Instruction Manual

Calibration gas generator
Permeater

PD-1C

Important Notices

Read this manual thoroughly before use.
Keep this manual with product in a safe place.

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IM07PD1CE2

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1. Introduction

Read and understand instruction manuals before use.

- "Permeater PD-1C Instruction manual (this document)"
- " Operation Manual for Permeation Tube"
- "Operation Manual for Diffusion Tube"

Before using this instrument, read these manuals carefully and use the products correctly according to their contents.
Keep the manuals in a safe place for future reference.

About this instruction manual

■ Do not use this instrument until you understand the contents of the instruction manual.
■ When lending or transferring this instrument, be sure to attach the instruction manual to the instrument.
■ If the instruction manual or warning labels are lost or damaged, immediately contact our sales department or distributor.
■ The instruction manual contains instructions for safe operation. Please read "2. Safety Precautions"carefully before use.

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2. For safe use

■ To use this instrument correctly, be sure to observe the following warning statements. The warnings are serious safety instructions.
■ This instrument is a calibration gas preparation instrument. Do not use it for any purpose other than the intended use.
■ This instrument must only be used by specialists skilled in the handling of chemicals.
■ When preparing calibration gases with this instrument, use permeation tubes (hereinafter referred to as P-tubes) and diffusion tubes (hereinafter referred to as D-tubes) of GASTEC products.

GASTEC Corporation shall not be responsible for any accident that occurs in a situation that is contrary to the above items.

On the product and in the instruction manual, warnings and safety precautions are classified according to the magnitude and urgency of the danger or damage, using the following indications. The marks and symbols may differ from the actual product in shape, size and position. In addition, the following symbols are used to ensure the correct and safe use of the product.

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⚠WARNING: This symbol indicates a potentially hazardous situation that, if not avoided, will result in death or serious injury to the operator.
△NOTE: This means advice for proper use, such as the prevention of product failure.

	This means that toxic/skin corrosive/health hazardous gas or liquid is generated, which may cause death or serious injury.
	This means that flammable, inflammable, combustible or oxidizing gas or liquid is generated and there is a risk of ignition or catching fire.
	This means that there is a risk of bursting/eruption. This means that there is a risk of high concentration of gas.

⚠WARNING

① Many of the calibration gases prepared by this instrument are toxic, skin corrosive, health hazardous or environmental hazardous, so they should be used in a local exhaust ventilation system or in a place with adequate indoor ventilation.

② Keep away from ignition sources such as high heat, high temperatures, sparks, open flames, cigarettes, etc., as many of the calibration gases prepared by this instrument are flammable, combustible, or oxidizing.

③ When handling P-tubes and D-tubes, be sure to wear appropriate protective equipment such as protective glasses, impervious protective clothing, protective gloves or footwear.

④ Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.

⑤ This instrument is not explosion-proof. Do not allow calibration gas to come in contact with any part other than the calibration gas path.

⑥ P-tubes are sealed in intermediate packaging and storage(inner) packaging. To prevent inhalation of toxic gases, the intermediate packaging and storage(inner) packaging of the P-tube should be opened in a local exhaust ventilation system.

⑦ Always work in the local exhaust ventilation system when filling organic solvents into D-Tube.

⑧ If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion. The temperature setting of PD-1C should be set below the "maximum temperature" on the P-tube storage container label.

⑨ If the temperature inside the TUBE HOLDER exceeds the "maximum temperature" on the P-tube storage container label, immediately switch to the clean-up mode with the TUBE HOLDER lid closed. Do not open the lid of the TUBE HOLDER because high concentration of gas may be accumulated in the TUBE HOLDER. Remove and Dispose of the P-tube after 24 hours of dilution gas flow.

⑩ After use, P-tubes should be disposed of properly in accordance with the "Operation Manual for Permeation Tube".

⑪ Once the P-tube has exceeded the "maximum temperature" on the P-tube storage container label, do not reuse it.

⑫ Do not apply external pressure or shock to the P-tube, or do not scratch or cut the P-tube. The internal liquefied gas may be gushed out. Gas pressure may remain even when there is no liquid remaining in the P-tube, such as when disposing of the P-tube.

