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**(54) DEVICE AND CORRESPONDING METHOD FOR THE DISPERSION OF GAS IN LIQUIDS**

VORRICHTUNG UND ENTSPRECHENDES VERFAHREN ZUR DISPERSION VON GAS IN FLÜSSIGKEITEN

DISPOSITIF ET PROCÉDÉ CORRESPONDANT POUR LA DISPERSION DE GAZ DANS DES LIQUIDES

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**Description**Field of the invention

5 **[0001]** The present invention relates in general to the technical field of the mixing and dispersion of gas in liquids and more particularly its object is an innovative device and a corresponding method, both intended to improve the mixing and/or the dispersion of gas or mixtures of gas in liquids, with the latter to be considered in the broader sense of the term therefore comprising, purely by way of a non-limiting example, drinks, process liquids, effluent, sludge, food pastes and other types, mousses, foams, etc.

10 **[0002]** To this end the device and the method of the invention allow the gaseous phase to be distributed and dispersed finely and homogeneously, in the form of gas bubbles with dimensions of the order of  $\mu\text{m}$ , in the liquid phase, so as to obtain a high surface of interface between liquid and gas and therefore encourage the subsequent transfer of material between the two phases.

15 **[0003]** Consequently, as will be deduced from the following description, the device and the method of the invention can be advantageously applied, without thereby wanting to limit the field of application thereof or their general nature, in order to mix:

- carbon dioxide, i.e.  $\text{CO}_2$ , in water or drinks in general, whether non-alcoholic or alcoholic, as preliminary stage of carbonation or gassing of these drinks;
- 20 - a gas, constituted for example by oxygen, or a mixture of gases in a liquid, as preliminary stage for their subsequent solubilisation;
- a gas or a mixture of gases in a liquid, as preliminary stage for the extraction or stripping of other gases dissolved in the same liquid;
- a gas or a mixture of gases for the formation of mousses, foams or similar products.

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Background of the invention and prior art

**[0004]** It is known that the speed of transfer of material between two phases depends also on the interface between them, i.e. on the surface which separates these two phases, and that, with the same volume of a gaseous phase mixed and dispersed in the form of bubbles in a liquid phase, the surface of the interface between these two phases increases as the dimension of the bubbles decreases.

30 **[0005]** It also has to be considered that the gas bubbles immersed in a liquid are pushed upwards, through the effect of the known law of physics known as the principle or law of Archimedes, by a force depending on the volume of the bubble, and that the speed of rising resulting from this also depends on the dimensions of the bubbles, decreasing as they decrease.

35 **[0006]** The result of this is that the space that the gas bubbles dispersed in a liquid phase have to cover before, possibly, exiting the liquid phase and therefore ceasing contact and exchange with it, needs times which depend, with the same other parameters, on the dimensions of the bubbles, increasing as the latter decrease, so that bubbles with smaller dimensions lead to greater times of dwell and rise in the liquid phase to the full advantage of the transfer of material between the two phases, liquid and gaseous.

40 **[0007]** In brief, the aforesaid considerations relating to the phenomenon of the dispersion of a gas in a liquid and to the various aspects of this phenomenon lead to the conclusion that in order to encourage the exchange of material between gas and liquid it is necessary to have gas bubbles which have dimensions which are as small and reduced as possible, so as to obtain both high exchange surfaces, with the same volume of gas dissolved in the liquid phase, and high times of dwell of the bubbles in contact with the liquid phase.

45 **[0008]** There are many methods currently known and used in the art, in line with the previous considerations, for obtaining the mixing of gases, in the form of gaseous bubbles of small dimensions of the order of  $\mu\text{m}$ , in liquids.

50 **[0009]** For example these methods, corresponding to prior art, can be based on the use of static mixers, as described by the patents US 3,923,288 and EP 0 121 342 A2, or can be intended to create mainly effects of turbulence, in the flow of the two-phase fluid, in turn obtained by sudden lowerings of pressure due to special geometries and configurations of the areas traversed by the same flow of the two-phase liquid, as described by the patents US 2008/0140261 A1, DE 20209039 U1, US 3,179,385 A, EP 1359997 A2, EP 2492002 A1.

55 **[0010]** More particularly these latter patents propose solutions and systems, for dispersing and mixing gas in liquids, which have aspects and features which are at least in part shared also by the present invention, where these features are used in an innovative manner so as to improve significantly the performances with respect to known and existing systems, as illustrated in detail here below.

**[0011]** For the sake of completeness the following patent documents are also mentioned DE 10 2007 052642 A1, US 5,841,055 A, US 2,817,500, WO 92/16288 A1 which generally describe cavitation systems, homogenizers, devices, and

similar apparatuses, which are provided for different applications, as for example for mixing two components, in solid, liquid or gaseous form, and in which a flow of a fluid is intercepted so as to undergo a pressure drop.

**[0012]** Nonetheless the need is felt for the methods and devices currently known for the mixing of gas in liquids, in particular in industrial processes wherein the liquid flows continuously, to be the object of further improvements and are such as to bring further advantages and achieve an increasingly forced micronisation and dispersion of the gas bubbles in the liquid.

**[0013]** In particular the need is felt for the improvements and the advantages to be achieved and obtained in this technical field of the mixing of gas in liquids, towards which the present invention is therefore aimed, to relate to the following points of special interest:

- allow easy regulation and control of the dimensions of the bubbles and of their homogeneous mixing in the liquid phase;
- guarantee the features, as illustrated and recommended in the previous point, also in the presence of sudden variations in the flow of the gas and of the liquid, i.e. of their flow rate, as occurs in many industrial processes;
- allow an easy cleaning and sanitisation of the device or equipment wherein the dispersion of the gas in the liquid is performed, as required especially in the food industry.

#### Summary of the invention

**[0014]** Therefore a first object of the present invention is to propose and make a device and a corresponding method, for the dispersion and mixing of gas in liquids, which meet the aforesaid needs felt in the industry, and in particular allow, in the most widely differing working conditions wherein the device and the method are applied, an easy regulation and control of the dimensions of the gas bubbles and of their homogeneous mixing in the liquid phase.

**[0015]** A second object, in any case connected to the first, of the present invention is also that of proposing and making a device and a corresponding method for the dispersion and mixing of gas in liquids which significantly improves the results that can be obtained with respect to the devices and methods currently known and in use, in particular in terms of a higher degree of micronisation of the gas bubbles in the liquid.

**[0016]** The above objects can be considered to be fully achieved by the device for the dispersion and mixing of gas in liquids having the features defined by the main independent claim 1, and also by the corresponding method defined by the independent claim 10.

**[0017]** Particular embodiments of the present invention are moreover defined by the dependent claims.

**[0018]** As illustrated here below in the description, the present invention achieves and improves the dispersion and mixing of a gas in a liquid through the activation in the two-phase fluid, i.e. gas-liquid, both of turbulent movements and of a system of shear stresses and forces, in turn produced by one or more sudden lowerings, or jumps, of pressure, and also by particular geometric configurations of the mechanical components and parts in contact with the flow of the two-phase fluid.

**[0019]** More particularly the starting point of the present invention is the consideration that if the value or the values of the jump or jumps in pressure, whereto the flow of the two-phase fluid is subject, remains/remains constant albeit in the presence of variations in the rate of flow of the two-phase fluid, the energy also does not vary and therefore remains substantially constant, per unit of two-phase fluid, which is associated with the variation of pressure present in the same flow of the two-phase fluid and is transferred to the unit of two-phase fluid.

**[0020]** As a result, although taking account of the variability of the physical phenomena, the effects also remain constant that are generated by this energy, transferred to the base fluid unit, i.e. both the increase in speed of the flow of the two-phase fluid and, with it, the corresponding increase in the turbulence and the shear forces acting in the same flow of the two-phase fluid, so that the features of mixing of the gas in the liquid also remain substantially constant.

**[0021]** In the description that is to follow, for reasons of simplicity of disclosure but without thereby undermining the general nature and limiting the scope of the invention, it will be assumed that the two-phase flow, i.e. the flow of the mixture of liquid and gas through the device that is the object of the invention, is subject to a single jump in pressure, denoted by  $\Delta P$ .

**[0022]** Therefore the device and the method of the invention allow advantageously this jump in pressure  $\Delta P$  to be maintained constant, also when the rate of the two-phase flow varies, without resorting to the usual and conventional systems and rings of regulation, adopted in the prior art, usually achieved by means of measurements of the pressure of the two-phase fluid and the actuation, on the basis of the pressure values measured, of electric-pneumatic valves, with the consequent negative effects and the relative problems due to the inevitable transient regimes of regulation.

**[0023]** In contrast with these known systems, in the device and corresponding method of the invention the constancy of the jump in pressure  $\Delta P$  is instead actuated and achieved with simple self-regulating equipment and systems, and in any case easy to regulate, as will be illustrated here below in the description.

**[0024]** Moreover, a very important thing which deserves to be underlined, the device and the method of the invention,

being apt to keep effectively under control the features of mixing of the gas in the liquid also in the presence of variations of the liquid-gas two-phase flow, allow the elimination or at least the minimisation of the effects of the transient regimes which occur when regulations are performed.

**[0025]** Thanks to the aforesaid features and performances, the device and the method of the invention can find an advantageous application in many industrial processes, including, merely by way of a non-limiting example, mention of carbonation and subsequent bottling of drinks, wherein the faults during filling of the bottles can also be frequent and reflect in effects and actions which vary the flow rate, also suddenly, of the gassed drink which feeds the bottling system.

**[0026]** In fact, in this application, the device and the method of the invention, by appropriately controlling the jump in pressure  $\Delta P$  and in particular maintaining it constantly conforming to a given value, as specified previously, allow advantageously the maintaining and the effectively keeping under control of the constancy of the features of the gas bubbles, i.e. of CO<sub>2</sub>, which are mixed and dispersed in the drink, therefore also the constancy of the optimal conditions of mixing, so as to control also the features of the end product.

#### Brief description of the drawings

**[0027]** These and other objects, features and advantages of the present invention will be made clearer and evident by the following description of one of its preferred embodiments, given by way of a non-limiting example, with reference to the accompanying drawings, in which:

Fig. 1 is a generic diagram which shows a device, in accordance with the present invention, inserted in a wider working context in which the device of the invention receives and is traversed by a two-phase fluid, i.e. comprising a liquid phase and a gaseous phase, and operates in order to improve the mixing and the dispersion of the gaseous phase in the liquid phase in the flow of the two-phase fluid through the device;

Fig. 2 is a schematic view, partial but more detailed, which shows in longitudinal section the device of the invention of Fig. 1, aimed at improving the mixing and the dispersion of gas in liquids;

Fig. 3 is a schematic and partial view which shows in cross section, along line III-III of Fig. 2, the device of the invention;

Fig. 4 is a schematic view, in longitudinal section, aimed at showing the forces which act on a mixing element included in the device of the invention and govern the functioning thereof;

Fig. 4A is a schematic view which shows on enlarged scale the area of a passage opening or section defined between a head of the mixing element and an inner surface of an internal conduit, of the device, in which the two-phase fluid flows;

Fig. 5 is a schematic view which illustrates a further part of the device of the invention apt to regulate and maintain constant the jump in pressure between an upstream area and a downstream area of the mixing element included in the device of the invention, during the variation in the working conditions and in particular in the flow rate of the liquid and of the gas which flows through the device;

Fig. 6 shows schematically, in longitudinal section, a variant of the device of the invention for the mixing of gas in liquids;

Figs. 7, 8, 9 and 10 show in schematic form some variants of the configuration of the area of the mixing element included in the device of the invention; and

Fig. 11 is a working block diagram which illustrates the functioning of the device, according to the present invention, for improving the mixing and dispersion of gas in liquids;

#### Description of a first preferred embodiment of the device of the invention

**[0028]** Referring to the drawings, a device, according to the present invention, intended to improve the dispersion and mixing of gas in liquids, is denoted overall by 10.

**[0029]** As shown schematically in Fig. 1, the device 10 of the invention is part of and is inserted in a wider working or plant context, as part whereof the device 10 operates and receives a flow of a two-phase fluid denoted by (L+G), that is comprising a liquid or liquid phase L and a gas or gaseous phase G which is fed in the liquid phase L in an upstream area of the device 10, as indicated by an arrow, so as to form the two-phase fluid (L+G).

**[0030]** In detail, in the aforementioned plant or working context, shown in Fig. 1, wherein the device 10 of the invention operates and is integrated, it is possible to identify:

- a feed conduit CA of the liquid L;
- a preliminary mixing stage MP, where a first mixing of the gas G takes place in the liquid L, of known features, i.e. made up of elements in themselves known such as, by way of a non-limiting example, static mixers of normal use, candles or porous baffles, tubes of the Venturi type, injectors, etc., wherein this preliminary mixing stage MP is provided to receive from the feed conduit CA the two-phase flow (L+G), i.e. the liquid L after it has received along

the feed conduit CA the gas G, and to supply, downstream of the preliminary mixing stage MP, the two-phase flow (L+G) to the mixer device 10, the object of the present invention, where a further and definitive mixing and dispersion of the gas G in the liquid L take place;

- a stage of use or generic utility, denoted by UT, placed downstream of the mixer device 10 of the invention and apt to receive the two-phase flow, denoted by (L+G)', after the mixing and final dispersion of the gas G in the liquid L in the device 10, wherein this generic utility UT can be constituted, by way of a non-limiting example, by a storage tank or by an actual apparatus or plant, such as a bottling plant, which receives and uses the flow of the two-phase fluid (L+G)'; and
- a regulation member OR which is placed, along the feed conduit CA of the liquid L, just before the area in which the feed conduit CA receives the gas G, upstream of the preliminary mixing stage MP, wherein this regulation member OR has the function of regulating the flow rate of the liquid L, as a function of possible requests by the use stage UT.

**[0031]** The lines for feeding the liquid L and the gas G are also provided with appropriate members of movement, control and regulation of the liquid phase L and of the gaseous one G, in themselves known and therefore, for reasons of simplicity, not shown and indicated in Fig. 1.

**[0032]** By way of a non-limiting example of application of the invention, the use stage UT can be constituted, as already specified, by a plant for bottling gassed drinks, which receives and uses the flow of the two-phase fluid (L+G)' supplied by the device 10 of the invention, wherein, for the purpose of proper functioning of the bottling plant, the regulation member OR is used to regulate appropriately the feeding of the liquid L so as to maintain constant or in general keep under control the level of the drink in the use stage UT, where the gassed drink is bottled.

**[0033]** The regulation member OR can also be positioned downstream of the preliminary mixing stage MP or of the mixer device 10 of the invention.

**[0034]** It is also clear that, should the regulation member OR be positioned downstream of the preliminary mixing stage MP or of the mixer device 10, appropriate regulation members, not indicated in the drawings, can be provided to allow a correct functioning of the plant and in particular to maintain constant the weight ratio required between the liquid L and the gas G.

**[0035]** It is also specified that the preliminary mixing stage MP represents only one possibility and is therefore to be referred to one of the many possible applications of the invention, also not being possibly necessary according, mainly, to the viscosity, density and surface tension of the liquid L, and the features of the two-phase fluid required.

**[0036]** The function of the preliminary mixing stage MP is essentially that of mixing the gas G in the liquid L in a preliminary and coarse way, with the formation of bubbles also of medium-large dimensions, up to a few mm, provided they are distributed in a sufficiently homogeneous manner in the liquid L, for the sole purpose of allowing the mixer device 10, the object of the invention, to operate in optimal conditions.

**[0037]** More particularly this preliminary mixing stage MP, provided to perform a preliminary mixing of the gas in the liquid, has the purpose of avoiding the undesired pulsations of a part, constituted by a mixing element and configured as a piston sliding axially, of the device 10 of the invention, as will be illustrated in greater detail here below, when describing the functioning thereof.

**[0038]** In Fig. 1 a single device 10 of the invention is shown and indicated, even if two or even more devices 10 may be required and necessary, placed in series, as a function of the specific application and of the features of the liquid L and of the flow of the two-phase fluid, similarly to how it is already specified in relation to the preliminary mixing stage MP.

**[0039]** Fig. 2 shows in greater detail the parts of the device 10 of the invention.

**[0040]** In brief, referring to Fig. 2, the device 10 of the invention is apt to receive in input the flow of the two-phase fluid, shown with an arrow and denoted by (L+G), comprising therefore a liquid phase L and a gaseous phase G dispersed in the liquid phase L and for example coming from a preliminary mixing stage MP as described previously with reference to Fig. 1, and to supply at the outlet a corresponding flow of two-phase fluid, again indicated by an arrow and denoted by (L+G)', wherein the gaseous phase G has been appropriately dispersed and micronized in the liquid phase L during the passage of the two-phase fluid (L+G) through the device 10, as described in greater detail here below.

**[0041]** In detail the device 10 of the invention comprises:

- an outer body 11, extending along a longitudinal axis X of the device 10 and defining internally a conduit 11' for the flow of the two-phase fluid (L+G) through the same device 10; and
- a mixer, denoted overall by 12, housed in the body 11 of the device 10 between an inlet section and an outlet section of the conduit 11', comprising a mixing member or element 13, sliding along the axis X of the body 10, in order to intercept and co-operate with the two-phase fluid (L+G) which flows through the conduit 11'.

