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Fine bubble technology — General principles for usage and measurement of fine bubbles —

Part 3: Methods for generating fine bubbles

Technologie des fines bulles — Principes généraux pour l'utilisation et la mesure des fines bulles —

Partie 3: Méthodes pour générer des fines bulles

Reference number
ISO 20480-3:2021(E)

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Foreword

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This document was prepared by ISO/TC 281, *Fine bubble technology*.

Any feedback or questions on this document should be directed to the user's national standards body. The complete list of these bodies is available at www.iso.org/members.html.

A list of all the parts in ISO 20480 series can be found on the ISO website.

Introduction

Until now the terminology, method and corresponding technology for the generation of fine bubbles have not been standardized. The new project to standardize the terminology of fine bubble generating systems and the corresponding technology is thought to have significant influences on the market as follows:

— convenience of customers when purchasing or using fine bubble generating system and its techniques will be improved, and owing to the improvement of their convenience, it can be expected to boost fine bubble industries;

— standardization of terminology will enhance commonality in the field of generating system performance. Improvement in performances in hardware and software will also prospectively lead to market growth of the manufacturing industries of fine bubble generating system;

— standardization of terminology will enable the application markets to be boosted in creating new markets, as well as unifying existing markets.

In addition to existing fine bubble technology standards, by specifying "common terms" of generation principles, it will allow best practices to use common terms for fine bubble generating systems as well as the market expansion is expected.

Fine bubble technology — General principles for usage and measurement of fine bubbles —

Part 3: Methods for generating fine bubbles

1 Scope

This document describes methods for generating fine bubbles.

2 Normative references

The following documents are referred to in the text in the sense that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20480-1, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 1: Terminology*

ISO 20480-2, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 2: Categorization of the attributes of fine bubbles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20480-1 and ISO 20480-2, and the following apply.

ISO and IEC maintain terminological databases for the use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
flow path
passage that conveys fluid

[SOURCE: ISO 5598:2020, 3.2.302]

3.2
cavitation
formation and collapse of bubbles in a liquid when the pressure falls to or below the liquid vapour pressure, the collapse releases energy, sometimes with an audible sound and vibration

[SOURCE: ISO 16904:2016, 3.7]

3.3
Venturi tube
device which consists of a convergent inlet which is conically connected to the cylindrical part called the “throat” and an expanding section called “divergent” with a conical shape

[SOURCE: ISO 5167-1:—[1)], 3.2.5]

1) Under preparation. Stage at the time of publication ISO/DIS 5167-1:2021.

3.5
impeller
spinning disc in a centrifugal pump with protruding vanes, which is used to accelerate the fluid in the pump casing

[SOURCE: ISO 13501:2011, 3.1.51]

3.6
solubility
maximum mass of a solute that can be dissolved in a unit volume of solution measured under equilibrium conditions

[SOURCE: ISO 17327-1:2018, 3.16]

3.7
surfactant
surface active substance that reduces the surface tension of the solution

[SOURCE: ISO 8124-7:2015, 3.7]

3.8
critical micelle
state of maximum concentration of dispersing agent before micelles form

[SOURCE: ISO 14887:2000, 3.4]

3.9
ultrasound
high frequency (over 20 kHz) sound waves which propagate through fluids and solids

[SOURCE: ISO 20998-1:2006, 2.22]

3.10
self-priming
suction of fluid into flow path without using a mechanism for feeding pressure

3.11
nozzle
structure that accelerates and releases fluid

3.12
porous membrane
membrane containing pores (voids)

3.13
non-condensable gas
air and/or other gases which is not liquefied under the conditions of a saturated steam

[SOURCE: ISO 11139:2018, 3.183]

3.14
electrolysis
process in which electric current is used to promote a chemical reaction

