provided with an opening 22a at its bent portion. A rod member 25 is inserted into the pipe 22 and the air bubble generating member 23a through the opening 22a. The rod member 25 is fixed to a fixed support member at the end of its portion extending out the opening 22a. The rod member 25 is provided with a first cover member 26a at its portion near the fixed end, a second cover member 26b at its opposite end, and a brush 27 at the portion near the opposite end. The first cover member 26a, the second cover member 26b and the brush 27 are fixed to the rod member 25.

[0181] When the pipe 22 is not being supplied with wash water and the wash water discharging nozzle 21 is out of operation, the above described integrated members are driven to the right in Figures 10(a) to 10(c) by the driving apparatus not shown in Figures 10(a) to 10(c). Thus, the opening 22a of the pipe 22 is closed by the first cover member 26a as shown in Figure 10(b).

[0182] Before the pipe 22 is supplied with wash water, the above described integrated members are driven to the left as shown in Figure 10(c) by the driving apparatus not shown in Figures 10(a) to 10(c). The fixed and immovable brush 27 scrapes the inner surface of the air bubble generating member 23a to remove fouling matter adhered to the inner surface of the air bubble generating member 23a. The second cover member 26b closes the opening 22a of the pipe 22.

[0183] The pipe 22 is supplied with wash water, the air bubbles generated by the air bubble generating member 23a are mixed with the flowing wash water and a bubble flow spouts from the wash water discharging nozzle 21.

[0184] After the completion of the spouting of the bubble flow from the wash water discharging nozzle 21, the above described integrated members are driven to the right as shown in Figure 10(b) by the driving apparatus not shown in the Figures. The fixed and immovable brush 27 scrapes the inner surface of the air bubble generating member 23a to remove fouling matter adhered to the inner surface of the air bubble generating member 23a. The first cover member 26a closes the opening 22a of the pipe 22.

[0185] If an automatic cleaning device for the internal surface of the air bubble generating member as described above is incorporated in a wash water spouting apparatus using water containing a lot of ions liable to deposit such as calcium ions, magnesium ions etc., maintenance of the wash water spouting apparatus becomes easy and the function of the wash water spouting apparatus can be maintained for a long time.

D. Third embodiment

[0186] A wash water spouting apparatus in accordance with the third embodiment of the present invention will be described.

[0187] A wash water spouting apparatus C is incorporated in a washing system, installed on a toilet bowl, for washing regions of the human body such as the anus and private parts. As shown in Figure 11, city water is supplied to a heat exchanger 31 through an electromagnetic cut-off valve 30 capable of controlling water pressure. The heat exchanger 31 is provided with a heater 32, a first water level sensor 33 and a second water level sensor 34 for detecting the water level in the heat exchanger to prevent the heat exchanger 31 from heating when empty, and a temperature sensor 35 for monitoring the water temperature in the heat exchanger. The water heated to an appropriate temperature is led to a water passage selector valve 37 through a release valve 36. The water passage selector valve 37 controls the flow rate of the water and selects the water passage to be supplied with the water according to the operation input to a controlling unit 38 by the user. City water of controlled flow rate is supplied to the selected one of a plurality of water passages. Air pressurized by a pump 40 is led to an air passage selector valve 41. The air passage selector valve 41 selects the air passage to be supplied with the pressurized air according to the operation input to the controlling unit 38 by the user. The pressurized air is supplied to the selected one of a plurality of air passages.

[0188] As shown in Figures 12 and 13, the end portion of the nozzle 39 is formed as a detachable nozzle head 39a. The nozzle head 39a is provided on its upper surface with outlet ports 42 and 43 for washing the anus and outlet ports 44 and 45 for washing the private parts. An air bubble mixing apparatus 46 is disposed beneath the outlet port 44. The air bubble mixing apparatus 46 has a straight-cylinder-shaped air bubble generating member 46a made of a porous sintered compact of resin material. A large number of independent pores are formed in the inner surface of the air bubble generating member 46a. The air bubble generating member 46a is press fitted to the nozzle head 39a at its both ends to be fixed to the nozzle head 39a. The inner diameter of the air bubble generating member 46a is made larger at its one end portion than at its remaining portion. The inner surface of the air bubble generating member 46a forms a wash water passage. The downstream end of the wash water passage formed by the inner surface of the air bubble generating member 46a is directed obliquely upward. The downstream end of the wash water passage formed by the inner surface of the air bubble generating member 46a communicates with the outlet port 44 through a straight wash water passage 47 formed in the nozzle head 39a and extending obliquely upward. The upstream end of the wash water passage formed by the inner surface of the air bubble generating member 46a communicates with a wash water passage 48 formed in the nozzle head 39a. The wash water passage 48 extends beyond the air bubble generating member 46a to the end of the nozzle head 39a to communicate with a straight wash water passage 49 formed in the nozzle head 39a and extending obliquely upward. The wash water passage 49 communicates with the outlet port 45. The upstream end of the wash water passage 48 is connected to a wash water pipe disposed in the nozzle 39. The wash water pipe is not shown in Figure 13. A pressure chamber 46b is formed around the air bubble generating member 46a. The pressure chamber 46b communicates an air passage 50 formed in the nozzle head 39a. The upstream end at the air passage 50 is connected to an air pipe disposed in the nozzle 39. The air pipe is not shown in Figure 13.

[0189] Air bubble mixing apparatuses similar to the air bubble mixing apparatus 46 are disposed beneath the outlet ports 42 and 43. A wash water pipe and an air pipe communicating with the air bubble mixing apparatus beneath the outlet port 42 and a wash water pipe and an air pipe communicating with the air bubble mixing apparatus beneath the outlet port 43 are disposed in the nozzle 39.

[0190] The members downstream of the water passage selector valve 37 form the wash water spouting apparatus C.

[0191] In Figure 11, reference numeral 51 indicates a controller of the washing system for the human body and reference numeral 52 indicates an electric power supplying element or a controlling unit of a main power source. Reference numeral 53 indicates a sensor for detecting use of the toilet bowl.

[0192] The present washing system for the human body starts when the sensor 53 detects use of the toilet bowl. When a user operates the controlling element 38 to select the spout of the wash water from the outlet ports 44 and 45, city water is supplied to the wash water passage 48 through the water passage selector valve 37 and the wash water pipe disposed in the nozzle 39 and pressurized air is supplied to the air passage 50 through the air passage selector valve 41 and the air pipe disposed in the nozzle 39. A large number of micro air bubbles are mixed with and substantially uniformly dispersed in the water through the air bubble mixing apparatus 46 to generate a bubble flow. The bubble flow spouts from the outlet port 44. The water not mixed with air bubble spouts from the outlet port 45. The bubble flow and the flow of the water without air bubbles strike against the target surface to wash it.

[0193] When the user makes a selection to spout the wash water from the outlet port 42 or 43, the wash water is supplied to the air bubble mixing apparatus disposed beneath the outlet port 42 or 43 through the water passage selector valve 37 and the wash water pipe disposed in the nozzle 39 and the pressurized air is supplied to the air bubble mixing apparatus disposed beneath the outlet port 42 or 43 through the air passage selector valve 41 and the air pipe disposed in the nozzle 39. A large number of micro air bubbles are mixed with and substantially uniformly dispersed in the city water through the air bubble mixing apparatus disposed beneath the outlet port 42 or 43 to generate a bubble flow. The bubble flow spouts from the outlet port 42 or 43. The bubble flow strikes against the target surface to wash it.

[0194] In the wash water spouting apparatus C, the wash water passage 47 downstream of the air bubble generating member 46a extends substantially straight. If the wash water passage 47 is curved, centrifugal force acting on the micro air bubbles dispersed in the wash water is liable to merge them with one another when the bubble flow passes by the curved portion. Thus, the bubble flow is liable to become a slug flow or a froth flow. If the wash water passage 47 extends substantially straight, merging of the micro air bubbles under centrifugal force is prevented and the bubble flow is maintained.

[0195] In the wash water spouting apparatus C, the air bubble mixing apparatus 46 is disposed in the nozzle head 39, more specifically, beneath the outlet port 44 formed in the nozzle head 39a. Thus, the residence time of the bubble flow in the wash water passage is reduced, the probability of merging of the air bubbles dispersed in the water before the spouting of the bubble flow is reduced, and the probability of the maintenance of the bubble flow until the spouting of the bubble flow is increased.

[0196] In the wash water spouting apparatus C, the nozzle head 39a provided with the air bubble mixing apparatus 46 is detachably connected to the nozzle 39. Thus, it is easy to detach the nozzle head 39a from the nozzle 39 and wash the inner surface of the air bubble generating member 46a. Thus, the air bubble mixing apparatus 46 can be maintained easily.

[0197] In the wash water spouting apparatus C, the air bubble generating member 46a is fixed to the nozzle head 39a by press fitting. Air is therefore prevented from mixing with the water through the gap formed at the fixed part. Thus, unexpectedly large air bubbles are prevented from mixing with the wash water.

[0198] In the wash water spouting apparatus C, the inner diameter of the air bubble generating member 46a is made larger at its press fitting part than at the remaining part. Therefore, the inner diameter of the press fitting part becomes equal to that of the remaining part after the press fitting of the air bubble generating member 46a. Thus, the generation of turbulence in the wash water is prevented and the air bubbles are prevented from merging into large bubbles.

[0199] In the wash water spouting apparatus C, the air bubble generating member 46a is press fitted at its both ends. The inner diameter of the air bubble generating member 46a is set larger at one end of the air bubble generating member 46a than at the other part of the air bubble generating member 46a. If the air bubble generating member 46a is press fitted at both ends, it can be firmly fixed to the nozzle head 39a. However, the air bubble generating member 46a is generally made by powder molding. If the inner diameter of the air bubble generating member 46a is set larger at both ends of the air bubble generating member 46a than at the remaining part of the air bubble generating member 46a, burrs are formed at one end of the air bubble generating member 46a because of the arrangement of the molds. Therefore, it is preferable that the part where the inner diameter is set larger than at the remaining part be limited to one end.

[0200] In the wash water spouting apparatus C, the air bubble generating member 46a is disposed in the nozzle head 39a and beneath the outlet port 44 with the downstream end of the wash water passage formed by the inner surface of the air bubble generating member 46a directed upward. Thus, the wash water passage 47 downstream of the air bubble generating member 46a can extend substantially straight to prevent merging of the air bubbles.

[0201] In the present washing system for the human body, the water passage selector valve 37 and the air passage selector valve 41 are synchronously driven by a pair of motors. The water passage selector valve 37 and the air passage selector valve 41 may be driven by a single motor. The air pump 40 is a rolling pump. The air pump 40 may be a vane pump, a rotary pump, a linear pump, etc. Since the heat exchanger 31 is of the hot-water-storage type, it is fairly free from temperature change or uneveness of temperature. The heat exchanger 31 may be of the instantaneous type, which is compact and can discharge hot water continuously, or of the semi-hot-water-storage type, which has advantages of both the hot-water-storage and instantaneous types. The hot water storage tank of the semi-hot-water-storage type heat exchanger is smaller than that of conventional hot-water-storage type heat exchanger. The capacity of the heater of the semi-hot-water-storage type heat exchanger is larger than that of conventional hot-water-storage type heat exchanger. The semi-hot-water-storage type heat exchanger is therefore excellent in heating capability, like the instantaneous type heat exchanger, and fairly free from uneveness of temperature. In the semi-hot-water-storage type heat exchanger, a small hot water storage tank disposed downstream of the heat exchanger operates as a temperature butter to store the wash water for a predetermined time and thereby decrease the uneveness of temperature distribution in the wash water. The semi-hot-water-storage type heat exchanger is excellent in energy saving effect and increases the convenience of the washing system for the human body. The air mixing factor may be made controllable by the user to control the degree of the stimulation. In such case, the air mixing factor is preferably controlled independently of the control of the flow rate of the wash water. A heater may be disposed in the air pump 40 to supply hot air to the air bubble mixing apparatus 46. In such case, the heat exchanger 31 may generate low temperature hot water of 25 to 30°C and the low temperature hot water may be mixed with the hot air to be heated to body temperature. Thus, a bubble flow of body temperature can be spouted. The heat insulation of the heat exchanger 31 can be wade thin and the size of the washing system for the human body can be reduced because the heat exchanger 31 generates low temperature hot water of 25 to 30°C. It is possible to eliminate the heat exchanger 31 and supply the air bubble mixing apparatus 46 with cold water and hot air, thereby generating a bubble flow of hot water.

[0202] Figure 14 is a diagram showing an example of the relation between the diameter of just generated air bubbles and the flow velocity of wash water in the wash water spouting apparatus C. As is clear from Figure 14, the diameter of generated air bubbles can be controlled by controlling the velocity of the wash water. When the velocity of the wash water is high, a large shear force is applied to the air bubbles being generated. Thus, the air bubbles are swept away by the wash water at the first stage of generation to be mixed with and dispersed in the wash water. Therefore, if the velocity of the wash water is high, the diameter of the air bubbles is small. When the velocity of the wash water is constant, the diameter of the air bubbles varies substantially in proportional to the opening area of the independent pores formed in the surface of the air bubble generating member contacting the wash water. Therefore, if the velocity of the wash water is constant, the diameter of the generated air bubbles can be controlled by selecting the diameter of the independent pores.

[0203] Figure 15 is a diagram showing an example of the relation between the degree of the growth of air bubbles and the residence time of the air bubbles in the wash water passage in the wash water spouting apparatus C. In Figure 15, Db indicates the diameter of the air bubbles just after generation and D indicates the diameter of the air bubbles after residence in the wash water passage. As is clear from Figure 15, the air bubbles merge with one another to grow in diameter as the residence time in the wash water passage increases. Therefore, it is possible to control the diameter of the air bubbles by controlling the residence time or the air bubbles in the wash water passage. It is possible to control the residence time of the air bubbles in the wash water passage by controlling the flow rate of the wash water and thereby controlling the diameter of the air bubbles. When the flow rate of the wash water is low, the velocity of the wash water is low, the residence time of the air bubbles in the wash water passage is long, air bubbles of large size are obtained, and a bubble flow generating a gentle stimulation is obtained. When the flow rate of the wash water is high, the velocity of the wash water is high, the residence time of the air bubble in the wash water passage is short, the air bubbles of small size are obtained, and a bubble flow generating a strong stimulation is obtained.

E. Fourth embodiment

[0204] A wash water spouting apparatus in accordance with the fourth embodiment of the present invention will be described.

[0205] As shown in Figures 16 and 17, a wash water spouting apparatus D of the present embodiment has a wash water discharging nozzle 60. The end portion of the nozzle 60 is formed as a detachable nozzle head 60a. The nozzle head 60a is provided with a first outlet port 61 and a second outlet port 62. The wash water discharging nozzle 60 and the nozzle head 60a are provided with a wash water passage 63 connected to the first outlet port 61 and a wash water passage 64 connected to the second outlet port 62. The sectional area of the wash water passage 64 is set larger than that of the wash water passage 63. The wash water discharging nozzle 60 is provided with a movable air bubble mixing apparatus 65 at is base. The air bubble mixing apparatus 65 has a cylindrical air bubble generating member 65a made of porous material and forming a wash water passage. A large number of independent pores are formed in the inner surface of the air bubble generating member 65a. The sectional area of the wash water passage in the air bubble generating member 65a gradually increases from the upstream end toward the downstream end. A pressure chamber 65b is formed around the air bubble generating member 65a. The air bubble generating member 65 is provided with a nipple 66 connected to the upstream end of the wash water passage in the air bubble generating member 65 and an inverted L-shaped nipple 67 communicating with the pressure chamber 65b. The nipple 66 connects to a wash water source through a flexible tube which is not shown in the Figures. The nipple 67 connects to a pressurized air source through a flexible tube which is not shown in the Figures. The air bubble generating member 65 is adapted to be slidable in a guide member 68 fixed to the base of the wash water discharging nozzle 60. An opening 69 formed in the guide member 68 communicates with the wash water passage 63. An opening 70 formed in the guide member 68 communicates with the wash water passage 64. The guide member 68 is provided with an element 71 engaging a driving belt not shown in the Figures. The guide member 68 is provided with a spring 72 biasing the air bubble mixing apparatus 65. The wash water spouting apparatus D is incorporated in a washing system installed on a toilet bowl for washing regions of the human body such as the anus or the private parts. The washing system is not shown in the Figures.

[0206] In the wash water spouting apparatus D, wash water is supplied to the air bubble mixing apparatus 65 from the wash water source not shown in the Figures. Pressurized air is supplied to the air bubble mixing apparatus 65 from the pressurized air source not shown in the Figures. A large number of micro air bubbles are mixed with and substantially uniformly dispersed in the wash water passing through the wash water passage formed by the inner surface of the air bubble generating member 65a through a large number of independent pores formed in the inner surface of the air bubble generating member 65a to generate a bubble flow. As is clear from Figure 16, the generated bubble flow passes through the opening 69 of the guide member 68 and the wash water passage 63 and spouts from the first outlet port 61.

[0207] The driving belt not shown in the Figures starts to push the element 71 of the guide member 68 to move the wash water discharging nozzle 60 in the direction indicated by arrows in Figure 17 or toward the nozzle head 60a. When the wash water discharging nozzle 60 moves toward the nozzle head 60a, the nipple 67 engages a fixed projection member 73, causing the air mixing apparatus 65 to move against the biasing force of the spring 72. As a result, as is clear from Figure 17, the wash water passage formed by the inner surface of the air bubble generating member 65a communicates with the opening 70 of the guide member 68. As is clear from Figure 17, the wash water containing the air bubbles generated by the air bubble generating member 65a passes through the opening 70 of the guide member 68 and the wash water passage 64 and spouts from the second outlet port 62.