**[0042]** The outer body 11, defining the conduit 11', extends in a longitudinal direction along the main axis X of the device 10 and is composed of two parts, 11-1 and 11-2 respectively, each one constituted by a single part, connected

one to the other at the head in a known manner, for example by means of a threaded sleeve 11-3.

**[0043]** The first part 11-1 of the body 11 is in turn made up of a first portion 11-1a, with hollow truncated cylinder shape, corresponding to the inlet area of the device 10; a second union portion 11-1b, with conical shape along an angle  $\alpha$ ; and a third portion 11-1c, again with hollow truncated cylinder shape, of greater diameter than the first portion 11-1a.

**[0044]** The second part 11-2 of the body 11 in turn is constituted by a first portion 11-2a, with hollow truncated cylinder shape, directly connected to the third portion 11-1c of the first part 11-1 of the body 11 by means of the threaded sleeve 11-3; a second union portion 11-2b, with conical shape; and a third portion 11-2c, corresponding to the outlet area of the device 10, again with hollow truncated cylinder shape, of smaller diameter than the first portion 11-2a.

**[0045]** The first portion 11-1a of the first part 11-1 of the body 11 and the third portion 11-2c of the second part 11-2 of the body 11, corresponding respectively to the inlet area of the conduit 11' of the flow of the two-phase fluid (L+G) and to the area of outlet from the conduit 11' of the flow of the two-phase fluid (L+G)', after the passage through the device 10, are associated with known connection means, denoted by 15, for example in the form of threaded sleeves, apt to connect tightly the body 11 of the device 10, on the one side, with the feed conduit CA which feeds the flow of the two-phase fluid (L+G) to the device 10, and, on the other side, with the conduit which receives the flow of the two-phase fluid (L+G)', after it has been appropriately mixed by passing through the device 10, to convey it towards the utility UT.

**[0046]** The mixing element 13 of the mixer 12 is in turn constituted by a head 13a, apt to receive and intercept the two-phase fluid (L+G) which enters and flows in the conduit 11', and a piston 13b, in one part and integral with the head 13a, wherein this piston 13b is housed and axially sliding, along the axis X of the device 10, in a guide 14 defined by the body 11.

**[0047]** The head 13a of the mixing element 13, shown schematically in Fig. 2 with a cylindrical body of diameter greater than the diameter of the piston 13b, is apt to co-operate, sliding axially, with the inner conical surface, denoted by 11-1b', of the second conical portion 11-1b of the first part 11-1 of the outer body 11 of the device 10, so as to define a passage opening or section, denoted by B, of the two-phase fluid (L+G) from the upstream area to that downstream of the same head 13a.

**[0048]** This passage opening or section B, defined between the head 13a of the mixing element 13 and the inner conical surface 11-1b' of the conduit 11', is such as to entail a jump in pressure in the flow of two-phase fluid (L+G) through the device 10, as explained in greater detail here below describing the functioning of the device 10.

**[0049]** As shown in the sectioned view of Fig. 3, the guide 14, formed along the axis X of the device 10, which houses slidably the piston 13b of the mixing element 13, is supported inside the body 11 by a spoke 16 formed in one part with the first portion 11-2a of the second part 11-2 constituting together with the first part 11-1 the body 11 of the device 10.

**[0050]** The configuration of the device 10 further comprises a passage, denoted by 17 and shown in Figs. 2 and 3, part of the conduit 11' defined inside the body 11, wherein this passage 17 places in communication the inlet area and the outlet area of the same conduit 11' so as to ensure an adequate flow of the two-phase fluid (L+G) through the device 10; and a further and other passage, denoted by 18, having the function of placing in communication the area of the guide 14, which houses slidably the piston 13b of the mixing element 13, with further and essential parts, described here below, of the device 10.

**[0051]** Therefore, as shown in Fig. 2, the head 13a and the piston 13b which make up the mixing element 13 are configured so as to be subjected, from one side, in the flow direction of the two-phase fluid (L+G) through the device 10, to a first pressure, denoted by P1, present in the two-phase fluid (L+G) in the area, denoted by A1, immediately upstream of the head 13a of the mixing element 13, and, from another side and in the opposite direction, both to a second pressure, denoted by P2, present in the two-phase fluid (L+G) in the area, denoted by A2, immediately downstream of the head 13a of the mixing element 13, and to a third pressure or force, denoted by Pp, acting on a face of the piston 13b of the mixing element 13, in the area, denoted by A3, of the guide 14.

**[0052]** Detection or sensor means are also provided, schematised with a small ball in Fig. 2, apt to detect the pressure P1 present in the flow of the two-phase fluid (L+G) in the upstream area A1 of the head 13a of the mixing element 13, the pressure P2 present in the flow of the two-phase fluid (L+G) in the downstream area A2 of the same head 13a, and the pressure Pp present in the area A3 adjacent to and limited by the guide 14 which houses slidably the piston 13b.

**[0053]** For the sake of clarity, Fig. 4 shows schematically the forces F1, F2, Fp which, through the effect respectively of the pressures P1, P2 present in the two-phase fluid (L+G) respectively in the upstream area A1 and downstream area A2 of the head 13a, co-operating with the inner conical surface 11-1b' of the portion 11-1b of the body 11, and of the pressure Pp present in the area A3 of the guide 14 which houses slidably the piston 13b, act in opposite directions along the axis X on the mixing element 13 and therefore govern the functioning of the device 10 of the invention.

**[0054]** In particular, as shown in Fig. 4, the forces F1 and F2 act on opposite sides on the head 13a of the mixing element 13, the first in the same direction of the flow of the two-phase fluid (L+G) through the device 10 and the second in the opposite direction, while the force Fp acts, on the face of the piston 13b facing the guide 14, in the direction opposite to that of the flow of the two-phase fluid (L+G).

**[0055]** According to a salient feature of the present invention, the device 10 comprises further control means, denoted overall by 20 and shown schematically in Fig. 5, associated with the mixer 12 and the respective mixing element 13,

having the function of controlling the third pressure  $P_p$  or corresponding force  $F_p$  acting on the piston 13b in the area of the respective guide 14, so as to maintain, during variation of the operating conditions of the device 10, and typically during variation of the flow rate of the flow of the two-phase fluid (L+G) which traverses the device (10), the pressure difference  $\Delta P = (P_1 - P_2)$ , between the pressure  $P_1$  of the two-phase fluid (L + G) in the upstream area  $A_1$  of the head 13a and the pressure  $P_2$  in the downstream area  $A_2$  of the same head 13a of the mixing element 13, conforming to a given value or within a given range of variation.

**[0056]** In this way, i.e. thanks to the action of these control means 20 aimed at keeping constantly under control the pressure difference  $\Delta P = (P_1 - P_2)$  in the two-phase fluid (L+G) between the upstream area  $A_1$  and the downstream one  $A_2$  of the head 13a of the mixing element 12, the device 10 of the invention acquires the capacity to improve and increase the dispersion and mixing of the gaseous phase G in the liquid phase L of the two-phase fluid (L+G) which flows through the conduit 11' of the device 10 and thereby reduce the size of the gas bubbles dispersed in this two-phase fluid, as will be explained in greater detail here below when describing the functioning of the device 10.

**[0057]** In detail these control means 20 are made up of a mechanism or device, schematised in Fig. 5, which completes the configuration of the device 10 and allows proper functioning thereof in order to improve and increase the dispersion of the gaseous phase G in the liquid phase L of the two-phase fluid (L+G) which flows through the same device 10, wherein this mechanism 20 is composed of:

- a box 21 containing a gas  $G_1$ , for example air;
- a conduit 22, formed in continuation of the passage 18 defined by the body 11 of the device 10, which places in communication the box 21 with the area  $A_3$  of the guide 14 that slidably houses the piston 13b of the mixing element 13; and
- two conduits or lines 23 and 24, in communication with the box 21, provided with respective pressure regulators 26 and 27 or functionally similar members, whereof the first with function of pressure reducer, denoted by PR, and the second with overflow valve function, denoted by VS.

**[0058]** More particularly, as illustrated in greater detail here below when describing the functioning of the device 10, these conduits 23 and 24 allow and have the function of feeding and extracting selectively the gas  $G_1$  into or from the box 21, so as to maintain in the same box 21 a pressure value suitable for the proper functioning of the device 10 in order to control the dispersion of the gaseous phase G in the liquid phase of the two-phase fluid (L+G) which flows through the device 10.

**[0059]** The gas  $G_1$  which fills the box 21 can also be the same gas G that is dispersed and mixed in the liquid L by means of the device 10 of the invention.

#### Functioning of the device of the invention

**[0060]** A description will now be given of the functioning of the device 10 of the invention.

**[0061]** Given that the efficacy of this functioning, that is to say the capacity of the device 10 for improving the dispersion and mixing of the gaseous phase G in the liquid phase L of the two-phase fluid (L+G) which flows through the same device 10, is based and depends in turn, as already anticipated and will be made clear here below by the description, on the proper control of the mixing element 13 by control means 20, so as to maintain constant or at least within a given range of variation, during variation of the operating conditions wherein the device 10 operates, for example during variation of the flow rate of the two-phase fluid (L+G) and/or of the pressure  $P_2$  in the downstream area of the head 13a of the mixing element 13, the difference in pressure between the pressure  $P_1$  present in the two-phase fluid (L+G) in the upstream area  $A_1$  of the head 13a of the mixing element 13, that is upstream of the passage opening or section B of the two-phase fluid (L+G) defined between the head 13a of the mixing element 13 and the inner surface 11-1b' of the conduit 11', and the pressure  $P_2$  present in the two-phase fluid (L+G) in the downstream area  $A_2$  of the same head 13a of the mixing element 13, i.e. downstream of the aforesaid passage opening or section B of the two-phase fluid (L+G).

**[0062]** In detail, in the functioning and effective use of the device 10, with the two-phase fluid (L+G) which feeds the device 10 and flows through the respective conduit 11', the mixing element 12, being hit by the flow of the two-phase fluid (L+G), is subject to slide axially with the piston 12b in the guide 14.

**[0063]** Therefore this sliding of the piston 13b along the respective guide 14 also varies the position of the head 13a of the mixing element 13 with respect to the inner surface, denoted by 11-1b' in Figs. 2 and 4, of the conical union 11-1b of the body 11, i.e. of the conduit 11', and this variation varies also the breadth of the passage section B, between the head 13a and this inner surface 11-1b' of the conical union 11-1b, which is traversed by the two-phase fluid (L+G) coming from the area  $A_1$  upstream of the head 13a.

**[0064]** For clarity, Fig. 4A shows schematically the area of this passage opening or section B, defined between the head 13a of the mixing element 13 and the inner surface 11-1b' of the conical union 11-1b, i.e. of the conduit 11', wherein the axial sliding of the head 13a along the axis X which determines the variation of the passage opening B is indicated

by a double arrow and shown with dotted and dashed line.

**[0065]** It is also pointed out, with reference to the diagrams of Figs. 2, 4 and 4A, that the extent of the axial sliding along the axis X of the head 13a, that is of the mixing element 13, from a position of contact with the inner conical surface 11-1b' of the conical union 11-1b, in order to obtain a given passage opening or section B of the two-phase fluid (L+G), depends on the diameter of the cylindrical head 13a and on the angle  $\alpha$  of the conical surface 11-1b', increasing as these two parameters decrease.

**[0066]** In this first preferred embodiment 10 it is assumed for the sake of simplicity that the head 13a of the mixing element 13 and the conical surface 11-1b' have in section a circular shape, but it is clear that other shapes and configurations are possible without this altering or modifying the functioning of the device 10.

**[0067]** Therefore, during the passage of the two-phase fluid (L+G), the head 13a of the mixing element 13 takes on a position, with respect to the conical union 11-1b, such that the various forces applied to the mixing element 13 are balanced, that is the resultant of the forces applied to the mixing element 13 is equal to zero, wherein this position of equilibrium, assumed by the mixing element 13, corresponds to a given free section, between the head 13a and the conical surface 11-1b', which allows the passage of the flow of two-phase fluid (L+G) coming from the upstream area A1 of the head 13a.

**[0068]** More particularly, in these conditions, as already illustrated previously with reference to the diagram of Fig. 4, the mixing element 13 is subject to the following three forces, which are balanced, acting along the axis X of the device 10, that is in the direction of the axial movement of the mixing element 13:

F1: resultant of the forces exerted, through the effect of the pressure P1 present in the two-phase fluid (L+G) in the upstream area A1 of the head 13a, on the front section or face, denoted by S1, of the same head 13a, along the axis X of the mixing element 13 and in the same direction of the flow of the two-phase fluid (L+G);

F2: resultant of the force exerted, through the effect of the pressure P2 present in the two-phase fluid (L+G) in the downstream area A2 of the head 13a, on the rear section or face, denoted by S2, of the head 13a, again along the axis X of the mixing element 13 but in the opposite direction to that of the flow of the two-phase fluid (L+G);

Fp: force exerted on the section or face Sp of the piston 13b in the area A3 adjacent to the respective guide 14, in the same direction of the force F2 and therefore in the direction opposite to that of the flow of the two-phase fluid (L+G) through the device 10.

**[0069]** Therefore, assuming that the transient phenomena and the dynamic pressures due to the speed and accelerations of the two-phase fluid (L+G) in the passage, through the section B, from the upstream area A1 to the downstream one A2 of the head 13a are overlooked, in consideration also of the fact that the values of these dynamic pressures are in any case usually low and negligible in relation to the value  $\Delta P$ , that is to the jump in pressure between the upstream area and the downstream one of the head 13a normally required in order to obtain effective mixing of the gas G in the liquid L, the balance that is achieved, in the capacity functioning of the device 10, among the various forces acting on the mixing element 13, can be expressed with the following formula:

$$F1 = F2 + Fp \text{ (a)}$$

**[0070]** This formula (a) can in turn also be written as:

$$P1 \times S1' = P2 \times (S1' - Sp') + Fp, \quad \text{(b)}$$

that is:

$$P1 \times S1' = P2 \times (S1' - Sp') + Pp \times Sp' \quad \text{(c)}$$

where S1' is the area of the front face S1 of the head 13a which is hit by the flow of the two-phase fluid (L+G), in the upstream area A1 of the head 13a, and Sp' is the area of the face Sp of the piston 13b, facing onto the area A3, so that (S1'-Sp') is the area of the rear face S2 of the head 13a whereon the pressure P2 acts in the downstream area A2 of the head 13a.

**[0071]** Therefore the following formula is obtained:

$$(P1 - P2) = \Delta P = (Pp - P2) \times Sp'/S1' \quad \text{(d)}$$

which defines the jump in pressure  $\Delta P$  whereto the two-phase fluid (L+G) is subject through the passage section B defined by the head 13a in co-operation with the inner surface 11-b' of the conduit 11', from the upstream area A1 to the downstream one A2 of the head 13a of the mixing element 13.

**[0072]** The preceding formulas which define, as illustrated previously, the equilibrium of the various forces acting on the mixing element 13, serve to better understand how the device 10 operates and functions.

**[0073]** In detail, in the functioning of the device 10, the pressure Pp, acting on the piston 13b in the area of the respective guide 14, is constantly controlled by the control means 20, that is by the mechanism described previously and schematised in Fig. 5, so that the pressure difference  $\Delta P = (P1-P2)$  between the pressure P1 present in the two-phase fluid (L+G) which flows through the device 10, in the upstream area A1 of the head 13a, and the pressure P2 present in the same two-phase liquid (L+G) in the downstream area A2 of the same head 13a of the mixing element 13, is constantly conforming to a given value or within a given range of variation.

**[0074]** For this purpose this mechanism 20, comprising, as described previously, a box 21 of appropriate capacity, which contains a gas G1 such as for example air and is connected by means of the conduits 18 and 22, formed in continuation one of the other, to the area A3 of the guide 14 in which the mixing element 13 slides, controls appropriately the pressure Pp by the feeding/extraction of gas into /from the box 21.

**[0075]** In particular, as also indicated by arrows in Fig. 5, the feeding of gas in the box 21 is performed by means of the conduit 23, associated with the pressure reducer 26, while the extraction of gas from the box 21 is performed via the conduit 24, associated with the overflow valve 27, wherein these two conduits 23 and 24 can be associated with further members of regulation and control in themselves known.

**[0076]** The formula (d), given that the area Sp' of the face Sp of the piston 13b and the area S1' of the front face S1 of the head 13a of the mixing element 13 take on fixed values which depend on the construction of the device 10 and on its dimensions, highlights that, for a given construction and given dimensions of the device 10 of the invention, in order to maintain constant  $\Delta P$ , that is the jump in pressure whereto the two-phase fluid (L+G) is subject from the upstream area to the downstream area of the head 13a, it is necessary and sufficient to maintain constant the value of  $(Pp-P2)$  by means of the control means 20.