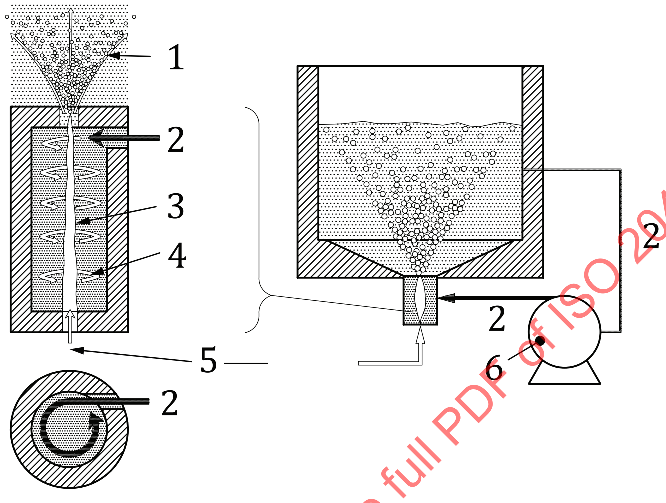
Note 1 to entry: In the case of water, the separation reaction generating hydrogen and oxygen is a typical example.

[SOURCE: ISO/TR 15916:2015, 3.34]

4 Examples of methods for generating fine bubbles

4.1 Swirling flow system (for microbubble generation)

Liquid is made to swirl around the interior of a cylinder at a high speed, reducing the pressure near the central axis of the cylinder and thereby causing gas to be sucked in from the outside. Within the cylinder, centrifugal separation occurs where low-density gas is located at the centre and high-density liquid is located at the cylinder wall. The gas column is pulverized by the fierce shear flow to produce fine bubbles, see Figure 1.



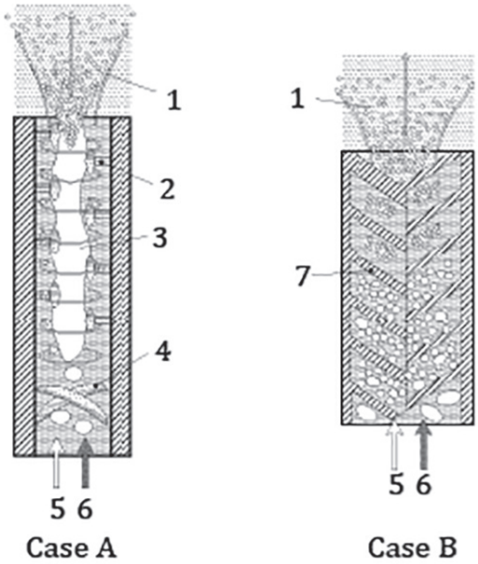
Key

1 fine bubbles
2 liquid
3 gas column
4 swirling flow
5 gas
6 pump

Figure 1 — Schematic diagram of fine bubble generation using swirling flow system

4.2 Static mixer system (for microbubble generation)

This system does not use mechanical pulverization. The flow path has a complex structure, and the circulatory drive force of the liquid produces a vortex flow which is primarily responsible for creating a large viscous shear force that pulverizes the gas. Protrusions on the inner wall of the cylinder produce vortex in the liquid flow, and the large bubbles carried along with the liquid are pulverized by the shear force to produce fine bubbles, see Figure 2.



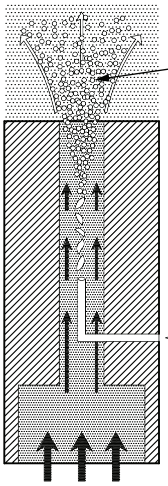
Key

1 fine bubbles
2 blade
3 gas column
4 guide vanes
5 gas
6 liquid
7 obstructions

Figure 2 — Schematic diagram of fine bubble generation using static mixer system

4.3 Ejector system

This system uses sudden narrowing and widening of the flow path, produces negative pressure and sucks air passively. The negative pressure produced when a fluid is passed through a narrow flow path at a high speed is used to suck in gas. The gas that is sucked in is pulverized thoroughly by cavitation caused by the widening of the downstream path, resulting in forming bubbles, see Figure 3.



Key

1 fine bubbles

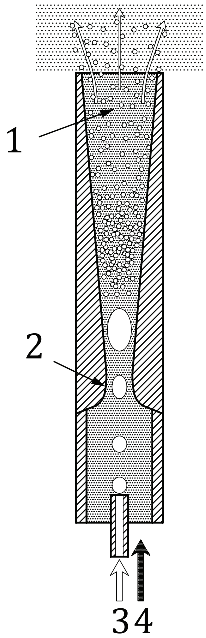
2 suction gas

3 liquid

Figure 3 — Schematic diagram of fine bubble generation using ejector system

4.4 Venturi system

When a liquid that contains large bubbles passes through a Venturi tube with a narrowed cross-sectional area and a widened one, a sudden drop in pressure occurs when the liquid passes the throat section causes a temporal expansion of bubbles, and the subsequent sudden restoration of pressure and the shock wave cause a forceful breakup of the large bubbles. This method does not necessarily require the self-priming using reduction section, see Figure 4.



