US 20060022361A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2006/0022361 A1
Cho et al. (43) Pub. Date: Feb. 2, 2006

(54) BUBBLE GENERATING ARRANGEMENT, SYSTEM & METHOD

(76) Inventors: **Yong Min Cho**, Silver Spring, MD (US); **Philip Yong Kim**, Adelphi, MD (US)

Correspondence Address:
HARNESS, DICKEY & PIERCE, P.L.C.
P.O. BOX 8910
RESTON, VA 20195 (US)

(21) Appl. No.: 11/197,314

(22) Filed: Aug. 5, 2005

Related U.S. Application Data

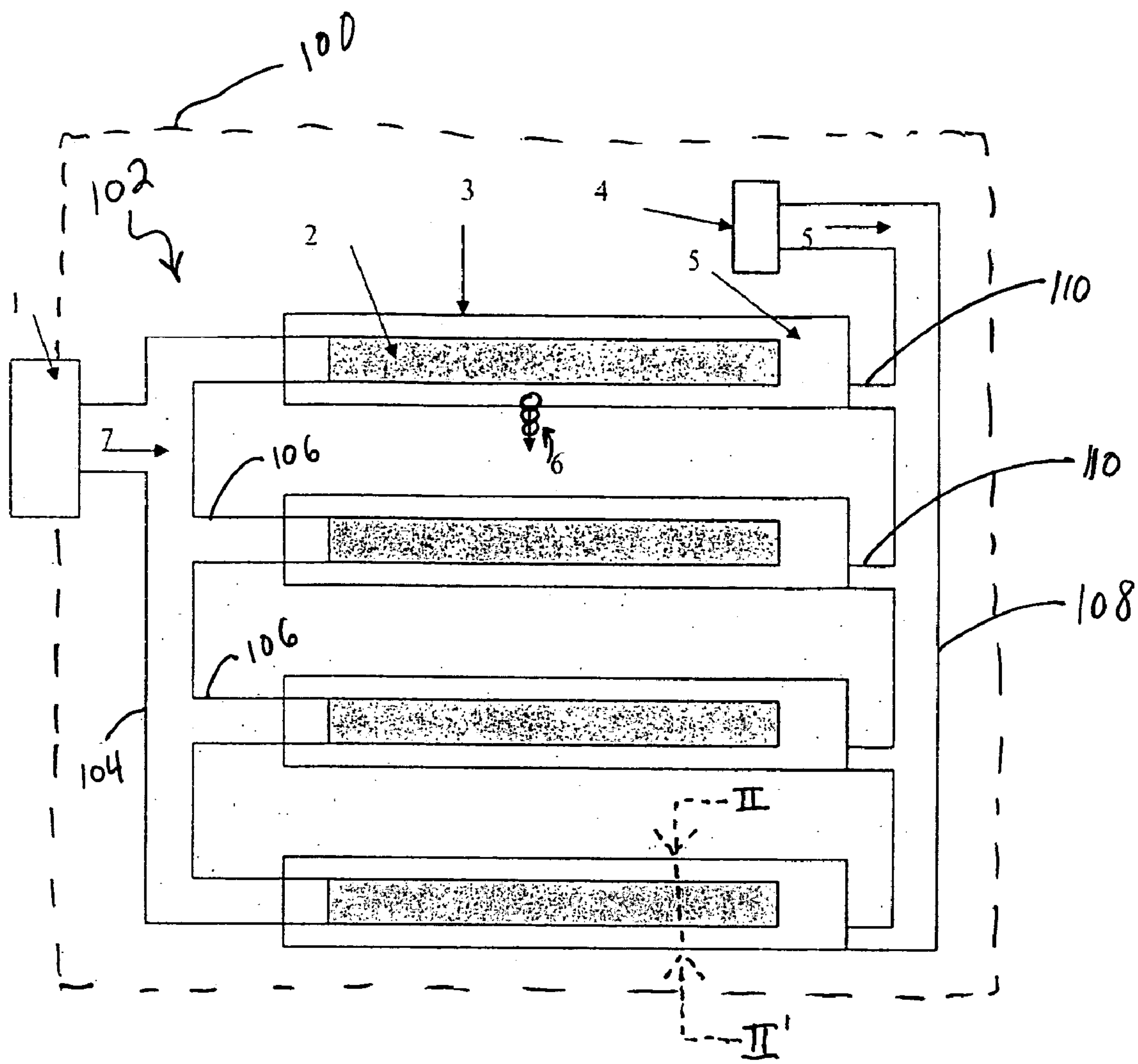
(63) Continuation-in-part of application No. 10/901,418, filed on Jul. 30, 2004.

