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Fine bubble technology — Industrial and consumer device applications —

Part 1: Assessment of water pressure driven nozzles by evaluating size and concentration indices of generated fine bubbles

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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

A list of all parts in the ISO 7429 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Fine bubble (FB) technology has been used in a wide range of fields, including cleaning, water treatment, agro- and aqua-culture, liquid crystal, semiconductor and solar cell manufacturing, new functional material manufacturing, chemistry, cosmetics, medicine and pharmaceuticals, and food and drinking water. The market has been expanding from B to B market to B to C market, and the market has started up rapidly and is in the process of further growth.

In particular, nozzles as consumer devices are growing rapidly in the consumer market as FB generation technology has improved. Nozzles are devices that are divided into various types, such as insertion type, submerged type, and open type, and each type has its own characteristics. The insertion type, in which the nozzle is installed in the middle of the pipe and FB is mixed into the water used, is the most widely available in the market and is widely used in industrial applications such as cleaning, water treatment, agriculture and aquaculture, as well as for home use. The submerged type is installed in a water tank to generate FB in the cleaning tank, and is widely used for hot water nozzles in baths and water supply in tanks in fisheries and agriculture. The open type, which functions by passing through the air and coming into contact with the object (FB generation), is used for hand washing and kitchen faucets. Nozzles have a wide variety of applications and are one of the most widespread key devices for fine bubble generation in various industrial and household applications.

However, in some cases, the characteristics of FBs cannot be fully confirmed, and the devices are not functioning as well as they should. Therefore, in order for microbubble technology to maintain its reliability as a technology used in industrial and consumer applications around the world, there is a need for a method to evaluate the effectiveness and efficiency of the generating system, and standardization of the nozzle evaluation is needed. The most important characteristic is the number concentration and size index of the generated fine bubbles.

Thus, devices that are versatile in terms of application, small, portable anywhere in the world, and affordable are also important as they can contribute to the sustainable development goals (SDGs).

This document provides a method for evaluating the size and concentration index of microbubbles generated by nozzles, which will serve as a basis for fair and appropriate trade of FB nozzle devices leading to widespread use of the products. The users of this document are, directly, nozzle manufacturers, manufacturers of FB generators and systems, manufacturers and builders of FB application systems and facilities, and nozzle evaluation companies. Users of industrial cleaning equipment and water utilities can also use this document.

Fine bubble technology — Industrial and consumer device applications —

Part 1:
Assessment of water pressure driven nozzles by evaluating size and concentration indices of generated fine bubbles

1 Scope

This document specifies the evaluation methods for size and concentration indices of fine bubbles (FBs) generated through a nozzle. It only applies to FB dispersions (FBDs) in water generated through the nozzle. It describes the sampling method for a FBD from the nozzle into the retention container and the measurements of size and concentration indices.

Major applications of the equipment include components of various industrial water systems and consumer baths and kitchens.

2 Normative references

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

ISO 20298-1, *Fine bubble technology — Sampling and sample preparation for measurement — Part 1: Ultrafine bubble dispersion in water*

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

ISO 21910-1, *Fine bubble technology — Characterization of microbubbles — Part 1: Off-line evaluation of size index*

3 Terms and definitions

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

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

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

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

3.1
nozzle
device driven by water pressure applied from outside that discharges fine bubble water into the air or water through a single columnar pass

Note 1 to entry: Various types of fine bubble generating technologies such as venturi tube type and ejector type are used as fine bubble nozzles.

4 Types of nozzles

There are a lot of types on nozzles in the commercial market, which are categorized into three types, composed of insertion, submerged and open terminal types.

Detailed examples used in the market are included in Annex A.

5 Requirements

5.1 Samples

FB dispersions in water used to test nozzles shall be generated using clean test systems with clean water and clean gasses such as air, nitrogen or oxygen.

The degrees of purity of water and gasses depend on the purpose of the test.

The FBD shall not contain stabilizing agents such as surfactants.

If the accuracies of the measurements of size and concentration indices are critically important (for example, application to the accreditation of a FB business), ISO Grade 1 (see ISO 3696) water purity is recommended for the water used to generate a FBD.

5.2 Measuring instruments

When the measuring instruments are selected for evaluating size and concentration indices of FBs generated from the nozzle, the following requirements for the concentration and the size range shall be considered. These requirements depend on the characteristics of the test sampled.

a) The total number concentrations and the total volume concentration of the entire sample including FBs and contaminants (solid and liquid particles) shall be measured. Water can be used to dilute the FBD when its concentration exceeds the limits of the measurement technique.

b) The size range of the entire sample including FBs, contaminants, and aggregates of contaminants shall be measured. Different instruments can be used to identify larger aggregates.

NOTE The particle-tracking analysis method can be used for evaluating the number of concentrations, and the laser diffraction method can be used to evaluate the volume concentration. ISO/TR 23015 can be referred to for details of techniques, which can be used to evaluate a FBD in water.