**[0077]** Therefore, in fact, in the functioning of the device 10, the control means 20 perform the function of controlling the pressure Pp of the gas G1, acting on the piston 13b in the area A3 of the guide 14, so as to maintain constant and conforming to a given value, appropriately established, the difference between the pressure Pp and the pressure P2 of the two-phase fluid (L+G) in the downstream area A2 of the head 13, or at least so as to maintain this difference within a given range of variation defined by the tolerance which is allowed and admissible in order to obtain further a good and optimal degree of solubilisation, that is of dispersion and mixing of the gaseous phase in the liquid phase of the two-phase fluid which flows through the device 10.

**[0078]** More specifically the control means 20 activate selectively, on the basis of the values of the pressure P1 and P2 which is present in the two-phase fluid (L+G) which flows in the areas A1 and A2 respectively upstream and downstream of the head 13a of the mixing element 13, and on the basis of the value of the pressure Pp which is present in the area A3 adjacent to the guide 14, as detected by the special pressure sensors included in the device 10, the valves 26 and 27, associated with the conduits 23 and 24, so as to feed or extract the gas G1 from the box 21 and consequently control the pressure Pp, in the area A3 of the guide 14, so as to maintain the difference  $(Pp-P2)$  within the required range, as illustrated previously.

**[0079]** For the sake of clarity the working block diagram of Fig. 11 illustrates this functioning of the control means 20, essential part of the device 10, to maintain the difference  $\Delta P = (P1-P2)$ , between the pressures P1 and P2 present in the two-phase fluid (L+G) in the areas A1 and A2 respectively upstream and downstream of the head 13a of the mixing element 13, that is upstream and downstream of the passage section B defined by the head 13a in co-operation with the inner surface 11-1b' of the conduit 11', conforming in time to a constant pre-established value or at least within a required range in order to obtain an optimal dispersion and mixing of the gas G in the liquid L of the two-phase fluid (L+G) which flows through the device 10.

**[0080]** In particular the following table describes the steps which correspond to the blocks 100-103 of the working block diagram of Fig. 11, in which the output of the step corresponding to block 102 can be affirmative (YES) or negative (NO).

Block	Description
100	FLOW OF THE TWO-PHASE FLUID (L+G) THROUGH THE DEVICE (10)

(continued)

Block	Description
101	MEASUREMENT OF THE PRESURE (P1, P2) OF THE TWO-PHASE FLUID (L+G) IN THE UPSTREAM AREA (A1) AND IN THE DOWNSTREAM AREA (A2) OF THE HEAD (13a) OF THE SLIDING MIXING ELEMENT (13), THAT IS UPSTREAM AND DOWNSTREAM OF THE PASSAGE SECTION (B) OF THE TWO-PHASE FLUID DEFINED BY THE HEAD (13a) OF THE SLIDING MIXING ELEMENT WITH THE INNER SURFACE OF THE CONDUIT (11') WHEREIN THE TWO-PHASE FLUID (L+G) FLOWS THROUGH THE DEVICE (10), AND MEASUREMENT OF THE PRESSURE (PP) ACTING ON THE PISTON (13b) OF THE SLIDING MIXING ELEMENT (13) IN THE AREA OF THE RESPECTIVE GUIDE (14)
102	DIFFERENCE BETWEEN THE PRESSURES ( $\Delta P = (P1-P2)$ ) OF THE TWO-PHASE FLUID (L+G) IN THE UPSTREAM AREA (A1) AND DOWNSTREAM AREA (A2) OF THE HEAD (13a) OF THE SLIDING MIXING ELEMENT (132) CONFORMING TO A GIVEN VALUE OR AT LEAST WITHIN A GIVEN RANGE OF VARIATION ?
103	INTERVENTION OF THE CONTROL MEANS (20) IN ORDER TO SELECTIVELY FEED OR EXTRACT GAS (G1) INTO/FROM THE BOX (21), INCLUDED IN THE CONTROL MEANS (20) AND IN COMMUNICATION WITH THE AREA (A3) OF THE GUIDE (14) OF THE PISTON (13b) OF THE MIXING ELEMENT (13) IN ORDER TO MAINTAIN IN TIME THIS DIFFERENCE ( $\Delta P = (P1-P2)$ ) CONFORMING TO THE GIVEN VALUE OR AT LEAST WITHIN THE GIVEN RANGE OF VARIATION

**[0081]** Naturally, assuming a given value of the pressure P1 in the upstream area A1 of the head 13a, should in the functioning of the device 10 the value of the pressure P2, in the downstream area of the head 13a, not vary but remain constant, the control means 20 in practice never have to intervene except, solely, to maintain constant the value of the pressure Pp of the gas G1 in the area of the guide 14 which houses slidably the piston 13b.

**[0082]** The device 10 can be applied and operate in different working contexts and situations, in which the functioning of the device 10 is governed by the formulas illustrated previously.

**[0083]** For example the device 10 can be applied in working contexts and production processes in which the value of the pressure P2 remains, for practical effects and taking account of the variability of the physical phenomena in reality, substantially constant in the downstream area A2 of the head 13a of the mixing element 13, that is downstream of the passage opening B, between the mixing head 13 and the inner surface of the conduit 11', which entails the pressure jump  $\Delta P = (P1-P2)$ .

**[0084]** For example, without these applications having a limiting value, the device 10 can be associated with an isobaric bottling plant of gassed drinks, where the pressure in the utility UT, as schematised in Fig. 1 and coinciding with the head of the bottling machine, remains constant during operation, or the device 10 can be used for the extraction or stripping of gases dissolved in a liquid, wherein in this application the utility UT fed by the device 10 is made up of a tank kept at constant pressure.

**[0085]** In these applications, in which, as mentioned, the value of the pressure P2 does not vary but is substantially constant, in order to minimise the transient regimes which can influence the value of the pressure Pp in the area of the guide 14 and therefore avoid as far as possible the departures of this pressure Pp from the permitted range, so as to minimise also interventions by the control means 20 to actuate the valves 26 and 27 to feed/extract gas into/from the box 21 with the consequent and inevitable oscillations in the value of  $(Pp-P2)$ , that is of  $\Delta P = (P1-P2)$ , the volume of the box 21, of the area A3 limited by the guide 14, and the diameter of the piston 13b, that is the area of the face Sp of the piston 13b that receives the pressure Pp, are dimensioned in such a way that the ratio between the volume Vs covered by the axial stroke of the piston 13b, during the functioning of the device 10, that is during the sliding movement of the piston 13b along the respective axis X, and the volume Vt defined by the volumes of the area A3 limited by the guide 14, by that of the conduits 18 and 22 that place in communication the area A3 of the guide 14 with the box 21, and by the volume of the same box 21, is coherent and compatible with the pre-established value or the range of variation within which the pressure difference  $\Delta P = (P1-P2)$  has to be maintained in order to obtain a proper functioning of the device 10.

**[0086]** Moreover, assuming that in these applications the transformations of the fluid take place in isothermic conditions and therefore the law of the gases in the formula  $P \times V = \text{Constant}$  applies, where P is the pressure and V is the volume of the gas, it is deduced that if the value of the volume Vs, covered by the axial stroke of the piston 13b along the guide 14, is small with respect to the value of the volume Vt, the variations in pressure in the gas G1 will also consequently be small and reduced, and more exactly the percentage variation of the pressure Pp acting on the piston 13b will be the same in absolute value, but opposite in terms of the percentage variation of the volume Vt.

**[0087]** It is also pointed out that if the seal between the piston 13b and the respective seat 14 is formed in such a way that there are no seepages of gas, it is possible to pressurise initially the box 21, with the gas G1 contained in its interior,

to the values of pressure required for the proper functioning of the device 10.

**[0088]** Therefore in this case, during the service and the functioning of the device 10 to keep constant or in general under control the value of  $\Delta P = (P1-P2)$ , there will be no need to restore the gas G1 contained in the box 21.

**[0089]** Further, again taking account of the specific working circumstances wherein the device 10 is applied and in particular when these operating circumstances require that the pressure difference ( $\Delta P = (P1-P2)$ ) between the pressure P1 of the two-phase fluid in the upstream area of the head 13a of the mixing element 13 and the pressure P2 of the two-phase fluid in the downstream area of the head 13a of the mixing element 13 is maintained constant during the functioning of the device 10, the sealed sliding coupling between the piston 13b and the respective slide guide 14 can be advantageously formed, using known methods and techniques, such as to allow the device 10 to operate without the intervention of the pressure regulators 26, 27.

**[0090]** In fact this system has the advantage of eliminating any transient regimes of pressure in the box 21 and therefore also transient regimes of the value of the pressure  $\Delta P = (P1-P2)$  between the pressure P1 in the upstream area and the pressure P2 in the downstream area of the head 13a of the mixing element 13.

**[0091]** It is clear therefore that the above systems, closely connected to the specific circumstances of operation in which the device of the invention is applied, allow performances which are significantly better with respect to those which can be obtained with existing techniques and which are not in any way contemplated by the latter.

**[0092]** More particularly, in order to create the abovementioned seal between the piston 13b and the respective guide 14 so as to avoid seepages and leaks of gas through the guide 14 and therefore also avoid having to restore the gas G1, it is possible to insert an appropriate liquid, preferably but not exclusively the same liquid of the gassing process which flows through the device 10, between the gas G1 contained in the box 21 and the piston 13b.

#### Description of a second preferred embodiment of the invention

**[0093]** Fig. 6 shows a variant or second preferred embodiment, denoted by 110, of the mixer device of the invention, wherein the parts corresponding to those included in the first preferred embodiment 10, previously described and shown in Fig. 2, will be denoted for reasons of clarity with the same reference numerals.

**[0094]** More specifically, in this second embodiment 110 of the device of the invention corresponding also to a second mode of functioning with respect to that already described with reference to the device 10, the force which is applied to the piston 13b, in the area A3 limited by the respective guide 14, is determined, instead of the mechanism 20, that is by the pressure of a gas, by a spring, denoted by 50, which is housed in the area of this guide 14 and is configured so as to vary, during the axial movement of sliding of the piston 13b along the guide 14, the intensity of the force applied by the same spring 50 to the piston 13b, in order to allow the proper functioning of the device 110 to improve the mixing and the dispersion of the gas G in the liquid L of the two-phase fluid (L+G) which flows through the device 110.

**[0095]** In greater detail, in this second embodiment 110, the spring 50 is dimensioned and selected in such a way as to exhibit appropriate characteristics of elasticity such as to ensure, during the variation of the working conditions in which the device 110 operates, and in particular during the variation of the flow rate of the two-phase fluid (L+G) which flows through the same device 110, that the pressure difference ( $\Delta P = (P1-P2)$ ) between the pressure P1 of the two-phase fluid (L+G) in the upstream area A1 and that P2 in the downstream area A2 of the head 13a of the mixing element 13 remains conforming to a given value, appropriately established, or at least within a given range of variation such as to improve, in fact, the mixing and dispersion of the gaseous phase G in the two-phase fluid (L+G) which passes through the device 110.

**[0096]** In other words, in this second embodiment 110, shown in Fig. 6, by appropriately dimensioning the spring 50 and selecting its elastic characteristic, as also by configuring in an appropriate manner the geometry of the device 110, it is possible to succeed in obtaining the same working features and performances of the first embodiment 10 of the device of the invention, shown in Figs. 2 and 4, in order to improve the mixing and dispersion of gas G in a liquid L in a flow of a two-phase fluid (L+G).

**[0097]** Naturally, in the case of this second embodiment 110, the considerations relating to the volume  $V_t$  and  $V_s$  disclosed previously with reference to the first embodiment 10, should be replaced with similar considerations relating to the elasticity constant of the spring 50 and on its range.

**[0098]** More particularly, in this second embodiment 110, the spring 50 is selected and dimensioned in such a way that, during the functioning of the device 110, the value of the elasticity constant of the spring 50 multiplied by the stroke of the sliding piston 13b is such as to entail a corresponding variation of the elastic force applied by the spring 50 on the same piston 13b within the range required, so as to ensure the proper functioning of the device 110 to improve the dispersion of the gaseous phase G in the two-phase liquid (L+G) which flows through the device 110.

**[0099]** Further, this second embodiment 110 of the device of the invention comprises a perforated ring nut, denoted by 51 in Fig. 6, which is coupled to the guide 14 by means of a threading or with other similar systems, in which this threaded coupling has the function of allowing the regulation, by screwing varyingly the ring nut in the guide 14, of the length of the spring 50 when assembling the device 110, and therefore of regulating the force applied by the same spring

50 to the piston 13b.

**[0100]** Finally the hole formed in the ring nut 51 has the purpose of allowing the free circulation, during the axial movements of the piston 13b, of the two-phase fluid (L+G) between the area A3 of the guide 14 which houses the spring 50 and the area wherein the two-phase fluid (L+G) flows through the device 110.

**[0101]** It is therefore clear, from what is described, that the present invention achieves in full the objects set, and in particular provides a new and innovative device, which can be integrated in a wider working context, apt to receive a flow of a two-phase fluid, that is comprising a liquid phase and a gaseous phase, and to improve and keep effectively under control the mixing and dispersion, in this two-phase flow, of the gaseous phase in the liquid one.

## 10 Variants

**[0102]** Without prejudice to the basic concepts of the present invention, it is also clear that the device, described hitherto, for improving the dispersion and mixing of gas in liquids, can be the subject of variants and further improvements and modifications may be made thereto, also derived and derivable from the prior art, without thereby departing from the scope of the same invention.

**[0103]** For example, as already explained, in the embodiment 10 the head 13a of the mixing element 13 has been, for reasons of simplicity, schematised with a body of cylindrical shape, yet naturally other shapes and configurations are possible, always coming within the concept of the invention, both of this head and of the surface 11-1b' of the internal conduit 11', defined by the body 11 of the device 10, with which it cooperates in order to define the passage section B of the two-phase fluid (L+G) from the upstream area to the downstream area of the head 13a.

**[0104]** More particularly, in order to encourage the process of dispersion of the gas in the liquid, should the features of the liquid, of the gas and of the desired mixing require it, variants are possible in which the sliding mixing element head has geometric features such as sharp edges or various rough parts, apt to encourage turbulence, the shear forces and the dispersion of the gas in the liquid.

**[0105]** In this respect, Figs. 7 and 8 show in detail the device 10 in the area of the head 13a of the mixing element 13, and in particular two different embodiments of this area and of the head 13a, in turn co-operating with the inner surface 11-1b' of the conduit 11' defined by the body 11 of the device 10, wherein these two embodiments of the head 13a are denoted respectively by 13a' and 13a" in Figs. 7 and 8.

**[0106]** In detail in the embodiment shown in Fig. 7, the head 13a' of the mixing element 13 has a conical shape apt to co-operate with the inner conical surface of the second portion 11-1b of the first part 11-1 of the body 1.

**[0107]** Moreover this head 13a' exhibits, along a circumferential area at the base of its conical shape, a plurality of geometrical rough parts, denoted by 25, of various types, for example in the form of grooves, knurls, cuts, etc., which have the function of encouraging the turbulence of the two-phase fluid which flows through the device 10 and the shear forces whereto the same two-phase fluid is subject, and therefore improve the dispersion and mixing of the gas in the liquid.

**[0108]** Instead, in the embodiment shown in Fig. 8, the head 13a" of the mixing element 13 has again a conical shape, yet which is smooth and without grooves and other geometrical rough parts, and is also apt to co-operate with an edge defined by the inner surface of the conduit 11' along which the two-phase fluid (L+G) flows through the device 10.

**[0109]** Similarly, in order to encourage the process of dispersion of the gas in the liquid, it is possible to form knurls, sharp edges or various rough parts also on the surfaces of the conduit 11', defined by the body 11, which are in contact with the two-phase fluid (L+G) which flows, along this conduit 11', through the device 10 or 110 of the invention.

**[0110]** Figs. 9 and 10 show two further variants in which, without undermining the general nature of the concept of the invention, the mixing element 13 is specifically composed of two heads, denoted by 13c' and 13c", which are placed along the axis of the piston 13b of the mixing element 13, wherein these two heads 13c' and 13c" are apt to co-operate by sliding axially, in a similar manner to how it is illustrated for the preceding embodiments, with the inner conical surface of the conduit 11' wherein the two-phase fluid (L+G) flows.

**[0111]** In detail, in the variant shown in Fig. 9, the two heads 13c' and 13c" of the mixing element 13 co-operate with a common conical surface 11-1b' defined by the conduit 11', that is by the conical portion 11-1b of the body 11.

**[0112]** Instead, in the variant shown in Fig. 10, the two heads 13c' and 13c" of the mixing element 13 co-operate with two respective conical surfaces, separate, denoted by 11-1d' and 11-1d", defined by the conduit 11'.

**[0113]** Therefore these two variants shown in Figs. 9 and 10 are configured so as to divide the total or overall jump in pressure  $\Delta P_{tot}$  into two separate areas along the conduit 11', that is between the two upstream and downstream areas of the first head 13c' and between the two upstream and downstream areas of the second head 13c".