⑬ If any abnormality is found in the appearance of the P-tube, corrosion of the stainless steel crimps, or cracks in the fluoroplastic tubing, immediately discontinue use and discard the P-tube.

⑭ Do not open the TUBE HOLDER when a power failure occurs with P-tube or D-tube in it, as highly concentrated gas will accumulate in the TUBE HOLDER. P-tube and D-tube should be removed after at least 30 minutes of dilution gas flow.

⑮ P-tubes and D-tubes should be loaded into and removed from the TUBE HOLDER with the dilution gas always flowing. If the dilution gas is stopped, highly concentrated gas will be generated.

⑯ Remove the P-tube when the PD-1C is not in use. If the P-tube is left in the TUBE HOLDER with the dilution gas stopped, a high concentration of gas will accumulate.

⑰ P-tubes/D-tubes should be loaded into the TUBE HOLDER after at least 30 minutes of dilution gas flow. If the P-tube or D-tube was not removed at the last time of use, there is a possibility that highly concentrated gas may have accumulated in the TUBE HOLDER.

⑱ P-tubes should be sealed and stored in the storage container provided with the P-tube. The maximum storage temperature is indicated on the P-tube storage container as "-5°C or lower" or "25°C or lower". The minimum storage temperature is -25°C. If P-tubes are stored at temperatures lower than -25°C, there is a possibility of temporary leakage of filling gas due to the difference in expansion coefficients of the tubes and crimps when they are returned to room temperature.

⑲ Dilution gas must be supplied through a dustproof filter. If a dust filter is not used, the flow controller may malfunction or the flow accuracy may deteriorate.
- Use a dust filter which is capable of withstanding a pressure of 1.2 MPa or higher.
- The dust filter should be replaced in a timely manner as it may be blocked after prolonged use.

⑳ When using air compressed by an oilless compressor for dilution gas, remove airborne contaminants through an activated carbon or silica gel before the dust filter.
- Use a cylinder which is capable of withstanding a pressure of 1.2 MPa or higher to fill activated carbon

or silica gel.
・Activated carbon and silica gel should be replaced in a timely manner as they become contaminated with long-term use.

㉑ To prevent electrical shock, use a power outlet with a protective ground connection. If the power cord does not connect to protective earth, connect the GND terminal on the backside of the main unit to protective earth.

㉒ Do not open the case of the main unit. There is a risk of electric shock due to the 100-240 V AC wiring inside the main unit. There is also a risk of injury from the cooling fan.

㉓ Do not disassemble or modify this instrument. Failure to do so may result in electric shock, fire, gas leakage or malfunction.

㉔ Do not insert anything into or through the ventilation holes on the back or bottom of the main unit. Doing so may cause electric shock, fire, gas leakage, or malfunction.

㉕ Use a power cord that complies with the laws and regulations of the country/region where this instrument is used and meets the safety requirements of that country/region. Handle the cord in accordance with the following warnings. Failure to do so may result in electric shock, fire or malfunction.
・Do not modify the power cord.
・Do not bend the power cord.
・Do not pull on the power cord.
・Do not place heavy objects on the power cord.
・Keep the power cord away from heat sources.

㉖ Do not use fuses of differing ratings. Failure to do so may cause an electric shock, fire or malfunction.

㉗ Do not subject this instrument to vibration. Vibration may loosen tubes, piping connections, etc., causing the calibration gas to leak.

㉘ Do not use or store the instrument with condensation. Doing so may cause electric shock, fire, or malfunction.

㉙ When moving or transporting the instrument, remove the P-tube/D-tube, disconnect the power cord, dilution gas piping, and calibration gas piping, and drain the water from the temperature water bath. Do not move the instrument on its side or upside down. There is a possibility of electric shock or malfunction.

㉚ Do not use the instrument under abnormal conditions such as unusual smells or noises. Doing so may cause electric shock, fire, or gas leakage.

㉛ If the power cannot be turned off using the power switch due to a Switch malfunction or other reason, pull the power cord out of the AC INLET or unplug it from the power outlet.

△Note:

① Dilution gases should be supplied at pressures between 0.15 and 0.6MPa. Exceeding 0.6MPa may cause damage the instrument.

② Use Nitrogen or Air as the dilution gas. Use of other gases may cause abnormal flow or internal corrosion.

