

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS B 9946 : 2019

(JOA/JSA)

**Ozone treatment apparatus for
water and wastewater including
other oxidation uses—
Specifications of apparatus and
measurement methods for ozone
concentration**

ICS 13.060.25;13.060.30

Reference number : **JIS B 9946 : 2019 (E)**

Date of Establishment: 2011-11-21

Date of Revision: 2019-08-20

Date of Public Notice in Official Gazette: 2019-08-20

Investigated by: Japanese Industrial Standards Committee
Standards Board for ISO area

JIS B 9946:2019, First English edition published in 2021-05

Translated and published by: Japanese Standards Association
Mita MT Building, 3-13-12, Mita, Minato-ku, Tokyo, 108-0073 JAPAN

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Ozone Association (JOA)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS B 9946:2011**), which has been technically revised.

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NOTE Based on Article 9 of the Supplementary Provisions to the Unfair Competition Prevention Act etc., any submission of proposal, or employment of procedures such as deliberation by the Japanese Industrial Standards Committee under the previous Industrial Standardization Act shall be deemed to have been conducted pursuant to the provision of Article 12, paragraph (1) of the revised Industrial Standardization Act.

Ozone treatment apparatus for water and wastewater including other oxidation uses—Specifications of apparatus and measurement methods for ozone concentration

Introduction

This Japanese Industrial Standard was established in 2011 and has been revised at this time mainly to respond to the advance in technology of ozone resistant materials and the increased availability of ozone treatment apparatus.

No corresponding International Standard has been established at this point.

Persons using this Standard should be familiar with properties and proper handling of artificially-generated ozone and its relevant apparatus, as well as any applicable regulations. Due attention should also be paid to health of workers during ozone measurements.

1 Scope

This Standard stipulates general specification items (performance requirements) for ozone treatment apparatus (hereafter referred to as treatment apparatus) used in such areas as industrial water and wastewater, sewage water and drinking water, as well as the methods of ozone concentration measurement.

This Standard is applicable to treatment apparatuses with a rated ozone generation capacity (total generation capacity if the apparatus consists of a series of ozone-generating processes) of 0.5 kg/h or greater.

The method for calculation of this capacity is provided in Annex A.

NOTE A treatment apparatus is used for the purposes of destruction of organic substances and trace toxic substances, disinfection, and decolouring and deodourizing. The apparatus consists of a series of processes or units, including ozone generation, ozone contact, and ozone destruction at ozone concentration control points (hereafter referred to as process control points) where ozone concentrations are properly measured and controlled.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 7957 *Continuous analyzers for ozone and oxidants in ambient air*

JIS B 8265 *Construction of pressure vessel—General principles*

JIS K 0804 *Gas detector tube measurement system (Length-of-stain type)*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions apply.

3.1

ozone

molecule consisting of three oxygen atoms

3.2

generated ozone amount

amount of ozone generated by an ozone generator in a unit time

3.3

ozone concentration

volume, mass or mole of ozone in a unit volume or unit mass of gas or liquid

3.4

chemical analysis

analytical methods that apply to the samples in gas-washing bottles or sample containers and are based on such methods as titration and spectrophotometry, but excluding continuous analyses

3.5

ozone monitor

instrument capable of measuring ozone concentration in samples continuously

3.6

ozone detector

device or instrument capable of measuring ozone concentration easily

3.7

generated ozone concentration

ozone concentration at the outlet of an ozone generator

3.8

ozone dosage

mass of ozone (g) injected into a unit volume of water (m^3)

Ozone dosage is expressed in units of mass-per-volume concentration (g/m^3 or mg/L).

3.9

waste ozone concentration

ozone concentration at the outlet of an ozone contactor

3.10

exhaust ozone concentration

ozone concentration at the outlet of a waste ozone treatment unit

3.11

required ozone amount

amount of ozone required for the intended treatment

3.12

dissolved ozone concentration

concentration of ozone that is dissolved in an aqueous phase

3.13

ambient ozone concentration around ozone treatment apparatus

concentration of ozone in the ambient air around the treatment apparatus

3.14

characteristic curve between ozone generator-input power and generated ozone concentration

characteristic curve that shows the relationship between the ozone generator power input and the generated ozone concentration

3.15

gravimetric method

analytical method that is based upon the measurement of aqueous sample mass and subsequently converts the mass into a volume

3.16

volumetric method

analytical method that is based upon the measurement of a given volume of aqueous samples by means of a device such as a pipette

3.17

input power

electric power at a power supply inlet side

3.18

electrical power consumption rate

input electric energy per unit generated ozone amount (kWh/kg-O₃)

It is used as a performance index of an ozone generation unit.