[0208] The sectional area of the wash water passage 64 is larger than that of the wash water passage 63. Therefore, when the flow rate of the wash water passing through the wash water passage 63 is equal to that of the wash water passing through the wash water passage 64, the velocity of the wash water passing through the wash water passage 64 is lower than that of the wash water passing through the wash water passage 63. The length of the wash water passage 63 is substantially equal to that of the wash water passage

64. The residence time of the bubble flow in the wash water passage 64 is therefore longer than that of the bubble flow in the wash water passage 63. As a result, the diameter of the air bubbles contained in the bubble flow spouting from the outlet port 62 becomes larger than that of the air bubbles contained in the bubble flow spouting from the outlet port 61. Thus, the stimulation generated by the bubble flow spouting from the outlet port 62 is softer than that generated by the bubble flow spouting from the outlet port 61. If the outlet port 61 is used for washing the anus and the outlet port 62 is used for washing the private parts and the bubble flow is selectively supplied to one of the outlet port through the wash water passage selecting apparatus as described above, the convenience of the washing system for the human body increases.

[0209] If the air supply is stopped when the wash water spouting apparatus D is operating, the wash water may flow into the pressure chamber 65b, the air passage, etc. through the pores in the air bubble generating member 65a because of the osmotic pressure or the pressure caused by the resistance of the wash water passage, etc. Therefore, it is preferable to supply a small quantity of pressurized air to the pressure chamber and mix a small quantity of air with the wash water through the air bubble generating member 65a even when spouting of wash water without air bubble is desired. If the air is spouted for a predetermined time to remove the wash water left in the wash water discharging nozzle 60 after the the spouting of the wash water is stopped, water drops, dirt, etc. adhering to the part of the nozzle near the outlet port 61 or 62 are also removed.

[0210] Figures 18 shows an example of the effect of the air bubble pump obtained by the wash water spouting apparatus D.

[0211] In Figure 18, E_t / E_w indicates energy amplifying effect. E_t is the output energy of the bubble flow just downstream of the air bubble mixing apparatus 65 and E_w is the energy of the wash water just upstream of the air bubble mixing apparatus 65. Overall efficiency of the air bubble pump is expressed by $E_t /(E_w + E_a)$. The Overall efficiency is the output energy divided by the sum of the all input energies. E_a is the energy of the mixed air. E_t , E_w and E_a are expressed by the following formulae.

$$E_w = P_w Q_w + (\rho_w / 2) Q_w V_w^2$$

$$E_t = P_t Q_t + (\rho_t / 2) Q_t V_t^2$$

$$E_a = P_a Q_a$$

[0212] In the above formulae, P is pressure, Q is volume flow rate, ρ is density and V is velocity. The suffix w indicates wash water just upstream of the air mixing apparatus 65 and not yet mixed with air, the suffix t indicates the wash water of two-phase flow just downstream of the air mixing apparatus 65 and already mixed with air and the suffix a indicates air. Pa is the air mixing pressure of the air bubble mixing apparatus 65 before the pressure loss occurring when the air passes through the air bubble mixing apparatus 65. If a large number of micro air bubbles are generated and simultaneously mixed with and substantially uniformly dispersed in the flow of the wash water, the mixed air bubbles operate as an air bubble pump to accelerate the wash water, thereby increasing the energy of the wash water. If the diameter of the mixed air bubbles is small, the rigidity of the air bubbles is high. The air bubbles therefore do not deform or vibrate easily in the wash water. Thus, the energy loss caused by the air bubbles contained in the wash water becomes small.

[0213] A washing system for regions of the human body such as the anus or private parts with small energy consumption can be installed at a place of low water pressure such as the uppermost floor of a high-rise multifamily dwelling house, the second floor of an ordinary dwelling house, etc. if the air bubble mixing apparatus 65 operating as a bubble pump is incorporated in the washing system for the human body. When a water pump is installed in order to install a washing system for the human body at a place of low water pressure, the size of the water pump can be reduced if the air bubble mixing apparatus 65 is incorporated in the washing system for the human body. When a water pump is connected to the city water piping to pump up the city water, a storage tank open to the atmosphere needs to be disposed between the city water piping and the water pump to prevent backflow of waste water caused by the influence of the operation of the water pump on the pressure of the city water. The air bubble pump constituted by the air bubble mixing apparatus 65 operates on a working principle quite different from those of conventional pumps and does not affect the pressure of the city water. Therefore, the air bubble pump constituted by the air bubble mixing apparatus 65 can be connected directly to the city water piping. Thus, when a washing system for the human body is installed at a place of low water pressure, the construction of the washing system for the human body can be greatly simplified.

[0214] If the air bubble mixing apparatus 65 is used, the pressure of the city water can be decreased and the pressure necessary for mixing the air can be decreased.

[0215] When the air bubble mixing apparatus 65 is used in an area where the hardness of the water is high, the independent pores formed in the inner surface of the air bubble generating member 65a are liable to be clogged by the compounds of hardness components such as calcium carbonate, etc. If the independent pores are clogged, the flow rate of the mixed air decreases. When the air bubble mixing apparatus 65 is used in an area where the hardness of the water is high, therefore, the wash water passage upstream of the air bubble mixing apparatus 65 is preferably provided with a normally-closed opening for receiving acid water. If the acidic water is passed through the air bubble generating member 65a, the compounds of hardness components adhered to the inner surface of the air bubble generating member 65a are easily dissolved and removed. An acidic water generator may be disposed in order to generate acidic water when necessary. The acidic water generator may be an apparatus for electrolyzing the wash water to generate the acidic water or an apparatus for adding an acidic water soluble material to the wash water. The acidic water generator may be operated at predetermined time intervals to wash the inner surface of the air bubble generating member 65a or operated by the user when necessary.

[0216] Figure 19 shows an air bubble generating member 65a' wherein independent pores are formed by a nylon mesh. In the air bubble generating member 65a' , a nylon mesh 74 with independent pores arranged mesh-like is heat adhered to a cylindrical and latticelike support member 75. The air bubble generating member 65a' has high strength. The shape of the pores in the mesh 74 can be adjusted freely by selecting the diameter of fibers, the space between fibers or the orientation of fibers.

F. Measures for preventing degradation of air bubble generating member function.

[0217] Measures for preventing the deposition of calcium carbonate on the inner surfaces of the air bubble generating members 3a, 13a, 46a and 65a of the wash water spouting apparatuses A, B, C and D and degradation with age of the functions of the air bubble generating members 3a, 13a, 46a and 65a were discussed based on tests.

(1) Identification of main component of scale

[0218] City water was passed through a cylindrical porous body, pressurized air was supplied to the outside surface of the cylindrical porous body, air bubbles were mixed with the city water passing through the porous body and the city water mixed with the air bubbles was discharged from the porous body. With continuation of the flow of the city water mixed with the air bubbles, scale adhered to the surface of the water passage in the porous body to the point of preventing the mixing of the air bubbles with the water. The main component of the scale was identified to be calcium carbonate by X-ray diffraction.

(2) Flow test of city water not mixed with air bubbles.

[0219] A half length of a capillary made of acrylic porous material was immersed in one of the following three coating agents, taken out from the coating agent and dried.

[0220] A half length of a capillary made of polyethylene porous material was immersed in one of the following three coating agents, taken out from the coating agent and dried.

① A mixed coating agent of acrylic coating agent and silicon coating agent (acrylic main agent Q166 produced by Mitsui Toatsu Kagaku Co.,Ltd., silicon FS710 produced by Nippon Oil & Fats Co.,Ltd., hardener P53-70S produced by Mitsui Toatsu Kagaku Co.,Ltd. and toluene solvent were mixed. Weight ratio of main coating to hardener was set at 5 to 1. Proper quantities of silicon coating and solvent were added.)

② A coating agent mainly composed by alkyl polysiloxane (GLASKA (A agent, B agent) produced by Nippon Gosei Gomu Co.,Ltd. and isopropyl alcohol were mixed. Weight ratio of A agent to B agent was set at 3 to 1. Proper quantity of isopropyl alcohol was added.)

③ A coating agent setting at room temperature to become glass (GO-100-SX (main agent, hardener) produced by Nikko Co.,LTD. was used. Weight ratio of main agent to hardener was set at 10 to 1.)

[0221] City water adjusted to a hardness of 300 and with no air bubbles mixed in was circulated at a flow rate of 0.5 dm^3/minute through the capillary made of acrylic porous material and the capillary made of polyethylene porous material.

[0222] After the flow of the city water had been continued for a predetermined time, the surfaces of the water passages in the capillaries were observed visually. The results are shown in Figure 20.

[0223] Following facts can be seen from Figure 20.

① In the capillary made of acrylic porous material, the mixed coating agent of acrylic coating agent and silicon coating agent, and the coating agent setting at room temperature to become glass are effective for preventing the deposit of calcium carbonate.

② In the capillary made of polyethylene porous material, the mixed coating agent of acrylic coating agent and silicon coating agent, and the coating agent mainly composed by alkyl polysiloxane are effective for preventing the deposit of calcium carbonate.

③ Any one of the mixed coating agent of acrylic coating agent and silicon coating agent, the coating agent mainly composed of alkyl polysiloxane and the coating agent setting at room temperature to become glass contains a component containing siloxane linkage (Si-O linkage). Thus, a coating agent containing siloxane linkage is effective for preventing the deposition of calcium carbonate.

(3) Flow test of city water with air bubbles mixed in.

① Confirmation test of the effect of flow program on the suppression of the deposition of calcium carbonate.

[0224] A capillary made of polyethylene porous material without surface finishing (outside diameter × inside diameter × length = 8 mm × 2 mm × 10 mm, mean diameter of pores = 26 μm) was set in a pressure chamber, air was supplied to the pressure chamber through an air pump at a flow rate of 1 dm^3/minute, city water adjusted to a hardness of 300 was passed through the capillary at a flow rate of 0.5 dm^3/minute, with the supply of air to the pressure chamber being continued, and a bubble flow was discharged from the capillary. The layout of the measuring apparatus is shown in Figure 21.

[0225] The pressure increase of the air flowing in the pressure chamber with time passage was measured for three flow programs: continuous, repeated cycles of one minute continuous flow and 5 seconds rest (continuous air flow) and repeated cycles of one minute continuous flow and 30 seconds rest (continuous air flow). The test results are shown in Figure 22.

[0226] It is clear from Figure 22 that the speed of the pressure increase of the air flowing in the pressure chamber is lower when the flow of the city water in the capillary is intermittently stopped than when the flow of the city water in the capillary is uninterrupted. Thus, it is clear that the deposit of calcium on the surface of the water passage in the capillary made of polyethylene porous material is suppressed by intermittently stopping the flow of the city water in the capillary. It is thought that the air spouting from the pores in the surface of the water passage when the flow of the city water in the water passage is stopped removes the scale adhered to the surface of the water passage. It is clear from Figure 22 that the city water flow programs consisting of repeated cycles of one minute flow and 5 seconds rest and repeated cycles of one minute flow and 30 seconds rest have substantially the same effects on the suppression of the deposition of calcium carbonate.

[0227] The following tests were carried out using the measuring apparatus shown in Figure 21. Air was supplied to the pressure chamber through the air pump at a flow rate of 1 dm^3/minute, city water adjusted to a hardness of 150 was passed through the capillary made of polyethylene porous material at a flow rate of 0.5 dm^3/minute, with the supply of air to the pressure chamber being continued, and a bubble flow was discharged from the capillary.

[0228] The pressure increase of the air flowing in the pressure chamber with time passage was measured for two flow programs: a) continuous and b) repeated cycles of one minute continuous flow and 5 seconds rest. The test results are shown in Figure 23.

[0229] It is clear from Figure 23 that the deposit of calcium on the surface of water passage of the capillary made of polyethylene porous material is suppressed by intermittently stopping the flow of the city water in the capillary even if the hardness of the city water flowing in the water passage changes.

② Confirming test of the effect of coating agent on the suppression of the deposition of calcium carbonate.

[0230] The following tests were carried out using the measuring apparatus shown in Figure 21. A capillary made of acrylic porous material (outside diameter × inside diameter × length = 8 mm × 2 mm × 10 mm, mean diameter of pores = 40 μm) coated with a mixed coating agent of acrylic coating agent, silicon coating agent and fluororesin (acrylic main agent Q166 produced by Mitsui Toatsu Kagaku Co.,Ltd., silicon FS710 produced by Nippon Oil & Fats Co.,Ltd., fluororesin F200 produced by Nippon Oil & Fats Co.,Ltd., hardener P53-70S produced by Mitsui Toatsu Kagaku Co.,Ltd. and toluene solvent were mixed. Weight ratio of main coating agent to hardener was set at 5 to 1. Proper quantity of silicon coating and fluororesin were added.) was set in the pressure chamber, air was supplied to the pressure chamber through the air pump at a flow rate of 1 dm^3/minute, city water adjusted to a hardness of 300 was passed through the capillary at a flow rate of 0.5 dm^3/minute, with the supply of the air to the pressure chamber being continued, and a bubble flow was discharged from the capillary. The pressure increase of the air flowing in the pressure chamber with time passage was measured during repeated cycles of one minute continuous flow and 5 seconds rest. The test results are shown in Figure 24. The results of the same test carried out on a capillary made of acrylic porous material of the same size without surface finishing are also shown in Figure 24.

[0231] It is clear from Figure 24 that the rate of the pressure increase of the air flowing in the pressure chamber is decreased and the deposition of calcium carbonate on the inner surface of the capillary made of acrylic porous material is suppressed by surface finishing with the mixed coating agent of acrylic coating agent, silicon coating agent and fluororesin.

[0232] The following tests were carried out using the measuring apparatus shown in Figure 21. A capillary made of acrylic porous material (outside diameter × inside diameter × length = 8 mm × 2 mm × 10 mm, mean diameter of pores = 36 μm) coated with a mixed coating agent of acrylic coating agent and silicon coating agent (acrylic main agent Q166 produced by Mitsui Toatsu Kagaku Co.,Ltd., silicon FS710 produced by Nippon Oil & Fats Co.,Ltd., hardener P53-70S produced by Mitsui Toatsu Kagaku Co.,Ltd. and toluene solvent were mixed. Weight ratio of main coating to hardener was set at 5 to 1. Silicon content was set at 0 weight%, 0.3 weight%, and 3 weight%. Proper quantity of solvent was added.) was set in the pressure chamber, air was supplied to the pressure chamber through the air pump at a flow rate of 1 dm^3/minute, city water adjusted to a hardness of 300 was passed through the capillary at a flow rate of 0.5 dm^3/minute, with the supply of the air to the pressure chamber being continued, and a bubble flow was discharged from the capillary. The pressure increase of the air flowing in the pressure chamber with time passage was measured during repeated cycles of one minute continuous flow and 5 seconds rest. The test results are shown in Figure 25.

[0233] It is clear from Figure 25 that the deposition of calcium carbonate on the inner surface of the capillary made of acrylic porous material is suppressed by surface finishing with the mixed coating agent of acrylic coating agent and silicon coating agent which contains no fluororesin. It is also clear from Figure 25 that the ratio of the silicon in the mixed coating agent is preferably 0.3 weight %.

[0234] The following tests were carried out using the measuring apparatus shown in Figure 21. A capillary made of acrylic porous material (outside diameter × inside diameter × length = 8 mm × 2 mm × 10 mm, mean diameter of pores = 30 μm) coated with a coating agent setting at room temperature to become glass (GO-100-SX (main agent, hardener) produced by Nikko Co.,Ltd. was used. Weight ratio of main agent to hardener was set at 10 to 1.) was set in the pressure chamber, air was supplied to the pressure chamber through the air pump at a flow rate of 1 dm^3/minute, city water adjusted to a hardness of 150 was passed through the capillary at a flow rate of 0.5 dm^3/minute, with the supply of the air to the pressure chamber being continued, and a bubble flow was discharged from the capillary. The pressure increase of the air flowing in the pressure chamber with time passage was measured during repeated cycles of one minute continuous flow and 5 seconds rest. The test results are shown in Figure 26. The results of the same test carried out on a capillary made of acrylic porous material of the same size without surface finishing are also shown in Figure 26.

[0235] It is clear from Figure 26 that the deposition of calcium carbonate on the inner surface of the capillary made of acrylic porous material is suppressed by surface finishing with the coating agent setting at room temperature to become glass.

[0236] The following tests were carried out using the measuring apparatus shown in Figure 21. A capillary made of polyethylene porous material (outside diameter × inside diameter × length = 8 mm × 2 mm × 10 mm, mean diameter of pores = 25 μm) coated with a mixed coating agent of acrylic coating agent and silicon coating agent (acrylic main agent Q166 produced by Mitsui Toatsu Kagaku Co.,Ltd., silicon FS710 produced by Nippon Oil & Fats Co.,Ltd., hardener P53-70S produced by Mitsui Toatsu Kagaku Co.,Ltd. and toluene solvent were mixed. Weight ratio of main coating to hardener was set at 5 to 1. Silicon content was set at 0.3 weight %. Proper quantity of solvent was added.) was set in the pressure chamber, air was supplied to the pressure chamber through the air pump at a flow rate of 1 dm^3/minute, city water adjusted to a hardness of 150 was passed through the capillary at a flow rate of 0.5 dm^3/minute, with the supply of the air to the pressure chamber being continued, and a bubble flow was discharged from the capillary. The pressure increase of the air flowing in the pressure chamber with time passage was measured during repeated cycles of one minute continuous flow and 5 seconds rest. The test results are shown in Figure 27.

[0237] It is clear from Figure 27 that the deposition of calcium carbonate on the inner surface of the capillary made of polyethylene porous material is suppressed by surface finishing with the mixed coating agent of acrylic coating agent and silicon coating agent.