6 Environment

Air cleanliness should be considered for measurements to prevent the introduction of impurities. Ambient temperature and atmospheric pressure should be constant to maintain the stability of FBs.

Air cleanliness, ambient temperature and atmospheric pressure depend on the local environment and can vary. However, these important settings can influence the evaluation process and should be recorded before performing evaluations.

If the accuracies of measurements of sizes and concentration indices are critically important, for example, the application to the accreditation of a FB business, air cleanliness according to ISO Class 7 (see ISO 14644-1) is recommended as the environment standard for the generation and measurement of a FBD in water.

7 Evaluation

7.1 General

When evaluating the size and concentration indices of FBs generated from the nozzle, one-way flow and circulation flow are used for microbubbles (MBs) and ultrafine bubbles (UFBs). These relations are given in Table 1 as an evaluation matrix. The variables to be evaluated depend on the purpose of the applications.

Table 1 — Evaluation matrix

	One-way flow	Circulation flow	Reference for evaluation
Microbubbles (MBs)	To be evaluated	To be evaluated [a]	ISO 21910-1
Ultrafine bubbles (UFBs)	To be evaluated	To be evaluated [b]	ISO 20298-1

[a] For applications such as baths and water treatment, the equilibrium state of microbubble dispersions (MBDs) is produced.

[b] The circulation flow is indispensable when the signal from UFBs is below the limit of detection.

7.2 Placement of the nozzle on the retention container

The nozzle shall be placed on the discharge port of the fitted nozzle submerged below the water surface. The water surface level can be maintained by overflow from the retention container.

Sufficient distance is required between the discharge port and wall or bottom of the retention container to prevent the destruction of FBs through collision.

When evaluating a nozzle that is used by submerging it deeply, it is necessary to adapt the test conditions such as submerging depth and water pressure to the actual operating environment.

For the generation of fine bubbles in the nozzle type, the differential pressure before and after the nozzle is important, and it is affected by the discharge pressure and water depth. An example is shown in Annex B.

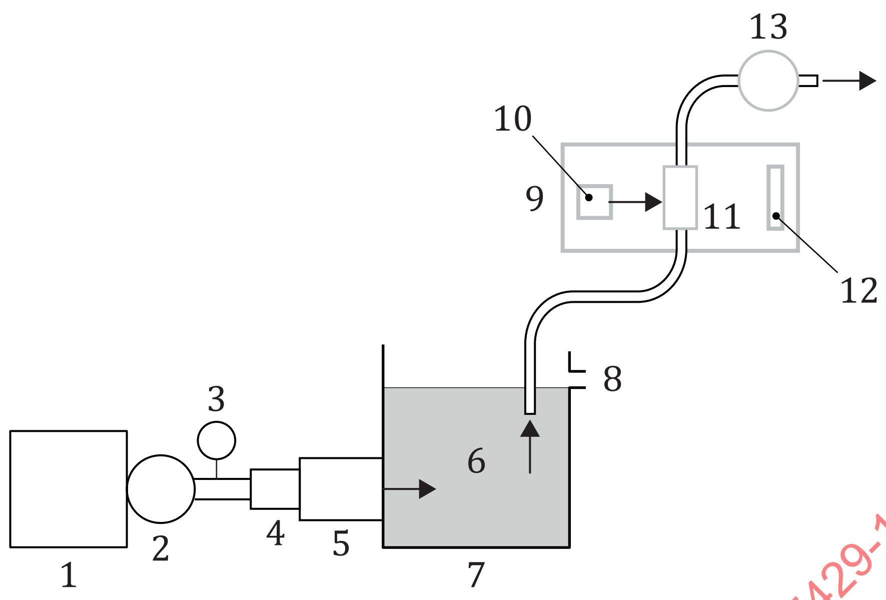
7.3 One-way flow

7.3.1 General

The evaluation of size and concentration indices of MBs shall use the one-way flow configuration. If the signal from UFBs is sufficient for measurements, the one-way flow configuration shall be used for UFBs as well.

7.3.2 Test system configuration

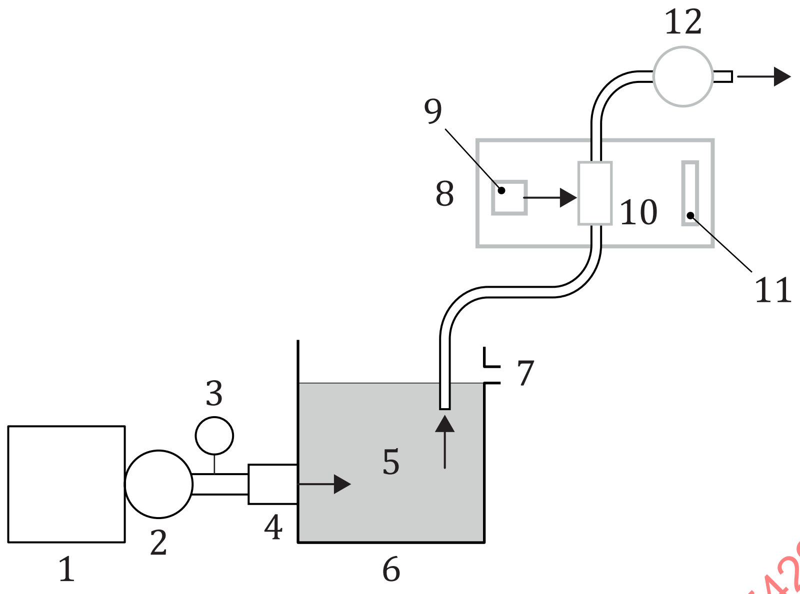
The test system configurations of one-way flow are shown in Figures 1 and 2.