**[0114]** More particularly the variant of Fig. 9 has such a geometry and such a configuration whereby, during the functioning of the device 10, the passage openings or sections B and B1, between the two heads 13c' and 13c" and the conical surface 11-1b' of the conduit 11' with which the two heads 13c' and 13c" co-operate, are different one from the other, wherein the difference between these two openings B and B1 depends on the distance d1 between the two heads 13c' and 13c" along the axis of the mixing element 13.

**[0115]** Instead, the variant of Fig. 10 has a geometry and a configuration in which the two heads 13c' and 13c" are

identical, as also the concities of the inner surfaces 11-1d' and 11-1d", so as to define identical passage openings or sections B and B1.

**[0116]** In these variants shown in Figs. 9 and 10, the regulation of the jumps in pressure, both the partial ones  $\Delta P$  and the overall one  $\Delta P_{tot}$ , takes place in a similar manner to what is described for the preceding embodiments of the device of the invention, therefore on the basis of the same physical laws and principles as illustrated previously, obviously taking account of the different and specific geometries and configurations of these two variants which produce, as explained previously, several partial jumps in pressure  $\Delta P$ , which can be identical or different one in relation to the other, and which summed together produce an overall jump in pressure  $\Delta P_{tot}$ .

**[0117]** Moreover, in line with what is already known and applied in the art, the device of the invention for the dispersion of gas in liquids can advantageously be associated with systems of insulation having the function of isolating it thermally in an appropriate manner with respect to the surrounding environment.

**[0118]** Further, the device of the invention can be associated with an electronic control system, for example of the type comprising a PLC or a similar electronic unit, aimed at governing and controlling automatically the various phases of the functioning of the device for dispersing a gas in a liquid.

## Claims

1. A device (10; 110) for improving the dispersion and mixing of gas in liquids, comprising:

- an outer body (11, 11-1, 11-2), extending along an axis (X), defining internally a conduit (11') for the flow, through the device (10), of a two-phase fluid ((L+G)), that is comprising a liquid phase (L) and a gaseous phase (G) dispersed in the liquid phase (L); and
- at least one mixer (12), housed in said body (11, 11-1, 11-2), between an inlet section (11-1a) and an outlet section (11-2c) of said conduit (11'), and in turn comprising a mixing member or element (13), slidable along the axis (X) of the body (11), in order to intercept and co-operate with the two-phase fluid ((L+G)) flowing through the conduit (11'),

wherein said mixing element (13) in turn comprises:

- a head (13a) suitable to receive and intercept the two-phase fluid ((L+G)) which enters the conduit (11'), said head (13a) being apt to co-operate, by sliding axially due to the pressure of the two-phase fluid (L+G), with the inner surface (11-1b') of the conduit (11') so as to define and vary an opening or passage section (B), entailing a jump in pressure ( $\Delta P = (P1-P2)$ ), of the flow of two-phase fluid ((L+G)) through the device (10), and
- a piston (13b), integral with said head (13a), sliding axially along a guide (14) defined by the body (11) of the device (10),

wherein said mixing element (13) is configured so as to be subjected, from one side, in the flow direction of the two-phase fluid ((L+G)) through the device (10), to a first pressure or force ( $P1, F1$ ) present in the two-phase fluid ((L+G)) in the area (A1) immediately upstream of the head (13a) of the mixing element (13), that is upstream of said passage section (B), and, from another side and in the opposite direction, both to a second pressure or force ( $P2, F2$ ) present in the two-phase fluid ((L+G)) in the area (A2) immediately downstream of the head (13a) of the mixing element (13), that is downstream of said passage section (B), and to a third pressure or force ( $Pp, Fp$ ) acting on a face ( $Sp$ ) of the piston (13b) of the mixing element (13), in the area (A3) of the respective guide (14);

wherein said device (10) further comprises control means (20; 50), associated with said mixer (12) and the respective mixing element (13), for controlling said third pressure or force ( $Pp$ ) acting on the piston (13b) in the area of the respective guide (14), so as to maintain, during variation of the operating conditions of the device (10) and typically, but not exclusively, of the flow rate of the two-phase fluid (L+G) flowing through the same device (10), the pressure difference ( $\Delta P = (P1-P2)$ ), corresponding to said pressure jump in the passage section (B) defined by the head (13a) of the sliding mixing element (13) in co-operation with the surface (11-1b') of said conduit (11'), between the pressure ( $P1$ ) of the two-phase fluid ((L+G)) in the upstream area (A1) of the head (13a) and the pressure ( $P2$ ) of the two-phase fluid ((L+G)) in the downstream area (A2) of the head (13a) of the mixing element (13), conforming in time to a given value or at least within a given range of variation, and thereby improve and increase, by suitably keeping under control the value of said pressure difference ( $\Delta P = (P1-P2)$ ), the dispersion and mixing of the gaseous phase (G) in the liquid phase (L) of the two-phase fluid ((L+G)) flowing through the device (10), as well as reduce the size of the gas bubbles dispersed in said two-phase fluid ((L+G));

wherein the inner surface (11-1b'), of said conduit (11'), with which the head (13a) of said mixer (12) is apt to co-operate by sliding axially, exhibits a conical configuration diverging in the sense of the flow of the two-phase fluid ((L+G)) through the conduit (11'), with the head (13a) of said mixer (12) co-operating with said inner surface (11-1b'), of said conduit (11'), exhibiting said conical diverging configuration;

**characterized in that** the device (10; 110) further comprises a passage (17), part of the conduit (11'), defined in said body (11), for the flow of the two-phase fluid ((L+G)) through the same device (10), with said passage (17) being formed in said body (11) separately from the guide (14) for said piston (13b) so as to place in communication an inlet area and an outlet area of said conduit (11'), both defined along the axis (X) of said outer body (11, 11-1, 11-2), and extending parallel to the axis (X) of said body (11, 11-1, 11-2) beyond said piston (13b);

- detection means, associated with said control means (20; 50), for detecting said first (P1) and second (P2) pressure of the two-phase fluid (L+G), which flows through the device (10), respectively in the upstream area (A1) and the downstream area (A2) of the head (13a) of the sliding mixing element (13) and for detecting said third pressure (Pp) acting on the piston (13b) of the mixing element (13) in the area (A3) of the respective guide (14); and

wherein said control means (20) comprise:

- a control device (20), associated with said mixer (12) and the respective mixing element (13), to control, as a function of the pressures (P1, P2, Pp) which are detected by said detection means, the third pressure (Pp) acting on the piston (13b) of the mixing element (13), in the area (A3) of the respective guide (14), so as to maintain, during variation of the operating conditions of the device (10), said pressure difference ( $\Delta P = (P1 - P2)$ ) between the pressure (P1) upstream and the pressure (P2) downstream of the head (13a) of the mixing element (13) conforming to said given value or at least within said given range of variation.

2. Device (10) for the dispersion and mixing of gas in liquids, according to claim 1, wherein said control device (20) comprises:

- a box or chamber (21) containing a fluid (G1);  
 - a conduit (22) providing communication between said box (21) and the area (A3) of said guide (14) that slidably houses the piston (13b) of the mixing element (13); and  
 - at least one conduit or line (23, 24), in communication with the box (21), associated with adjustment means, such as a pressure regulator (26, 27) or a valve or similar members, apt to regulate and control feeding and/or extraction of the fluid (G1), into and from the box (21) through said line (23, 24);

wherein, when said detection means detect that said pressure difference ( $\Delta P = (P1 - P2)$ ) between the pressure (P1) of the two-phase fluid ((L+G)) in the upstream area (A1) of the head (13a) and that (P2) in the downstream area (A2) of the head (13a) of the mixing element (13) is not conforming to said given value or is not within said given range of variation, said control device (20) is configured to selectively activate said adjustment means (26, 27) so as to supply or extract the fluid, in particular gas (G1), to/from the box (21) through said at least one line (23, 24) and thereby vary, in the area (A3) of the guide (14) of the piston (13b) of the mixing element (13), the third pressure or force (Pp, Fp) acting on the same piston (13b), in such a way as to maintain said pressure difference ( $\Delta P = (P1 - P2)$ ), between the pressure (P1) of the two-phase fluid ((L+G)) in the upstream area (A1) of the head (13a) and that (P2) in the downstream area (A2) of the head (13a) of the mixing element (13), constantly corresponding in time to said given value or within said given range of variation.

3. Device (10) for the dispersion and mixing of gas in liquids, according to claim 2, in which a sealing liquid is interposed between the gas (G1), contained in said box (21), and the piston (13b) of the mixing element (13), in order to ensure the seal between the same piston (13b) and the respective guide (14), said sealing liquid being the same liquid (L) in which the gas (G) is dispersed and mixed by means of the device (10).

4. Device (10) for the dispersion and mixing of gas in liquids, according to claim 2 or 3, wherein the volume of said box (21), the volume of the conduit (18, 22) which connects the box (21) to the sliding area (A3) delimited by the guide (14) which slidably houses the piston (13b) of the mixing element (13), and the volume of the sliding area (A3) define a total volume, filled with gas (G1), which is selected and dimensioned so as to be subjected, in the operation of the device (10), because of the axial sliding of the mixing element (13) and of the respective piston (13b) in the guide (14), to a minimum variation in percentage, and thereby determine a corresponding minimum

variation in percentage of the force (Fp) acting on the piston (13b), in line with the characteristics of the gas (G) and of the liquid (L) to be mixed and dispersed by means of the device (10).

5 5. Device (10) according to claim 2 or 3, wherein said piston (13b) and the respective slide guide (14) are coupled slidably and sealed and the sliding sealed coupling between said piston (13b) and said slide guide (14) is configured to allow the device (10) to operate without the intervention of said pressure regulators (26, 27), so as to eliminate any transient pressure regimes in the box (21) and therefore also transient regimes of the value of the pressure difference ( $\Delta P = (P1-P2)$ ) between the pressure (P1) of the two-phase fluid in the upstream area of the head (13a) of the mixing element (13) and the pressure (P2) of the two-phase fluid in the downstream area of the head (13a) of the mixing element (13), when it is required for said pressure difference ( $\Delta P = (P1-P2)$ ) to be maintained constant during the functioning of the device (10).

10 6. The device (110) for the dispersion and mixing of gas in liquids, according to claim 1, wherein said control means comprise:

15 - a spring (50), or similar resilient means, arranged in the area (A3) of the guide (14) that slidably houses the piston (13b) of the mixing element (13), said spring being apt to apply on the piston (13b) an axial force acting in the opposite direction to the flow of the two-phase fluid ((L+G) in the device (10),

20 wherein said spring (50) is dimensioned and selected in such a way as to exhibit appropriate characteristics of elasticity and of variation of the force applied to the piston (13b) during its axial sliding, so as to ensure, during variation of the operating conditions of the device (10), that the pressure difference ( $\Delta P = (P1-P2)$ ) between the pressure (P1) of the two-phase fluid ((L+G)) in the upstream area (A1) and that (P2) in the downstream area (A2) of the head (13a) of the mixing element (13) remains conforming to said given value or at least within said given range of variation.

25 7. Device (10; 110) for the dispersion and mixing of gas in liquids, according to any one of the preceding claims, wherein said mixing element (13) comprises at least two heads (13c', 13c'') apt to co-operate, by sliding axially due to the pressure of the two-phase fluid ((L+G)), with the inner surface (11-1b'; 11-1d', 11-1d'') of the conduit (11') so as to define and vary an opening or passage section (B, B1), entailing a pressure jump ( $\Delta P = (P1-P2)$ ), of the flow of the two-phase fluid ((L+G)) through the device (10).

30 8. Device (10; 110) for the dispersion and mixing of gas in liquids, according to claim 7, wherein said two heads (13c', 13c'') of said mixing element (13) are apt to co-operate, by sliding axially due to the pressure of the two-phase fluid (L+G), with a common inner conical surface (11-1b') or with two respective separate conical inner surfaces (11-1d'; 11-1d'') of the conduit (11').

35 9. Device (10; 110) for the dispersion and mixing of gas in liquids, according to any one of the preceding claims, wherein the head of the mixing element (13) is constituted by a solid body which can be selected from a group consisting of:

40 - a solid cylindrical body (13a; 13c', 13c'');  
 - a conical body (13a') exhibiting on its surface a plurality of asperities, in the form of grooves, knurls, cuts, or similar formations, aimed at favouring the turbulence of the two-phase fluid (L+G) flowing through the device (10); and  
 45 - a smooth conical body (13a'') apt to co-operate with its conical surface, in order to define the passage opening (B) for the flow of the two-phase fluid ((L+G)) through the device (10), with an edge defined by the conduit (11') along which the two-phase fluid (L+G) flows in the device (10).

50 10. Method for improving the dispersion and mixing of gas in liquids, comprising the following steps:

(a) providing a device (10) for the dispersion and mixing of gas in liquids comprising:

55 - an outer body (11, 11-1, 11-2), extending along an axis (X), defining internally a conduit (11') for the flow, through the device (10), of a two-phase fluid ((L+G)), that is comprising a liquid phase (L) and a gaseous phase (G) dispersed in the liquid phase (L); and  
 - at least one mixer (12), housed in said body (11, 11-1, 11-2), between an inlet section (11-1a) and an outlet section (11-2c) of said conduit (11'), and in turn comprising a mixing member or element (13), slidable along the axis (X) of the body (11), in order to intercept and co-operate with the two-phase fluid ((L+G))

flowing through the conduit (11'),

said mixing element (13) in turn comprising:

5 - a head (13a), apt to receive and intercept the two-phase fluid ((L+G)) which enters the conduit (11') and to co-operate, by sliding axially due to the pressure of the two-phase fluid (L+G), with the inner surface (11-1b') of the conduit (11') to define and vary an opening or passage section (B), entailing a pressure jump ( $\Delta P = (P1-P2)$ ), of the two-phase fluid ((L+ G)) through the device (10), and

10 - a piston (13b), integral with said head (13a), axially sliding along a guide (14) defined by the body (11) of the device (11),

and being configured so as to be subjected, from one side, in the flow direction of the two-phase fluid ((L+G)) through the device (10), to a first pressure or force (P1, F1) present in the two-phase fluid ((L+G)) in the area (A1) immediately upstream of the head (13a) of the mixing element (13), that is upstream of said passage section (B), and, from another side and in the opposite direction, both to a second pressure or force (P2, F2) present in the two-phase fluid ((L + G)) in the area (A2) immediately downstream of the head (13a) of the mixing element (13), that is downstream of said passage section (B), and to a third pressure or force (Pp, Fp) acting on a face (Sp) of the piston (13b) of the mixing element (13), in the area (A3) of the respective guide (14);

20 wherein the inner surface (11-1b'), of said conduit (11'), with which the head (13a) of said mixer (12) is apt to co-operate by sliding axially, exhibits a conical configuration diverging in the sense of the flow of the two-phase fluid ((L+G)) through the conduit (11'), with the head (13a) of said mixer (12) co-operating with said inner surface (11-1b'), of said conduit (11'), exhibiting said conical diverging configuration; and

25 **characterized in that** the device (10; 110) further comprises a passage (17), part of the conduit (11'), defined in said body (11), for the flow through the device (10) of the two-phase fluid ((L+G)), with said passage (17) being formed in said body (11) separately from the guide (14) for said piston (13b) so as to place in communication an inlet area and an outlet area of said conduit (11'), both defined along the axis (X) of said body (11, 11-1, 11-2), and extending at least partially parallel to the axis (X) of said body (11, 11-1, 11-2) beyond said piston (13b), and **in that** the method further comprises

30 (b) detecting at least one between said first (P1) and second pressure (P2), acting respectively in the upper area (A1) and in the downstream area (A2) of the head (13a) of the mixing element (13), and said third pressure (Pp), acting on the piston (13b) of the mixing element (13) in the area (A3) of the respective guide (14); and

35 (c) controlling, as a function of the value or of the values of pressures detected (P1, P2, Pp), the third pressure (Pp) acting on the piston (13b) in the area (A3) of the respective guide (14), so as to maintain, during variation of the operating conditions of the device (10) and typically, but not exclusively, of the flow rate of the two-phase fluid ((L+G)) flowing through the device (10), the pressure difference ( $\Delta P = (P1-P2)$ ), corresponding to the pressure jump determined by the passage section (B) defined between the head (13a) of the sliding mixing element (13) and the inner surface (11-1b') of the conduit (11'), between the pressure (P1) of the two-phase fluid ((L + G)) in the upstream area (A1) of the head (13a) and that (P2) in the downstream area (A2) of the head (13a) of the mixing element (13), conforming to a given value or at least within a given range of variation,

40 so as to improve and increase, by suitably keeping under control the value of said pressure difference ( $\Delta P = (P1-P2)$ ), the dispersion and mixing of the gaseous phase (G) in the liquid phase (L) of the two-phase fluid ((L + G)) flowing through the device (10) and thereby reduce the size of the gas bubbles dispersed in said two-phase fluid ((L+G)).