[0238] The following tests were carried out using the measuring apparatus shown in Figure 21. A capillary made of polyethylene porous material (outside diameter × inside diameter × length = 8mm × 2mm × 10 mm, mean diameter of pores = 25 to 30 μm) coated with a coating agent mainly composed by alkyl polysiloxane (GLASKA (A agent, B agent) produced by Nippon Gosei Gomu Co.,Ltd. and isopropyl alcohol were mixed. Weight ratio of A agent to B agent was set at 3 to 1. Proper quantity of isopropyl alcohol was added.) was set in the pressure chamber, air was supplied to the pressure chamber through the air pump at a flow rate of 1 dm^3/minute, city water adjusted to hardnesses of 150 and 300 was passed through the capillary at a flow rate of 0.5 dm^3/minute, with the supply of the air to the pressure chamber being continued, and a bubble flow was discharged from the capillary. The pressure increase of the air flowing in the pressure chamber with time passage was measured during repeated cycles of one minute continuous flow and 5 seconds rest. The results obtained in the test using the city water of hardness of 150 are shown in Figure 28 and the results obtained in the test using the city water of hardness of 300 are shown in Figure 29.

[0239] It is clear from Figures 28 and 29 that the deposition of calcium carbonate on the inner surface of the capillary made of polyethylene porous material is suppressed by surface finishing using the coating agent mainly composed of alkyl polysiloxane.

G. Application of the wash water spouting apparatus to various kinds of apparatuses

G-1 Application to a washing system for regions of the human body such as the anus or the private parts.

[0240] The wash water spouting apparatus A shown in Figure 5 can be applied to a washing system installed on a toilet bowl for washing regions of the human body such as the anus or the private parts. In a washing system for the human body provided with the wash water spouting apparatus A, the pipe 2 is provided with a closing valve at its part upstream of the continuous flow valve 5, the pipe 2 is provided with a heater for heating wash water at its part between the continuous flow valve 5 and the air bubble mixing apparatus 3 and a driving apparatus for driving the wash water discharging nozzle 1 is provided. In the washing system for the human body, a bubble flow is spouted to achieve high detergency, gentle stimulation and high effect of water saving.

[0241] In the washing system for the human body provided with the wash water spouting apparatus A, the controller 4e may variably control the voltage applied to the air pump 4c.

[0242] The voltage applied to the air pump 4c is variably controlled, the rate of the mixing of air with the wash water or the rate of the mixing of air bubbles with the wash water is variably controlled periodically or at random, and the detergency and the stimulation effect of the wash water is variably controlled. Thus, the convenience of the washing system for the human body increases.

[0243] In the washing system for human body provided with the wash water spouting apparatus A, the pipe 4a may be provided with a pressure sensor at its part downstream of the air pump 4c to variably control the voltage applied to the air pump 4c by the controller 4e according to the output of the pressure sensor. A rotation speed sensor for detecting the rotation speed of the air pump 4c may be disposed to variably control the voltage applied to the air pump 4c by the controller 4e according to the output of the rotation speed sensor. The pipe 4a may be provided with a release valve to the atmosphere at its part downstream of the air pump 4c to control the opening and closing motion of the release valve by the controller 4e. If the voltage applied to the air pump 4c is controlled according to the pressure in the pipe 4e downstream of the air pump 4c, if the voltage applied to the air pump 4c is controlled according to the rotation speed of the air pump 4c or if the opening and closing motion of the release valve to the atmosphere disposed at the part of the pipe 4a downstream of the air pump 4c is controlled, the rate of the mixing of the air with the wash water or the rate of the mixing of the air bubbles with the wash water is variably controlled and the detergency and the stimulation effect of the wash water are variably controlled. Thus, the convenience of the washing system for the human body increases.

[0244] In the washing system for the human body provided with the wash water spouting apparatus A, the controller 4e may open the closing valve disposed at the part of the pipe 2 upstream of the continuous flow valve 5 for a predetermined period of time to pass the wash water through the wash water spouting apparatus A. The controller 4e may drive the air pump 4c for a predetermined period of time. If the wash water is passed through the wash water spouting apparatus A for a predetermined period of time or the air pump 4c is driven to supply the bubble generating member 3a with pressurized air for a predetermined period of time, the air bubble generating member 3a is automatically maintained and the function of the washing system for the human body is maintained for a long time.

[0245] In the washing system for the human body provided with the wash water spouting apparatus A, the controller 4e may close the closing valve disposed at the part of the pipe 2 upstream of the continuous flow valve 5 intermittently to stop the passage of the wash water through the wash water spouting apparatus A intermittently. If the passage of the wash water through the wash water passage is stopped intermittently while the operation of the air pump 4c is continued, air is spouted from the air bubble generating member 3a to remove calcium carbonate adhered to the inner surface. Thus, the deposition of calcium carbonate on the surface of the wash water passage in the air bubble generating member 3a is effectively suppressed.

[0246] In the washing system for the human body provided with the wash water spouting apparatus A, the controller 4e may open the closing valve disposed at the part of the pipe 2 upstream of the continuous flow valve 5 to pass wash water through the wash water spouting apparatus A or drive the air pump 4c after the operation switch of the washing system for the human body is turned on and before the wash water discharging nozzle 1 is driven to a predetermined position. If such preliminary actions are carried out, the wash water discharging nozzle 1 moved to the predetermined position can reliably spout a bubble flow.

[0247] In the washing system for the human body provided with the wash water spouting apparatus A, the pipe 4a may be provided with a volatile constituent mixing apparatus at its part downstream of the air pump 4c. If a volatile constituent such as odor removing agent, fragrance agent, etc. is mixed with air in the air bubbles, the convenience of the washing system for the human body increases. G-2 Application to a hot-water supplying apparatus.

[0248] The wash water spouting apparatus A shown in Figure 5 can be applied to a hot-water supplying apparatus. As shown in Figure 30, the pipe 2 is provided with a flow rate sensor 80, a cold-water temperature sensor 81, a heater 82, a hot-water temperature sensor 83, a mixing apparatus 84 for mixing cold water with hot water, a mixed-water temperature sensor 85 and a water flow rate control valve 86. These members are disposed in series in the order of the flow rate sensor 80, the cold-water temperature sensor 81, the heater 82, the hot-water temperature sensor 83, the mixing apparatus 84, the mixed-water temperature sensor 85 and the water flow rate control valve 86 from upstream to downstream relative to the water flow. The wash water spouting apparatus A is disposed downstream of the water flow rate control valve 86. The wash water discharging nozzle 1 of the wash water spouting apparatus A forms such an apparatus as a shower nozzle or water faucet in a bath room, a water faucet in a washroom, etc. The controller 4e of the wash water spouting apparatus A also controls the operation of the heater 82, the mixing apparatus 84, the water flow rate control valve 86, etc.

[0249] In the hot-water supplying apparatus, the controller 4e controls the operation of the heater 82 to generate hot-water of desired temperature according to the water flow rate detected by the water flow sensor 80, water temperature detected by the cold-water temperature sensor 81 and the hot-water temperature detected by the hot-water temperature sensor 83. The controller 4e controls the mixing apparatus 84 to mix the hot water with the water thereby generating mixed-water of appropriate temperature according to the hot-water temperature detected by the hot-water temperature sensor 83 and the mixed-water temperature detected by the mixed-water temperature sensor 85. The controller 4e controls the operation of the water flow rate control valve 86 to pass the mixed-water of appropriate temperature and flow rate through the pipe 2. The controller 4e controls the operation of the air pump 4c of the wash water spouting apparatus A to mix a large number of micro air bubbles with the mixed-water of appropriate temperature passing through the pipe 2. A bubble flow of hot-water spouts from the shower nozzle or water faucet in a bath room, water faucet in a washroom, etc. formed by the wash water discharging nozzle 1 of the wash water spouting apparatus A. It is possible to dispose a flow rate sensor just upstream of the shower nozzle or the water faucet to stop the air pump 4c when the hot water spouts from the shower nozzle or the water faucet thereby spouting the hot water without air bubbles.

[0250] In the hot-water supplying apparatus having the wash water spouting apparatus A, the consumption of hot-water decreases because of the water saving effect of the wash water spouting apparatus A. Thus, the size of the heater 82 can be reduced, the size of the hot-water supplying apparatus can be reduced and the energy consumed by the hot-water supplying apparatus can be saved.

G-3 Application to a showering apparatus.

[0251] The wash water spouting apparatus A shown in Figure 5 can be applied to a showering apparatus. As shown in Figures 31(a) and 31(b), in the wash water spouting apparatus A applied to a showering apparatus, the wash water discharging nozzle 1 forms a shower head and the air bubble mixing apparatus 3 is disposed in the wash water discharging nozzle 1. The air bubble generating member 3a comprises a columnar body $3a_1$ made of a porous material and a pair of end plates $3a_2$ sealing both ends of the columnar body $3a_1$. The columnar body $3a_1$ and the end plates $3a_2$ are provided with many penetration holes $3a_3$. The penetration holes $3a_3$ formed in the columnar body Sa_1 are provided with a large number of independent pores at their surrounding surfaces. The air bubble generating member 3a is press fitted in the wash water discharging nozzle 1. A dispersing plate 1a is detachably connected to the end of the wash water discharging nozzle 1. The dispersing plate 1a is provided with many discharge holes $1a_1$ communicating with the penetration holes $3a_3$ of the air bubble generating member 3a. A pressure chamber 3b is formed around the air bubble generating member 3a. The wash water discharging nozzle 1 is provided with a wash water passage 1b communicating with the the penetration holes $3a_3$ of the air bubble generating member 3a and an air passage 1c communicating with the pressure chamber 3b. The wash water passage 1b is connected to the pipe 2 and the air passage 1c is connected to the pipe 4a. The present showering apparatus has the same structure as the hot-water supplying apparatus shown in Figure 30 except that the wash water discharging nozzle 1 forms a shower head and the air bubble mixing apparatus 3 is disposed in the wash water discharging nozzle 1.

[0252] In the present showering apparatus, hot-water of appropriate temperature and pressurized air are supplied to the wash water discharging nozzle 1. The hot-water passes through the wash water passage 1b and flows into the penetration holes $3a_3$ of the air bubble generating member 3a. The pressurized air passes through the air passage 1c and flows into the pressure chamber 3b. The pressurized air becomes a large number of micro air bubbles by passing through the air bubble generating member 3a and the air bubbles are mixed with and substantially uniformly dispersed in the hot-water passing through the penetration holes $3a_3$. A bubble flow wherein a large number of micro air bubbles are mixed with and dispersed in the hot-water passes through the dispersing plate 1a to form a shower of a bubble flow.

[0253] In the showering apparatus having the wash water spouting apparatus A, high detergency and high effect of water saving are obtained.

G-4 Application to a hair washing apparatus

[0254] The wash water spouting apparatus A shown in Figure 5 can be applied to a hair washing apparatus. As shown in Figures 32 to 34, a basin 90 is provided with a discharge hole 90a at its bottom. The basin 90 is provided with a plurality of shower nozzles 91 for washing the side portion and the rear potion of a head, a plurality of shampoo nozzles 92 and a shower nozzle 93 at its side wall. The basin 90 is set on a base not shown in the Figures. The wash water spouting apparatus A applied to the showering apparatus shown in Figures 31(a) and 31(b) constitutes the wash water spouting apparatus having the shower nozzles 91 and 93. In the wash water spouting apparatus A applied to the present hair washing apparatus, the wash water and the pressurized air are supplied to a plurality of wash water discharging nozzles. Shampoo is supplied to the shampoo nozzle 92 from a shampoo source not shown in the Figures.

[0255] The user of the present hair washing apparatus puts the rear portion of the head on the basin 90 with his or her face upward. A cover not shown in the Figures is put on the basin 90 to cover the font portion and the top portion of the head. When the user pushes a control switch not shown in the Figures, the shampoo discharges from the shampoo nozzles 92 to wash the hair and the bubble flows of the wash water spout from the shower nozzles 91 and 93 to rinse the washed hair. Waste water is discharged from the discharge hole 90a. The cover not shown in the Figures prevents scattering of the shampoo and wash water during the hair washing operation.

[0256] In the hair washing apparatus comprising the wash water spouting apparatus A, high detergency and high effect of water saving can be obtained. In the hair washing apparatus comprising the wash water spouting apparatus A, the contact area between the wash water and the air is very large because a large number of air bubbles are mixed with and dispersed in the wash water. Thus, chlorine contained in the wash water (city water) is rapidly removed by deaeration. Thus, the hair is protected from damage by highly reactive chlorine because the chlorine is removed. It is possible to mix into the wash water a gas with a large rate of absorption in water, such as carbon dioxide, to accelerate the removal of chlorine by deaeration. In order to prevent the growth of miscellaneous bacteria, the removal of chlorine is carried out just before spouting of the wash water. When the wash water spouting apparatus A is applied to a washing apparatus for human skin, the skin is protected from damage by chlorine.

G-5 Application to a water faucet

[0257] The wash water spouting apparatus A shown in Figure 5 can be applied to a water faucet. As shown in Figures 35 to 37, in the wash water spouting apparatus A applied to a water faucet, the wash water discharging nozzle 1 forms a discharge head of a water faucet and the air bubble mixing apparatus 3 is disposed in the water discharging nozzle 1. The wash water discharging nozzle 1 is provided with a wash water passage 1d communicating with the air bubble generating member 3a and an air passage 1e communicating with the pressure chamber 3b. The wash water discharging nozzle 1 is fixed by a screw to a rotatable discharge pipe 101 of the water faucet body 100. The wash water passage 1d is connected to the pipe 2 through a pipe not shown in the Figures disposed in the discharge pipe 101 and the air passage 1e is connected to the pipe 4a through another pipe not shown in the Figures disposed in the discharge pipe 101. As shown in Figures 35 to 37, the present water faucet has the same structure as the hot-water supplying apparatus shown in Figure 30 except that the wash water discharging nozzle 1 forms a discharge nozzle and the air bubble mixing apparatus 3 is disposed in the wash water discharging nozzle 1.

[0258] In the present water faucet apparatus, the flow rates of the water and the air are controlled by the control member 100a of the water faucet body 100.

[0259] In the water faucet having the wash water spouting apparatus A, high detergency and high effect of water saving are obtained.

G-6 Application to a face washing apparatus

[0260] The wash water spouting apparatus A shown in Figure 5 can be applied to a face washing apparatus. The structure of the face washing apparatus may be the same as that of the hair washing apparatus shown in Figures 32 to 34.

[0261] In the face washing apparatus having the wash water spouting apparatus A, high detergency and high effect of water saving are obtained.

G-7 Application to an eye washing apparatus

[0262] The wash water spouting apparatus A shown in Figure 5 can be applied to an eye washing apparatus. The structure of the eye washing apparatus may be the same as that of the wash water spouting apparatus A shown in Figure 5 except that the pipe 2 downstream of the air mixing apparatus 3 is made flexible and the wash water discharging nozzle 1 is given handy size to facilitate the eye washing operation.

[0263] In the eye washing apparatus having the wash water spouting apparatus A, the gas-liquid ratio is set relatively low to obtain a gentle stimulation and adequate detergency.

G-8 Application to a palate washing apparatus

[0264] The wash water spouting apparatus A shown in Figure 5 can be applied to a palate washing apparatus. The structure of the palate washing apparatus may be the same as that of the wash water spouting apparatus A shown in Figure 5 except that the pipe 2 downstream of the air mixing apparatus 3 is made flexible and the wash water discharging nozzle 1 is made slender and given handy size to facilitate the palate washing operation.

[0265] In the palate washing apparatus having the wash water spouting apparatus A, high detergency and high effect of water saving are obtained.

G-9 Application to a hand washing apparatus

[0266] The wash water spouting apparatus A shown in Figure 5 can be applied to a hand washing apparatus. The structure of the hand washing apparatus may be the same as that of the water faucet shown in Figures 35 to 37. Otherwise the structure of the hand washing apparatus may be the same as that of the water faucet shown in Figures 35 to 37 except that a warm air discharging apparatus for drying the hands is disposed near the water faucet.

[0267] In the hand washing apparatus having the wash water spouting apparatus A, high detergency and high effect of water saving are obtained.

G-10 Application to a bath tub

[0268] The wash water spouting apparatus A shown in Figure 5 can be applied to a bath tub. The structure of the bath tub may be that wherein the wash water discharging nozzle 1 of the wash water spouting apparatus A is fitted to the side wall of a bath tub.

[0269] In the bath tub having the wash water spouting apparatus A, the bubble flow strikes against the human body to produce a massaging effect.

G-11 Application to ultrasonic cleaning apparatus

[0270] The wash water spouting apparatus A can be applied to an ultrasonic cleaning apparatus.

[0271] When a bubble flow strikes against a target surface, air bubbles with small density and small kinetic energy and water with large density and large kinetic energy between the adjacent air bubbles strike against the target surface alternately at short intervals. Thus a pressure fluctuation or vibration is generated at the target surface. The frequency of the vibration can be controlled by changing the number of the air bubbles striking against the target surface per unit time. It is possible to generate ultrasonic vibration with very high detergency. The ultrasonic vibration can reach and remove dirt that has entered wrinkles or crevices because the wavelength of the ultrasonic vibration is short. Thus, the detergency of the ultrasonic vibration is very high.

[0272] The ultrasonic vibration can wash the internal spaces of small crevices because its wavelength is short. But, the ultrasonic vibration cannot wash a broad area because it damps rapidly. Low frequency vibration with long wave length has low detergency but can wash a broad area because it damps slowly. It is possible to control the diameter of the air bubbles while keeping the flow rate of the air constant to control the number of the air bubbles striking against the target surface per unit time thereby controlling the frequency of the vibration generated on the target surface. That is, the strength of the detergency or the area on which the detergency acts can be controlled by controlling the diameter of the air bubbles. When the diameter of the air bubbles is large, the frequency of the vibration is low and a broad area can be washed thoroughly. When the diameter of the air bubbles is small, the frequency of the vibration is high and stubborn local dirt can be washed away. When the frequency of the vibration is high, the vibration damps rapidly on the surface of the human body to generate a strong stimulation on the surface of the skin. When the frequency of the vibration is low, the vibration generates a gentle stimulation on the surface of the skin. A vibration in the frequency range of 5 to 30 Hz substantially resonates with the free vibration of the portion of the human body near the skin surface to produce a high massaging effect. Thus, a vibration in the frequency range of 5 to 30 Hz can give the user the reeling that he or she is using a large quantity of wash water though he or she is actually using only a small quantity of wash water. H. A wash water spouting apparatus comprising an air bubble breaking apparatus

[0273] In any one of the aforementioned wash water spouting apparatuses, the air bubble generating member made of porous material generates micro air bubbles to mix and disperse them in the wash water. However, micro air bubbles may instead be produced by breaking air bubbles mixed with the wash water.