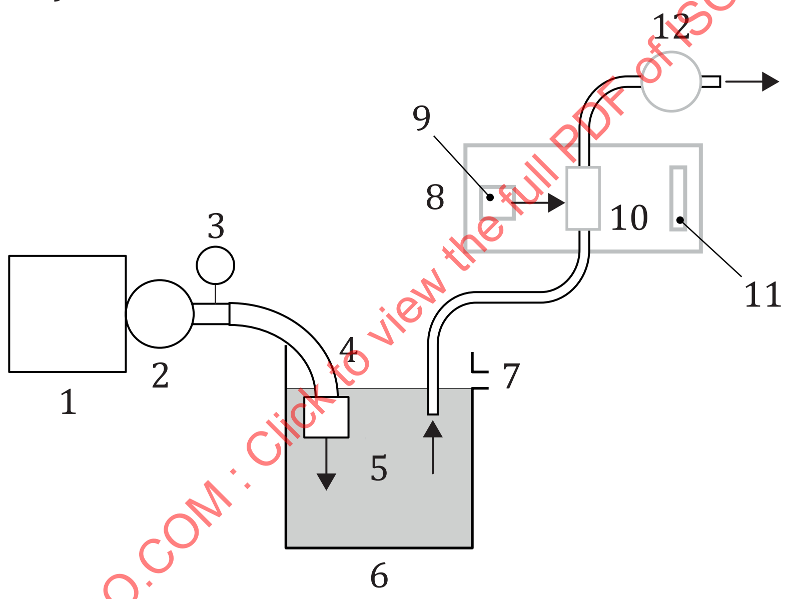
Key

1 raw water storage tank
2 pump
3 water pressure meter
4 nozzle
5 piping
6 fine bubble water
7 retention container
8 over flow
9 measuring instrument
10 light source
11 flow cell
12 sensor
13 drain pump

Figure 1 — Typical insertion-type nozzle configuration of a one-way flow test system



a) Direct connection of nozzle to retention container



b) Submerged type of nozzle in retention container

Key

1 raw water storage tank
2 pump
3 water pressure meter
4 open ended nozzle
5 fine bubble water
6 retention container
7 over flow
8 measuring instrument
9 light source
10 flow cell
11 sensor
12 drain pump

Figure 2 — Other configurations of one-way flow test systems

A water pressure meter maintains the predetermined water pressure for tests within the minimum fluctuation.

Refer to ISO 21910-1 for the measurement of MBs. Instruments employing dynamic image analysis methods, the laser diffraction method and the light extinction liquid-borne particle counter can be used.

A sample of UFBs from the retention container shall be acquired in accordance with ISO 20298-1.

7.3.3 Evaluation procedure

The evaluation procedure is as follows:

a) Rinse the wetting components of the test system including the retention container, the pump and the nozzle when using raw water to remove the existing contamination of solid particles and liquid.

b) Fill the raw-water storage tank and retention container with raw water.

c) Set the nozzle at the appropriate position of the retention container and introduce raw water into the nozzle.

d) Wait for a sufficient interval to acquire stable measurements.

   NOTE 1 This interval is predetermined through trial and error as appropriate for the test system.

e) Measure the size and concentration indices of the FBDs in water discharged from the nozzle.

NOTE 2 MBs are transferred into the instrument and measured in accordance with ISO 21910-1, UFBs are sampled and measured in accordance with ISO 20298-1.