③ Do not apply strong shocks. Failure or loss of accuracy may occur.

④ Do not use the instrument in a strong electromagnetic field, a strong electric field, or a strong magnetic field. Failure, loss of accuracy, or malfunction may occur.

⑤ Open the ventilation holes on the rear side of the instrument with a clearance of at least 5 cm. Do not

block the ventilation holes on the bottom. The water temperature may not reach the set value or the temperature accuracy may deteriorate. Also, the life of the internal electronic components may be shortened.

⑥ To maintain temperature uniformity in the TUBE HOLDER, check that the water level is within the H to L level of the WATER, and pour water when the water level is near the L level. During use, the water level will gradually decrease.

⑦ Even when this instrument is not in use, water should be changed at least once every three months. Water should also be changed if the water level gauge is dirty or if the water visible through the window of the water level gauge is dirty. Using dirty water may shorten the life of the pump and heater or cause the water level sensor to malfunction and fail to detect a drop in the water level. If the water level drops, the heater will run dry and fail.

⑧ Set the water temperature at least 5°C higher than the temperature of the location where the instrument is used.

⑨ When running the calibration gas, do not cause pressure fluctuations in the flow path. The flowmeter is calibrated with the outlet open. If pressure is applied to the outlet, the true flow rate cannot be obtained.

⑩ Calibration gas is supplied from two outlets. If pressure is applied to one of the outlets, the calibration gas may flow to one of the outlets without load, and the gas may not be led to the other outlet. When using the calibration gas, do not apply pressure to the outlet. Conversely, if a flow rate greater than the set flow rate is taken from one outlet, the atmosphere will be drawn in from the other unloaded outlet. Calibration gas should be taken within the set flow rate.

⑪ When the other outlet is blocked in order to use the calibration gas at the set flow rate, be careful not to cause pressure fluctuations in the instrument.

⑫ A mass flow controller is used to control the dilution gas, and the flow rate is a value converted to 25°C, 1 atm. Flow rate accuracy is guaranteed only for nitrogen and air.

⑬ When using several P-tubes of different types in the TUBE HOLDER, make sure that the gases do not chemically react with each other.

⑭ Avoid direct hand contact with the surface of the effective part of P-tube. If the surface is contaminated, the specified permeation rate cannot be obtained.

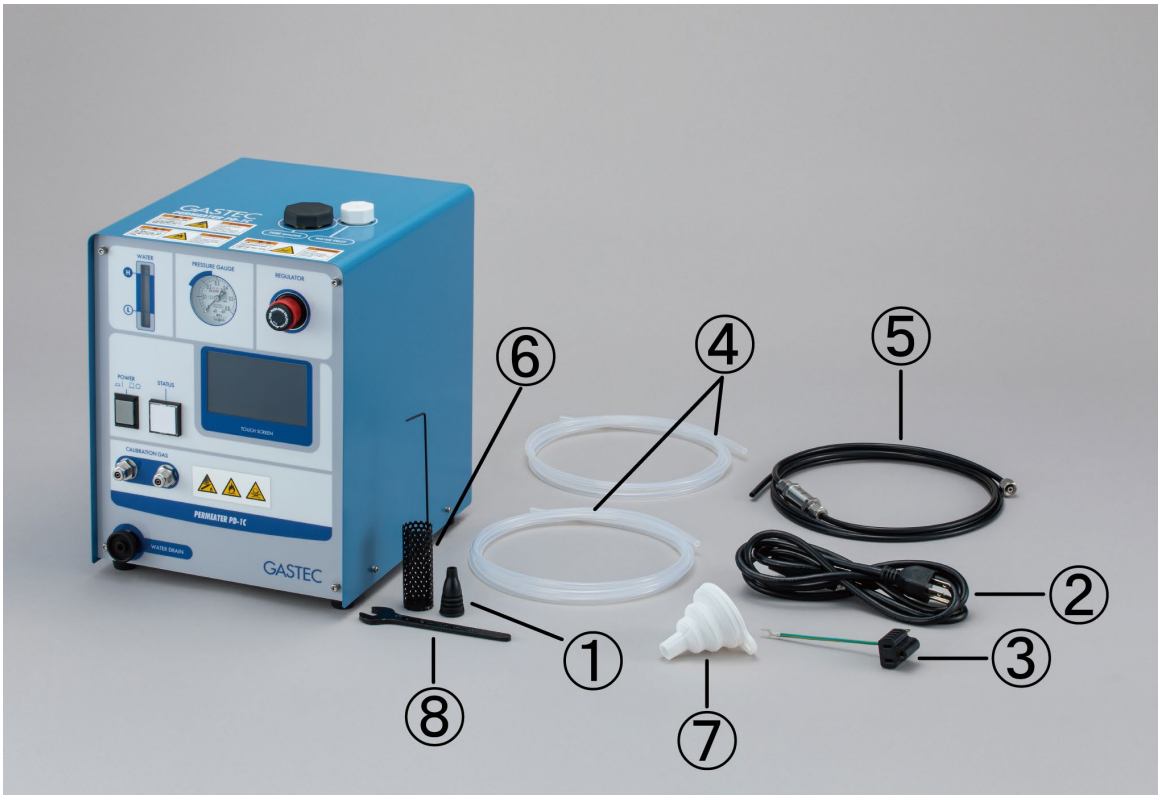
⑮ Do not use oil-cooled compressors to supply dilution gas.