[0274] As shown in Figure 38, in a wash water spouting apparatus E, a pipe 110 forming a wash water passage is provided with a continuous flow valve 111, an air mixing apparatus 112 and an air bubble breaking apparatus 113. These members are disposed in series in the order of the continuous flow valve 111, the air mixing apparatus 112 and the air bubble breaking apparatus 113 from upstream to downstream relative to the water flow. The pipe 110 is provided with a wash water discharging nozzle 114 at its downstream end.

[0275] The air mixing apparatus 112 is constituted by a pipe 112a forming a wash water passage and a capillary 112b crossing the pipe 112a substantially at right angles to open at the inner surface of the pipe 112a.

[0276] The air bubble breaking apparatus 113 comprises a pipe 113a forming a wash water passage and a baffle plate 113b with a single opening $113b_1$ disposed in the pipe 113a as shown in Figure 39(a), a pipe 113a forming a wash water passage and a baffle plate 113c with a plurality of openings $113c_1$ disposed in the pipe 113a as shown in Figure 39(b) or a pipe 113a forming a wash water passage and a mesh 113d disposed in the pipe 113a as shown in Figure 39(c). The mesh 113d comprises a plurality of woven cloths made of resin fibers or metal fibers, a plurality of unwoven cloths, or the like stacked on one another.

[0277] A forced air supplying apparatus 115 having an air pump 115a is connected to the capillary 112b of the air bubble mixing apparatus 112.

[0278] In the wash water spouting apparatus E, the pressurized air supplied by the forced air supplying apparatus 115 is mixed with the wash water passing through the pipe 112a through the capillary 112b. The air bubbles generated at the end of the capillary 112b grow in the direction perpendicular to the flow of the wash water because the capillary 112b opens at the inner surface of the pipe 112a. Shear force is therefore applied to the air bubbles by the wash water passing through the pipe 112a and the air bubbles leave the end of the capillary 112b entrained by the wash water at the first stage of generation. Thus, air bubbles of relatively small diameter are mixed with the wash water. When the wash water containing air bubbles of small diameter passes through the opening $113b_1$ of the baffle plate 113b of the air bubble breaking apparatus 113 or the openings $113c_1$ of the baffle plate 113c of the air bubble breaking apparatus 113, the sectional area of the wash water passage decreases, the velocity of the flow of the wash water increases, the shear force applied to the air bubbles of small diameter by the wash water increases and the air bubbles of small diameter are broken into micro air bubbles. When the wash water containing air bubbles of small diameter passes through the mesh 113d of the air bubble breaking apparatus 113, the air bubbles of small diameter are broken by the mesh 113d into micro air bubbles. A bubble flow wherein a large number of micro air bubbles are mixed with and dispersed in the wash water spouts from the wash water discharging nozzle 114. The spouting bubble flow increases the detergency of the wash water and achieves a water saving effect.

[INDUSTRIAL APPLICABILITY OF THE INVENTION]

[0279] In accordance with the present invention, a wash water spouting apparatus which can increase the detergency of the wash water, achieve a gentle stimulation effect and achieve a water saving by a large amount is provided.

Claims

1. A wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water and air bubble mixing means for mixing air bubbles with the wash water passing through a wash water passage.

2. A wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water and air bubble mixing means for generating a large number of micro air bubbles while preventing merging of the air bubbles, mixing the air bubbles with the wash water passing through a wash water passage, and dispersing the air bubbles in the wash water passing through the wash water passage.

3. A wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed substantially uniformly in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water and air bubble mixing means for generating a large number of micro air bubbles, while preventing merging of the air bubbles, mixing the air bubbles with the wash water passing through a wash water passage, and dispersing the air bubbles substantially uniformly in the wash water passing through the wash water passage.

4. A wash water spouting apparatus comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water and air bubble mixing means for generating a large number of micro air bubbles and mixing the air bubbles with the wash water passing through a wash water passage, wherein the relation between E_w and E_t is $E_w < E_t$, where E_w is the energy of the wash water passing through the wash water passage just upstream of the air bubble mixing means and E_t is the energy of the wash water passing through the wash water passage just downstream of the air bubble mixing means.

5. A wash water spouting apparatus for spouting a bubble flow wherein a large number of micro air bubbles are dispersed in wash water, comprising wash water spouting means, wash water supplying means for supplying the wash water spouting means with wash water, air bubble mixing means for mixing air bubbles with the wash water passing through a wash water passage and air bubble breaking means for breaking air bubbles mixed with the wash water into micro air bubbles.

6. A wash water spouting apparatus of any of claims 1 to 5, further comprising forced air supplying means for force supplying the air bubble mixing means with air.

7. A wash water spouting apparatus of any of claims 1 to 6, wherein the mean diameter of the micro air bubbles in the bubble flow is 100μ m to 1000μ m.

8. A wash water spouting apparatus of any of claims 1 to 7, wherein the ratio of the volume flow rate of the air mixed with the wash water to the volume flow rate of the wash water is 0.5 : 1 to 4.0 : 1.

9. A wash water spouting apparatus of any of claims 1 to 8, wherein the sectional area of the wash water passage at the air bubble mixing means and downstream of the air bubble mixing means is larger than the projected area of a sphere of a diameter equal to the mean diameter of the mixed air bubbles and the sectional area of the wash water passage downstream of the air bubble mixing means is larger than or equal to that at the air bubble mixing

means.

10. A wash water spouting apparatus of any of claims 1 to 9, wherein the wash water passage downstream of the air bubble mixing means extends substantially straight.

11. A wash water spouting apparatus of any of claims 1 to 10, wherein the air bubble mixing means is disposed in the wash water spouting means.

12. A wash water spouting apparatus of claim 11, wherein the air bubble mixing means is disposed in the vicinity of the outlet port of the wash water spouting means.

13. A wash water spouting apparatus of claim 12, wherein the part of the wash water spouting means in the vicinity of the outlet port is detachably connected to the remaining part.

14. A wash water spouting apparatus of any of claims 1 to 13, wherein the air bubble mixing means has an air bubble generating member provided with a large number of independent pores at its surface contacting the wash water passing through the wash water passage.

15. A wash water spouting apparatus of claim 14, wherein the independent pores are disposed regularly and in a lattice.

16. A wash water spouting apparatus of any of claims 1 to 13, wherein the air bubble mixing means comprises an air bubble generating member having mesh construction at its surface contacting the wash water passing through the wash water passage.

17. A wash water spouting apparatus of claim 14 or claim 15, wherein the air bubble generating member is made of an aggregate of substantially spherical particles.

18. A wash water spouting apparatus of claim 17, wherein the mean diameter of the substantially spherical particles is 50 μm to 300 μm.

19. A wash water spouting apparatus of claim 17, wherein the space between the substantially spherical particles is 50 μm to 300 μm.

20. A wash water spouting apparatus of any of claims 17 to 19, wherein a filling factor of the substantially spherical particles is larger than or equal to 70 %.

21. A wash water spouting apparatus of claim 14 or 15, wherein the air bubble generating member is made of a hot formed compact of heat fusible powder.

22. A wash water spouting apparatus of any of claims 14 to 21, wherein the surface of the air bubble generating member contacting the wash water extends flush with the inner surface of the wash water passage.

23. A wash water spouting apparatus of any of claims 14 to 22, wherein the air bubble generating member is a cylindrical porous body forming the wash water passage.

24. A wash water spouting apparatus of claim 23, wherein an air passage is formed around the cylindrical porous body.

25. A wash water spouting apparatus of claim 23 or 24, wherein the sectional area of the wash water passage formed in the cylindrical porous body is constant or gradually increases from the upstream end to the downstream end.

26. A wash water spouting apparatus of any of claims 23 to 25, wherein the cylindrical porous body is fixed to the wash water spouting means by press fitting.

27. A wash water spouting apparatus of claim 26, wherein the inner diameter of the cylindrical porous body is made larger at the press fitting part of the cylindrical porous body than at the remaining part of the cylindrical porous body.

28. A wash water spouting apparatus of claim 27, wherein the cylindrical porous body is press fitted at its both ends and the inner diameter of one of the press fitting parts is made larger than that of the remaining part of the cylindrical porous body.

29. A wash water spouting apparatus of any of claims 14 to 28, wherein all or part of the air bubble generating member is made of water repellent material, or a water repellent finish is applied to the surface of the wash water passage formed in the air bubble generating member.

30. A wash water spouting apparatus of any of claims 14 to 28, wherein all or part of the air bubble generating member is made of hydrophilic material, or a hydrophilic finish is applied to the surface of the wash water passage formed in the air bubble generating member.

31. A wash water spouting apparatus of any of claims 14 to 28, wherein the surface of the wash water passage formed in the air bubble generating member is coated by a surface finishing agent for preventing the deposition of calcium.

32. A wash water spouting apparatus of claim 31, wherein the surface finishing agent contains siloxane linkage.

33. A wash water spouting apparatus of claim 31, wherein the surface finishing agent contains acrylic agent and silicon agent.

34. A wash water spouting apparatus of claim 31, wherein the air bubble generating member is a porous polyethylene body and the surface finishing agent contains alkylpolysiloxane.

35. A wash water spouting apparatus of claim 31, wherein the air bubble generating member is a porous acrylic body and the finishing agent contains cold setting glass.

36. A wash water spouting apparatus of any of claims 1 to 35, further comprising solute concentration control means for solving a solute in the wash water to a predetermined concentration.

37. A wash water spouting apparatus of claim 6, further comprising flow control means for intermittently stopping the flow of the wash water in the wash water passage when the forced air supplying means operates.

38. A wash water spouting apparatus of claim 6 or 37, wherein the wash water supplying means has a wash water storage tank, and the forced air supplying means force supplies the air to the air bubble mixing means and the wash water storage tank to pressurize the wash water thereby discharging the wash water from the wash water storage tank.

39. A wash water spouting apparatus of claim 38, wherein a pipe connecting the forced air supplying means with the wash water storage tank and/or a pipe connecting the forced air supplying means with the air bubble mixing means are provided with pressure control valves.

40. A wash water spouting apparatus of claim 38 or 39, wherein the size, weight and electric power consumption of the wash water spouting apparatus are determined to be convenient for portable use.

41. A washing system for regions of the human body such as the anus and private parts comprising the wash water spouting apparatus of any of claims 1 to 40.

42. A washing system for regions of the human body such as the anus and private part comprising the wash water spouting apparatus of claim 6 or any of claims 37 to 40 and a controller for driving the wash water supplying means and the forced air supplying means for a predetermined period of time.

43. A washing system for regions of the human body such as the anus and private parts of claim 41 or 42, wherein the air bubble mixing means has an air bubble generating member wherein a large number of independent pores are formed in the surface contacting the wash water passing through a wash water passage, the air bubble generating member is formed by a porous cylindrical body forming the wash water passage, the porous cylindrical body is disposed in the wash water spouting means and in the vicinity of the outlet of the wash water spouting means, and the downstream end of the porous cylindrical body is directed upward.

44. A washing system for regions of the human body such as the anus and private parts of any of claims 41 or 43, further comprising volatile constituent mixing means for mixing a volatile constituent with the air to be supplied to the air mixing means forming the wash water passage.

45. A washing system for regions of the human body such as the anus and private parts of any of claims 41 or 44, wherein the wash water spouting means has a plurality of outlet ports and the bubble flow is selectively fed to one of the plurality of outlet ports through passage selecting means.

46. A showering apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

47. A hair washing apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

48. A face washing apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

49. An eye washing apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

50. A palate washing apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

51. A hand washing apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

52. A water faucet comprising the wash water spouting apparatus of any of claims 1 to 40.

53. A bath tub comprising the wash water spouting apparatus of any of claims 1 to 40.

54. An ultrasonic washing apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

55. A hot-water supplying apparatus comprising the wash water spouting apparatus of any of claims 1 to 40.

Fig. 1 (a)

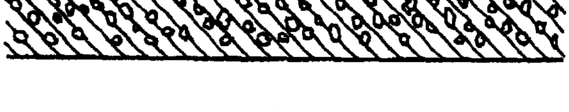


Fig. 1 (b)

Fig. 1 (c)

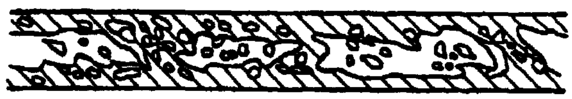


Fig. 1 (d)

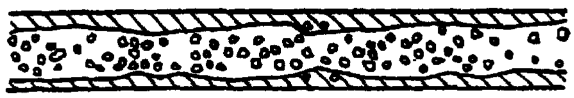


Fig. 2

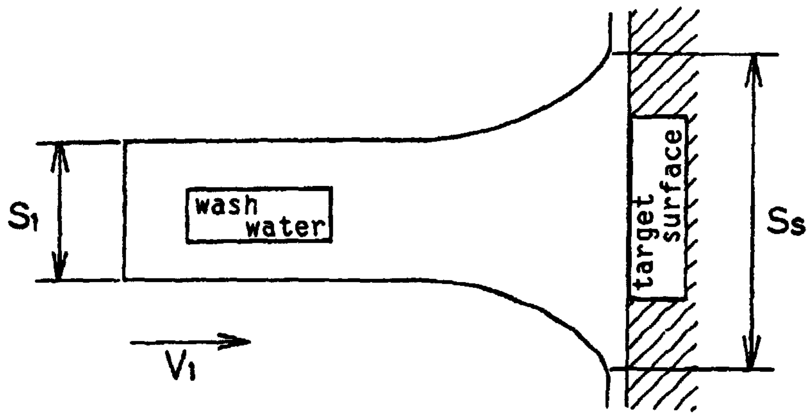


Fig. 3

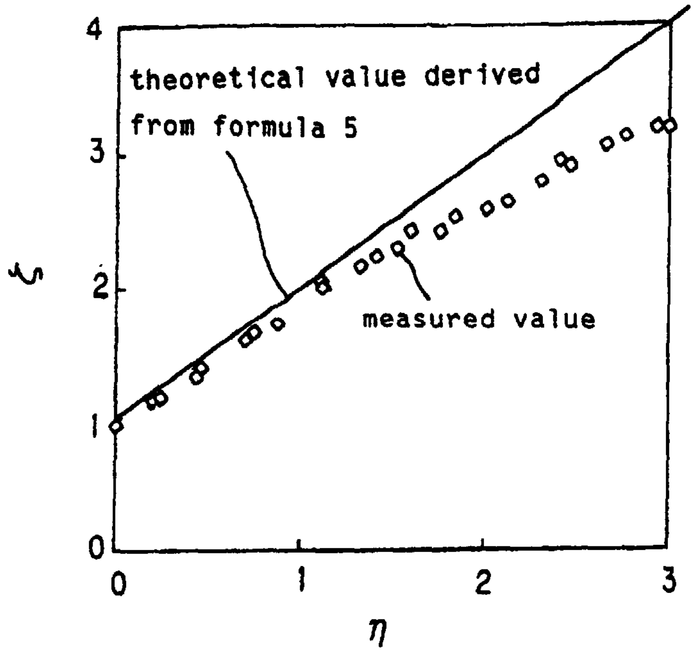

4
3
2
1
0
ζ
theoretical value derived
from formula 5
measured value
0
1
2
3
η

Fig. 4

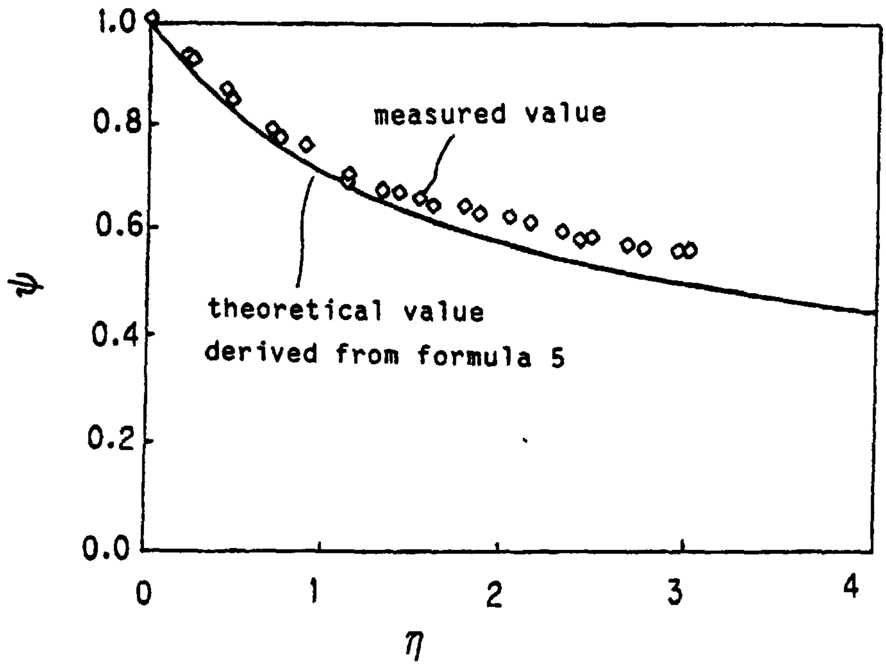

1.0
0.8
0.6
0.4
0.2
0.0
ψ
measured value
theoretical value
derived from formula 5
0
1
2
3
4
η