Key

1 fine bubbles

2 throat section

3 gas

4 liquid

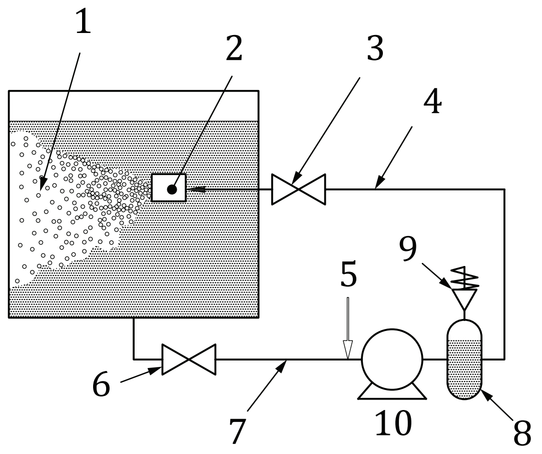
Figure 4 — Schematic diagram of fine bubble generation using venturi system

4.5 Pressurized dissolution system (for microbubble generation)

The water in a container is sucked in by a pressurizing pump. When the liquid flow passes through a narrower cross section, the gas is sucked from outside into the pipe due to the negative static pressure. The introduced gas is forcefully mixed with the water. The water oversaturated with gas in a pressurized state returns to normal pressure when it passes through the nozzle. As a result, the generation of bubble nuclei is promoted. The bubble nuclei that are discharged into the liquid as the liquid flows from the nozzle grow to numerous fine bubbles through the absorption of oversaturated dissolved gas as a result of mass transfer, see Figure 5.

NOTE 1 No recirculation stream is used for the fine bubble generating system. All the volume flow is saturated with air end decompressed (full stream saturation).

NOTE 2 The pressurized air is introduced to the pressure side of the pump, usually directly into the saturator (retention tank/surplus gas separation).



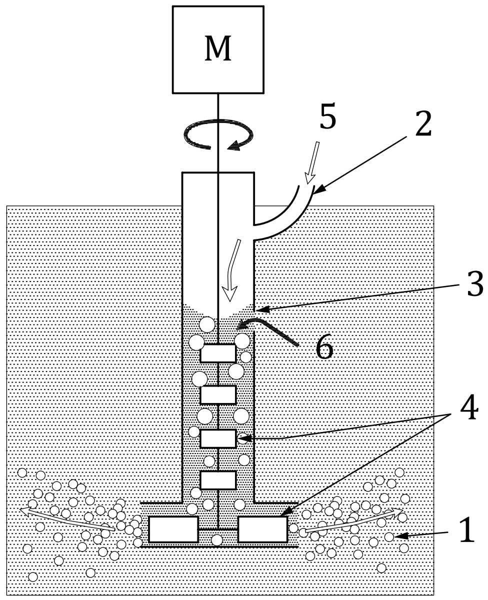
Key

1 fine bubbles
2 nozzle
3 decompression valve
4 pressured pipe
5 gas inlet
6 back-pressure regulating valve
7 decompressed pipe
8 surplus gas separator/retention tank/saturator
9 vent
10 compressor

Figure 5 — Schematic diagram of fine bubble generation using pressurized dissolution system

4.6 Mechanical shear system

In this system, fine bubbles are generated by means of the forcible liquid flow produced by a motor and an impeller. The rotating blades introduce gas into the manifold as well as liquid. The agitation blades and turbulent eddies forcefully pulverize large bubbles at the gas-liquid discharge ports of the generator. The liquid containing fine bubbles is discharged into the centrifugal direction, see Figure 6.