Publication Classification

(51) Int. Cl.
C10J 1/08 (2006.01)
(52) U.S. Cl. 261/122.1

(57) **ABSTRACT**

An arrangement to generate foam, the arrangement comprising: a porous material; a plenum having an aperture disposed to supply gas to the porous material; and a tub containing a foamable liquid, disposed to at least partially submerge the porous material in the foamable liquid; foam being generated as the gas is injected via the porous material into the foamable liquid.



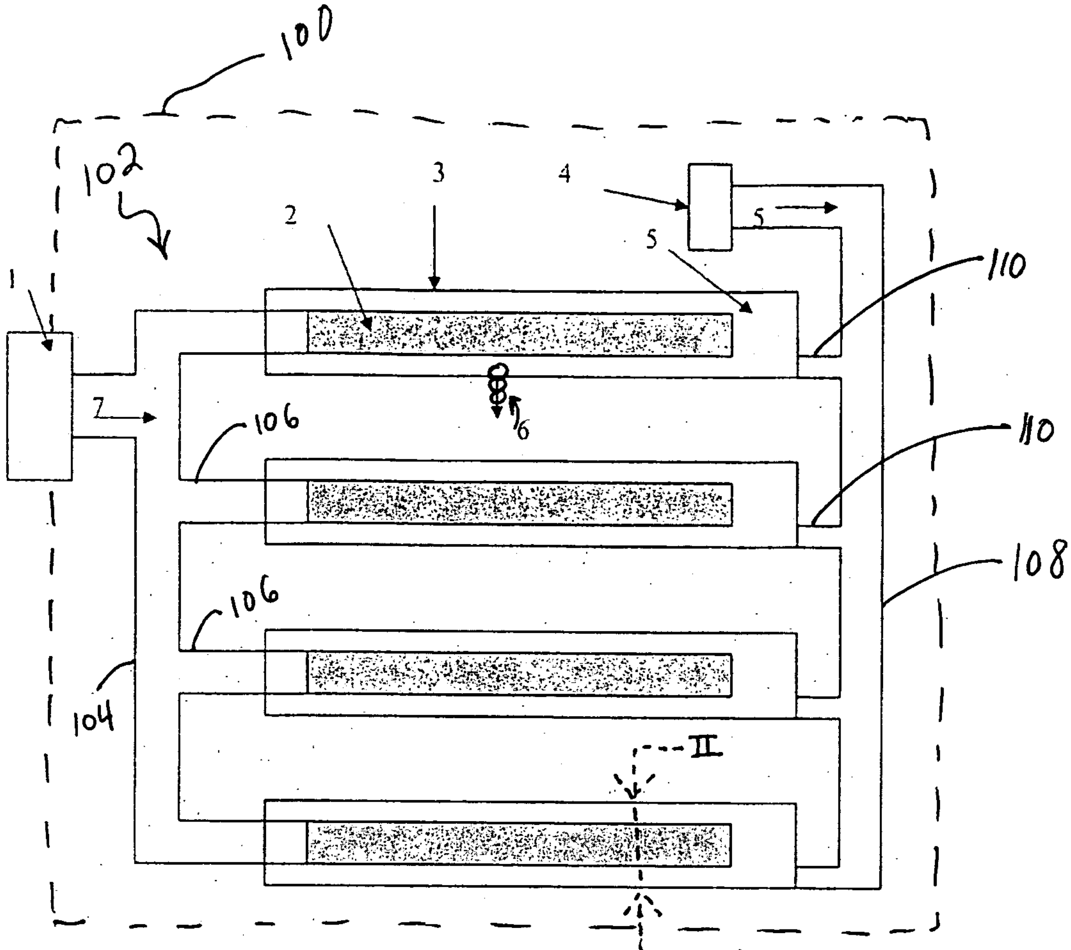


Figure 1

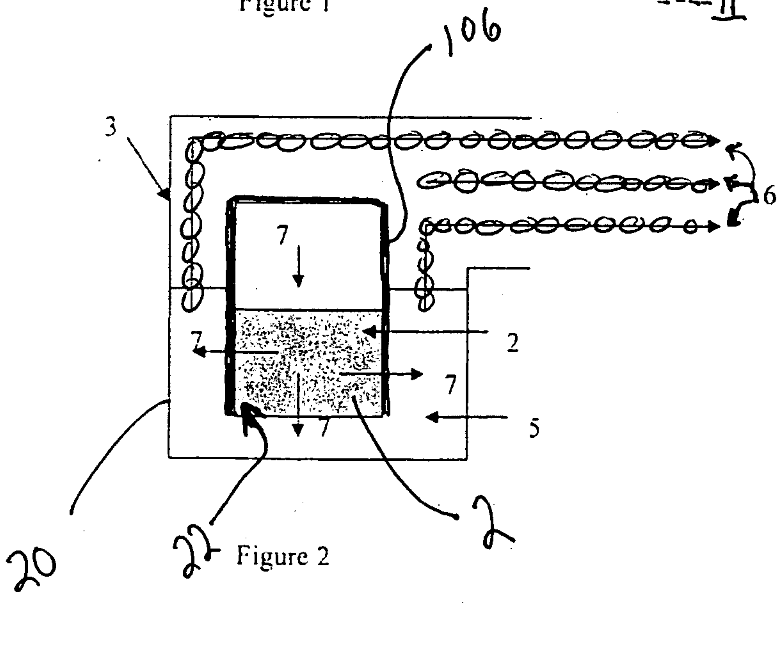


Figure 2

BUBBLE GENERATING ARRANGEMENT, SYSTEM & METHOD

PRIORITY INFORMATION

[0001] This application claims priority under 35 U.S.C. §120 upon a non-provisional U.S. patent application having Ser. No. 10/901,418 filed Jul. 30, 2004, the disclosure of which is incorporated herein in its entirety.

BACKGROUND OF THE PRESENT INVENTION

[0002] Foaming technologies for use in fire suppression and fire fighting are generally known. Such foaming technologies are typically classified in one of two categories of foam, namely air-aspirated foam and compressed-air foam.

[0003] The older of the two is air-aspirated foam. A stream of foamable solution is piped to a nozzle at a given pressure and at a given speed. The nozzle is configured so as to produce an increase in the speed and the turbulence, and consequently a drop in the pressure, of the foamable solution. The pressure drop draws air into the nozzle where it becomes entrained by the turbulence of the foamable solution. A stream of liquid (albeit containing entrained air) is ejected at the nozzle.

[0004] The newer of the two is compressed-air foam. Compressed air is injected into the stream of foamable solution inside the pipe away from the nozzle. That is, compressed air forces its way into the foamable stream away from the nozzle rather than being aspirated (or drawn) into the stream of foamable solution at the nozzle. Here, similarly, a stream of liquid (albeit containing entrained air) is ejected at the nozzle.

SUMMARY OF THE PRESENT INVENTION