7.4 Circulation flow for ultrafine bubbles (UFBs)

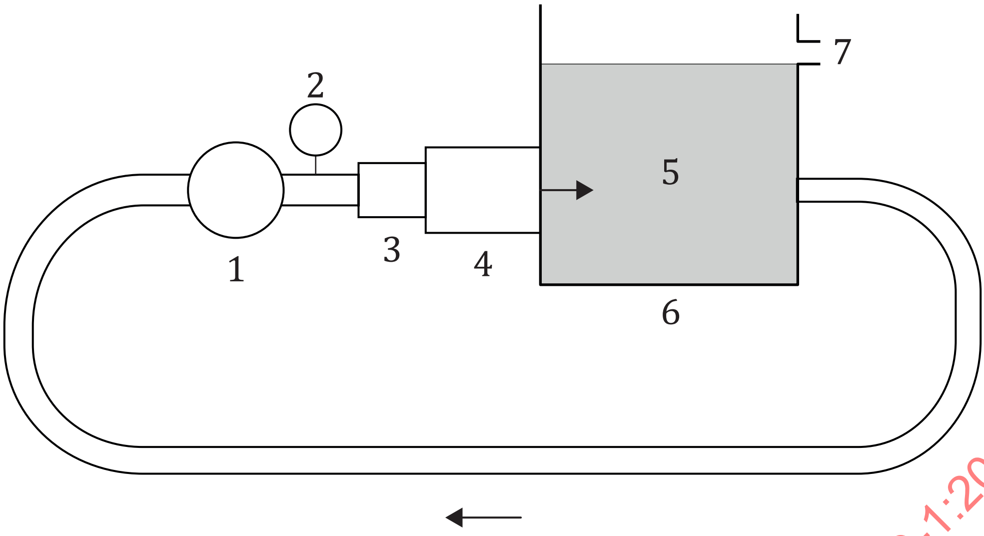
7.4.1 General

A circulation flow configuration shall be used for the evaluation of the nozzle when the concentration is insufficient to measure the size and concentration indices of UFBs.

A circulation flow configuration shall not be used for MBs generated from the nozzle, because size and concentration become unstable.

7.4.2 System configuration for UFBs

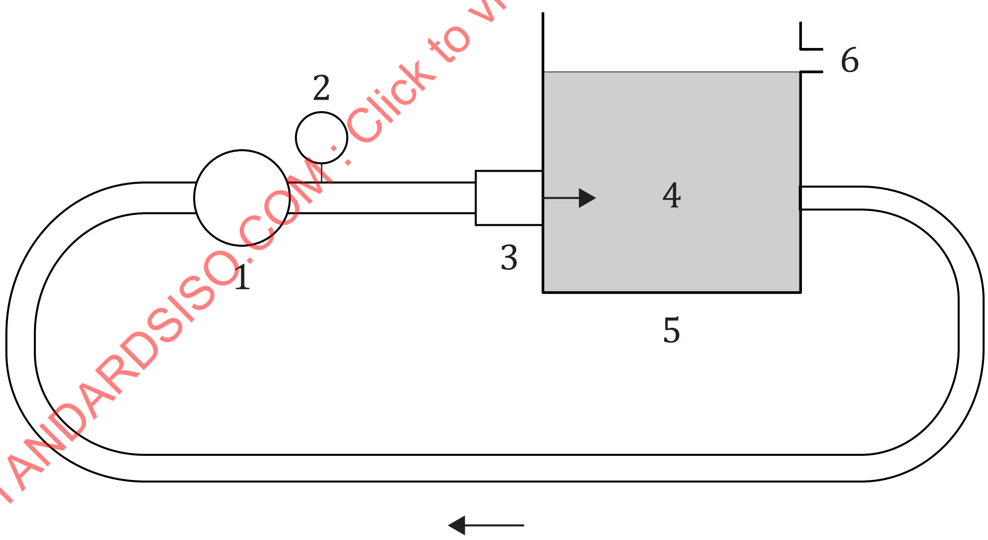
The test system configurations of circulation flow for UFBs are shown in Figures 3 and 4.



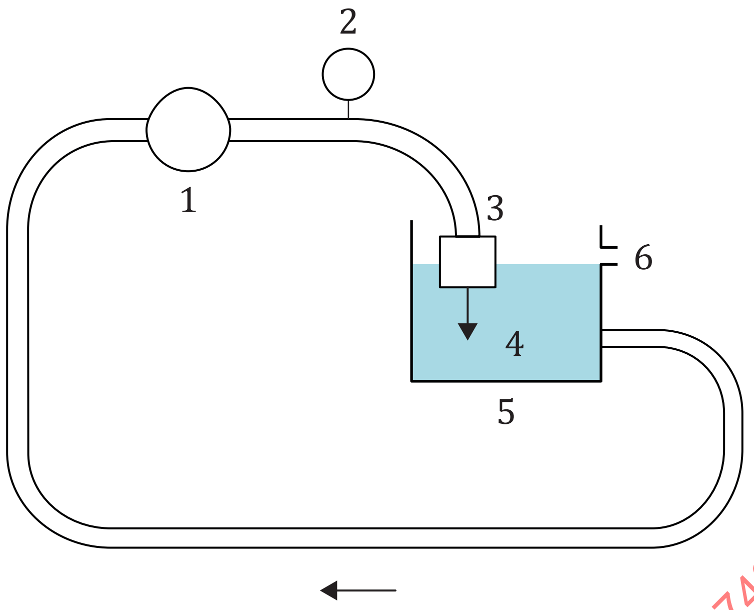
Key

1 pump
2 water pressure meter
3 nozzle
4 piping
5 fine bubble water
6 retention container
7 over flow

Figure 3 — Typical insertion-type nozzle configuration of a circulation-flow test system



a) Direct connection type of nozzle to retention container



b) Submerged type of nozzle in retention container

Key

1 pump

2 water pressure meter

3 open ended nozzle

4 fine bubble water

5 retention container

6 over flow

Figure 4 — Other configurations of circulation flow test systems

Water is circulated between the nozzle and retention container.