45 **11.** Method according to claim 10, wherein the step (c) of controlling the third pressure (Pp) acting on the piston (13b) in the area (A3) of the respective guide (14), is performed by controlling and varying appropriately the pressure of a gas (G1) that operates on the piston (13b) and fills this area (A3) adjacent to the guide (14) that slidably houses the piston (13b), or is performed by means of a spring (50), exhibiting a special elastic characteristic, apt to apply a suitable variable force on the piston (13b) during its axial sliding.

50 **12.** A plant comprising a device (10; 110) according to any one of claims 1 to 9 or configured so as to implement the method according to claim 10 or 11, wherein the plant comprises:

55 - one or more devices (10; 110), according to any one of claims 1 to 9, arranged in series; and  
 - a preliminary mixing stage (MP), where the two-phase fluid (L+G) is subjected to a preliminary mixing before accessing the device (10; 110) or the devices where a further and final mixing and dispersion of the gas (G) in

the liquid (L) takes place.

## Patentansprüche

5

1. Gerät (10; 110) zur Verbesserung der Dispersion und des Mischens von Gas in Flüssigkeiten, umfassend:

10

- einen äußeren Körper (11, 11-1, 11-2), der sich entlang einer Achse (X) erstreckt und im Inneren eine Leitung (11') für den Fluss eines zweiphasigen Fluids ((L+G)) durch das Gerät (10) definiert, das eine flüssige Phase (L) und eine in der flüssigen Phase (L) dispergierte gasförmige Phase (G) umfasst; und  
 - mindestens einen Mischer (12), der in dem Körper (11, 11-1, 11-2) zwischen einem Einlassabschnitt (11-1a) und einem Auslassabschnitt (11-2c) der Leitung (11') angeordnet ist und seinerseits ein Mischglied oder -element (13) umfasst, das entlang der Achse (X) des Körpers (11) verschiebbar ist, um das zweiphasige Fluid ((L+G)), das durch die Leitung (11') fließt, zu unterbrechen und mit ihm zusammenzuwirken,

15

wobei das Mischelement (13) seinerseits umfasst:

20

- einen Kopf (13a), der geeignet ist, das zweiphasige Fluid ((L+G)), das in die Leitung (11') eintritt, aufzunehmen und zu unterbrechen, wobei der Kopf (13a) geeignet ist, durch axiales Gleiten aufgrund des Drucks des zweiphasigen Fluids (L+G) mit der Innenfläche (11-1b') der Leitung (11') zusammenzuwirken, um einen Öffnungs- oder Durchgangsabschnitt (B) zu definieren und zu variieren, was einen Drucksprung ( $\Delta P = (P1-P2)$ ) des Flusses des zweiphasigen Fluids ((L+G)) durch das Gerät (10) zur Folge hat, und

25

- einen Kolben (13b), der mit dem Kopf (13a) fest verbunden ist und axial entlang einer Führung (14) gleitet, die durch den Körper (11) des Geräts (10) definiert ist,

30

wobei das Mischelement (13) so konfiguriert ist, dass es von einer Seite in der Richtung des Flusses des zweiphasigen Fluids ((L+G)) durch das Gerät (10) einem ersten Druck oder einer ersten Kraft ( $P1, F1$ ) ausgesetzt ist, der/die in dem zweiphasigen Fluid ((L+G)) in dem Bereich (A1) unmittelbar stromaufwärts des Kopfes (13a) des Mischelements (13), also stromaufwärts des Durchgangsabschnitts (B), vorhanden ist, und von einer anderen Seite und in der entgegengesetzten Richtung sowohl einem zweiten Druck oder einer zweiten Kraft ( $P2, F2$ ), der/die in dem zweiphasigen Fluid ((L+G)) in dem Bereich (A2) unmittelbar stromabwärts des Kopfes (13a) des Mischelements (13), d.h. stromabwärts des Durchgangsabschnitts (B), vorhanden ist, als auch einem dritten Druck oder einer dritten Kraft ( $Pp, Fp$ ), der/die in dem Bereich (A3) der jeweiligen Führung (14) auf eine Stirnfläche ( $Sp$ ) des Kolbens (13b) des Mischelements (13) wirkt;

35

wobei das Gerät (10) weiter Steuermittel (20; 50) umfasst, die mit dem Mischer (12) und dem jeweiligen Mischelement (13) assoziiert sind, um den dritten Druck oder die dritte Kraft ( $Pp$ ) zu steuern, der/die auf den Kolben (13b) im Bereich der jeweiligen Führung (14) wirkt, um so während der Veränderung der Betriebsbedingungen des Geräts (10), und typischerweise, aber nicht ausschließlich des Durchflusses des zweiphasigen Fluids (L+G), das durch dasselbe Gerät (10) fließt, die Druckdifferenz ( $\Delta P = (P1-P2)$ ), die dem Drucksprung in dem Durchgangsabschnitt (B) entspricht, der durch den Kopf (13a) des gleitenden Mischelements (13) im Zusammenwirken mit der Oberfläche (11-1b') der Leitung (11') definiert ist, zwischen dem Druck ( $P1$ ) des zweiphasigen Fluids ((L+G)) in der stromaufwärts gelegenen Zone (A1) des Kopfes (13a) und dem Druck ( $P2$ ) des zweiphasigen Fluids ((L+G)) in der stromabwärts gelegenen Zone (A2) des Kopfes (13a) des Mischelements (13) im Laufe der Zeit bei einem gegebenen Wert oder zumindest innerhalb eines gegebenen Variationsbereichs zu halten, und die Dispersion und das Mischen der Gasphase (G) in der flüssigen Phase (L) des zweiphasigen Fluids ((L+G)), das durch das Gerät (10) fließt, zu verbessern und zu erhöhen, sowie die Größe der in dem zweiphasigen Fluid ((L+G)) dispergierten Gasblasen zu verringern, indem der Wert der Druckdifferenz ( $\Delta P = (P1-P2)$ ) in geeigneter Weise unter Kontrolle gehalten wird;

45

wobei die Innenfläche (11-1b') der Leitung (11'), mit der der Kopf (13a) des Mischers (12) durch axiales Gleiten zusammenwirken kann, eine konische Konfiguration aufweist, die Flussrichtung des zweiphasigen Fluids ((L+G)) durch die Leitung (11') divergiert, wobei der Kopf (13a) des Mischers (12) mit der Innenfläche (11-1b') der Leitung (11') zusammenwirkt und die konische divergierende Konfiguration aufweist;

50

**dadurch gekennzeichnet, dass** das Gerät (10; 110) weiterhin einen Durchgang (17) umfasst, der Teil der Leitung (11') ist und in dem Körper (11) definiert ist, für den Fluss des zweiphasigen Fluids ((L+G)) durch dasselbe Gerät (10), wobei der Durchgang (17) in dem Körper (11) separat von der Führung (14) des Kolbens (13b) ausgebildet ist, um einen Einlassbereich und einen Auslassbereich der Leitung (11') miteinander zu verbinden, die beide entlang der Achse (X) des äußeren Körpers (11, 11-1, 11-2) definiert sind und sich parallel zur Achse (X) des Körpers (11, 11-1, 11-2) über den Kolben (13b) hinaus erstrecken;

55

- Detektionsmittel, die mit den Steuermitteln (20; 50) assoziiert sind, zum Detektieren des ersten ( $P1$ ) und des

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zweiten (P2) Drucks des zweiphasigen Fluids (L+G), das durch das Gerät (10) strömt, im stromaufwärtigen Bereich (A1) bzw. im stromabwärtigen Bereich (A2) des Kopfes (13a) des gleitenden Mischelements (13) und zum Detektieren des dritten Drucks (Pp), der auf den Kolben (13b) des Mischelements (13) im Bereich (A3) der jeweiligen Führung (14) wirkt; und

5

wobei die Steuermittel (20) umfassen:

- ein Steuergerät (20), das mit dem Mischer (12) und dem jeweiligen Mischelement (13) assoziiert ist, um in Abhängigkeit von den Drücken (P1, P2, Pp), die von den Detektionsmitteln detektiert werden, den dritten Druck (Pp) zu steuern, der auf den Kolben (13b) des Mischelements (13) im Bereich (A3) der jeweiligen Führung (14) wirkt, um so während der Änderung der Betriebsbedingungen des Geräts (10) die Druckdifferenz ( $\Delta P = (P1 - P2)$ ) zwischen dem Druck (P1) stromaufwärts und dem Druck (P2) stromabwärts des Kopfes (13a) des Mischelements (13) in Übereinstimmung mit dem vorgegebenen Wert oder zumindest innerhalb des vorgegebenen Variationsbereichs zu halten.

10

15

2. Gerät (10) zum Dispergieren und Mischen von Gas in Flüssigkeiten, gemäß Anspruch 1, wobei das Steuergerät (20) umfasst:

- eine Box oder Kammer (21), die ein Fluid (G1) enthält;  
- eine Leitung (22), die eine Verbindung zwischen der Box (21) und dem Bereich (A3) der Führung (14) bereitstellt, die den Kolben (13b) des Mischelements (13) gleitend aufnimmt; und  
- mindestens eine Leitung oder Verbindung (23, 24), die mit der Box (21) in Verbindung steht und mit Steuermitteln, wie einem Druckregler (26, 27) oder einem Ventil oder ähnlichen Elementen, assoziiert ist, die geeignet sind, die Zufuhr und/oder Entnahme des Fluids (G1) in die und aus der Box (21) durch die Leitung (23, 24) zu regulieren und zu steuern;

20

25

wobei, wenn die Detektionsmittel detektieren, dass die Druckdifferenz ( $\Delta = (P1 - P2)$ ) zwischen dem Druck (P1) des zweiphasigen Fluids ((L+G)) im stromaufwärtigen Bereich (A1) des Kopfes (13a) und demjenigen (P2) im stromabwärtigen Bereich (A2) des Kopfes (13a) des Mischelements (13) nicht dem vorgegebenen Wert entspricht oder nicht innerhalb des vorgegebenen Variationsbereichs liegt, das Steuergerät (20) konfiguriert ist, um die Einstellmittel (26, 27) selektiv zu aktivieren, um das Fluid, insbesondere Gas (G1), durch die mindestens eine Leitung (23, 24) zu/aus dem Gehäuse (21) zuzuführen oder zu entnehmen und dadurch im Bereich (A3) der Führung (14) des Kolbens (13b) des Mischelements (13) den dritten Druck oder die dritte Kraft (Pp, Fp), die auf denselben Kolben (13b) wirkt, so zu variieren, dass die Druckdifferenz ( $\Delta P = (P1 - P2)$ ) aufrechterhalten wird, zwischen dem Druck (P1) des zweiphasigen Fluids ((L+G)) im stromaufwärts gelegenen Bereich (A1) des Kopfes (13a) und dem Druck (P2) im stromabwärts gelegenen Bereich (A2) des Kopfes (13a) des Mischelements (13) aufrechtzuerhalten, der zeitlich konstant dem vorgegebenen Wert entspricht oder innerhalb des vorgegebenen Variationsbereichs liegt.

30

35

3. Gerät (10) zum Dispergieren und Mischen von Gas in Flüssigkeiten nach Anspruch 2, bei dem eine Dichtungsflüssigkeit zwischen dem in der Box (21) enthaltenen Gas (G1) und dem Kolben (13b) des Mischelements (13) angeordnet ist, um die Dichtheit zwischen demselben Kolben (13b) und der jeweiligen Führung (14) zu gewährleisten, wobei die Dichtungsflüssigkeit dieselbe Flüssigkeit (L) ist, in der das Gas (G) mittels des Geräts (10) dispergiert und gemischt wird.

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4. Gerät (10) zum Dispergieren und Mischen von Gas in Flüssigkeiten nach Anspruch 2 oder 3, wobei das Volumen der Box (21), das Volumen der Leitung (18, 22), die die Box (21) mit dem Gleitbereich (A3) verbindet, der durch die Führung (14) begrenzt ist, die den Kolben (13b) des Mischelements (13) verschiebbar aufnimmt, und das Volumen des Gleitbereichs (A3) ein Gesamtvolumen definieren, das mit Gas (G1) gefüllt ist, das so ausgewählt und dimensioniert ist, dass es im Betrieb des Geräts (10) aufgrund des axialen Gleitens des Mischelements (13) und des jeweiligen Kolbens (13b) in der Führung (14) einer minimalen prozentualen Schwankung unterworfen ist, und dadurch eine entsprechende minimale prozentuale Schwankung der auf den Kolben (13b) wirkenden Kraft (Fp) bestimmt, die den Eigenschaften des Gases (G) und der mit Hilfe des Geräts (10) zu mischenden und zu dispergierenden Flüssigkeit (L) entspricht.

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5. Gerät (10) nach Anspruch 2 oder 3, wobei der Kolben (13b) und die jeweilige Gleitführung (14) gleitend und abgedichtet gekoppelt sind und die gleitende abgedichtete Kopplung zwischen dem Kolben (13b) und der Gleitführung (14) so konfiguriert ist, dass das Gerät (10) ohne den Eingriff der Druckregler (26, 27) arbeiten kann, um jegliche instationären Druckregime in der Box (21) und somit auch instationäre Regime des Wertes der Druckdifferenz

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( $\Delta P = (P1 - P2)$ ) zwischen dem Druck (P1) des zweiphasigen Fluids in der stromaufwärtigen Zone des Kopfes (13a) des Mischelements (13) und dem Druck (P2) des zweiphasigen Fluids in der stromabwärtigen Zone des Kopfes (13a) des Mischelements (13) zu eliminieren, wenn die Anforderung besteht, dass diese Druckdifferenz ( $\Delta P = (P1 - P2)$ ) während der Funktionalität des Geräts (10) konstant gehalten wird.

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6. Gerät (110) zum Dispergieren und Mischen von Gas in Flüssigkeiten nach Anspruch 1, wobei das Steuermittel umfasst:

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- eine Feder (50) oder eine ähnliche elastische Einrichtung, die in dem Bereich (A3) der Führung (14) angeordnet ist, die den Kolben (13b) des Mischelements (13) gleitend aufnimmt, wobei die Feder ausgebildet ist, um auf den Kolben (13b) eine axiale Kraft auszuüben, die in der entgegengesetzten Richtung zum Fluss des zweiphasigen Fluids ((L+G)) in dem Gerät (10) wirkt,

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wobei die Feder (50) so dimensioniert und ausgewählt ist, dass sie geeignete Elastizitäts- und Veränderungseigenschaften der auf den Kolben (13b) während seines axialen Gleitens ausgeübten Kraft aufweist, so dass während der Veränderung der operativen Bedingungen des Geräts (10) gewährleistet ist, dass die Druckdifferenz ( $\Delta P = (P1 - P2)$ ) zwischen dem Druck (P1) des zweiphasigen Fluids ((L+G)) in der stromaufwärts gelegenen Zone (A1) und dem Druck (P2) in der stromabwärts gelegenen Zone (A2) des Kopfes (13a) des Mischelements (13) mit dem genannten vorgegebenen Wert oder zumindest innerhalb des genannten vorgegebenen Variationsbereichs konform bleibt.

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7. Gerät (10; 110) zum Dispergieren und Mischen von Gas in Flüssigkeiten gemäß einem der vorhergehenden Ansprüche, wobei das Mischelement (13) mindestens zwei Köpfe (13c', 13c'') umfasst, die ausgebildet sind, um durch axiales Gleiten aufgrund des Drucks des zweiphasigen Fluids ((L+G)) mit der Innenfläche (11-1b'; 11-1d'; 11-1d'') der Leitung (11') zusammenwirken, um einen Öffnungs- oder Durchgangsabschnitt (B, B1) zu definieren und zu variieren, was einen Drucksprung ( $\Delta P = (P1 - P2)$ ) des Flusses des zweiphasigen Fluids ((L+G)) durch das Gerät (10) zur Folge hat.

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8. Gerät (10; 110) zum Dispergieren und Mischen von Gas in Flüssigkeiten gemäß Anspruch 7, wobei die beiden Köpfe (13c'; 13c'') des Mischelements (13) ausgebildet sind, um durch axiales Gleiten aufgrund des Drucks des zweiphasigen Fluids (L+G) mit einer gemeinsamen konischen Innenfläche (11-1b') oder mit zwei jeweiligen separaten konischen Innenflächen (11-1d'; 11-1d'') der Leitung (11') zusammenzuwirken.

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9. Gerät (10; 110) zum Dispergieren und Mischen von Gas in Flüssigkeiten nach einem der vorhergehenden Ansprüche, wobei der Kopf des Mischelements (13) durch einen festen Körper gebildet wird, der aus einer Gruppe ausgewählt werden kann, die besteht aus:

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- einem festen zylindrischen Körper (13a; 13c', 13c'');  
- einem konischen Körper (13a'), der auf seiner Oberfläche eine Vielzahl von Unebenheiten in Form von Rillen, Rändelungen, Einschnitten oder ähnlichen Gebilden aufweist, die die Turbulenz des zweiphasigen Fluids (L+G), das durch das Gerät (10) fließt, begünstigen sollen; und  
- einen glatten konischen Körper (13a''), der ausgebildet ist, um mit seiner konischen Oberfläche zusammenzuwirken, um die Durchgangsöffnung (B) für den Fluss des zweiphasigen Fluids ((L+G)) durch das Gerät (10) zu definieren, mit einem Rand, der durch die Leitung (11') definiert ist, entlang der das zweiphasige Fluid (L+G) in dem Gerät (10) fließt.