[0005] An embodiment of the present invention provides an arrangement to generate foam, the arrangement comprising: a porous material; a plenum having an aperture disposed to supply gas to the porous material; and a tub containing a foamable liquid, disposed to at least partially submerge the porous material in the foamable liquid; foam being generated as the gas is injected via the porous material into the foamable liquid.

[0006] Another embodiment of the present invention provides a system to suppress fire within a substantially enclosed volume, comprising: a first plurality of foam generators, each foam generator including stream-forming means for forming a second plurality of low-speed streams of gas and for introducing the same into a foamable liquid, the foamable liquid being at about atmospheric pressure.

[0007] Another embodiment of the present invention provides a method of generating foam comprising: providing a porous material; at least partially submerging the porous material in a foamable liquid; forcing a gas into the foamable liquid via the porous material.

[0008] Another embodiment of the present invention provides an arrangement to generate foam, the arrangement comprising: a tub containing a foamable liquid; stream-forming means for forming a plurality of low-speed streams of gas and for introducing the same into the foamable liquid.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a top view block diagram of a bubble generating system according to an embodiment of the present invention.

[0010] **FIG. 2** is a quasi cross-section of a bubble generator according to an embodiment of the present invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0011] The present invention will be described more fully with reference to the accompanying drawings, in which example embodiments of the present invention are shown. It should be understood, however, that example embodiments of the present invention described herein can be modified in form and detail without departing from the spirit and scope of the present invention. Accordingly, the embodiments described herein are provided by way of example and not of limitation, and the scope of the present invention is not restricted to the particular embodiments described herein.