Fig. 5

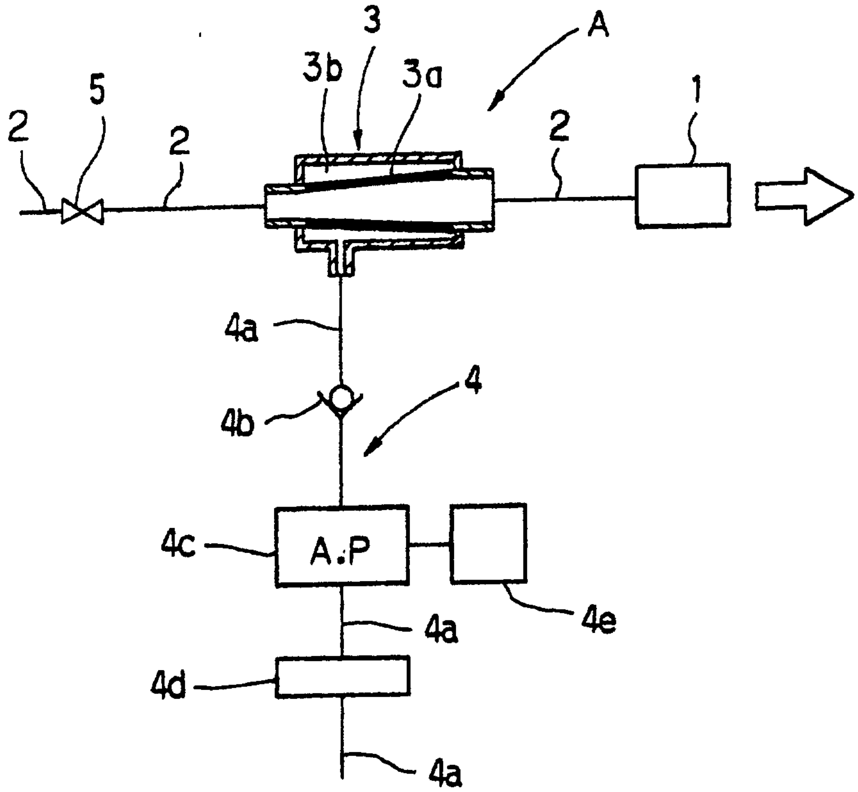


Fig. 6

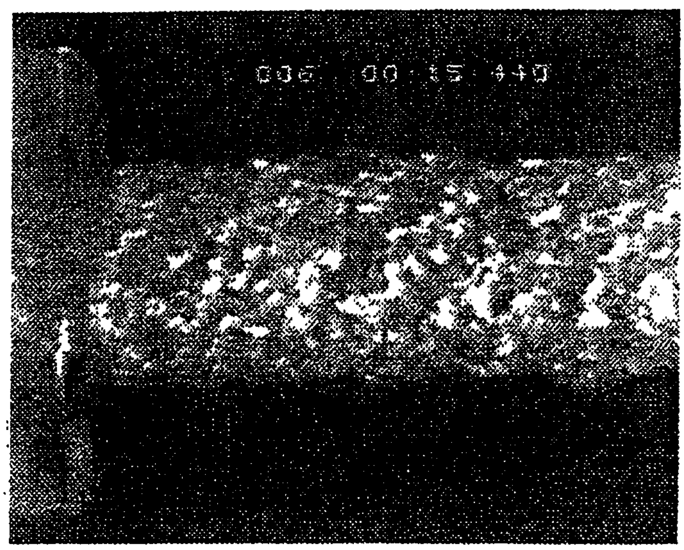


Fig. 7

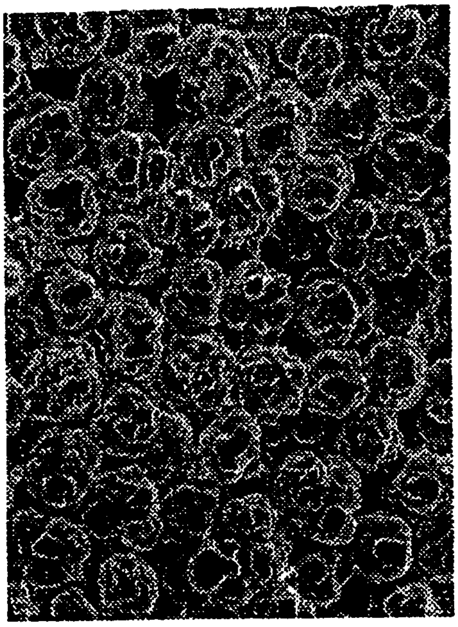
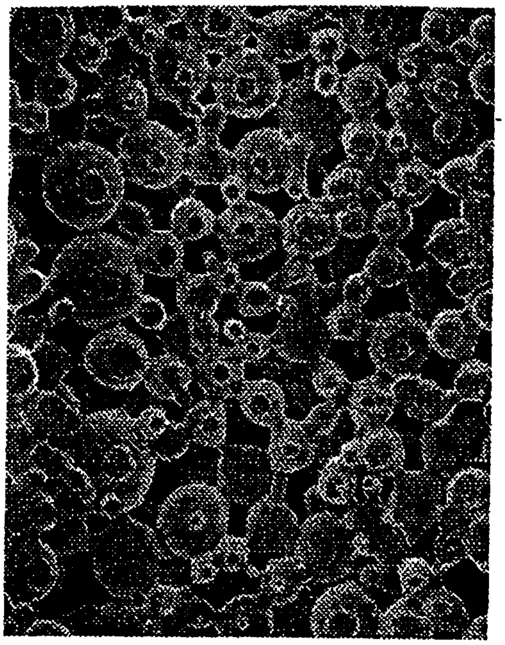


Fig. 8



F i g . 9

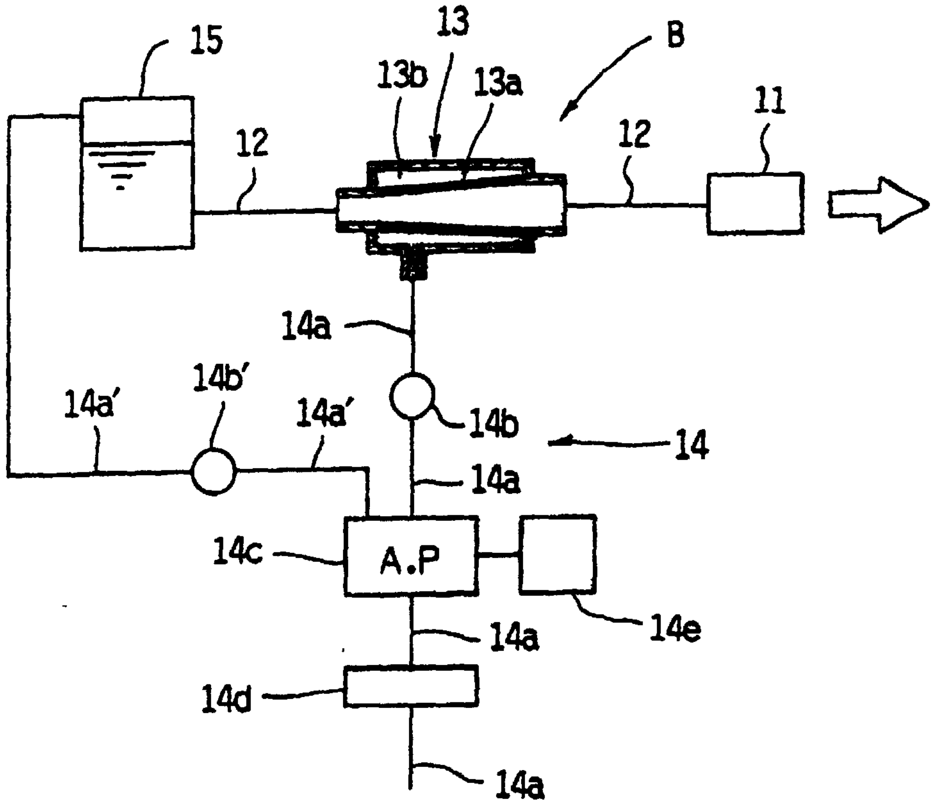

15
13
B
13b
13a
11
12
12
14a
14b'
14a'
14a'
14b
14
14a
14c
A.P
14e
14a
14d
14a

Fig. 10 (a)

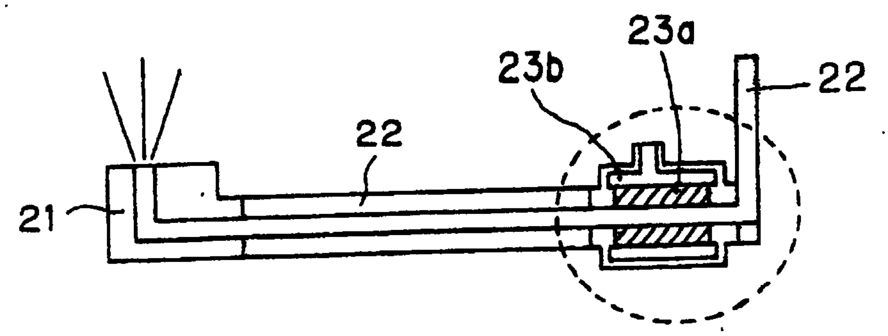


Fig. 10 (b)

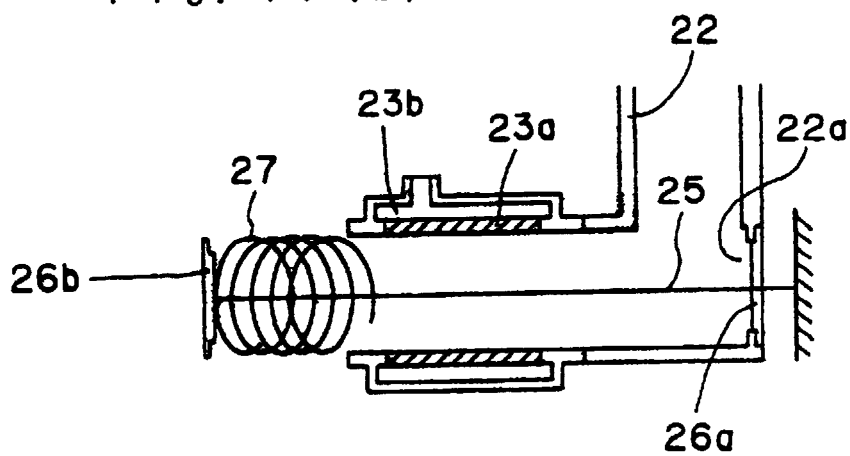


Fig. 10 (c)

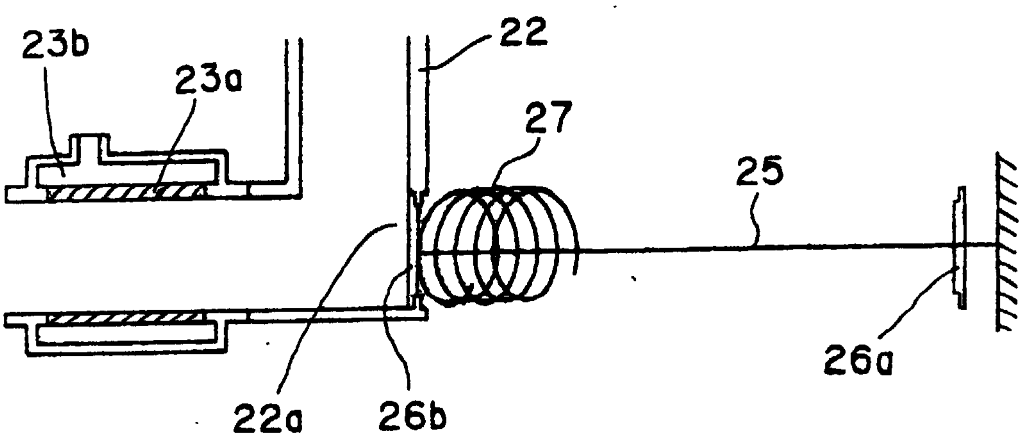


Fig. 11

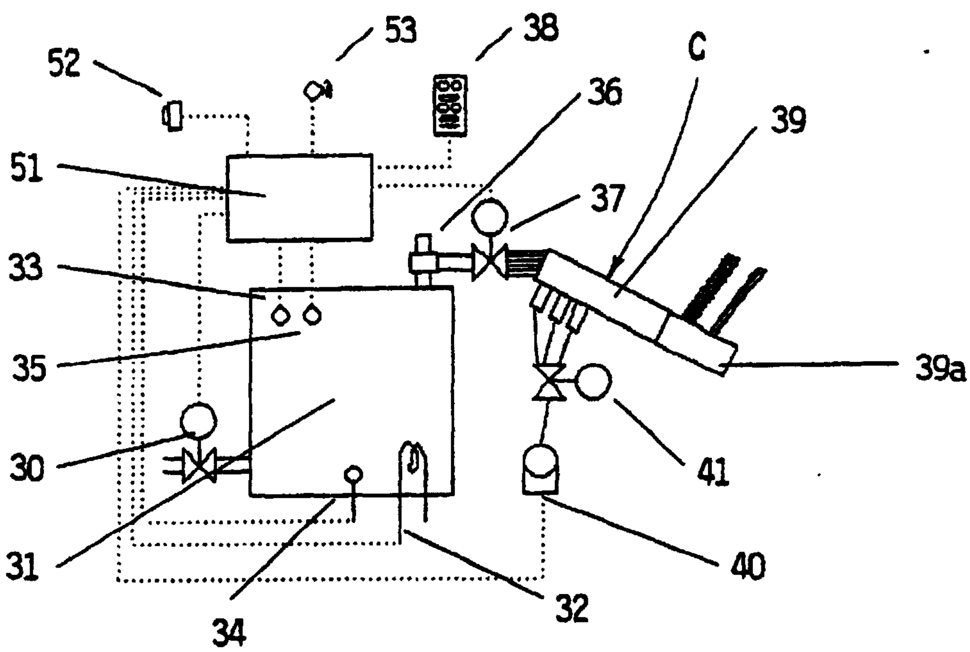


Fig. 12

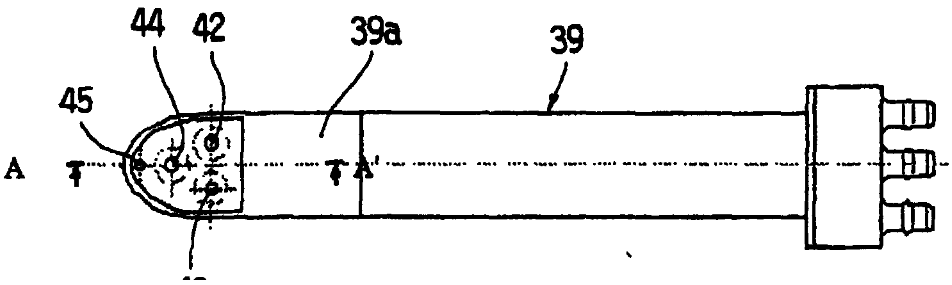


Fig. 13

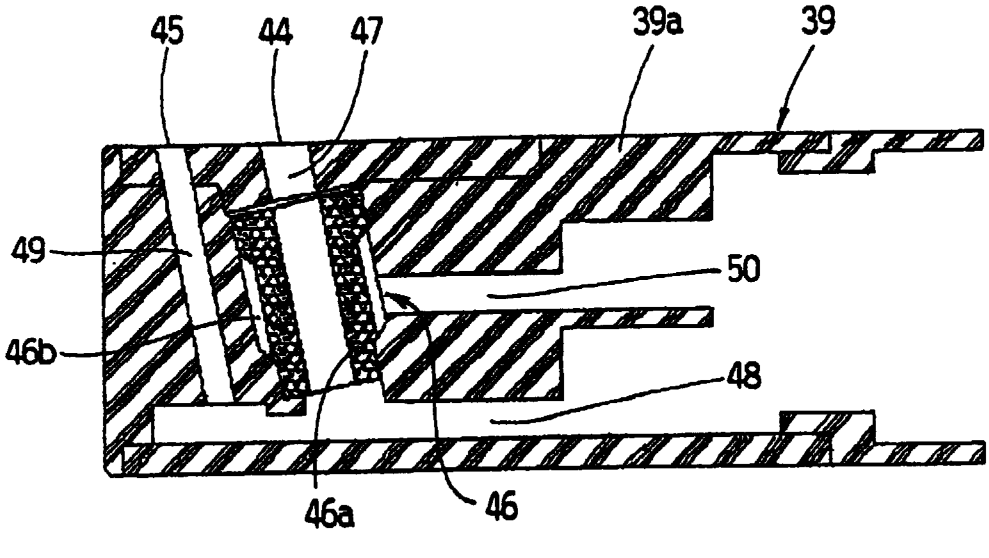


Fig. 14

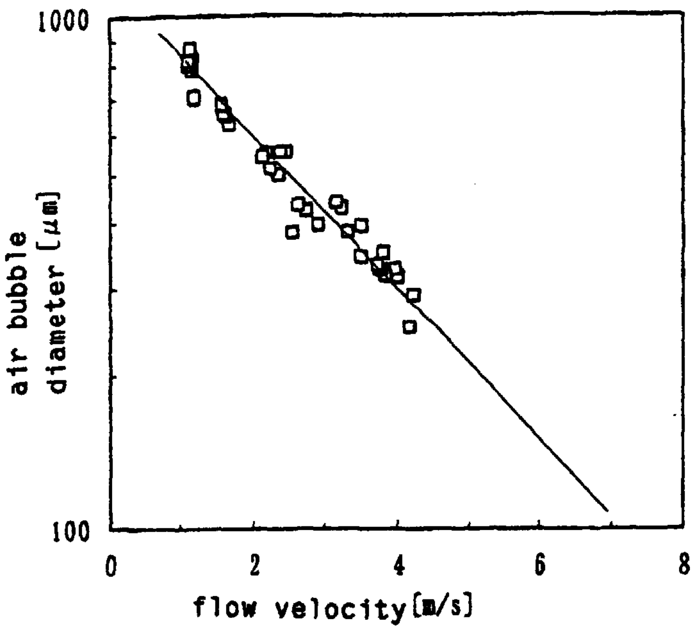

1000
100
air bubble
diameter [μm]
0
2
4
6
8
flow velocity[m/s]