⑯ When loading P-tubes/D-tubes into the TUBE HOLDER, use the tube holding cage provided. If the tube holding cage is not used, the P-tube/D-tube cannot be removed. Using the tube holding cage also prevents the P-tube/D-tube from being incorrectly placed in the WATER INLET.

⑰ Be careful not to put water into TUBE HOLDER. Doing so may result in malfunction.

3. Contents of the package

The package of this product contains the following accessories. Make sure you have all these together.



Item		Qty	description
①	Rubber stopper	1	Equipment for holding a standard thermometer inserted in a constant temperature water bath
②	Power cord	1	Cord for power supply*
③	Conversion adapter	1	2-pole/3-pole conversion plug*
④	Tube for calibration gas	2	FEP tube O.D. φ6 x I.D. φ4 2m
⑤	Tube for dilution gas (with dust filter)	1	O.D. φ6 x I.D. φ4 2m (withstanding pressure 1.0MPa, breaking pressure 3.0MPa) Dust filter (with standing pressure 17.1MPa, and collect particle size of 100μm or larger)
⑥	Tube holding cage	1	Container for loading P-tube or D-tube in TUBE HOLDER
⑦	Funnel**	1	Used for pouring water into the tempterature water bath
⑧	Spanner	1	Used for connecting dilution gas tubings
Instruction manual		1	

*The item(s) may vary by country or region.
**The funnel is packaged folded as shown in the picture on the right.

4. Product Overview

Most environmental and industrial measuring instruments for measuring gas concentration use calibration gas to calibrate the scale and perform measurements. Therefore, reliable calibration gases are naturally required to obtain reliable measurement values. Calibration gases are also required for the measurement of odours by olfaction, research on gas analysis methods, tests on the effects of gases on animals and plants, and tests on the effects of specific gases on various materials.

Calibration gases can be prepared by static or dynamic methods.

In the static method, gases are mixed in a vessel. Therefore, in the case of chemically active gas, the gas reacts with the vessel wall. In the case of condensable gas, adsorption and condensation phenomena occur on the vessel wall due to a drop of the ambient temperature, etc., and the gas concentration may change over time. Static methods are therefore simple in terms of equipment and operation, but there are limits to the types of gases that can be produced and the concentration range.

On the other hand, dynamic methods are prepared by continuously mixing gases. This means that even chemically active or condensable gases are less affected by adsorption or condensation and can be used to generate concentrations in the low concentration range that cannot be achieved with static methods, and can also cover a wide concentration range.

Calibration gas generator Permeater is a dynamic calibration gas generator that uses P-tubes and D-tubes as gas source and continuously generates trace concentrations of gas.