[0012] In particular, the relative thicknesses and positioning of structures or regions may be reduced or exaggerated for clarity. In other words, the figures are not drawn to scale. Further, a structure is considered as being formed "on" another structure when formed either directly on the referenced structure or formed on other structures overlaying the referenced structure.

[0013] Reference number similarities from one figure to the next suggest at least similar components/items.

[0014] **FIG. 1** is a top view block diagram of a bubble generating system **102** according to an embodiment of the present invention.

[0015] In **FIG. 1**, bubble generating system **102** is disposed within a substantially enclosed volume **100**, e.g., the interior of a warehouse, a compartment of a ship, etc. System **102** can include: a plurality of bubble generators **3**, each of which can include a porous material **2**; a source **1** of gas **7**, e.g., air; a network **104** of pipes that supply gas **7** to bubble generators **3**; a source **4** of foamable liquid **5** (i.e., a solution which can form a foam when mixed with a gas); and a network **108** of pipes that supply foamable liquid **5** to bubble generators **3**.

[0016] Network **104** can include a plurality of plenums **106** that connect to the plurality of bubble generators **3**, respectively. Source **1** can be arranged to draw gas, e.g., from outside of, and introduce it into, volume **100**. Network **108** can include a plurality of branches **10** that connect to the plurality of bubble generators **3**, respectively.

[0017] The plurality of foam generators **3** can be dispersed within the substantially enclosed volume **100**. For example, at least a majority of the plurality of foam generators **3** can be dispersed proximate to a ceiling region (not depicted) of volume **100**.

[0018] Foamable liquid **5** can be an aqueous solution that includes at least an agent to reduce the surface tension of water. For example, foamable liquid **5** can be PYRO-COOL® brand, formula FEF solution, made available by Pyrocool Technologies Inc.

[0019] **FIG. 2** is a quasi cross-section of a bubble generator according to an embodiment of the present invention. The quasi cross-sectional perspective of **FIG. 2** corresponds to sectional II-II' of **FIG. 1**.

[0020] In **FIG. 2**, bubble generator **3** includes tub **20** which can be used to contain foamable liquid **5** received from branch **110** (not depicted in **FIG. 2**). In tub **20**, foamable liquid **5** can be at about atmospheric pressure. An end of plenum **106** can be disposed in tub **20**, more an end portion of plenum **106** that includes an aperture **22** can be disposed in foamable liquid **5** contained in tub **20**. Aperture **22** can be any shape, e.g., in **FIG. 2** it is depicted as rectangular.

[0021] Plenum **106** can be arranged so that aperture **22** can supply gas **7** to porous material **2**. More particularly, at least a portion of porous material **2** can be fit as a plug into aperture **22**, e.g., **FIG. 1** shows an example circumstance in which the entirety of porous material **2** is fitted into aperture **22**. Tub **20** is disposed to at least partially submerge porous material **2** in foamable liquid **5**, e.g., **FIG. 2** shows an example circumstance in which porous material **2** is fully submerged in foamable liquid **5**.

[0022] Porous material **2** can be a sponge, aerogel, e.g., silica aerogel, a porous resin, etc. Porous material **2** includes pores. More specifically, porous material **2** includes at least one of macropores, mesopores and macropores. Pore size is a significant factor in determining the size of the bubbles produced. The size of the bubbles will vary depending upon the size of volume **100**, the chemical composition of foamable liquid **5** and the capacity of source **1** & network **104**.

[0023] Foam generation will now be described.

[0024] Gas **7** is pumped by source **1** via network **104** such that plenums **106** deliver gas to porous material **2** at apertures **22** in plenums **106**. Without being bound by theory, the porous nature of porous material **2** acts to form a plurality (if not a multitude) of streams of gas, and the submergence of porous material **2** causes the streams to be introduced directly into foamable liquid **5**, where bubbles **6** are formed. In other words, gas **7** is injected via porous material **2** into foamable liquid **5**, and the speed of gas **7** in the streams is relatively low, e.g., as contrasted to the Background Art foam generation systems. Gas **7** experiences a pressure drop across porous material **2**. Bubbles **6** rise within foamable liquid **5** and eventually escape or bubble up and out so as to enter the atmosphere within substantially enclosed volume **100**. In contrast to the Background Art air-aspirated and compressed-air technologies, a liquid stream having entrained gas is not being ejected from porous material **2**.