Fig. 15

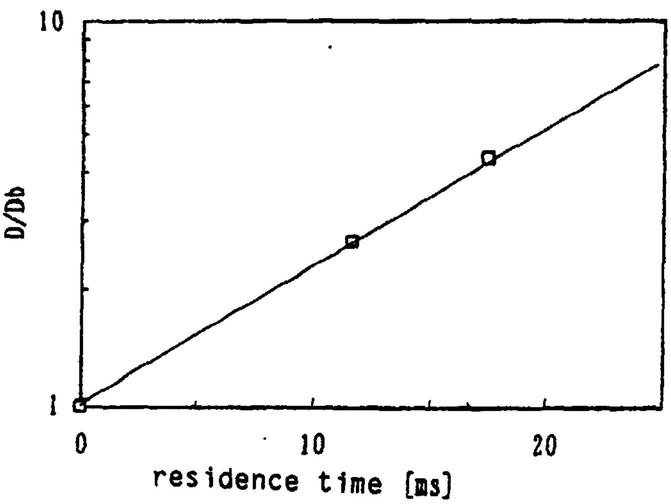

10
1
D/Db
0
10
20
residence time [ms]

Fig. 16

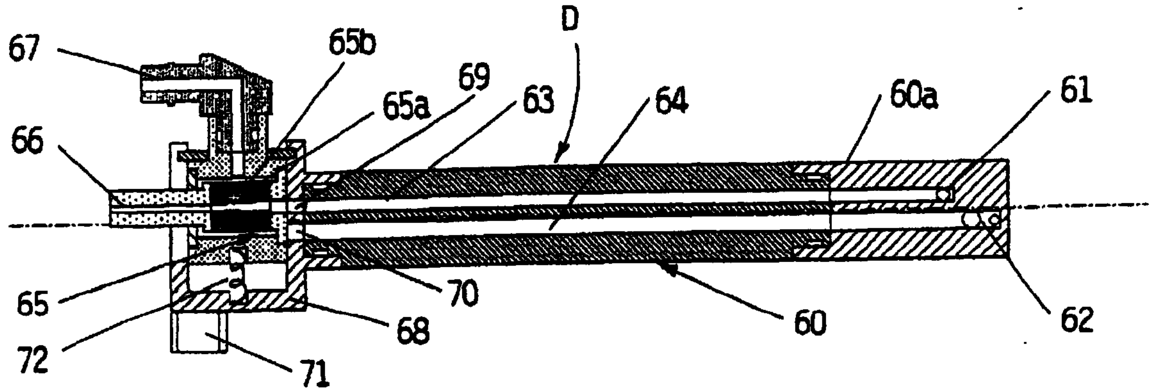

67
65b
D
69
65a
63
64
60a
61
66
65
72
71
68
70
60
62

Fig. 17

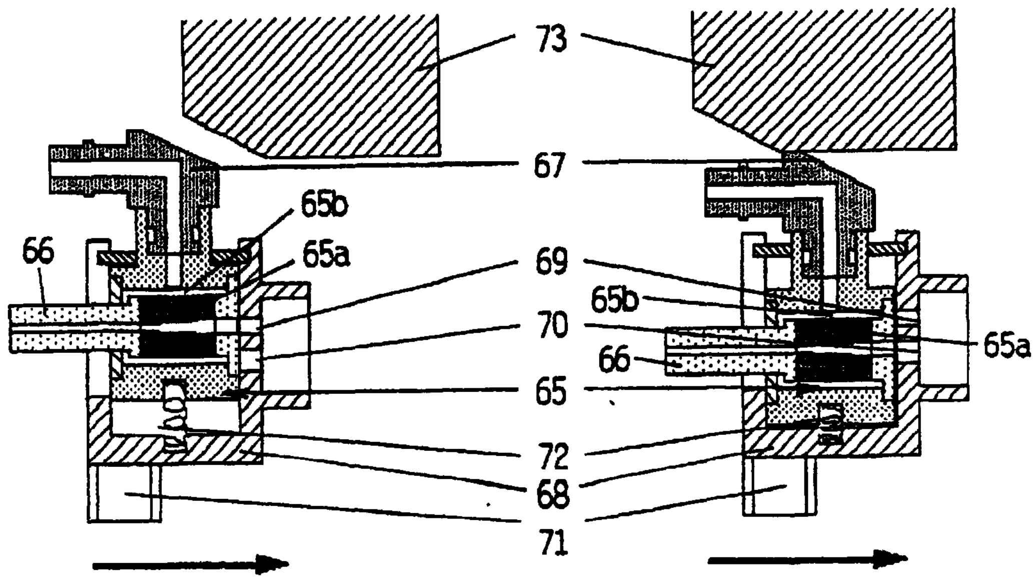

73
67
65b
65a
66
69
65b
70
66
65a
65
72
68
71

Fig. 18

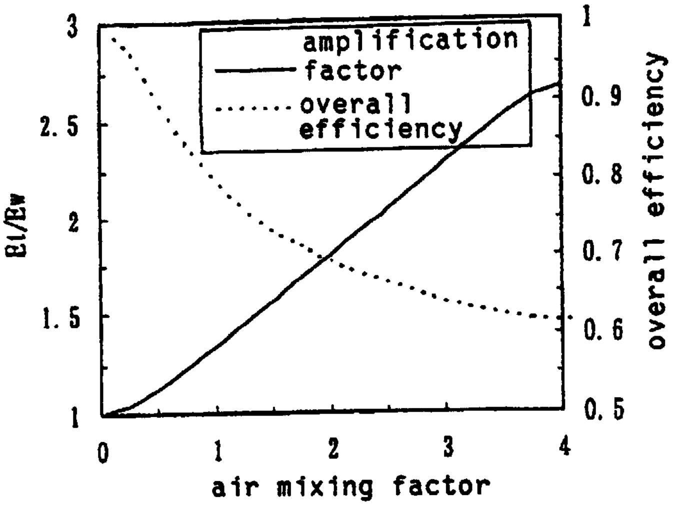

3
2.5
2
1.5
1
E1/Ew
1
0.9
0.8
0.7
0.6
0.5
overall efficiency
amplification factor
overall efficiency
0
1
2
3
4
air mixing factor

Fig. 19

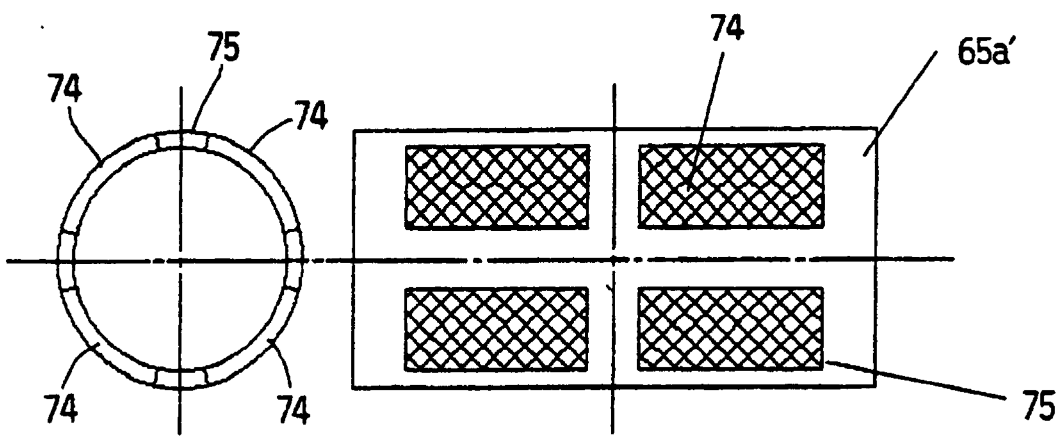

75
74
74
74
74
74
65a′
75

Fig. 20

	capillary made of acrylic porous material	capillary made of polyethylene porous material
mixed acrylic and silicon coating agent	△	○
coating agent mainly composed of alkyl polysiloxane	×	△
cold setting glass	○	×

○…… Deposition of calcium carbonate in the capillary much less at surface finished part than at part not surface finished.
Effect of surface finishing is large.

△…… Some difference observed between surface finished part and part not surface finished.

×…… Deposition of calcium carbonate at surface finished part is same as at part not surface finished.

F i g. 2 1

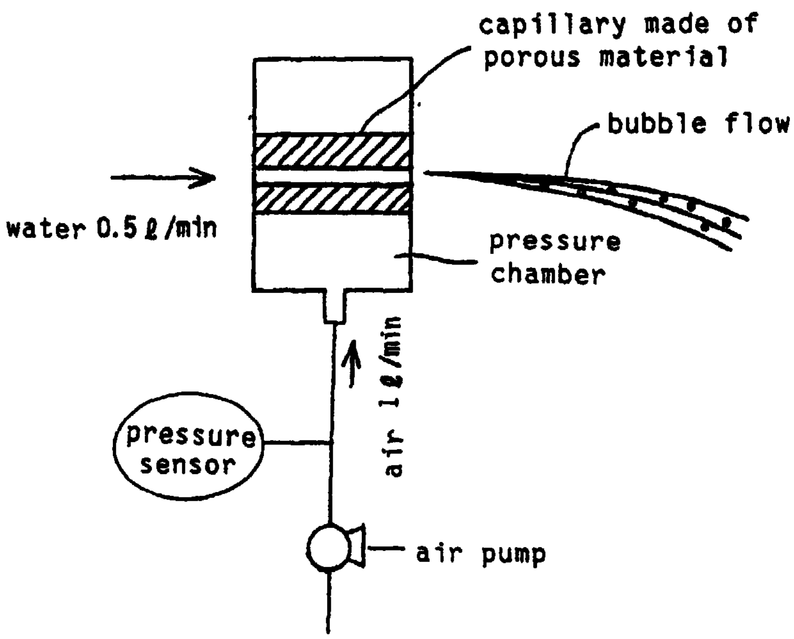

capillary made of
porous material
bubble flow
water 0.5 ℓ/min
pressure
chamber
air 1 ℓ/min
pressure
sensor
air pump

Fig. 22

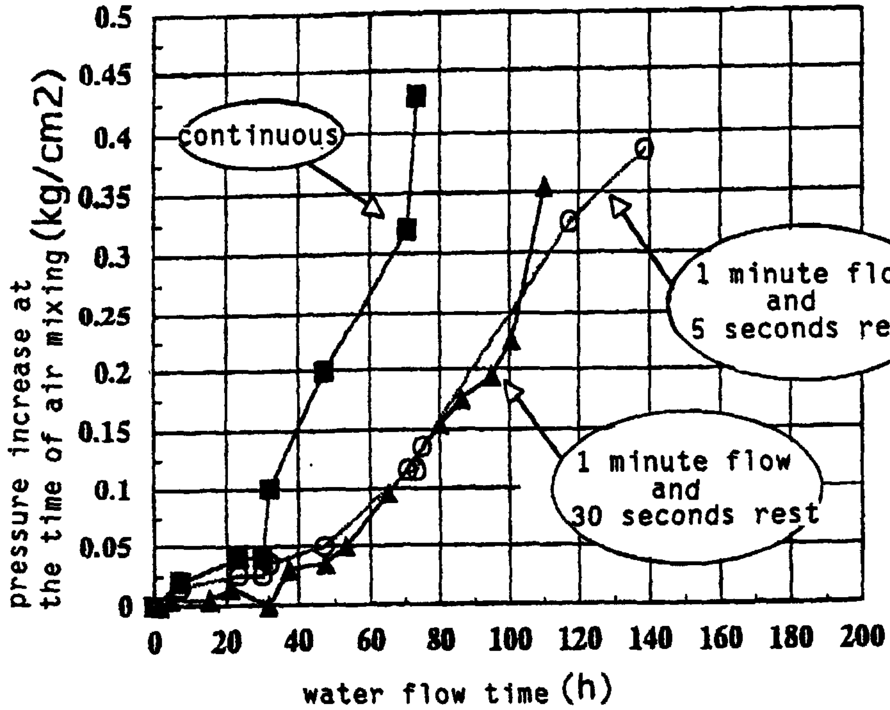

0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
pressure increase at
the time of air mixing (kg/cm2)
continuous
1 minute flow
and
5 seconds rest
1 minute flow
and
30 seconds rest
0 20 40 60 80 100 120 140 160 180 200
water flow time (h)

Fig. 23

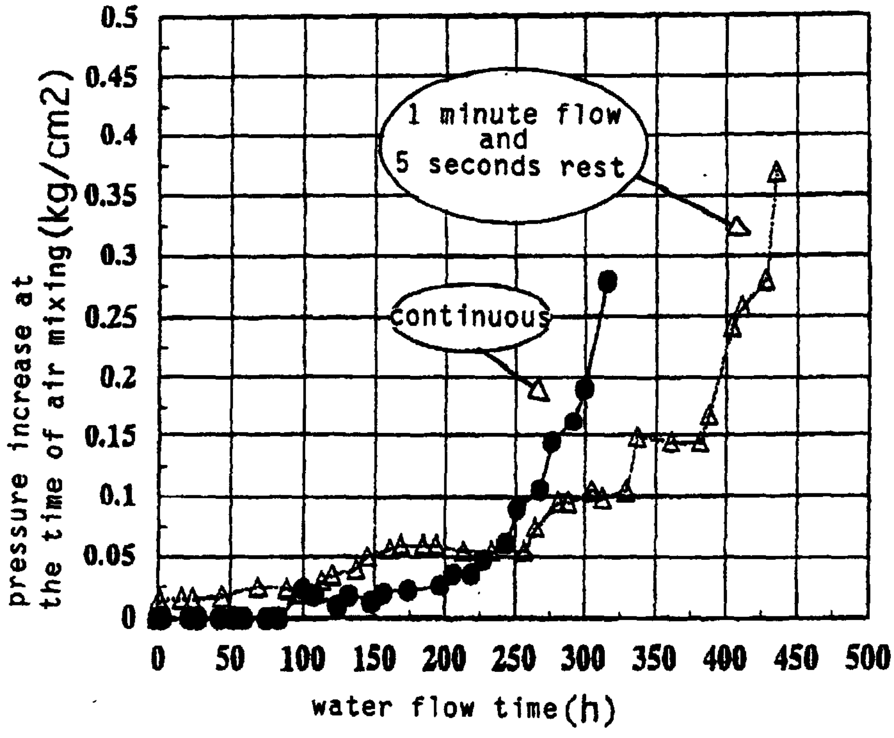

0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
pressure increase at
the time of air mixing (kg/cm2)
1 minute flow
and
5 seconds rest
continuous
0 50 100 150 200 250 300 350 400 450 500
water flow time (h)

Fig. 24

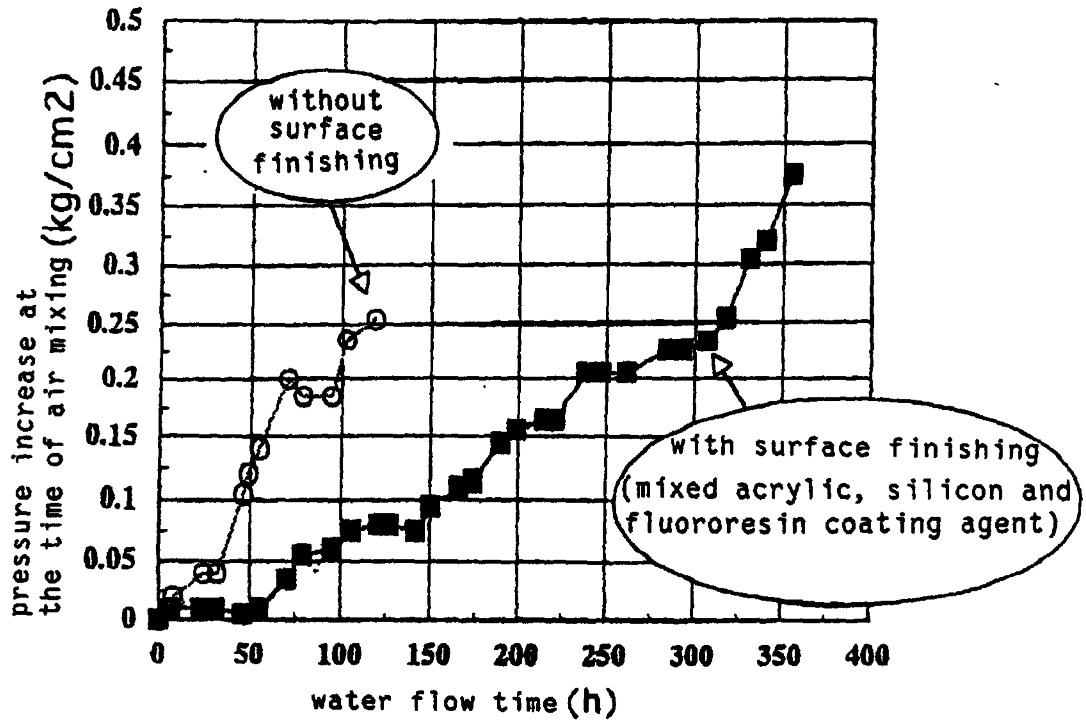

without surface finishing
with surface finishing (mixed acrylic, silicon and fluororesin coating agent)
pressure increase at the time of air mixing (kg/cm2)
water flow time (h)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
400