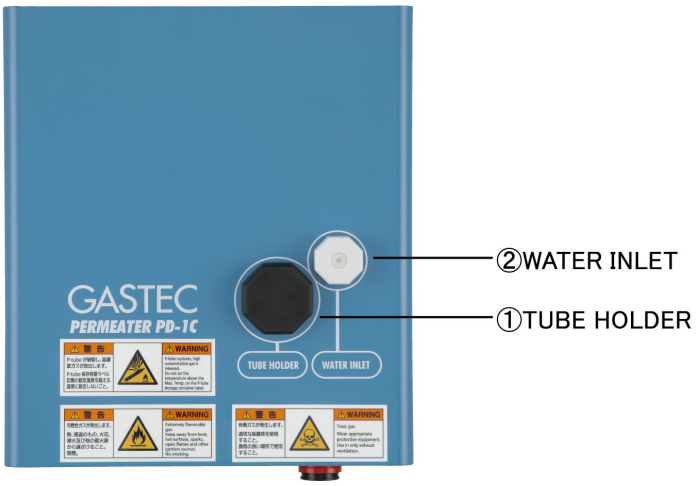
When a P-tube or D-tube is held in the temperature bath of a Permeater, the amount of gas or liquid in the tube that permeates through the tube wall or evaporates and diffuses, respectively, in unit time becomes constant. By feeding a constant volume of clean dilution gas into the Permeater, calibration gases can be prepared over a wide concentration range that is stable over a long period of time.

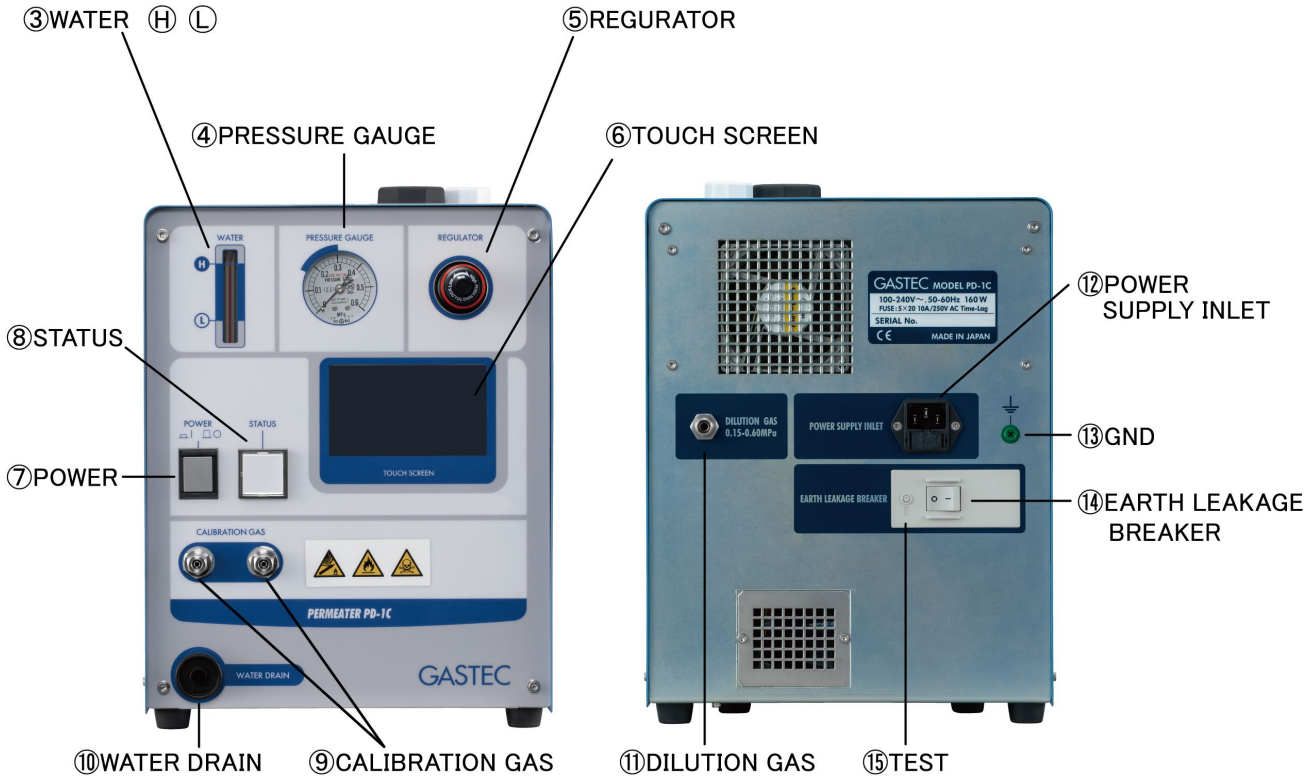
The P-tube calibration gas preparation method is used in Japan by the National Metrology Institute of Japan (NMIJ), National Institute of Standards and Metrology (AIST) as a source of formaldehyde primary reference gas, and by the National Institute of Standards and Technology (NIST) and the US Environmental Protection Agency (EPA) as a standard preparation method for calibration gas.