[0025] Some example calculations are provided for a specific albeit sample implementation of system **102**. Suppose that substantially enclosed volume **100** represents: R (cubic feet), and that system **100** should be able to fill volume **100** with bubbles in a time T_f minutes, e.g., $T_f=3$. Thus, system **102** must be capable of generating R/T_f of bubbles (in units of CFM). Assuming that there are N bubble generators such that there are N apertures **22**, and further describing apertures **22** as rectangular with a length L and a width D (D, e.g., is 0.24 feet (ft), then $L=R/(T_f*N*V*D)$, where W is the speed (in feet per minute (FM)) needed to achieve R. If $V=200{,}000\ ft^3$, $T_f=3$ minutes, N=20, D=0.25 ft and W=1000 ft/min, then L=14 ft.

[0026] An ideal rate of foam generation, R_i, can be scaled by compensation factors to obtain a desired rate of foam generation, R_d. At least two compensation factors can be: C_s, representing a compensation factor for the shrinkage that foam typically undergoes, e.g., $C_s=1.15$; and C_1, representing a compensation factor for leakage of the foam from the substantially enclosed volume **100**, e.g., $C_1=1.1$ (for slight leakage). As such, $R_d=C_sR_i$, $R_d=C_1R_i$ or $R_d=(Cs+C_1)R_i$.

[0027] Some further example calculations are provided for a second specific albeit sample implementation of system **102**. Suppose that the density of foamable liquid **5** is almost the same as water, the difference being negligible. Then, if porous material **2** is disposed to a depth of about 0.5 inches in foamable liquid **5**, then the minimum or threshold gas speed V_b (at the point where gas **7** is injected via porous material **2** into foamable liquid **5**) needed to generate a bubble within foamable liquid **5** is calculated as follows.

$$V_b=\sqrt{2*(\rho_{H2O}/\rho_{gas})*g*h)}$$

where ρ_{H2O} is the density of water (assumed to be substantially the same as the density of foamable liquid **5**), ρ_{gas} is the density of gas **7**, g is the acceleration due to gravity and h is the height (depth) of the foamable liquid **5**. Taking $\rho_{H2O}=1000$ kg per cubic meter, taking gas **7** to be air such that $\rho_{gas}=1.225$ kg per cubic meter, $g\approx10$ meter per square second and h=0.5 inches, then $V_b\approx14$ meters per second≈about 30 MPH (miles per hour).

[0028] While the speed of gas that exits porous material **2** into foamable liquid **5** should be at least V_b, as a practical matter there is also a maximum speed (V_{max}) above which bubble formation is retarded substantially. For example, $V_{max}\leqq(\approx1.5V_b)$, more particularly e.g., $V_{max}\approx1.2V_b$. It should be understood that the density of foamable liquid **5** influences the value of V_b.

[0029] Continuing the example calculations regarding the second specific albeit sample implementation of system **102**, assume that substantially enclosed volume **100** has a value $VOL=200{,}000\ ft^3$ and that $T_f=3$ minutes. Further assume that network **104** (including plenums **106**) is ideal such that no pressure drops are experienced therein, and that gas source **1** is a fan assembly with an 8 inch diameter (Area, $A=0.349\ ft^2$) that delivers gas at a speed S=150 mph (miles per hour) thus yielding a capacity of about 4200 CFM (cubic feet per minute)=0.349*150*3*1600/60. To fill VOL in time T_f, the air speed will be S=200000/3/60/0.349=3184 feet per sec=2387 mph. Therefore, such an instance of system **100** would need about 16 gas sources **1**. The total effective area of holes which porous material **2** represents to gas **7** blowing therethrough would be $A_{effective}=0.349*150/30=1.7$ square feet.

[0030] **FIG. 2** has depicted the example circumstance for system **102** in which aperture **22** can facilitate a downward flow of gas **7** into foamable liquid **5** via porous material **5**. Alternatively, e.g., system **100** can be arranged like, e.g., a sink in a kitchen/bathroom such that plenum **106** and aperture **22** can be positioned analogously to the drain pipe and the drain hole of the sink, and porous material **2** can be positioned analogously to a stopper inserted into the drain hole. Such an alternative arrangement has gas **7** flowing substantially continually upward from plenum **106**. In contrast, system **102** of **FIG. 2**, gas flows downward from plenum **106** and then changes direction, moving upward, in the form of bubbles when it becomes enclosed inside walls of foaming liquid **5** in tub **20**.