The water pressure meter maintains the predetermined water pressure for tests within the minimum fluctuation.

The UFB sample from the retention container shall be acquired in accordance with ISO 20298-1.

7.4.3 Evaluation procedure

The evaluation procedure for circulation flow is as follows:

a) Rinse the fluid-handling components of the test system including the retention container, the pump and the nozzle using raw water to remove the existing contamination of solid particles and liquid.

b) Fill the retention container with raw water.

c) Set the nozzle at the appropriate position in the retention container and start the circulation between the retention container and nozzle.

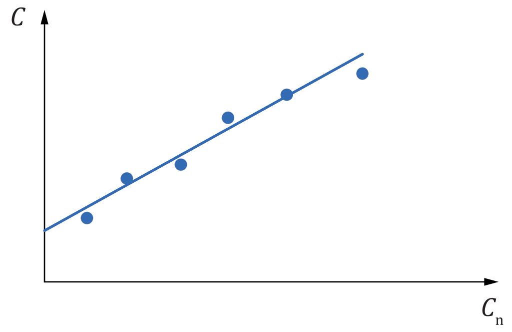
d) Repeat the sampling of the UFBD in water at regular intervals in accordance with ISO 20298-1.

NOTE When the circulation cycle number exceeds a certain level, the concentration reaches saturation and does not increase.

e) Measure the sizes and concentration indices of all samples sampled at step d) and stop the measurement when the concentration exceeds 100 million counts/ml.

f) Plot the relationship between the concentration indices and cycle number of circulations as shown in Figure 5.

g) Determine intercept and gradient from the data plotted as shown in Figure 5, assuming a linear function such as $y = ax + b$. The gradient "a" means the concentration index per 1 circulation cycle and intercept "b" means baseline (see Annex C).



Key

C concentration

C_n circulation cycle number

Figure 5 — Relationship between circulation cycle number and concentration index

An actual test data example is shown in Figure C.1.

7.5 Evaluation of the equilibrium state of microbubble dispersions (MBDs)

7.5.1 General

The half-lives of MBs are very short, the velocity between their generation and elimination is balanced during the circulation of MBs, and the upper limit of the concentration of MBs is reached early. By circulating the flow, the concentration of MBs is maintained at the upper limit.

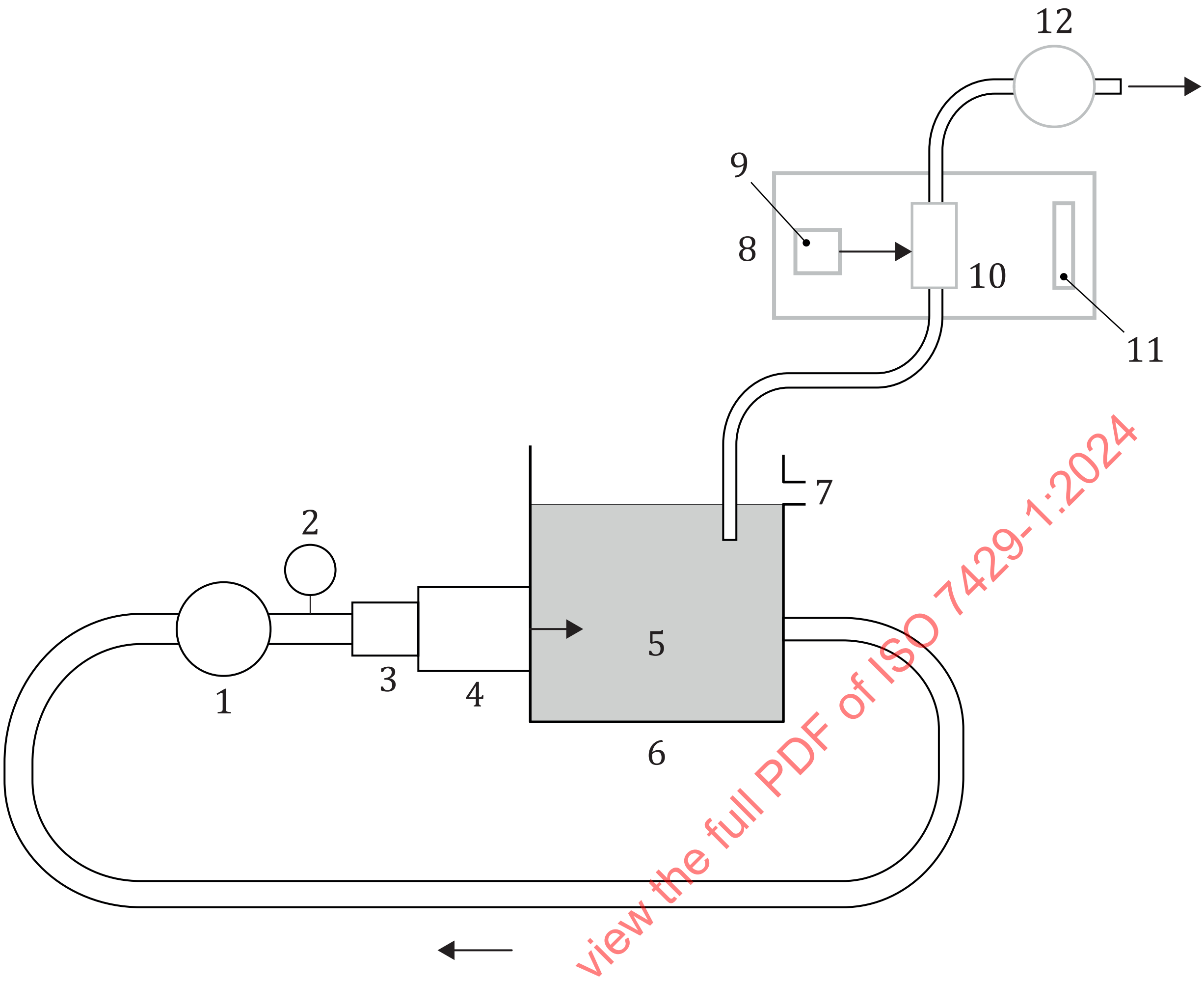
The equilibrium state of the entire system, including the nozzles is applied to various industrial use and consumer use such as the bathtub system. It shall therefore be assessed.