Fig. 25

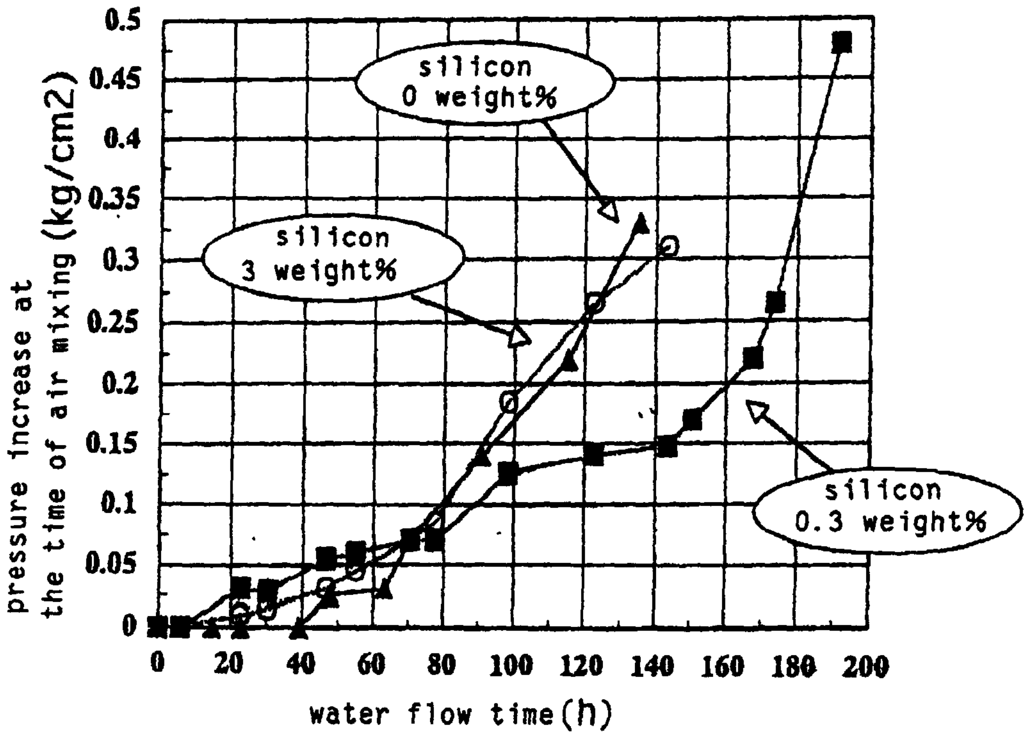

silicon 0 weight%
silicon 3 weight%
silicon 0.3 weight%
pressure increase at the time of air mixing (kg/cm2)
water flow time (h)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
180
200

Fig. 26

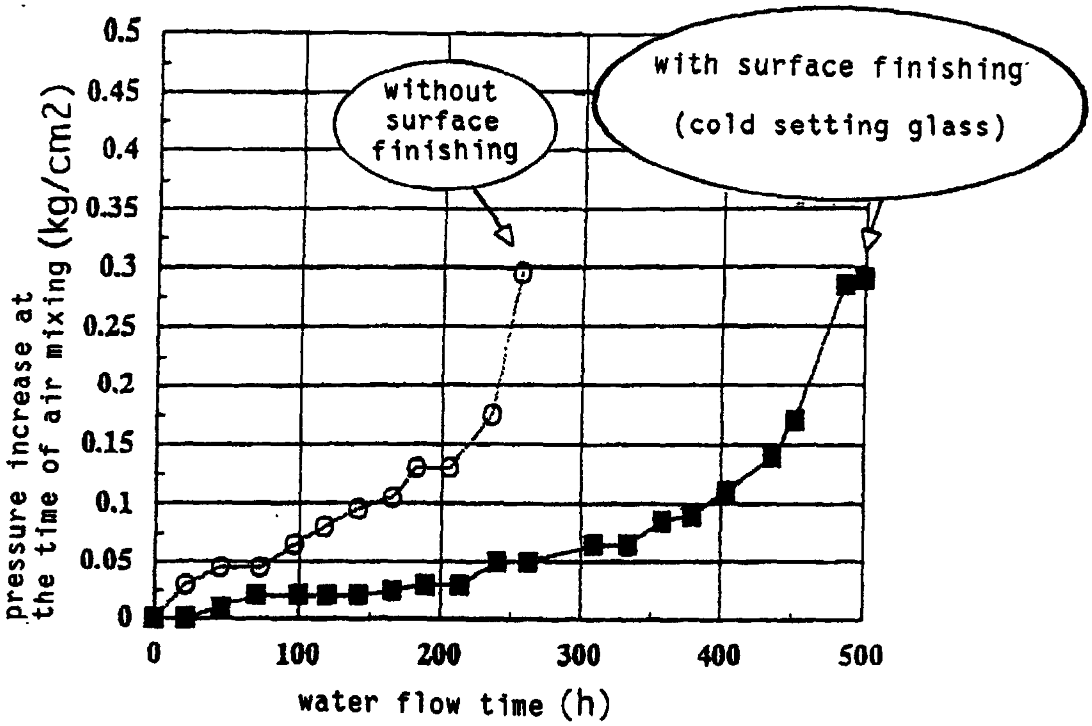

pressure increase at the time of air mixing (kg/cm2)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
without surface finishing
with surface finishing (cold setting glass)
0
100
200
300
400
500
water flow time (h)

Fig. 27

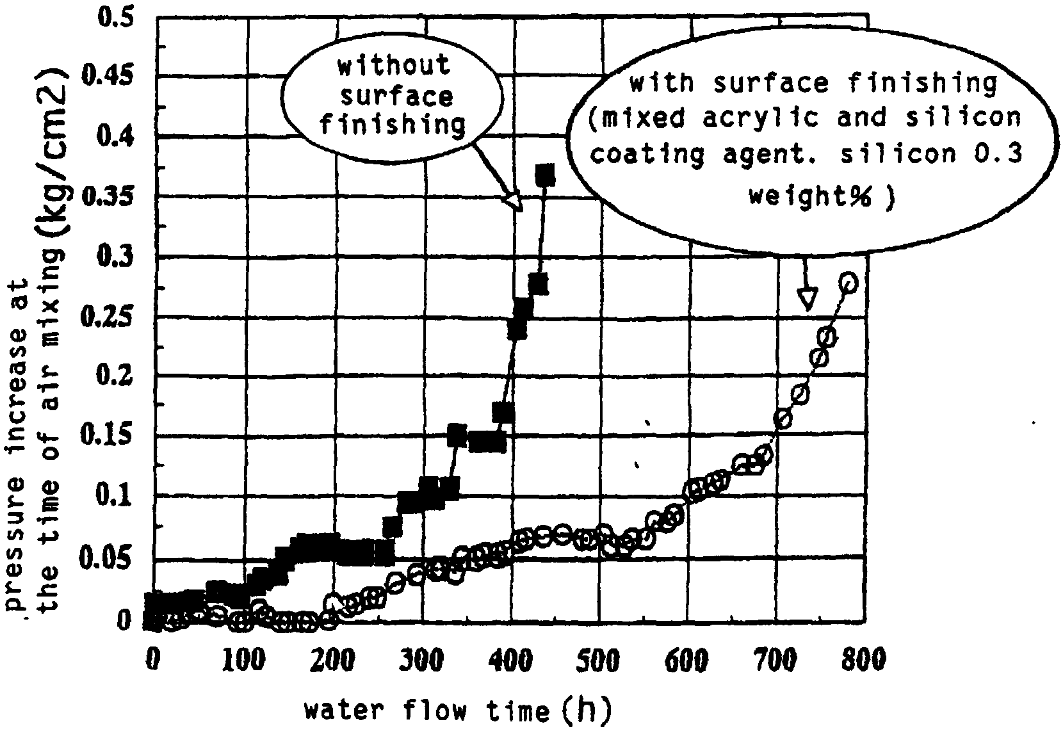

pressure increase at the time of air mixing (kg/cm2)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
without surface finishing
with surface finishing (mixed acrylic and silicon coating agent. silicon 0.3 weight%)
0
100
200
300
400
500
600
700
800
water flow time (h)

Fig. 28

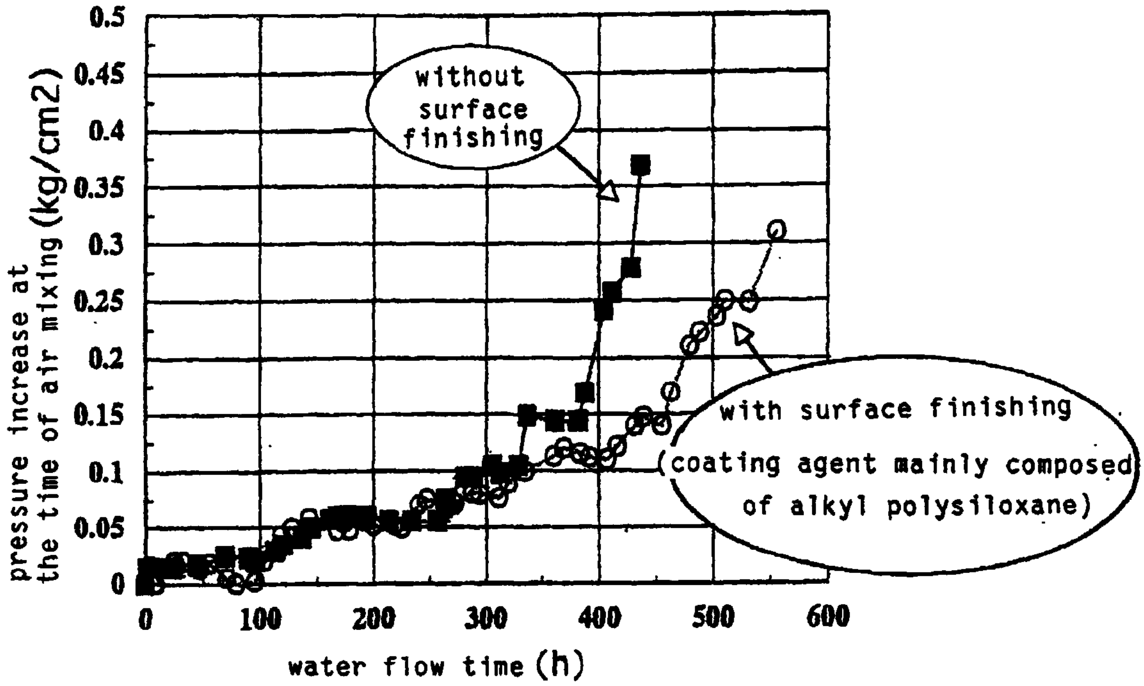
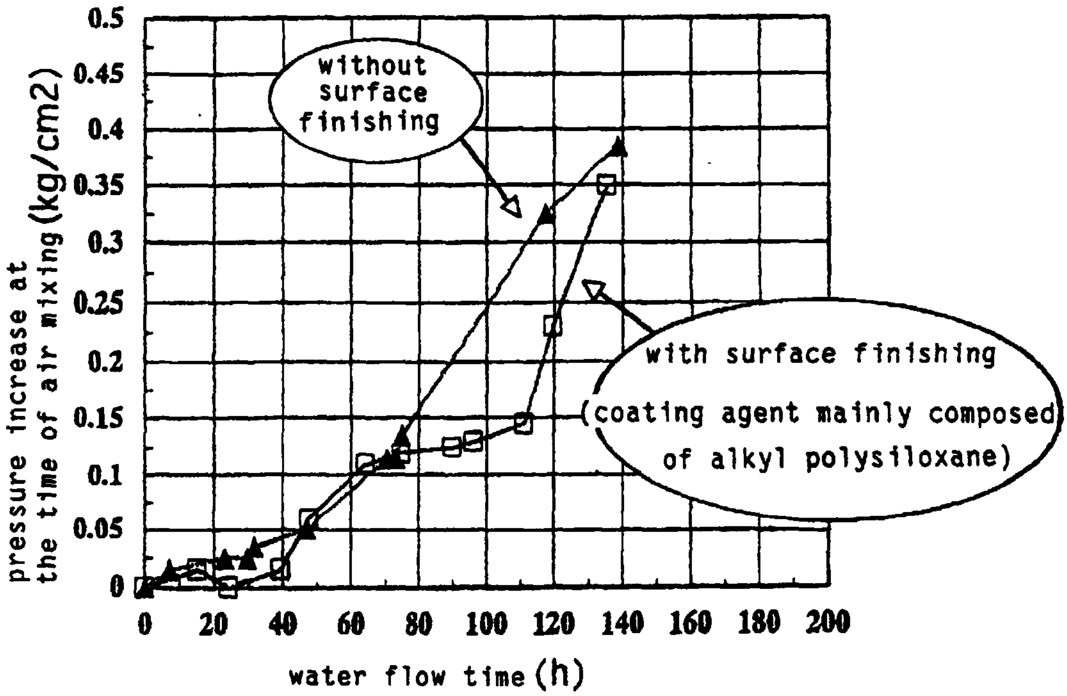

without surface finishing
with surface finishing
(coating agent mainly composed of alkyl polysiloxane)
pressure increase at the time of air mixing (kg/cm2)
water flow time (h)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
100
200
300
400
500
600

Fig. 29


without surface finishing
with surface finishing
(coating agent mainly composed of alkyl polysiloxane)
pressure increase at the time of air mixing (kg/cm2)
water flow time (h)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
20
40
60
80
100
120
140
160
180
200

F i g. 3 0

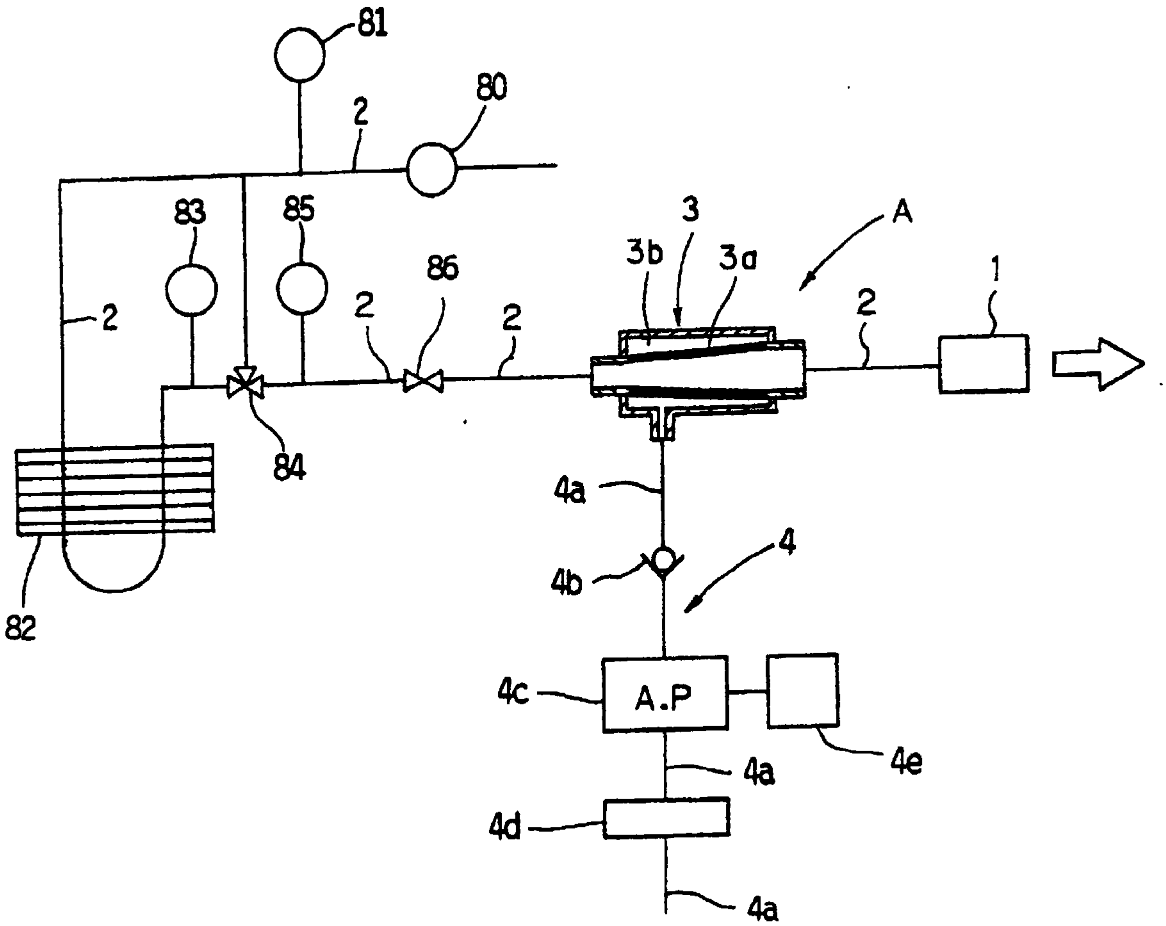


Fig. 31 (a)