About Permeation tube Method and Diffusion tube Method

(1) The determination of the calibration gas concentration is based on the measurement of the basic physical quantity of the target gas, i.e. the mass loss of the target gas and the dilution gas volume, which provides a high reliability.
(2) Both P-tube and D-tube can be used, enabling the preparation of trace concentration calibration gases for many substances (inorganic gases and organic gases).
(3) Calibration gases can be generated easily and continuously for a long period of time.
(4) Calibration gases can be prepared over a wide concentration range.

5. Names of parts and functions





① TUBE HOLDER

P-tube and D-tube loading and unloading ports. P-tubes and D-tubes are loaded in using the provided tube holding cage.

② WATER INLET

Water filling port for the constant temperature water bath. Use tap water (clean water). The capacity of the tank is approximately 1.5L.

③ WATER

Displays the water level in the constant temperature water tank. Keep the water level between L and H.

④ PRESSURE GAUGE
Displays the pressure of the dilution gas supplied to the gas flow controller. Keep the pressure in the blue band range.

⑤ REGURATOR
Control for the pressure of the dilution gas supplied to the gas flow controller

⑥ TOUCH SCREEN
Displays operation status

⑦ POWER
Power switch

⑧ STATUS
Status indicator

Status	Status indicator
Standby	Orange
Normal operation (temperature of the water batch is below 36°C)	Green
Normal operation (temperature of the water bath is 36°C or higher)	Green (blinking)
Error / Warning	Red

⑨ CALIBRATION GAS
Two calibration gas outlets.

⑩ WATER DRAIN
Constant temperature water tank drain port

⑪ DILUTION GAS
Dilution gas inlet

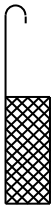
⑫ POWER SUPPLY INLET
Connector for IEC C13 (2 poles and earth connect) with fuse

⑬ GND terminal
This terminal is used to connect to protective grounding when the power outlet does not connect to protective grounding.

⑭ EARTH LEAKAGE BREAKER
This is the earth leakage breaker. It is switched ON during normal operation. It switches to OFF when a leakage current is detected.

⑮ TEST
This switch is used for testing the earth leakage breaker.

⑯ Tube holding cage (accessories)
Cage for loading P-tube or D-tube in TUBE HOLDER.



6. Installation and set up

⚠Warning

① Since the calibration gas is flammable and toxic, place the Permeater in a local exhaust ventilation system or in a place with sufficient room ventilation. Poisoning or fire may occur.

② Provide a sink near this instrument. If you come in contact with toxic substances or if they get into your eyes, rinse them off immediately.

③ If the calibration gas to be prepared is flammable, do not generate high heat, high temperature, sparks, or open flames in the same room. Do not smoke. Doing so may cause a fire.

④ If the calibration gas to be prepared is flammable, prepare a fire extinguisher.

⑤ Dilution gas must be supplied through a dustproof filter. If a dust filter is not used, the flow controller may malfunction or the flow accuracy may deteriorate.
- Use a dust filter which is capable of withstanding a pressure of 1.2 MPa or higher.
- The dust filter should be replaced in a timely manner as it may be blocked after prolonged use.

⑥ Use a power cord that complies with the laws and regulations of the country/region where this instrument is used and meets the safety requirements of that country/region. Failure to do so may result in electric shock, fire or malfunction.

⑦ Take measures to prevent the instrument from toppling over due to earthquakes or other causes. If the instrument falls over, there is a risk of injury due to diffusion of toxic/flammable gases or collision.