NOTE The ozone generation performance may be indicated by yield [generated ozone amount per unit input power (kg-O₃/kWh)].

4 Configuration

A treatment apparatus consists of a feed gas supply unit, an ozone generation unit, an ozone contact unit, and a waste ozone treatment unit as shown in Figure 1. In the figure, the process control points are shown as M1 to M4 (within the apparatus) and as M5 (ambient air around the apparatus).

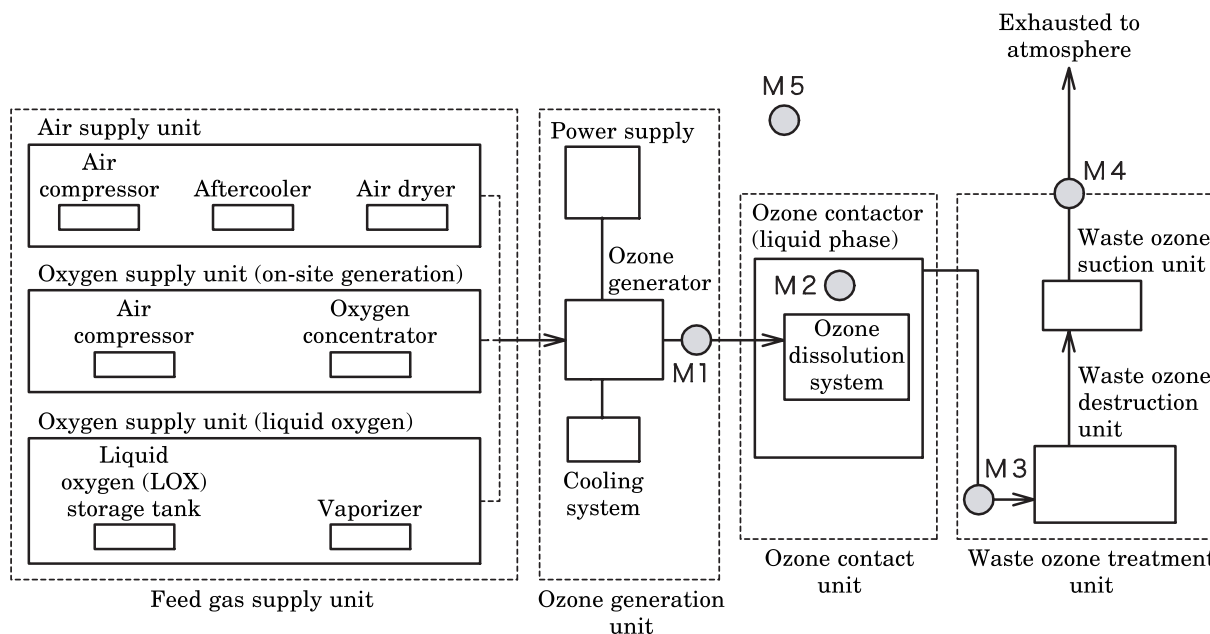


Figure 1 Basic configuration of treatment apparatus

a) **Feed gas supply unit** The feed gas supply unit feeds either air or oxygen gas to the ozone generation unit. An air supply described in 1) is used in an air-fed ozone system. An oxygen concentrator described in 2) or liquid oxygen storage system in 3) is used in an oxygen-fed ozone system.

1) **Air supply unit**, typically consisting of an air compressor or blower, an after-cooler, and an air dryer.