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10. Verfahren zur Verbesserung der Dispersion und des Mischens von Gas in Flüssigkeiten, das die folgenden Schritte umfasst:

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(a) Bereitstellen eines Geräts (10) zum Dispergieren und Mischen von Gas in Flüssigkeiten, umfassend:

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- einen äußeren Körper (11, 11-1, 11-2), der sich entlang einer Achse (X) erstreckt und im Inneren eine Leitung (11') für den Fluss eines zweiphasigen Fluids ((L+G)) durch das Gerät (10) definiert, das eine flüssige Phase (L) und eine in der flüssigen Phase (L) dispergierte gasförmige Phase (G) umfasst; und  
- mindestens einen Mischer (12), der in dem Körper (11, 11-1, 11-2) zwischen einem Einlassabschnitt (11-1a) und einem Auslassabschnitt (11-2c) der Leitung (11') untergebracht ist und seinerseits ein Mischglied oder -element (13) umfasst, das entlang der Achse (X) des Körpers (11) verschiebbar ist, um das zweiphasige Fluid ((L+G)), das durch die Leitung (11') fließt, zu unterbrechen und mit ihm zusammenzu-

wirken,

wobei das Mischelement (13) seinerseits Folgendes umfasst:

5 - einen Kopf (13a), der ausgebildet ist, das zweiphasige Fluid ((L+G)), das in die Leitung (11') eintritt, aufzunehmen und zu unterbrechen, und mit der Innenfläche (11-1b') der Leitung (11') durch axiales Gleiten aufgrund des Drucks des zweiphasigen Fluids (L+G) zusammenzuwirken, um einen Öffnungs- oder Durchgangsabschnitt (B) zu definieren und zu variieren, was einen Drucksprung ( $\Delta P=(P1-P2)$ ) des zweiphasigen Fluids ((L+ G)) durch das Gerät (10) zur Folge hat, und

10 - einem mit dem Kopf (13a) fest verbundenen Kolben (13b), der axial entlang einer durch den Körper (11) des Geräts (11) definierten Führung (14) gleitet, und so konfiguriert ist, dass er von einer Seite in Richtung des Flusses des zweiphasigen Fluids ((L+G)) durch das Gerät (10) einem ersten Druck oder einer ersten Kraft (P1, F1) ausgesetzt ist, der/die in dem zweiphasigen Fluid ((L+G)) in dem Bereich (A1) unmittelbar stromaufwärts des Kopfes (13a) des Mischelements (13), d.h. stromaufwärts des Durchgangsabschnitts (B), vorhanden ist, und von einer anderen

15 Seite und in der entgegengesetzten Richtung sowohl einem zweiten Druck oder einer zweiten Kraft (P2, F2), der/die in dem zweiphasigen Fluid ((L + G)) in dem Bereich (A2) unmittelbar stromabwärts des Kopfes (13a) des Mischelements (13), d.h. stromabwärts des Durchgangsabschnitts (B), vorhanden ist, als auch einem dritten Druck oder einer dritten Kraft (Pp, Fp), der/die in dem Bereich (A3) der jeweiligen Führung

20 (14) auf eine Stirnfläche (Sp) des Kolbens (13b) des Mischelements (13) wirkt; wobei die Innenfläche (11-1b') der Leitung (11'), mit der der Kopf (13a) des Mischers (12) ausgebildet ist, durch axiales Gleiten zusammenzuwirken, eine konische, im Richtung des Flusses des zweiphasigen Fluids ((L+G)) durch die Leitung (11') divergierende Konfiguration aufweist, wobei der Kopf (13a) des Mischers (12) mit der Innenfläche (11-1b'), der Leitung (11') zusammenwirkt und die konische divergierende Konfiguration aufweist; und

25 **dadurch gekennzeichnet, dass** das Gerät (10; 110) weiterhin einen Durchgang (17) umfasst, der Teil der Leitung (11') ist und in dem Körper (11) für den Fluss des zweiphasigen Fluids ((L+G)) durch das Gerät (10) definiert ist, wobei der Durchgang (17) in dem Körper (11) separat von der Führung (14) für den Kolben (13b) ausgebildet ist, um einen Einlassbereich und einen Auslassbereich der Leitung (11') in Verbindung zu bringen, die beide entlang der Achse (X) des Körpers (11, 11-1, 11-2) definiert sind und sich zumindest teilweise parallel zur Achse (X) des Körpers (11, 11-1, 11-2) über den Kolben (13b) hinaus erstrecken, und dadurch, dass das Verfahren weiter umfasst:

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35 (b) Detektieren von mindestens einem von dem ersten (P1) und dem zweiten Druck (P2), die jeweils im oberen Bereich (A1) und im stromabwärtigen Bereich (A2) des Kopfes (13a) des Mischelements (13) wirken, und dem dritten Druck (Pp), der auf den Kolben (13b) des Mischelements (13) im Bereich (A3) der jeweiligen Führung (14) wirkt; und

(c) Steuern des dritten Drucks (Pp), der auf den Kolben (13b) im Bereich (A3) der jeweiligen Führung (14) wirkt, in Abhängigkeit von dem Wert oder den Werten der detektierten Drücke (P1, P2, Pp), um während einer Änderung der Betriebsbedingungen des Geräts (10) und typischerweise, aber nicht ausschließlich, der Flussrate des zweiphasigen Fluids ((L+G)), das das Gerät (10) durchströmt, die Druckdifferenz ( $\Delta P=(P1-P2)$ ), die dem Drucksprung entspricht, der durch den Durchgangsabschnitt (B) bestimmt wird, der zwischen dem Kopf (13a) des gleitenden Mischelements (13) und der Innenfläche (11-1b') der Leitung (11') definiert ist, zwischen dem Druck (P1) des zweiphasigen Fluids ((L+G)) in der stromaufwärtigen Zone (A1) des Kopfes (13a) und demjenigen

40 (P2) in der stromabwärtigen Zone (A2) des Kopfes (13a) des Mischelements (13), bei einem bestimmten Wert oder zumindest innerhalb eines bestimmten Variationsbereichs zu halten, um die Dispersion und die Vermischung der gasförmigen Phase (G) in der flüssigen Phase (L) des zweiphasigen Fluids ((L + G)), das durch das Gerät (10) fließt, zu verbessern und zu erhöhen, und die Größe der in dem zweiphasigen Fluid ((L+G')) dispergierten Gasblasen zu verringern, indem der Wert der Druckdifferenz ( $\Delta P=(P1-P2)$ ) in geeigneter Weise

45 unter Kontrolle gehalten wird.

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11. Verfahren nach Anspruch 10, wobei der Schritt (c) des Steuerns des dritten Drucks (Pp), der auf den Kolben (13b) in dem Bereich (A3) der jeweiligen Führung (14) wirkt, durch Steuern und geeignetes Variieren des Drucks eines Gases (G1) durchgeführt wird, das auf den Kolben (13b) wirkt und diesen Bereich (A3) in der Nähe der Führung (14) füllt, die den Kolben (13b) gleitend aufnimmt, oder mittels einer Feder (50), die eine besondere elastische Eigenschaft aufweist und ausgebildet ist, um eine geeignete variable Kraft auf den Kolben (13b) während seines axialen Gleitens auszuüben.

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12. Anlage, umfassend ein Gerät (10; 110) nach einem der Ansprüche 1 bis 9 oder konfiguriert, um das Verfahren nach Anspruch 10 oder 11 durchzuführen, wobei die Anlage umfasst:

- ein oder mehrere Geräte (10; 110) nach einem der Ansprüche 1 bis 9, die in Reihe angeordnet sind; und
- eine Vormischstufe (MP), in der das zweiphasige Fluid (L+G) einer Vormischung unterzogen wird, bevor es in das Gerät (10; 110) oder die Geräte gelangt, in denen eine weitere und finale Vermischung und Dispersion des Gases (G) in der Flüssigkeit (L) erfolgt.

## 10 Revendications

1. Dispositif (10 ; 110) pour améliorer la dispersion et le mélange de gaz dans des liquides, qui comprend :

- un corps externe (11, 11-1, 11-2) s'étendant le long d'un axe (X) qui définit, en son sein, un conduit (11') destiné à l'écoulement, à travers le dispositif (10), d'un fluide biphasique ((L+G)) qui comprend une phase liquide (L) et une phase gazeuse (G) qui est dispersée dans la phase liquide (L) ; et
- au moins un dispositif de mélange (12) logé dans le corps en question (11, 11-1, 11-2), entre un tronçon d'entrée (11-1a) et un tronçon de sortie (11-2c) du conduit en question (11'), et qui comprend, quant à lui, un organe ou un élément de mélange (13) qui est capable de coulisser le long de l'axe (X) du corps (11) dans le but d'intercepter le fluide biphasique ((L+G)) qui s'écoule à travers le conduit (11') et de coopérer avec lui ;

dans lequel ledit élément de mélange (13) comprend à son tour :

- une tête (13a) qui est appropriée pour la réception et l'interception du fluide biphasique ((L+G)) qui pénètre dans le conduit (11'), ladite tête (13a) étant à même de coopérer, en coulissant dans la direction axiale sous l'effet de la pression qu'exerce le fluide biphasique (L+G), avec la surface interne (11-1b') du conduit (11') de façon à définir un tronçon d'ouverture ou de passage (B) et à faire varier ledit tronçon, ce qui entraîne un saut de pression ( $\Delta P = (P1-P2)$ ) de l'écoulement du fluide biphasique ((L+G)) à travers le dispositif (10) ; et
  - un piston (13b) réalisé en une seule pièce avec ladite tête (13a), qui coulisse dans la direction axiale le long d'un guide (14) qui est défini par le corps (11) du dispositif (10) ;
- dans lequel ledit élément de mélange (13) est configuré d'une manière telle qu'il est soumis, à partir d'un côté, dans la direction d'écoulement du fluide biphasique ((L+G)) à travers le dispositif (10), à une première pression ou à une première force (P1, F1) en vigueur dans le fluide biphasique ((L+G)) dans la zone (A1) qui est située directement en amont de la tête (13a) de l'élément de mélange (13), c'est-à-dire en amont du tronçon de passage en question (B), et, à partir d'un autre côté et dans la direction opposée, à la fois à une deuxième pression ou à une deuxième force (P2, F2) en vigueur dans le fluide biphasique ((L+G)) dans la zone (A2) qui est située directement en aval de la tête (13a) de l'élément de mélange (13), c'est-à-dire en aval du tronçon de passage en question (B), et à une troisième pression ou à une troisième force (Pp, Fp) qui s'exerce sur une face (Sp) du piston (13b) de l'élément de mélange (13), dans la zone (A3) du guide respectif (14) ;
- dans lequel le dispositif en question (10) comprend en outre un moyen de réglage (20 ; 50) qui est associé audit dispositif de mélange (12) et à l'élément de mélange respectif (13) à des fins de réglage de ladite troisième pression ou de ladite troisième force (Pp) qui s'exerce sur le piston (13b) dans la zone du guide respectif (14), d'une manière telle que l'on maintient, au cours de la variation des conditions de fonctionnement du dispositif (10) et de manière spécifique, mais non de manière exclusive, du débit du fluide biphasique (L+G) qui s'écoule à travers le même dispositif (10), la différence de pression ( $\Delta P = (P1 - P2)$ ) correspondant audit saut de pression dans le tronçon de passage (B), qui est défini par la tête (13a) de l'élément de mélange coulissant (13) en coopération avec la surface (11-1b') dudit conduit (11'), entre la pression (P1) du fluide biphasique ((L+G)) dans la zone en amont (A1) de la tête (13a) et la pression (P2) du fluide biphasique ((L+G)) dans la zone en aval (A2) de la tête (13a) de l'élément de mélange (13), en conformité temporelle avec une valeur donnée ou avec au moins une valeur qui se situe au sein d'une plage donnée de variations, et pour améliorer et augmenter de cette manière, en maintenant, de manière appropriée, sous contrôle la valeur de ladite différence de pression ( $\Delta P = (P1-P2)$ ), la dispersion et le mélange de la phase gazeuse (G) dans la phase liquide (L) du fluide biphasique ((L+G)) qui s'écoule à travers le dispositif (10), et pour ainsi également réduire la dimension des bulles de gaz à l'état dispersé dans ledit fluide biphasique ((L+G)) ;
- dans lequel la surface interne (11-1b') dudit conduit (11'), avec lequel la tête (13a) dudit dispositif de mélange (12) est à même de coopérer en coulissant dans la direction axiale, manifeste une configuration de forme conique qui diverge dans le sens de l'écoulement du fluide biphasique ((L+G)) à travers le conduit (11'), la tête (13a) du dispositif de mélange en question (12) coopérant avec ladite surface interne (11-1b'), du conduit en

question (11'), qui manifeste ladite configuration divergente de forme conique ;

**caractérisé en ce que**

5 - le dispositif (10 ; 110) comprend en outre un passage (17), à savoir une partie du conduit (11'), qui est défini dans le corps en question (11), pour l'écoulement du fluide biphasique ((L+G)) à travers le même dispositif (10), le passage en question (17) étant réalisé dans le corps en question (11) de manière séparée par rapport au guide (14) destiné au piston en question (13b), de manière à mettre en communication une zone d'entrée et une zone de sortie du conduit en question (11'), toutes deux étant définies le long de l'axe (X) dudit corps externe (11, 11-1, 11-2) et s'étendant parallèlement à l'axe (X) dudit corps (11, 11-1, 11-2) au-delà dudit piston (13b) ;

10 un moyen de détection, associé audit moyen de réglage (20 ; 50), qui est destiné à détecter ladite première pression (P1) et ladite deuxième pression (P2) du fluide biphasique (L+G) qui s'écoule à travers le dispositif (10), respectivement dans la zone en amont (A1) et dans la zone en aval (A2) de la tête (13a) de l'élément de mélange coulissant (13) et qui est destiné à détecter ladite troisième pression (Pp) qui s'exerce sur le piston (13b) de l'élément de mélange (13) dans la zone (A3) du guide respectif (14) ; et dans lequel ledit moyen de réglage (20) comprend :

20 - un dispositif de réglage (20) qui est associé audit dispositif de mélange (12) et audit élément de mélange respectif (13), dans le but de régler, en fonction des pressions (P1, P2, Pp) qui sont détectées par l'intermédiaire dudit moyen de détection, la troisième pression (Pp) qui s'exerce sur le piston (13b) de l'élément de mélange (13), dans la zone (A3) du guide respectif (14), de manière à maintenir, au cours de la variation des conditions de fonctionnement du dispositif (10), ladite différence de pression ( $\Delta P = (P1-P2)$ ) entre la pression (P1) en amont et la pression (P2) en aval de la tête (13a) de l'élément de mélange (13), en conformité avec ladite valeur donnée ou avec au moins une valeur qui se situe dans ladite plage de variations donnée.

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2. Dispositif (10) pour la dispersion et le mélange de gaz dans des liquides, selon la revendication 1, dans lequel ledit dispositif de réglage (20) comprend :

30 - un boîtier ou une chambre (21) qui contient un fluide (G1) ;  
 - un conduit (22) qui établit une communication entre ledit boîtier (21) et la zone (A3) dudit guide (14) dans lequel vient se loger en coulissement le piston (13b) de l'élément de mélange (13) ; et  
 - au moins un conduit ou une conduite (23, 24) qui entre en communication avec le boîtier (21), associé(e) à un moyen de régulation, tel qu'un régulateur de la pression (26, 27) ou une soupape ou des éléments similaires, capable de réguler et de commander l'alimentation et/ou l'extraction du fluide (G1) vers et à partir du boîtier (21) en passant par ladite conduite (23, 24) ;  
 - dans lequel, lorsque le ledit moyen de détection détecte le fait que ladite différence de pression ( $\Delta P = (P1-P2)$ ) entre la pression (P1) du fluide biphasique ((L+G)) dans la zone en amont (A1) de la tête (13a) et le fait que la pression (P2) dans la zone en aval (A2) de la tête (13a) de l'élément de mélange (13) manifestent un manque de conformité avec ladite valeur donnée ou ne rentre pas dans ladite plage de variations donnée, ledit dispositif de réglage (20) est configuré d'une manière telle que l'on active de façon sélective ledit moyen de régulation (26, 27) de façon à alimenter ou à extraire le fluide, en particulier du gaz (G1) vers/à partir du boîtier (21) en passant par ladite au moins une conduite (23, 24) et ainsi faire varier, dans la zone (A3) du guide (14) du piston (13b) de l'élément de mélange (13), la troisième pression ou la troisième force (Pp, Fp) qui s'exerce sur le même piston (13b), d'une manière telle que l'on maintient ladite différence de pression ( $\Delta P = (P1-P2)$ ), entre la pression (P1) du fluide biphasique ((L+G)) dans la zone en amont (A1) de la tête (13a) et la pression (P2) dans la zone en aval (A2) de la tête (13a) de l'élément de mélange (13), à une valeur qui correspond de manière constante dans le temps à ladite valeur donnée ou à une valeur qui se situe au sein de ladite plage de variations donnée.