7.5.2 Test system configuration for microbubbles (MBs)

The test system configuration required to produce the equilibrium state of an MBD is shown in Figure 6.

This equilibrium state of the system including the nozzles is very depending on components and conditions affecting the actual system operations for MBs.

Therefore, it is necessary to use a test system that is equivalent to the actual conditions in terms of container volume, size, materials, pipe length, pump, etc.



Key

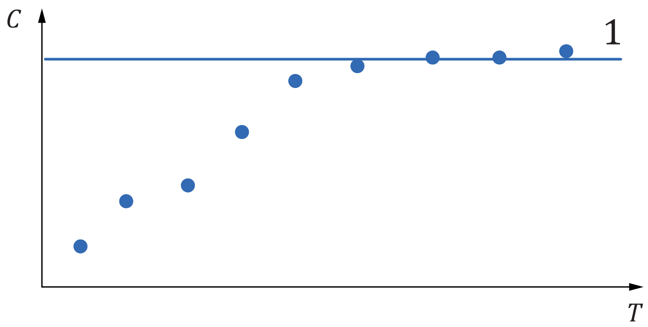
1 pump
2 water pressure meter
3 nozzle
4 piping
5 fine bubble water
6 retention container
7 over flow
8 measuring instrument
9 light source
10 flow cell
11 sensor
12 drain pump

Figure 6 — Typical configuration to produce the equilibrium state of an MBD

7.5.3 Equilibrium state of MBDs

By circulating the flow, the concentration state of MBs is maintained at the upper limit, as shown in Figure 7. The equilibrium status of MBDs is confirmed by evaluating the concentration of MBs.

An actual test data example is shown in Annex D, see Figure D.1.



Key

C concentration

T time

Figure 7 — Equilibrium state of MBDs

7.5.4 Evaluation procedure

The evaluation procedure for the equilibrium state of MBD is as follows.

a) Rinse the fluid-handling components of the test system including the retention container, the pump and the nozzle using raw water to remove the existing contamination of solid particles and liquid.

b) Fill the retention container with raw water.

c) Set the nozzle at the appropriate position in the retention container and start the circulation between the retention container and nozzle.

d) Repeat the sampling of the MBD in water at regular intervals in accordance with ISO 21910-1.

e) Measure the size and concentration indices of all samples sampled at step d).

f) Plot the relationship between the concentration indices and cycle number of circulations as shown in Figure 7.

g) Read the flattened level of MB concentration at the slope slows down over time and eventually flattens out.

8 Test report

The measurements of MBs and UFBs shall be in accordance with ISO 21910-1 and ISO 20298-1, respectively.

For each test of the nozzle device, the report shall include the following information:

a) all information necessary for the complete identification of the nozzle;

b) a reference to this document, i.e. ISO 7429-1:2024;

c) the sampling method for UFBD or the sample transfer method for MBD;

d) the test system configuration (one-way flow or circulation flow);

e) the test results or, if repeatability was checked, the final quoted result obtained;

f) all operating details not specified in this document, or those considered optional, together with details of any incidents, which can have influenced the test results;

g) any unusual features (anomalies) observed during the test;

h) the date of the test and the operator.

For the users of this document who have to review the test results using the test report for conformity assessment activities (including accreditation), the detailed items as shown in Annex E shall be reported in addition to the above-mentioned items, specifically when the test results are intended to be reviewed at conformity assessment activities.