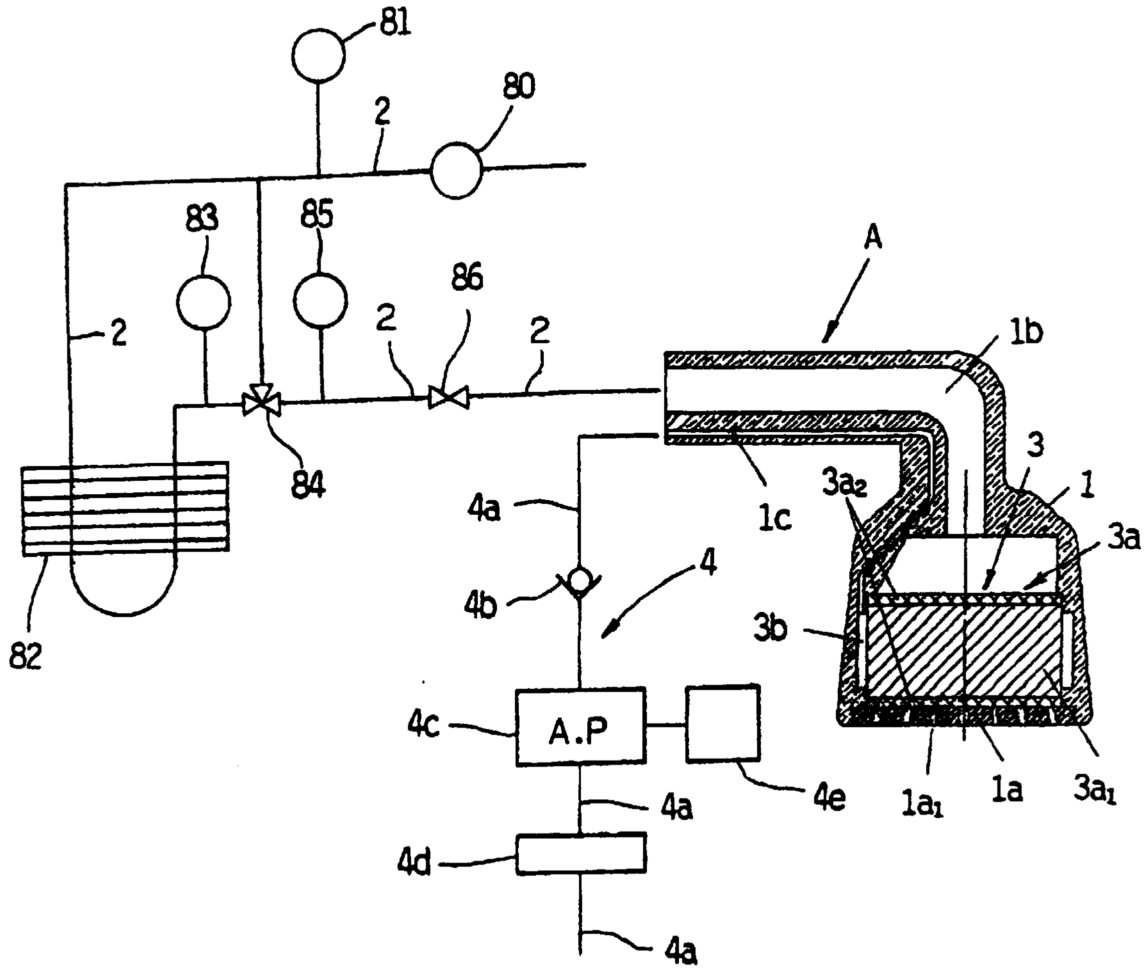


Fig. 31 (b)

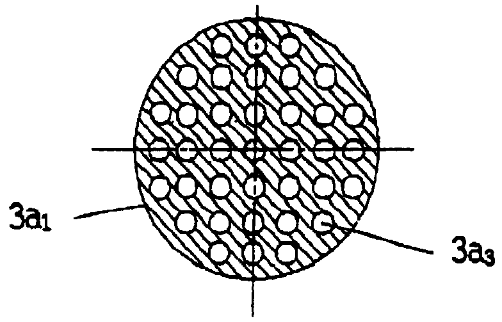


Fig. 32

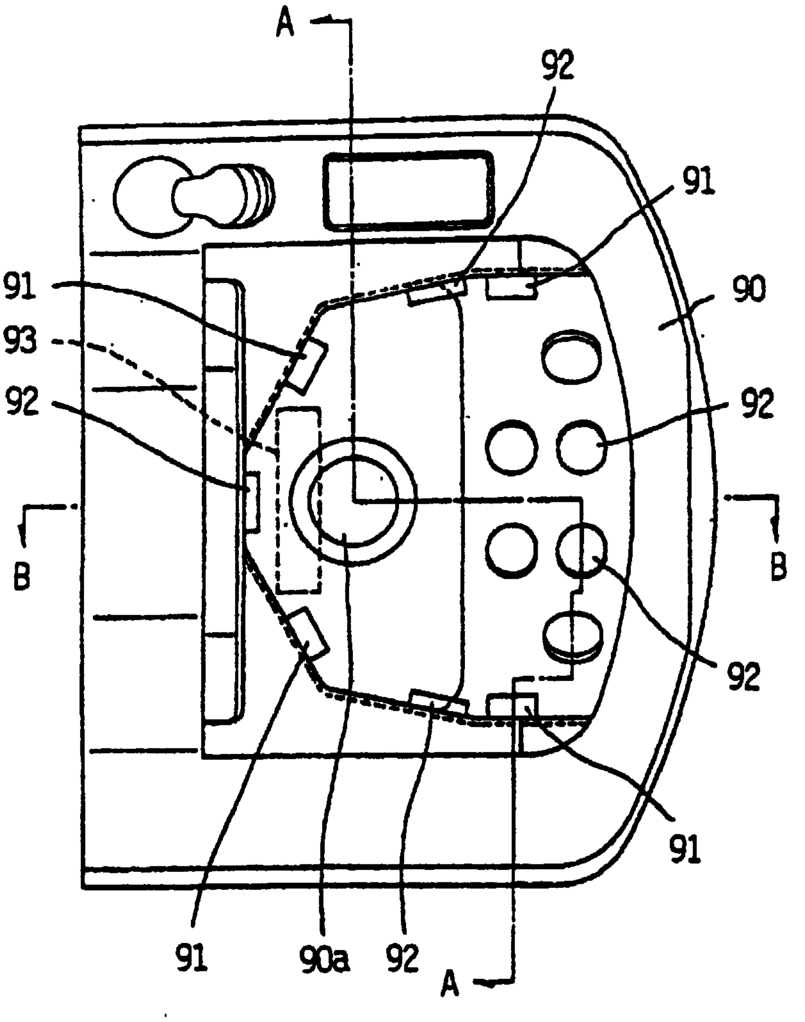


Fig. 33

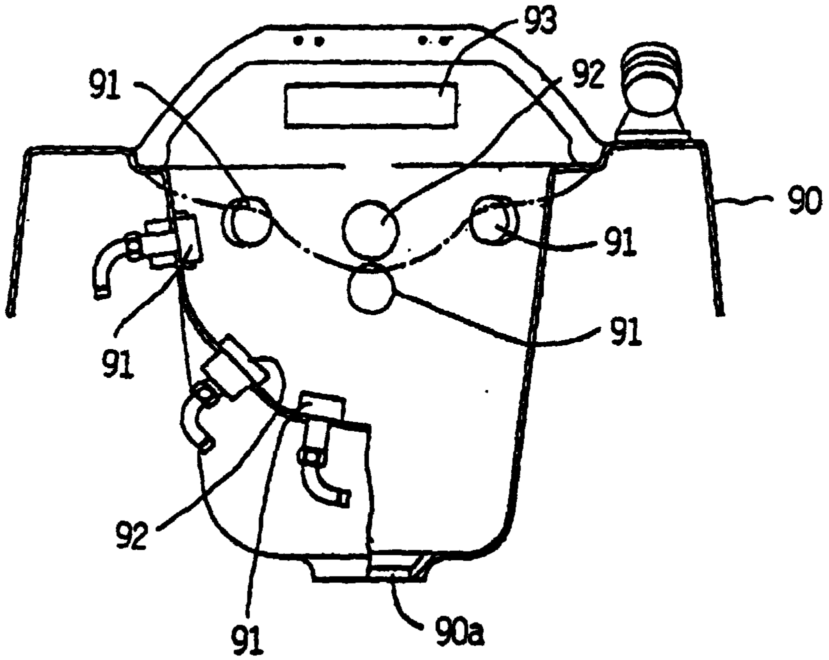


Fig. 34

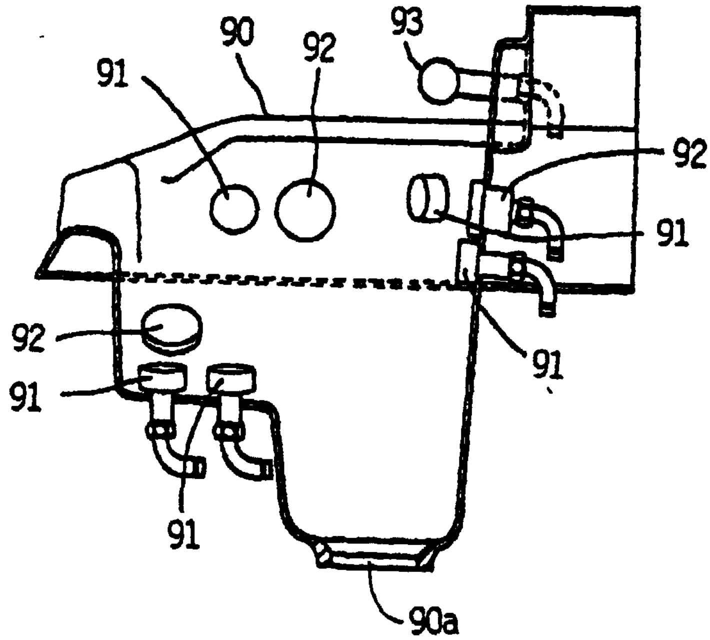


Fig. 35

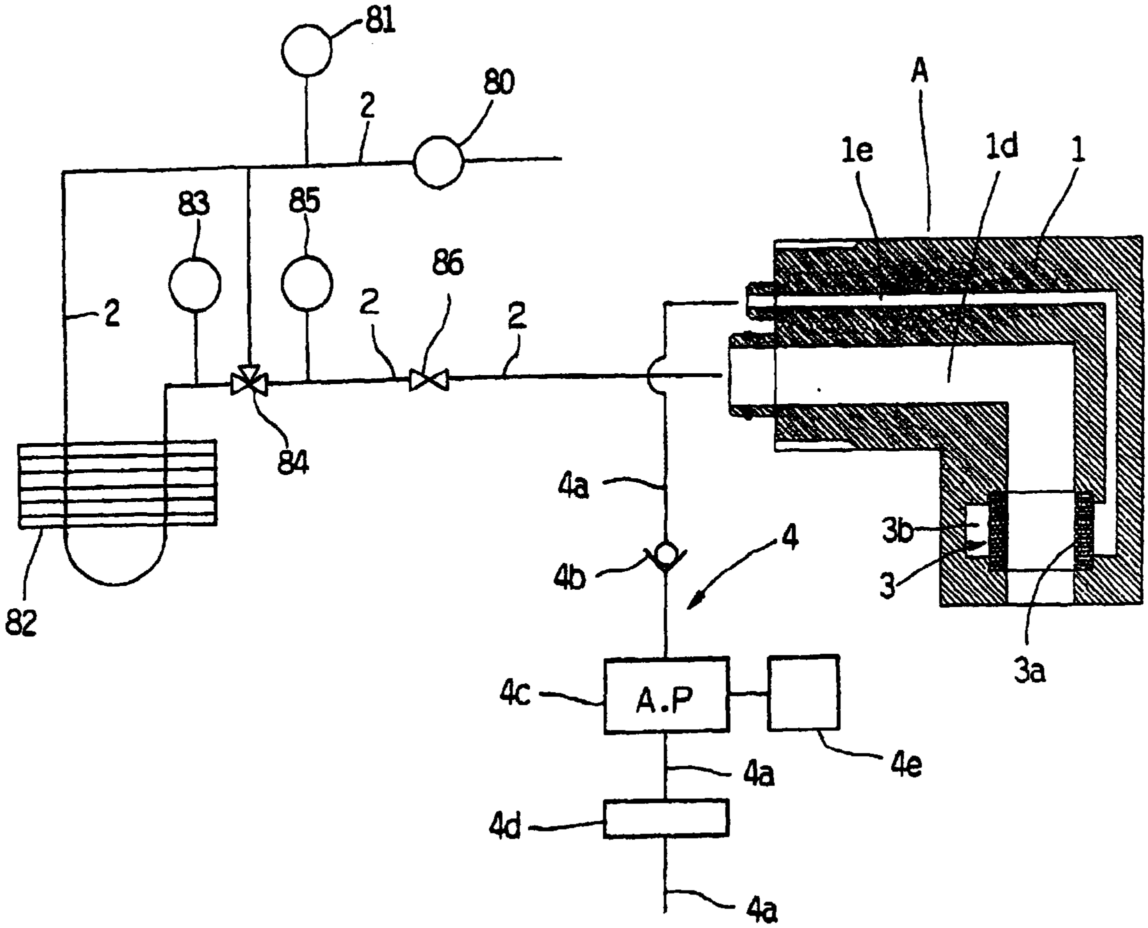


Fig. 36

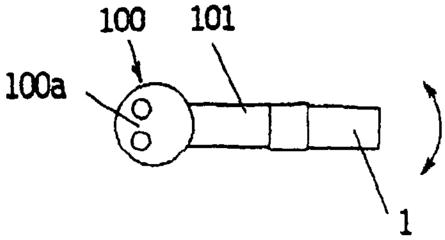


Fig. 37

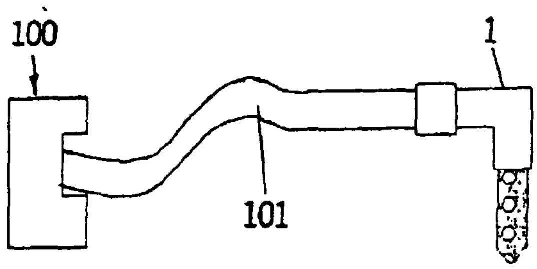


Fig. 38

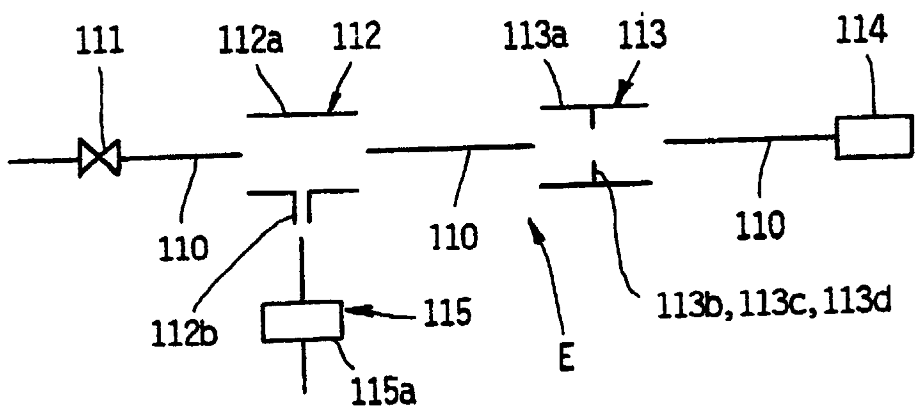
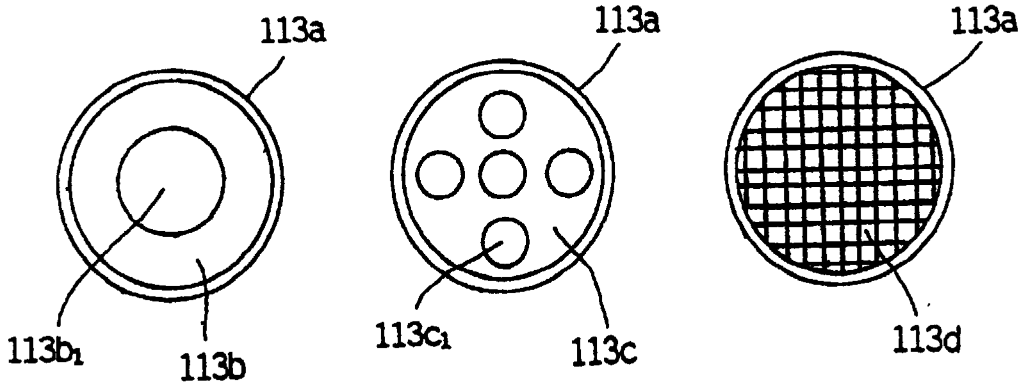


Fig. 39 (a) Fig. 39 (b) Fig. 39 (c)



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/03633

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] E03C1/042, E03C1/084, E03D9/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] E03C1/042, E03C1/084, E03D9/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1940-1996	Toroku Jitsuyo Shinan Koho	1994-1998
Kokai Jitsuyo Shinan Koho	1971-1998	Jitsuyo Shinan Toroku Koho	1996-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 8-338058, A (Matsushita Electric Industrial Co., Ltd.), 24 December, 1996 (24. 12. 96), Full text ; Fig. 10 (Family: none)	1-3, 11, 41
Y	Full text ; Fig. 10	4, 6-10 12, 13 46-55
A	Full text ; Fig. 10	5, 42, 45
X	JP, 5-33377, A (TOTO Ltd.), 9 February, 1993 (09. 02. 93), Full text ; Fig. 7 (Family: none)	1-3, 6 41
Y	Full text ; Fig. 7	4, 7-9, 10-12, 14-28, 42, 46-55
A	Full text ; Fig. 7	5, 13, 29-40, 43, 44

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 November, 1998 (09. 11. 98)	17 November, 1998 (17. 11. 98)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/03633

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 61-5427, Y2 (Noritz Corp., Janis Ltd.), 19 February, 1986 (19. 02. 86), Full text ; Figs. 1 to 4 (Family: none)	14, 17
A	Full text ; Figs. 1 to 4	15, 16, 18-21
Y	JP, 8-156751, A (K.K. Yasui), 18 June, 1996 (18. 06. 96), Full text ; Figs. 1 to 5 (Family: none)	38
A	Full text ; Figs. 1 to 5	39
Y	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 61156/1992 (Laid-open No. 24068/1994) (TOTO Ltd.), 29 March, 1994 (29. 03. 94), Full text ; Figs. 1 to 6 (Family: none)	46
Y	JP, 6-42856, B2 (Rinnai Corp.), 8 June, 1994 (08. 06. 94), Full text ; Figs. 1 to 6 (Family: none)	53

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