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3. Dispositif (10) pour la dispersion et le mélange de gaz dans des liquides, selon la revendication 2, dans lequel on intercale un liquide d'étanchéisation entre le gaz (G1), qui est contenu dans ledit boîtier (21), et le piston (13b) de l'élément de mélange (13), dans le but de garantir le joint d'étanchéité entre le même piston (13b) et le guide respectif (14), ledit liquide d'étanchéisation représentant le même liquide (L) que celui dans lequel le gaz (G) est dispersé et est mélangé par l'intermédiaire du dispositif (10).

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4. Dispositif (10) pour la dispersion et le mélange de gaz dans des liquides, selon la revendication 2 ou 3, dans lequel

le volume dudit boîtier (21), le volume du conduit (18, 22) qui relie le boîtier (21) de la zone de coulissement (A3) qui est délimitée par le guide (14) dans lequel vient se loger en coulissement le piston (13b) de l'élément de mélange (13), et le volume de la zone de coulissement (A3), définissent un volume total rempli avec du gaz (G1), qui est sélectionné et qui est dimensionné d'une manière telle qu'il est soumis, lors de la mise en service du dispositif (10), sur base du coulissement axial de l'élément de mélange (13) et du piston respectif (13b) dans le guide (14), à une variation minimale en pourcentage, et à déterminer de cette manière une variation minimale correspondante en pourcentage de la force (Fp) qui s'exerce sur le piston (13b), en conformité avec les caractéristiques du gaz (G) et du liquide (L) qui doivent être mélangés et dispersés par l'intermédiaire du dispositif (10).

5  
10 **5.** Dispositif (10) selon la revendication 2 ou 3, dans lequel ledit piston (13b) et le guide de coulissement respectif (14) sont couplés d'une manière apte à coulisser et en étanchéité et le couplage par coulissement rendu étanche entre ledit piston (13) et ledit guide de coulissement (14) est configuré d'une manière telle que le dispositif (10) peut fonctionner sans l'intervention desdits régulateurs de pression (26, 27) de manière à éliminer un quelconque régime de pression transitoire dans le boîtier (21) et par conséquent également des régimes transitoires de la valeur de la différence de pression ( $\Delta P = (P1-P2)$ ), entre la pression (P1) du fluide biphasique dans la zone en amont de la tête (13a) de l'élément de mélange (13) et la pression (P2) du fluide biphasique dans la zone en aval de la tête (13a) de l'élément de mélange (13), lorsqu'il est requis de maintenir ladite différence de pression ( $\Delta P = (P1-P2)$ ) constante au cours de la mise en service du dispositif (10).

20 **6.** Dispositif (110) pour la dispersion et le mélange de gaz dans des liquides selon la revendication 1, dans lequel ledit moyen de réglage comprend :

25 - un ressort (50) ou un moyen résilient similaire prévu dans la zone (A3) du guide (14) dans lequel vient se loger en coulissement le piston (13b) de l'élément de mélange (13), ledit ressort étant à même d'exercer sur le piston (13b) une force axiale qui agit dans la direction opposée à celle de l'écoulement du fluide biphasique ((L+G)) dans le dispositif (10) ;  
- dans lequel ledit ressort (50) est dimensionné et est sélectionné d'une manière telle qu'il manifeste des caractéristiques appropriées d'élasticité et de variation de la force qui s'exerce sur le piston (13b) au cours du coulissement axial de ce dernier, de manière à garantir, au cours des variations des conditions de fonctionnement du dispositif (10), le fait que l'on maintient la différence de pression ( $\Delta P = (P1-P2)$ ), entre la pression (P1) du fluide biphasique ((L+G)) dans la zone en amont (A1) et la pression (P2) dans la zone en aval (A2) de la tête (13a) de l'élément de mélange (13), en conformité avec ladite valeur donnée ou au moins avec une valeur qui se situe au sein de ladite plage de variations donnée.

35 **7.** Dispositif (10 ; 110) pour la dispersion et le mélange de gaz dans des liquides selon l'une quelconque des revendications précédentes, dans lequel ledit élément de mélange (13) comprend au moins deux têtes (13c', 13c'') qui sont à même de coopérer par coulissement dans la direction axiale sous l'effet de la pression du fluide biphasique ((L+G)) avec la surface interne (11-1b' ; 11-1d', 11-1d'') du conduit (11') de manière à définir et à faire varier un tronçon d'ouverture ou de passage (B, B1), ce qui a pour conséquence de déclencher un saut de pression ( $\Delta P = (P1-P2)$ ) de l'écoulement du fluide biphasique ((L+G)) à travers le dispositif (10).

45 **8.** Dispositif (10 ; 110) pour la dispersion et le mélange de gaz dans des liquides selon la revendication 7, dans lequel lesdites deux têtes (13c', 13c'') dudit élément de mélange (13) sont à même de coopérer par coulissement dans la direction axiale sous l'effet de la pression du fluide biphasique (L+G) avec une surface interne commune de forme conique (11-1b') ou avec deux surfaces internes coniques séparées respectives (11-1d', 11-1d'') du conduit (11').

**9.** Dispositif (10 ; 110) pour la dispersion et le mélange de gaz dans des liquides selon l'une quelconque des revendications précédentes, dans lequel la tête de l'élément de mélange (13) est constituée par un corps plein qui peut être sélectionné à partir d'un groupe constitué par :

50 - un corps plein de forme cylindrique (13a ; 13c', 13c'') ;  
- un corps de configuration conique (13a') qui manifeste, sur sa surface, un certain nombre d'aspérités, sous la forme de rainures, de stries réalisées par moletage, de découpes ou de configurations similaires, qui sont destinées à favoriser la turbulence du fluide biphasique (L+G) qui s'écoule à travers le dispositif (10) ; et  
55 - un corps lisse de forme conique (13a'') qui est capable de coopérer avec sa surface conique dans le but de définir l'ouverture de passage (B) pour l'écoulement du fluide biphasique ((L+G)) à travers le dispositif (10), qui comprend un bord défini par le conduit (11') le long duquel le fluide biphasique (L+G) s'écoule dans le dispositif (10).

10. Procédé pour améliorer la dispersion et le mélange de gaz dans des liquides, qui comprend les étapes suivantes dans lesquelles :

5 - (a) on procure un dispositif (10) pour la dispersion et le mélange de gaz dans des liquides, qui comprend :  
 - un corps externe (11, 11-1, 11-2) s'étendant le long d'un axe (X) qui définit, en son sein, un conduit (11') pour l'écoulement, à travers le dispositif (10), d'un fluide biphasique ((L+G)) qui comprend une phase liquide (L) et une phase gazeuse (G) qui est dispersée dans la phase liquide (L) ; et  
 - au moins un dispositif de mélange (12) logé dans le corps en question (11, 11-1, 11-2), entre un tronçon d'entrée (11-1a) et un tronçon de sortie (11-2c) du conduit en question (11'), et qui comprend, quant à lui, un organe ou un élément de mélange (13) qui est capable de coulisser le long de l'axe (X) du corps (11) dans le but d'intercepter le fluide biphasique ((L+G)) qui s'écoule à travers le conduit (11') et de coopérer avec lui ; ledit élément de mélange (13) comprenant quant à lui :

15 - une tête (13a) qui est capable de recevoir et d'intercepter le fluide biphasique ((L+G)) qui pénètre dans le conduit (11') et de coopérer, en couissant dans la direction axiale sous l'effet de la pression qu'exerce le fluide biphasique (L+G), avec la surface interne (11-1b') du conduit (11') de façon à définir un tronçon d'ouverture ou de passage (B) et à faire varier ledit tronçon, ce qui entraîne un saut de pression ( $\Delta P = (P1 - P2)$ ) du fluide biphasique ((L+G)) à travers le dispositif (10) ; et

20 - un piston (13b) réalisé en une seule pièce avec ladite tête (13a), qui coulisse dans la direction axiale le long d'un guide (14) qui est défini par le corps (11) du dispositif (11) ;

25 et qui est configuré d'une manière telle qu'il est soumis, à partir d'un côté, dans la direction d'écoulement du fluide biphasique ((L+G)) à travers le dispositif (10), à une première pression ou à une première force (P1, F1) en vigueur dans le fluide biphasique ((L+G)) dans la zone (A1) qui est située directement en amont de la tête (13a) de l'élément de mélange (13), c'est-à-dire en amont du tronçon de passage en question (B), et, à partir d'un autre côté et dans la direction opposée, à la fois à une deuxième pression ou à une deuxième force (P2, F2) en vigueur dans le fluide biphasique (L+G) dans la zone (A2) qui est située directement en aval de la tête (13a) de l'élément de mélange (13), c'est-à-dire en aval du tronçon de passage en question (B), et à une troisième pression ou à une troisième force (Pp, Fp) qui s'exerce sur une face (Sp) du piston (13b) de l'élément de mélange (13), dans la zone (A3) du guide respectif (14) ;

30 dans lequel la surface interne (11-1b') du conduit en question (11') avec laquelle la tête (13a) dudit dispositif de mélange (12) est à même de coopérer par coulissement dans la direction axiale, manifeste une configuration de forme conique qui diverge dans le sens de l'écoulement du fluide biphasique ((L+G)) à travers le conduit (11'), la tête (13a) du dispositif de mélange en question (12) coopérant avec ladite surface interne (11-1b'), du conduit en question (11'), qui manifeste ladite configuration divergente de forme conique ; et

35 **caractérisé en ce que**

40 - le dispositif (10 ; 110) comprend en outre un passage (17), à savoir une partie du conduit (11'), qui est défini dans le corps en question (11), pour l'écoulement, à travers le dispositif (10), du fluide biphasique ((L+G)), le passage en question (17) étant réalisé dans le corps en question (11) de manière séparée par rapport au guide (14) destiné au piston en question (13a), de manière à mettre en communication une zone d'entrée et une zone de sortie du conduit en question (11'), toutes deux définies le long de l'axe (X) dudit corps (11, 11-1, 11-2) et s'étendant au moins partiellement parallèlement à l'axe (X) dudit corps (11, 11-1, 11-2) au-delà dudit piston (13b) ;

45 et **en ce que** le procédé comprend en outre :

50 (b) le fait de détecter au moins une pression qui est choisie entre ladite première pression (P1) et ladite deuxième pression (P2) qui s'exercent respectivement dans la zone supérieure (A1) et dans la zone en aval (A2) de la tête (13a) de l'élément de mélange (13), et ladite troisième pression (Pp) qui s'exerce sur le piston (13b) de l'élément de mélange (13) dans la zone (A3) du guide respectif (14) ; et

55 - (c) le fait de régler, en fonction de la valeur ou des valeurs des pressions (P1, P2, Pp) qui ont été détectées, la troisième pression (Pp) qui s'exerce sur le piston (13b) dans la zone (A3) du guide respectif (14), d'une manière telle que l'on maintient, au cours de la variation des conditions de fonctionnement du dispositif (10), et de manière spécifique, mais non de manière exclusive, du débit du fluide biphasique ((L+G)) qui s'écoule à travers le dispositif (10), la différence de pression ( $\Delta P = (P1 - P2)$ ), à une valeur qui correspond au saut de pression qui a été déterminé par le tronçon de passage (B) défini entre la tête (13a) de l'élément de mélange coulissant (13) et la surface interne (11-1b') du conduit (11'), entre la pression (P1) du fluide

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biphasique ((L+G)) dans la zone en amont (A1) de la tête (13a) et la pression (P2) dans la zone en aval (A2) de la tête (13a) de l'élément de mélange (13), en conformité avec une valeur donnée ou au moins une valeur qui se situe dans une plage donnée de variations, d'une manière telle que l'on améliore et que l'on augmente, en maintenant, de manière appropriée, sous contrôle la valeur de ladite différence de pression ( $\Delta P = (P1-P2)$ ), la dispersion et le mélange de la phase gazeuse (G) dans la phase liquide (L) du fluide biphasique ((L+G)) s'écoulant à travers le dispositif (10), et que l'on réduit également la dimension des bulles de gaz à l'état dispersé dans ledit fluide biphasique ((L+G)).

11. Procédé selon la revendication 10, dans lequel l'étape (c), dans laquelle on règle la troisième pression (Pp) qui s'exerce sur le piston (13b) dans la zone (A3) du guide respectif (14), est mise en œuvre en procédant d'une manière appropriée à un réglage et à une variation de la pression d'un gaz (G1) qui agit sur le piston (13b) et qui remplit cette zone (A3) adjacente au guide (14) dans lequel vient se loger en coulissement le piston (13b), ou bien est mise en œuvre par l'intermédiaire d'un ressort (50) qui manifeste une caractéristique élastique spécifique, qui est capable d'exercer une force variable appropriée sur le piston (13b) au cours du coulissement axial de ce dernier.

12. Installation qui comprend un dispositif (10 ; 110) selon l'une quelconque des revendications 1 à 9 ou bien qui est configurée d'une manière telle que l'on met en œuvre le procédé selon la revendication 10 ou 11, dans laquelle l'installation comprend :

- un ou plusieurs dispositifs (10 ; 110) selon l'une quelconque des revendications 1 à 9, qui sont montés en série ; et
- un étage de mélange préliminaire (MP) dans lequel le fluide biphasique (L+G) est soumis à un mélange préliminaire avant d'accéder au dispositif (10 ; 110) ou aux dispositifs dans lequel/dans lesquels ont lieu un mélange et une dispersion supplémentaires et finals du gaz (G) dans le liquide (L).