[0031] Embodiments of the present invention having been thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the present invention, and all such modifications are intended to be included within the scope of the present invention.

What is claimed is:

1. An arrangement to generate foam, the arrangement comprising:

a porous material;

a plenum having an aperture disposed to supply gas to the porous material; and

a tub containing a foamable liquid, disposed to at least partially submerge the porous material in the foamable liquid;

foam being generated as the gas is injected via the porous material into the foamable liquid.

2. The foam-generating arrangement of claim 1, wherein:

the porous material is one of a sponge, an aerogel and a porous resin.

3. The foam-generating arrangement of claim 1, wherein:

the porous material includes at least one of macropores, mesopores and macropores.

4. The foam-generating arrangement of claim 1, wherein the pressure of the foamable liquid is about atmospheric pressure.

5. The foam-generating arrangement of claim 1, wherein at least a portion of the porous material is fitted as a plug into the aperture.

6. The foam-generating arrangement of claim 1, wherein the gas is air.

7. The foam-generating arrangement of claim 1, wherein a maximum speed V_{max} at which the gas is injected into the foamable liquid is

$$V_{max} \leqq (\approx 1.5 V_b),$$

where V_b is the minimum speed at which injection of the gas into the foamable liquid can achieve bubble formation.

8. The foam-generating arrangement of claim 7, wherein $V_{max} \approx 1.2 V_b$.

9. A system to suppress fire within a substantially enclosed volume, the system comprising:

a first plurality of foam generators, each foam generator including

stream-forming means for forming a second plurality of low-speed streams of gas and for introducing the same into a foamable liquid, the foamable liquid being at about atmospheric pressure.

10. The system of claim 9, wherein each stream-forming means includes a porous material via which the gas is introduced into the foamable liquid.

11. The system of claim 10, wherein the porous material is at least partially submerged in the foamable liquid.

12. The system of claim 9, wherein the second plurality of low-speed streams is a multitude.

13. The system of claim 9, further comprising:

a source of gas;

a plurality of plenums arranged to conduct gas to the plurality of stream-forming means, respectively.

14. The system of claim 9, wherein the first plurality of foam generators are dispersed within the substantially enclosed volume.

15. The system of claim 9, wherein at least a majority of the first plurality of foam generators are dispersed proximate to a ceiling region of the enclosed volume.

16. The system of claim 9, wherein the low-speed of the streams of gas has a maximum V_{max},

$$V_{max} \leqq (\approx 1.5 V_b),$$

where V_b is the minimum speed at which introduction of the gas into the foamable liquid can achieve bubble formation.

17. The system of claim 16, wherein $V_{max} \approx 1.2 V_b$.

18. A method of generating foam comprising:

providing a porous material;

at least partially submerging the porous material in a foamable liquid;

forcing a gas into the foamable liquid via the porous material.

19. The method of claim 18, further comprising:

using the foamable liquid at about atmospheric pressure.

20. The method of claim 18, further comprising:

using air as the gas.

21. The method of claim 18, wherein a maximum speed V_{max} at which the gas is forced into the foamable liquid is

$$V_{max} \leqq (\approx 1.5 V_b),$$

where V_b is the minimum speed at which the gas can be forced into the foamable liquid and still can achieve bubble formation.

22. The method of claim 21, wherein $V_{max} \approx 1.2 V_b$.

23. An arrangement to generate foam, the arrangement comprising:

a tub containing a foamable liquid;

stream-forming means for forming a plurality of low-speed streams of gas and for introducing the same into the foamable liquid.

24. The foam-generating arrangement of claim 23, wherein the plurality of low-speed streams is a multitude.

25. The foam-generating arrangement of claim 23, wherein the low-speed of the streams of gas has a maximum V_{max},

$$V_{max} \leqq (\approx 1.5 V_b),$$

where V_b is the minimum speed at which introduction of the gas into the foamable liquid can achieve bubble formation.

26. The foam-generating arrangement of claim 25, wherein $V_{max} \approx 1.2 V_b$.

* * * * *