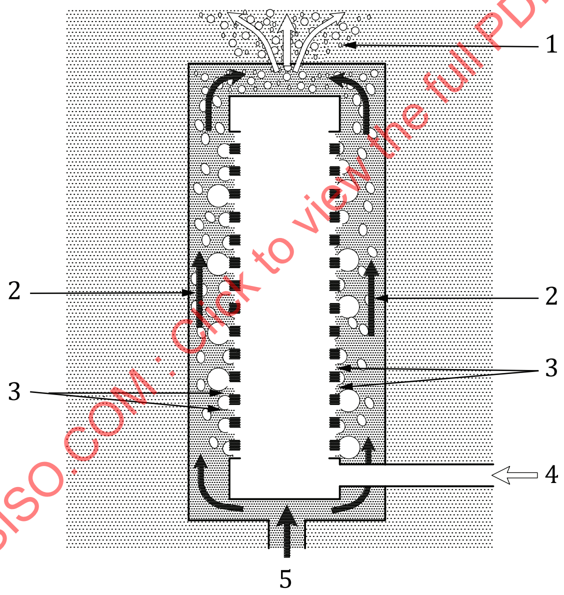
Key

1 fine bubbles
2 gas inlet
3 liquid inlet
4 rotating blade
5 gas
6 liquid
M motor

Figure 6 — Schematic diagram of fine bubble generation using mechanical shear system

4.7 Micropore system

In this system, gas is supplied to a cylinder composed of a porous membrane with micropores. The gas is slowly forced in from the extremely tiny holes formed in the solid surface that is submerged in the liquid. As a result, that tiny bubbles are exuded from these holes. The liquid flows in the circular path of a double-wall pipe that encloses the cylinder in the direction perpendicular to the direction of bubble expansion. The bubbles that ooze out from the micropores on the sides of the cylinder expand and are cut off from the holes by the shear force generated by the liquid. As a result, the bubbles flow downward, see Figure 7.

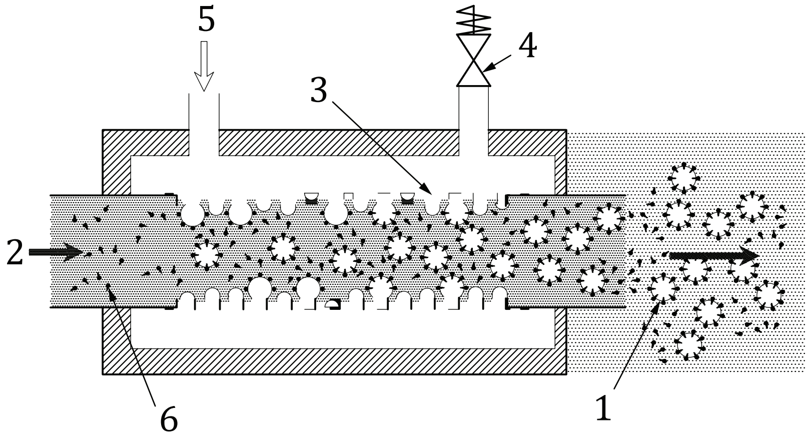


Key
1 fine bubbles
2 liquid flow
3 micropore
4 gas
5 liquid

Figure 7 — Schematic diagram of fine bubble generation using micropore system

4.8 Surfactant addition micropore system

In this method, surfactant is used to reduce the air-liquid interfacial tension in order to make the size of the bubbles smaller, even in situations where the external force that is applied to promote the separation of large bubbles using the micropore method in a rational way has reached its limit. The aqueous solution shall have surfactant concentration more than that of critical micelle, see Figure 8.



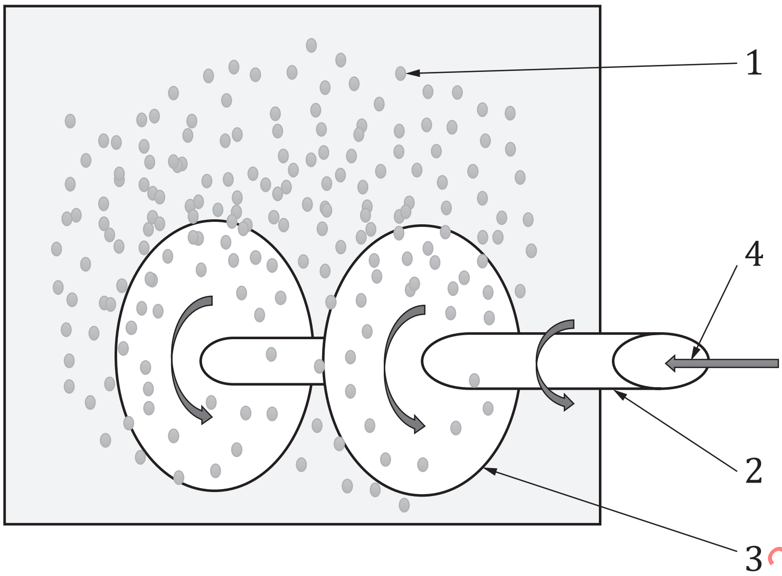
Key

1 ultrafine bubbles
2 liquid
3 micropore
4 safety valve
5 high-pressure gas
6 surfactants