- The air compressor feeds compressed air into the aftercooler.
- The aftercooler removes the heat of air compressed in the air compressor by heat exchange. Air-cooled heat exchanger, water-cooled heat exchanger or refrigerant dryer, either singularly or in combination, may be used.
- The air dryer removes moisture from cooled air. For the moisture removal, an activated alumina or zeolite desiccant may be used. Multiple desiccant dryers are operated in an alternating drying and regeneration cycle to produce dried air continuously.

2) **Oxygen supply unit (on-site oxygen generation)**, typically consisting of an air compressor or blower and an oxygen concentrator.

- The air compressor feeds compressed air into the oxygen concentrator.
- The oxygen concentrator enriches oxygen in the air. Impurities such as nitrogen and carbon dioxide are removed by molecular sieve media to achieve a feed gas with $\geq 90\%$ oxygen.

NOTE An oxygen concentrator is also referred to as an oxygen producing device or an oxygen generator.

3) **Oxygen supply unit [from liquid oxygen (LOX)]**, typically consisting of LOX storage tank(s) and vaporizer(s).

- The LOX storage tank stores LOX.
- The vaporizer vaporizes LOX from the LOX storage tank to gaseous oxygen.
- b) **Ozone generation unit**, typically consisting of ozone generator(s), a power supply, and a cooling system. Corona discharge (dielectric barrier discharge or creeping discharge) is currently the most common ozone generation method.
 - 1) **Ozone generator**, for artificially producing ozone from an oxygen-containing feed gas primarily by means of corona discharge.
 - 2) **Power supply**, for supplying electric power to the ozone generator at the voltage and frequency appropriate for ozone generation. A power supply unit typically consists of combination of inverters, step-up transformers, etc.
 - 3) **Cooling system**, for removing the heat generated by the excess energy at the ozone generator. Either an air-cooled or a water-cooled system may be used.
- c) **Ozone contact unit**, typically consisting of ozone contactor(s) and an ozone dissolution system.
 - 1) **Ozone contactor**, a tank where ozone is dissolved in water and reacts with target substance(s).
 - 2) **Ozone dissolution system**, for dissolving ozone gas in water. Dissolution methods include bubble diffusion, down flow tube injection, venture injection, and mechanical agitation.
- d) **Waste ozone treatment unit**, typically consisting of a waste ozone destruction unit and a waste ozone suction unit. However, no waste ozone suction unit is necessary if the ozone contactor is completely sealed.
 - 1) **Waste ozone destruction unit**, for destroying ozone exhausted from the ozone contactor into oxygen. Activated carbon, catalyst media, and heat can be used for the waste ozone destruction.
 - 2) **Waste ozone suction unit**, for withdrawing waste ozone from the ozone contactor and sending it into the waste ozone destruction unit. An air blower fan is typically used.
- e) **Process control point** Typically, ozone concentrations are measured at the process control points (M1 to M5) shown in Figure 1. Gas-phase ozone concentrations are measured at the process control points M1, M3, M4, and M5, whereas liquid-phase ozone concentrations are measured at the process control point M2. Based on the measured values at these points, the performance of treatment apparatus is verified, controlled, optimized, and maintained.

The following ozone measurement methods are used at the process control points.

- Chemical analyses for determining ozone concentration
- Ozone monitors for determining ozone concentration
- Ozone detectors for simple measurement

NOTE For the detailed configuration of an ozone treatment apparatus, see Reference [1] in Bibliography.

5 Specifications and requirements

5.1 Feed gas supply unit

5.1.1 Specifications

The manufacturer and user (hereafter referred to as the interested parties) of the treatment apparatus shall determine appropriate criteria for the following specification items.

- a) Feed gas characteristics (including gas type, dew-point temperature, and oxygen concentration)
- b) Feed gas flow rate
- c) Operating temperature, humidity, and other related parameters

5.1.2 Performance requirements

The performance requirements for feed gas supply unit shall be as follows.