Annex A
(informative)

Detailed examples of nozzle types

A.1 General views of classified nozzle types

The main features of each nozzle type are listed in Table A.1.

Table A.1 — General views of classification by nozzle types

Case	**1**	**2**	**3**
Term of type	Insertion type	Submerged type	Open terminal type
Installation	Installed or connected in the middle of piping	Installed or inserted into a water tank by opening the discharge port (including air diffusers)	Installed as FB water is injected into the atmosphere at the exit
Inlet	Joint connection, e.g. screw or flange, insertion	Joint connection, e.g. screw or flange, insertion	Joint connection, e.g. screw or flange, insertion
Outlet	Threaded or flanged connections	Installation by inserting into a tank or inserting into an access port	Open
Product features	Pipe cleaning that generates FBs in the pipe is possible. It is advantageous for agricultural and fishery technology, in which dissolved oxygen concentration is raised through FB generation by an external air intake in the piping.	— Wet cleaning using FB — Technology to improve dissolved oxygen concentration in the agro- and aqua-cultures — FB generation in bathtubs (consumer use), etc.	Commercialized as a stand-alone product for different applications, including a valve mechanism that includes a generator.

Table A.1 *(continued)*

Advantage	It can be connected in the middle of pipes and hoses that used to provide a simple FB generation function.	— The pressure is not applied (or is low) to the outlet and is not affected by the piping or equipment after the FB generating section. Therefore, the gas can be self-primed, and the FB generating function can be achieved. — A circulation system can be constructed, and it is therefore possible to increase the bubble concentration.	FB generation function that passes through the air and contacts the object. Easy to create a water flow pattern. It is less affected by water depth and water pressure than other methods.
Disadvantage	— Bubble characteristics of water immediately after passing through the nozzle alone are different from those when FBs are used, because the water is affected by the piping and water-conducting equipment after flowing through. — If pressure is applied to the outlet, it will not self-absorb gas. — The bubble concentration is low because of the 1-pass configuration.	— There are often restrictions on the installation of the water discharge component as well as on the installation of the water discharge part; and the water pressure at the depth shall be considered. — Water pressure at the depth of the water shall be considered, and the location is limited by the requirement for a generation tank.	The flow rate required for the purpose is often restricted.
Issues for use	The performance evaluation of a single nozzle and its incorporation in a device can differ. Causes include mismatch with water volume and pressure as well as instrumental effects after passing through the nozzle, which require attention to the overall system configuration.	Prerequisite for use in a water tank. If the required flow rate and other parameters are insufficient and the target performance level cannot be achieved, equipment such as a pump or blower compressor will be required.	When the amount of water is limited to the target object, there is a wide range of installation patterns and sizes to balance the flow rate.

A.2 Examples of nozzle structures

Detailed examples of nozzle structure types are shown in Table A.2.

Table A.2 — Examples of nozzle structure types

Case	1		2		3
Term of type	Insertion type		Submerged type		Open terminal type
Classification	FB adapter	UFB shower	UFB adapter	FB nozzle	FB nozzle
Function	FB generation	FB generation	Shear	Cavitation and mixing	FB and water flow pattern
Features	The air intake system is designed on a case-by-case basis by inserting it into the middle of the piping.	Connect the air intake adapter and then the UFB adapter to the hose.	UFB baths	Size selection according to the flow rate	Create a water flow containing FBs as a discharge port
Materials	Plastics or metal	Plastics or metal	Plastics	SUS	Plastics or metal

Table A.2 *(continued)*

Specifications	Inlet	Threaded or flanged connections to match the diameter	Air intake female adapter G1/2 on the inlet port side connecting the male	Submerged	Submerged	Screw thread
	Outlet	Threaded or flanged connections to suit the bore diameter	Air intake adapter G1/2 female on the hose inlet side connecting male	Pump	Submerged	Open
Applications	Industrial	Yes	Yes		Yes	Yes
	Domestic	Yes	Yes	Yes		
	Agro- and aqua-culture	Yes	Yes		Yes	Yes

A.3 Examples of market characteristics by nozzle type

Detailed examples of market characteristics by nozzle types are shown in Table A.3.