Figure 8 — Schematic diagram of fine bubble generation using surfactant-added micropore system

4.9 Microporous shear system

In this system, pressurized gas enters through the shaft into microporous ceramic disks. The microporous ceramic disks are mounted on the shaft and rotate together with the shaft. Both shaft and disks are submerged in the liquid. Rotation of the shaft generates shear forces on the disks which break bubbles forming on the disks. Thus, fine bubbles are created, see Figure 9.



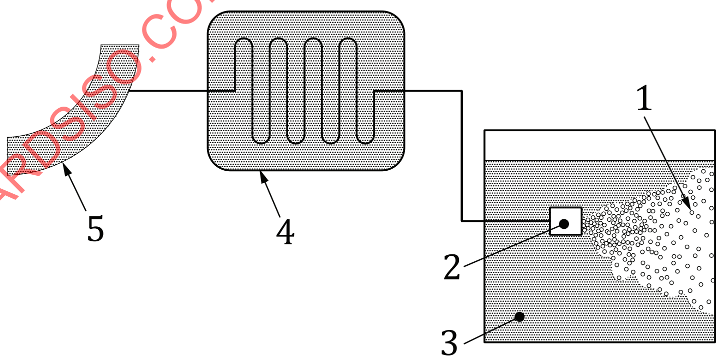
Key

1 fine bubbles
2 shaft
3 ceramic disk
4 air inlet

Figure 9 — Schematic diagram of fine bubble generation using microporous shear system

4.10 Heat separation system

As in the case of the pressurized dissolution fine bubble generation method, this method uses the change in the solubility of gas in the liquid. It also uses the change in solubility due to temperature change. In the saturated dissolved concentration of air in the liquid at room temperature, the solubility of gas is reduced when the liquid is heated. As a result, bubble nuclei grow into bubbles, see Figure 10.



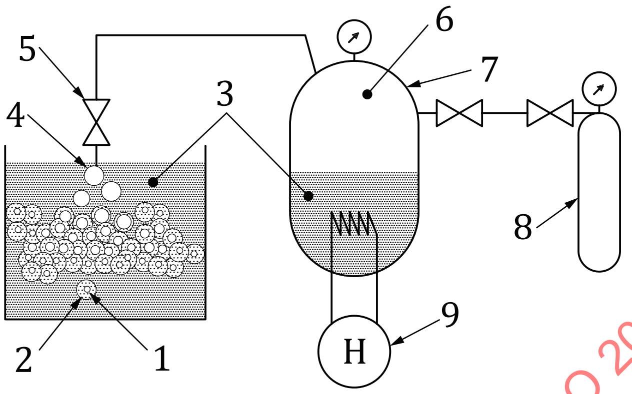
Key

1 fine bubbles
2 nozzle
3 hot liquid
4 heater
5 liquid pipe at normal temperature

Figure 10 — Schematic diagram of fine bubble generation using heat separation system

4.11 Mixed vapor condensation system

Pressurized steam that contains non-condensable gas (for example, nitrogen) is sprayed into the cooling water from a nozzle. Steam bubbles are generated but are rapidly cooled immediately after dispersion, then condensed. Thus, only the non-condensable gas components are not turned into liquid and become fine bubbles instead, see Figure 11.