- a) The dew-point temperature (under atmospheric pressure) of feed gas shall be $-50\text{ }^{\circ}\text{C}$ or less unless specified otherwise in presence of specific conditions upon agreement between the interested parties.
- b) The air supply unit and oxygen supply unit (on-site oxygen generation) shall conform to the requirement specified in **JIS B 8265** according to the operating pressure and container size.
- c) The oxygen supply unit (from LOX) of a greater capacity than specified shall conform to the requirements in **JIS B 8265**, as well as to the relevant laws and regulations such as the High Pressure Gas Safety Act and Fire Service Act.
- d) An air compressor, if used, shall have specifications satisfying the rules and regulations stipulated in the Noise Regulation Act and Vibration Regulation Act relevant to its capacity.
- e) A refrigerator in the air supply unit, if used, shall satisfy the rules and regulations stipulated in the High Pressure Gas Safety Act.
- f) All parts contacting with $\geq 25\%$ oxygen gas shall be oil-free.

5.2 Ozone generation unit

5.2.1 Ozone generator

5.2.1.1 Specifications

The interested parties shall determine appropriate criteria for the following specification items.

- a) Generated ozone amount and generated ozone concentration
- b) Cooling system, primary-side refrigerant temperature, and water quality (when a water-cooling system is used)
- c) Operating temperature, operating humidity, and other related parameters

- d) Maximum operating pressure

5.2.1.2 Performance requirements

The performance requirements for an ozone generator are as shown in Table 1.

Table 1 Performance requirements for ozone generator

Item	Requirement
Ozone leakage	There shall be no ozone leakage.
Earthing	Ozone generator shall be properly earthed according to its operating voltage and capacity.
Material	All parts contacting with ozone shall be ozone resistant.
Insulation resistance (between live part and earth)	$\geq 5 \text{ M}\Omega$ at 1 000 V DC
Mechanical pressure tightness	— A safety valve, pressure switch, or other means for preventing pressure rise shall be provided. — No leakage at water pressures lower than 1.5 times the maximum operating pressure or at gas pressures lower than 1.25 times the maximum operating pressure.
Oil-free treatment	All parts contacting with ozone or $\geq 25 \%$ oxygen gas shall be oil-free.
NOTE See B.2 for additional notes on ozone generator requirements.	

5.2.2 Power supply

5.2.2.1 Specifications

The interested parties shall determine appropriate criteria for the following specification items.

- a) Input current, input voltage, and input frequency
- b) Output current, output voltage, and output frequency
- c) Power supply capacity
- d) Operating temperature, humidity, and other related parameters

5.2.2.2 Performance requirements

The performance requirements for a power supply are as shown in Table 2.

The power supply for the insulation resistance test shall be an a.c. source of approximately sinusoidal waveform at 50 Hz or 60 Hz, having a 500 VA or greater capacity, and capable of providing a uniform voltage rise from zero to the specified test voltage.

Table 2 Performance requirements for power supply

Item	Requirement
Earthing	Steel base and metallic casing of the power supply equipment shall be properly earthed according to its operating voltage, intended purpose and capacity. A circuit breaker shall be provided as appropriate for the place of use.
Insulation resistance	$\geq 5 \text{ M}\Omega$ at 1 000 V DC
Dielectric strength	Stable when the applied voltage increases in gradual steps (at a speed measurable by a voltmeter) from zero to the following test voltages and is held for 1 min: — 10 kV ($2.2 \text{ kV} < \text{rated voltage} \leq 3.6 \text{ kV}$) — 16 kV ($3.6 \text{ kV} < \text{rated voltage} \leq 7.2 \text{ kV}$)
High voltage and high frequency	Electric shock prevention (e.g. protection cover, interlock) and harmonics suppression (e.g. filter) are required.
NOTE See B.3 for additional notes on power supply requirements.	

5.2.3 Cooling system

5.2.3.1 Specifications

The interested parties shall determine appropriate criteria for the following specification items.

- a) Cooling capacity
- b) Coolant type
- c) Operating temperature, humidity, and other related parameters

5.2.3.2 Performance requirements

A cooling system shall be designed to have a sufficient corrosion resistance and durability to cooling water, cooling air etc.

5.3 Ozone contact unit

5.3.1 Ozone contactor

5.3.1.1 Specifications

The interested parties shall determine appropriate criteria for the following specification items.

- a) Ozone dosage
- b) Water flow rate
- c) Contactor capacity
- d) Water depth
- e) Operating temperature, humidity, and other related parameters

5.3.1.2 Performance requirements

The performance requirements for a ozone contactor are as shown in following.