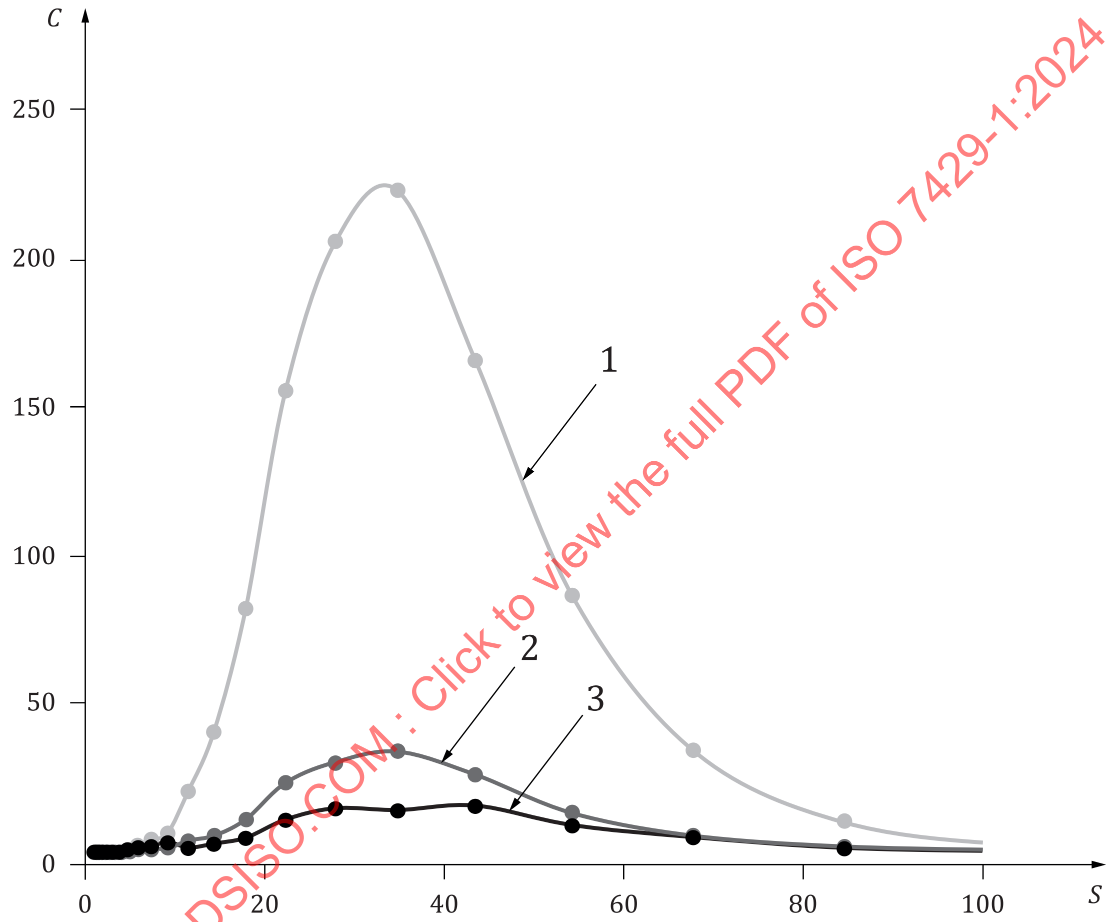
Table A.3 — Examples of market characteristics by nozzle type

Case	**1**	**2**	**3**
Term of type	Insertion type	Submerged type	Open terminal type
Typical application areas	Industrial, agro- and aquacultural, domestic etc.	Industrial, agro- and aquacultural, domestic etc.	Industrial, agro- and aquacultural, domestic etc.
Application Overview	— This pattern is common among manufacturers of each nozzle type. — The price range is variable. — In some cases, the existence of FBs is unconfirmed.	— Nozzles for hot water supply in baths and water supply in tanks in agriculture and fisheries. — It is difficult for a nozzle to perform well by itself compared to a pump or other device.	Most are embedded in equipment.
Cleaning applications	Incorporate the nozzle in the middle of the piping and mix FBs into the water.	FBs are generated in the washing tank and used for soaking and washing.	Directly apply flowing water to the object and include FBs in the water flow for flushing clean.
Agro- and aqua-cultural applications	Installed in the middle of irrigation piping.	— Installed in a water storage tank for irrigation. — Air diffusion fisheries and water treatment plants.	Installed at each water outlet for irrigation. Also used for washing.
Domestic applications	Nozzle attached to shower hose or washing-machine connection hose.	For bathing. However, it is not a bathing device with a pump.	Hand-wash basins and kitchen tubs. However, it is not the main body of the runner that provides the FB function.
Marketability, etc.	There are advantages such as integration into equipment.	There is a high possibility that FBs are included in the final discharge water of a water tank, etc., and it is therefore easy to increase reliability. Terminal shape restrictions for embedded products.	Can be commercialized as a stand-alone product with a valve mechanism that includes a generator.

Annex B
(informative)

Relation between fine bubble generation amount and water depth

Figure B.1 demonstrates the particle size distribution of microbubbles at each discharge pressure. As the discharge pressure increases (i.e. as the water depth increases), the peak height of the particle size distribution decreases.



Key

C concentration [MBs ml^{-1}]

S size [µm]

1 0 MPa (atmospheric pressure)

2 0,025 MPa (depth of water, about 2,5 m)

3 0,05 MPa (depth of water, about 5 m)

Figure B.1 — Particle size distribution of microbubbles per discharge pressure

The total number concentration of microbubbles obtained from the particle size distribution in Figure B.2 is plotted against the discharge pressure as affected by the water depth.

The number concentration of microbubbles generated decreases, as the discharge pressure increases with increase of the water depth.