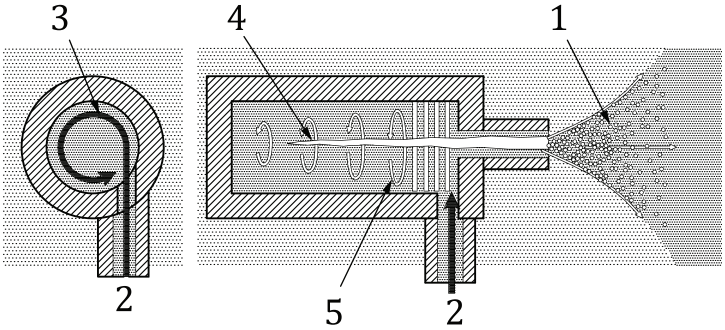
Key

1 fine bubbles
2 condensed water
3 water
4 steam bubble
5 valve
6 mixed steam
7 boiler
8 cylinder of non-condensable gas
9 heater

Figure 11 — Schematic diagram of fine bubble generation using mixed vapor condensation system

4.12 Swirling flow system (for ultra fine bubble generation)

This is an improved version of the swirling flow system using the microbubble generating system, which is designed to produce a stronger and more stable swirling flow. The gas that is brought into the cylinder in the bubble generator together with the liquid is forcefully pulverized by the strong shear flow, producing both tiny microbubbles and ultrafine bubbles, see Figure 12.



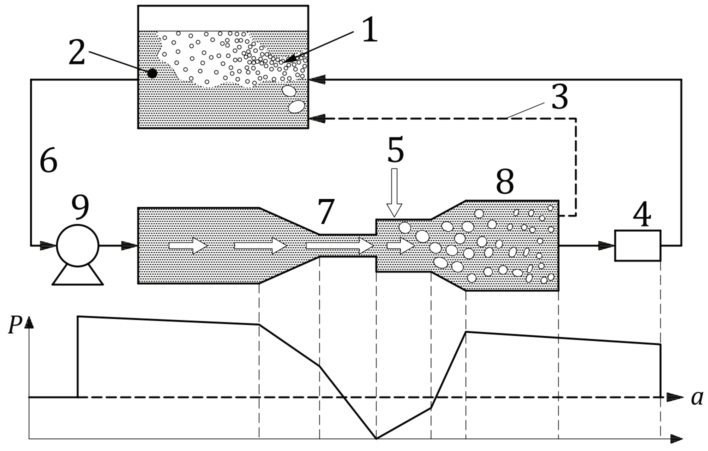
Key

1 fine bubbles
2 liquid and gas
3 swirling flow
4 gas column
5 swirling flow

Figure 12 — Schematic diagram of fine bubble generation using swirling flow system

4.13 Pressurized dissolution system (for ultra fine bubble generation)

The water in the tank is pressurized using a pump and force-fed to the pipe. The inner diameter of the pipe is reduced for the liquid flow to be accelerated to reduce the static pressure below atmospheric pressure. The difference in static pressures introduces the gas from outside to the pipe. Enlarged cross section following a part of the pipe reduces the flow speed of two-phase gas-liquid to allow sufficient mixing. The flow path is restricted in the nozzle section and the pressure in the pressurized solution section is maintained at a high level of producing the maximum dissolution of the gas in the water. The water has become saturated as a result of gas dissolution under high pressure. Subsequently the pressure is reduced to atmospheric pressure at the nozzle, and the dissolved gas, whose solubility has decreased, is turned into microbubbles that are separated out from the water. The microbubbles in the water tank gradually rise on the water, leaving clear water behind. The ultrafine bubbles do not rise and are retained in the water, see Figure 13.



Key

1 fine bubbles
2 water
3 surplus gas
4 nozzle
5 suction gas
6 liquid
7 throat section
8 gas-liquid pressurised dissolution section
9 compressor
P pressure
R flow path
a atmospheric pressure

Figure 13 — Schematic diagram of fine bubble generation using pressurized dissolution system

4.14 Static mixer system (for ultra fine bubble generation)

When liquid containing large bubbles passes along a complex winding flow path, considerable shear flow is generated as the liquid passes from one mini-chamber to the next, and the large bubbles in the liquid are gradually broken up. Moreover, when the liquid passes through certain mini-chambers, the two-phase gas-liquid flow is separated into flows to multiple mini-chambers. Meanwhile in other mini-chambers the two-phase gas-liquid flows from multiple interfacing mini-chambers flow together. For this reason, the liquid is folded into itself, dramatically along with the pulverization of the bubbles while increasing the speed at which the gas is dissolved into the liquid. The consequent cloudy white water is left to stand in order to allow all of the microbubbles to float up, while separating the microbubbles from the water and retaining ultrafine bubbles, see Figure 14.