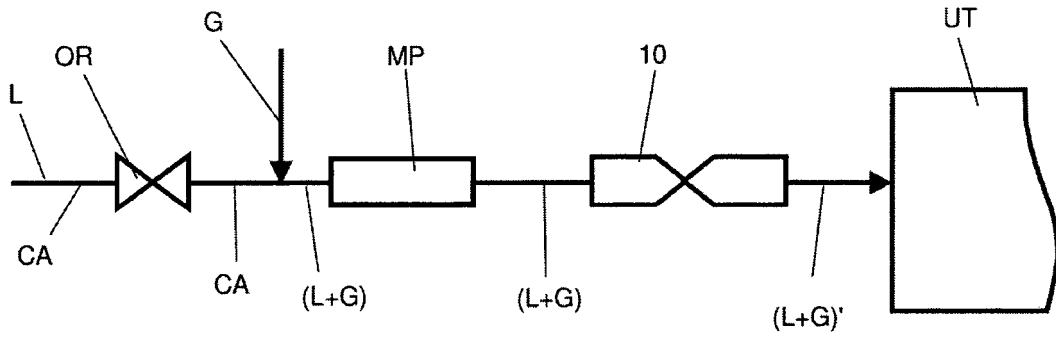


Fig. 1

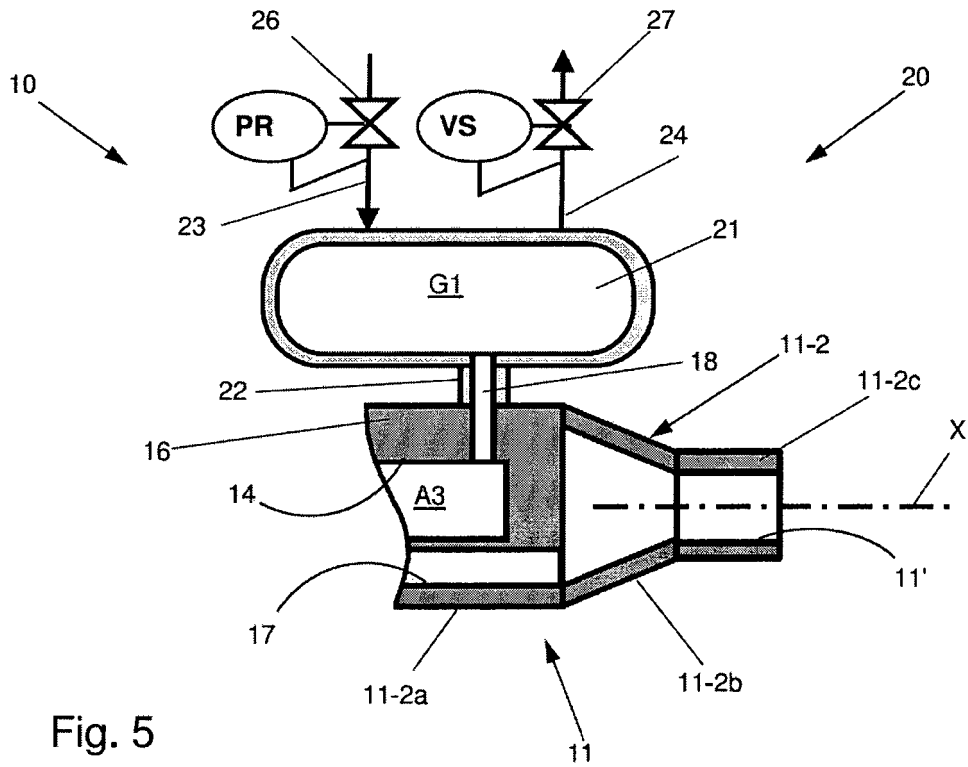


Fig. 5

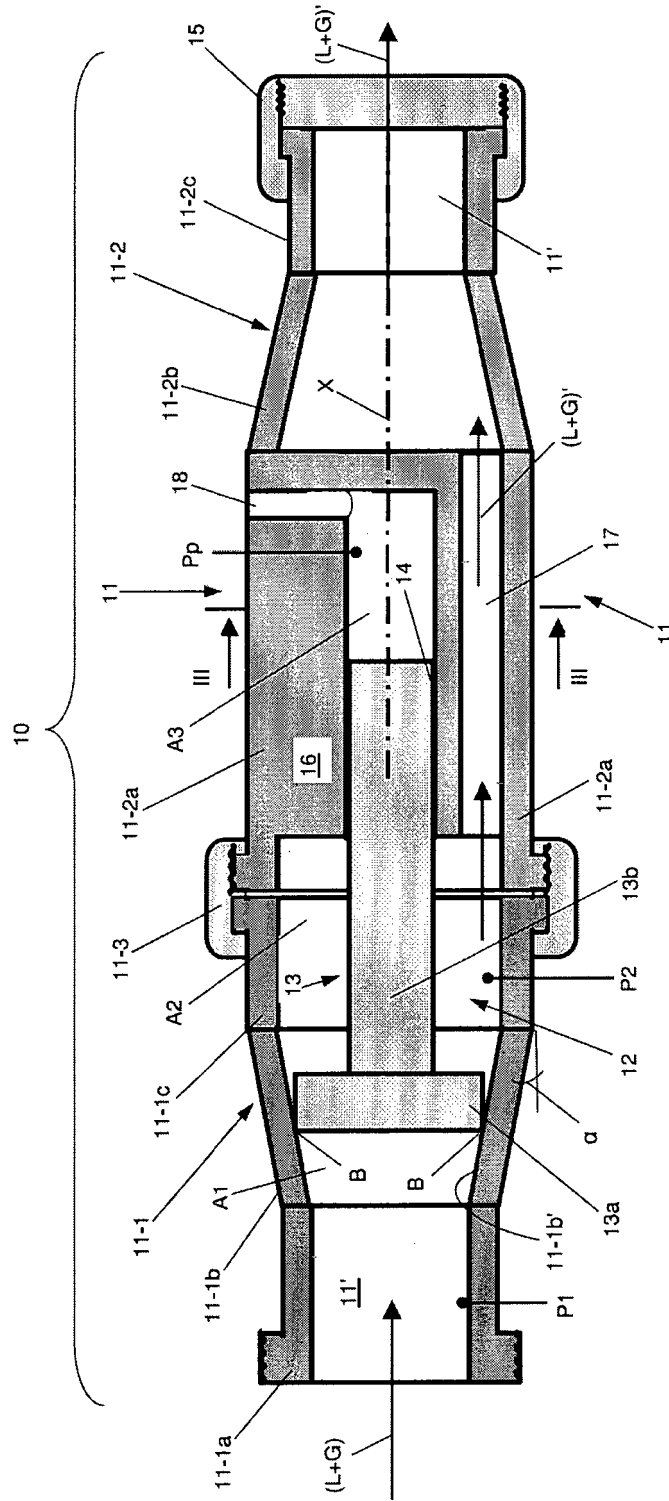


Fig. 2

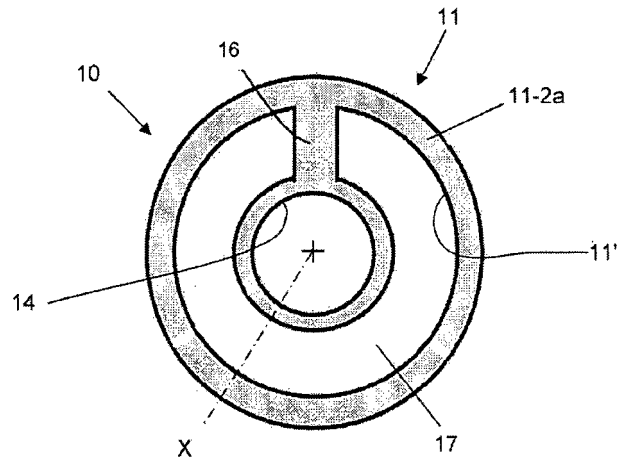


Fig. 3

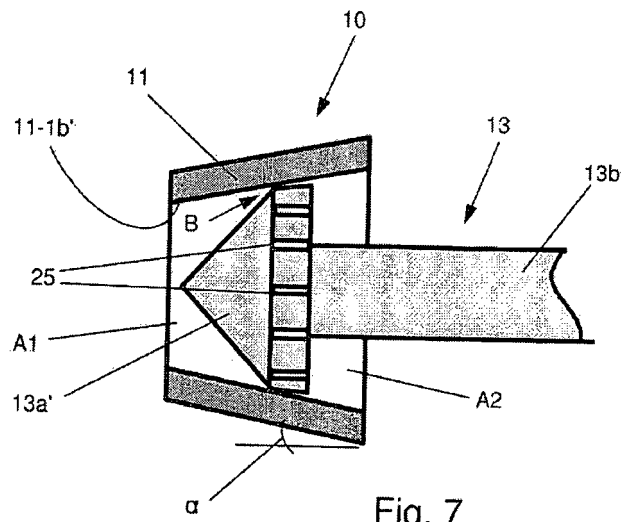


Fig. 7

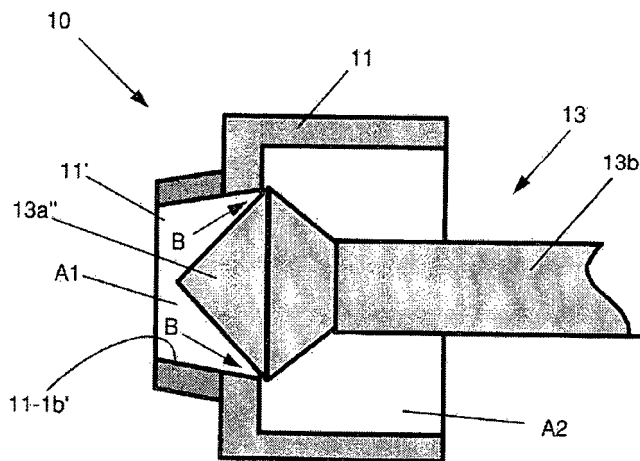


Fig. 8



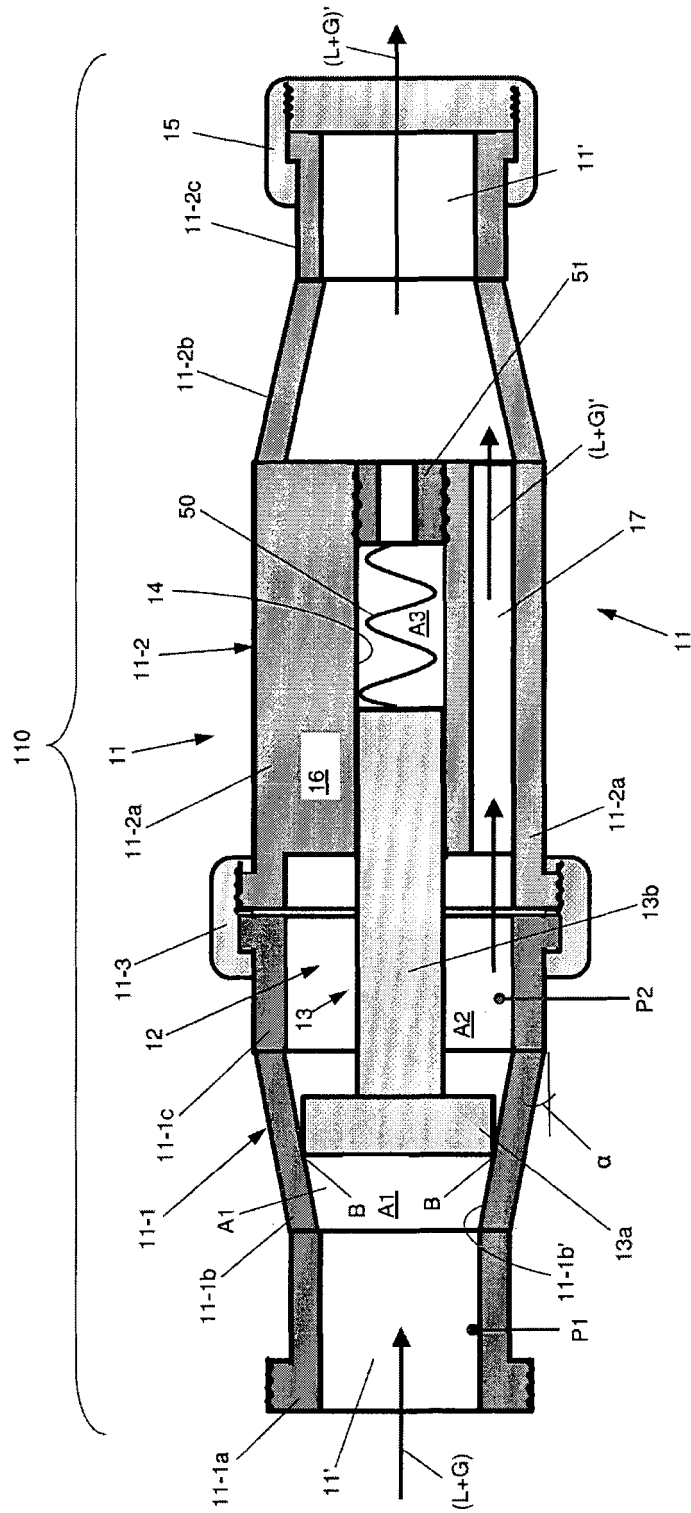


Fig. 6

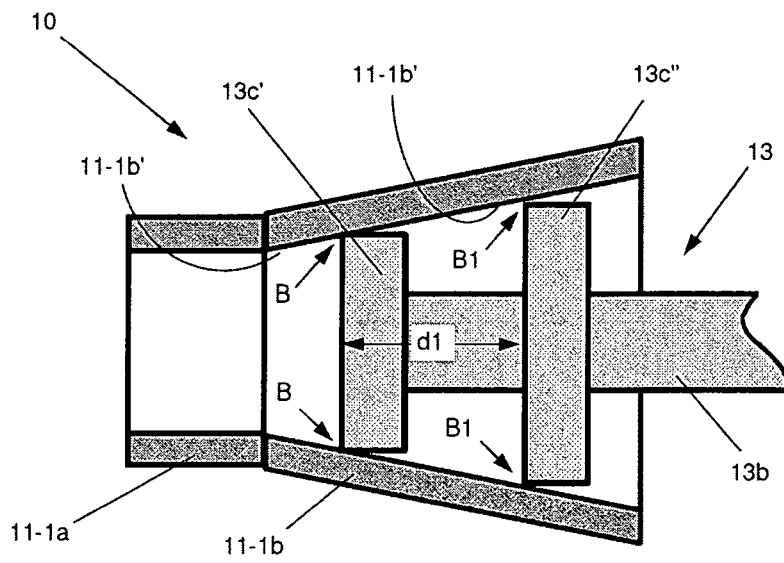


Fig. 9

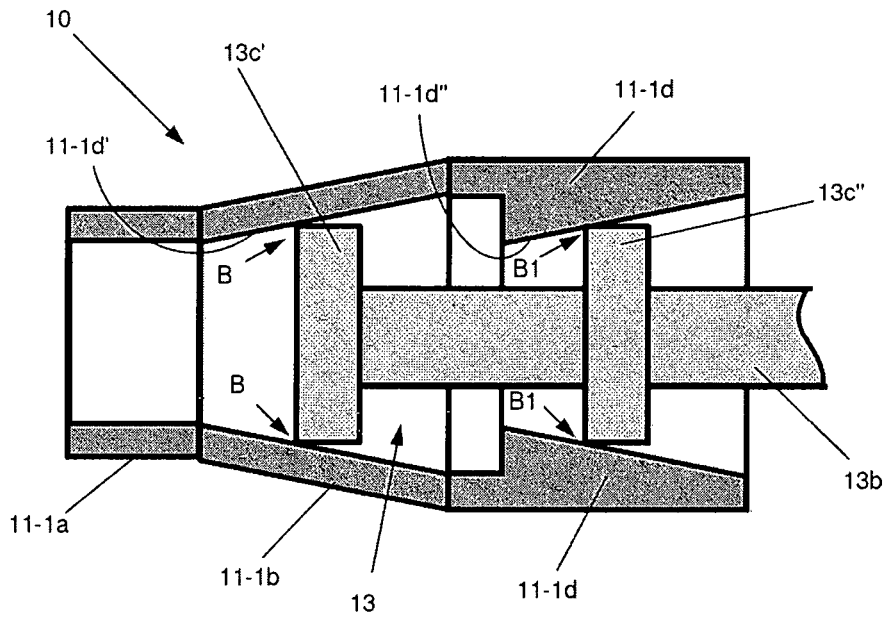


Fig. 10

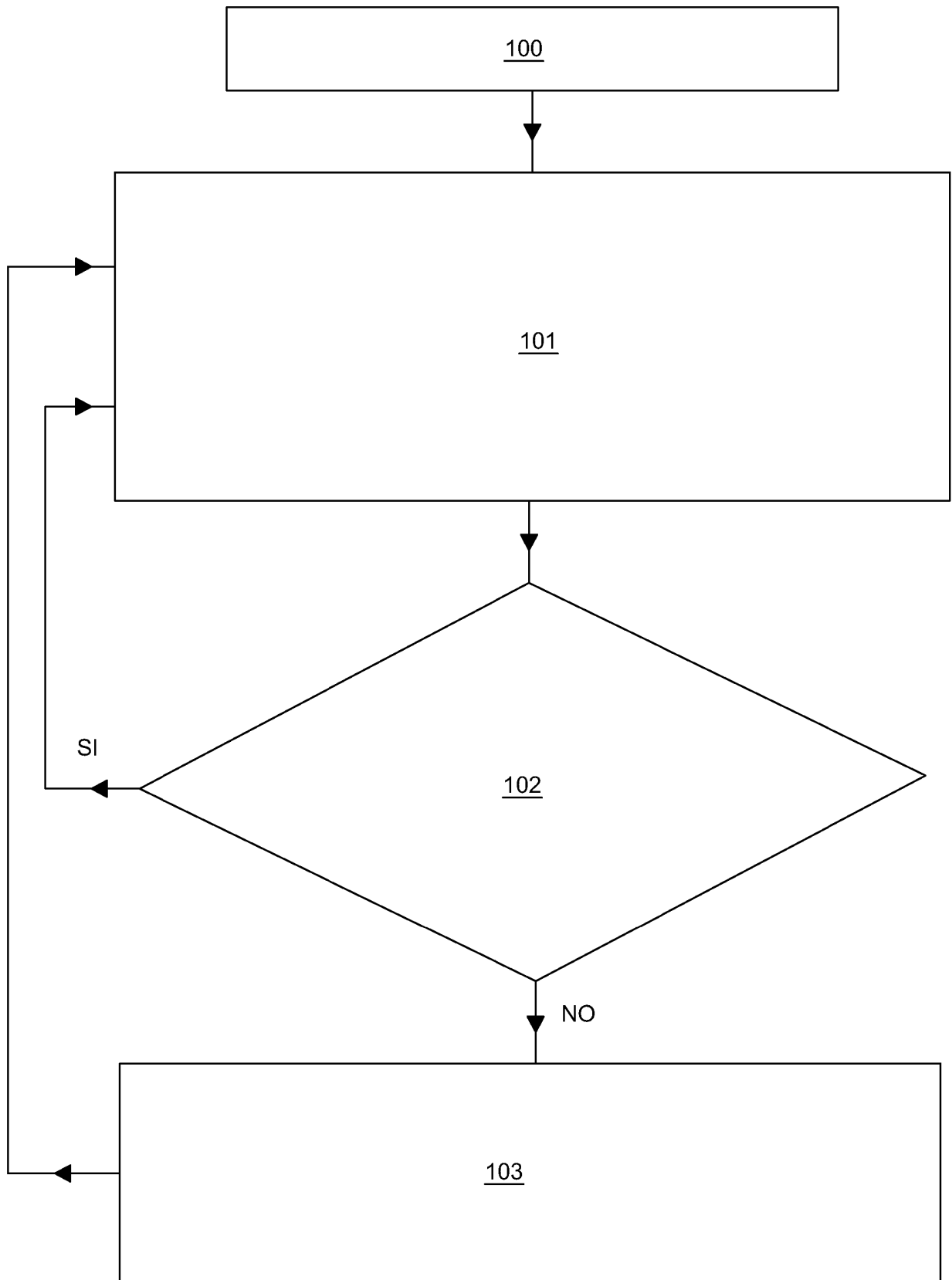


Fig. 11

**REFERENCES CITED IN THE DESCRIPTION**

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