- a) The ozone contactor shall be sealed during water and wastewater treatment. If a concrete tank, which cannot be completely sealed, is used, a negative pressure shall be maintained in the headspace above water by a waste ozone suction unit.
- b) All parts contacting with ozone or ozonated water shall be made of ozone resistant material.
- c) Measures shall be provided to prevent treated water from back-flowing from the ozone contactor into the ozone generator.

NOTE See **B.4** for additional notes on ozone contactor requirements.

5.3.2 Ozone dissolution system

The interested parties shall determine appropriate criteria for the following specification items.

- a) Dissolution method
- b) Gas flow rate
- c) Operating temperature and pressure

5.4 Waste ozone treatment unit

5.4.1 Waste ozone destruction unit

5.4.1.1 Specifications

The interested parties shall determine appropriate criteria for the following specification items.

- a) Waste ozone destruction method
- b) Catalyst type and amount (if catalyst is used)
- c) Applicable waste ozone concentration range, exhaust gas temperature and flow rate
- d) Operating temperature, humidity, and other related parameters

5.4.1.2 Performance requirements

The performance requirements for a waste ozone destruction unit are as shown in following.

- a) The waste ozone destruction unit shall be capable of achieving exhaust ozone concentration below 0.4 ppm.
- b) All parts contacting with ozone shall be made of ozone resistant material suitable for the concentration level.
- c) When the exhaust gas from the ozone contact unit contains bubbles and other substances which inhibit ozone destruction, a device for defoaming, washing, etc. the exhaust gas shall be provided so as to secure the performance of the waste ozone treatment unit.
- d) A unit using pyrolysis method shall be made of a material suitable for the operating temperature, structured to prevent direct human access to the hot parts, and

be heat-insulated and isolated from other equipment in accordance with the Fire Service Act.

NOTE Emission standard concentration of ozone for ensuring safety to people and environment is below 0.4 ppm; this concentration level is equivalent to that of the critical emergency official announcement of oxidants stipulated in Appended Table 5 of Order for Enforcement of the Air Pollution Control Act.

5.4.2 Waste ozone suction unit

The interested parties shall determine appropriate criteria for the following specification items.

- a) Waste ozone suction fan performance (such as air flow rate and suction pressure)
- b) Applicable waste ozone concentration range and exhaust gas temperature
- c) Operating temperature, humidity, and other related parameters

6 Ozone resistant materials

Ozone resistant materials shall be used for the parts and locations in a treatment apparatus where ozone gas and/or ozonated water comes into contact with equipment, auxiliary devices, pipes, valves, sensors, joints and instruments, sealants, and gaskets. Examples of ozone resistant materials are shown in Table 3.

These ozone resistant materials shall be selected based on specific ozone usage and conditions, such as dry or wet, and high or low concentration. Also, materials that can be replaced regularly shall be used to maintain their proper function and performance.

NOTE In order to enhance the performance more, the surface of ozone resistant materials may be lined with such materials as PFA, PTFE, PVC or titanium plate.

Table 3 Examples of ozone resistant materials

Unit	Equipment	Applicable ozone resistant material
Ozone generation unit	Ozone generator	SUS304, SUS316L, SUS821L, SUS323L, SUS329J3L, glass, ceramics, aluminium (with anticorrosion treatment), PTFE, EPDM, CSM, FFKM
	Cooling system	SUS304, SUS821L, SUS323L, titanium, FRP, brass
Ozone contact unit	Ozone contactor	Concrete, mortar, SUS304, SUS316L, SUS821L, SUS323L, SUS329J3L, PVDF, PVC, PTFE, FRP ^{a)} , EPDM, CSM, FFKM
	Ozone dissolution system	Ceramics, SUS304, SUS316L, SUS821L, SUS323L, SUS329J3L, PVDF
Waste ozone treatment unit	Waste ozone destruction unit	SUS304, SUS821L, SUS323L, PTFE, PVDF, FRP ^{a)} , EPDM, CSM, FFKM
	Waste ozone suction unit	SUS304, SUS821L, SUS323L, PVC, FRP ^{a)}
Note ^{a)} Recommended only where ozone concentration is below 100 ppm.		