⑧ Do not subject this instrument to vibration. Vibration may loosen tubes, piping connections, etc., causing the calibration gas to leak.

⑨ Install the power cord so that it can be pulled out from the AC INLET or from the power outlet in case the power switch cannot be used to turn off the power supply due to a switch malfunction or other reason.

△**Note:**

① Dilution gases should be supplied at pressures between 0.15 and 0.6MPa. Exceeding 0.6MPa may cause damage this instrument.

② Use nitrogen or air for the dilution gas. If other gases are used, the flow rate may be abnormal or internal corrosion may occur.

③ Do not install this instrument in locations subject to corrosive gases or dust. Doing so may make it impossible to maintain the performance of the instrument or shorten its service life.

④ Open the ventilation holes on the rear side of the instrument with a clearance of at least 5 cm. Do not block the ventilation holes on the bottom. The water temperature may not reach the set value or the temperature accuracy may deteriorate. Also, the life of the internal electronic components may be shortened.

6.1 Location

Install the instrumet in a location that satisfies the following conditions.

- ・Inside of a local exhaust ventilation system or a place with sufficient indoor ventilation
- ・Near a drainage facility
- ・ambient temperature is between 15 and 30 °C.
- ・No vibration

In addition, if the calibration gas to be prepared is flammable, the following conditions should be also satisfied.

- ・No objects that generate high heat, high temperature, sparks, or naked flames are present in the same room
- ・Smoking is prohibited
- ・There is a fire extinguisher nearby

• Use a table or bench on which this instrument is installed that satisfies the following conditions.

- ・Horizontal
- ・Flat
- ・Stable
- ・can adequately withstand a weight of 15 kg
- ・Width 25cm Depth 35cm (5cm clearance is required behind the instrument)
- ・At least 54 cm of space in height direction from the top (20 cm clearance from the top of the instrument is required)

6.2 Connection of the dilution gas

For the dilution gas, use nitrogen or air in a high-pressure gas container, or purified air compressed by an oilless compressor. The dilution gas should be regulated to 0.15 to 0.6 MPa with an external regulator and supplied to the DILUTION GAS (dilution gas inlet) of the Permeater.

△**Note:**

When the regulator in PD-1C is pressurized to a pressure greater than 0.4 Mpa, the safety valve works to release the dilution gas into the main unit case. During the release of the dilution gas, a leakage sound of dilution gas is heard. Adjust the REGURATOR by referring to "6.3 Adjustment of the dilution gas pressure".

a) When nitrogen or air in a high-pressure gas cylinder is used

The connection is shown in the figure below. Use the standard accessory tube for dilution gas with dust filter. Connect the outlet of the dust filter (30 cm tube attached) to the DILUTION GAS (dilution gas inlet) of the Permeater. The fitting of the DILUTION GAS (dilution gas inlet) is Swagelok® type. Follow the procedure below.

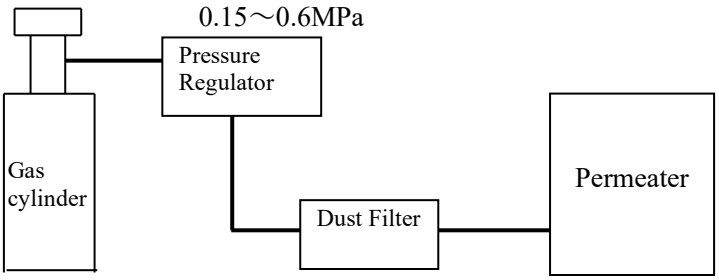
① Tighten the female nut on the short end of the tube to the male thread of the DILUTION GAS (dilution gas inlet) until it can be turned fully by hand.

② Use a 14mm spanner or the like to tighten the nut about 1/4 more.

③ Make sure that the nut is securely tightened and the tube is held.

Connect the inlet of the dust filter (with a 200cm tube) to the outlet of the pressure regulator.
The hose to be connected to the regulator is φ6 (outer diameter) × φ4 (inner diameter). Use a fitting that fits this size.
Replace the dust filter when it is blocked.

*Example of a connection



*An example of connection with high-pressure air cylinder

b) When using oil-less compressor

When using air compressed by an oilless compressor for dilution gas, remove airborne contaminants through an activated carbon or silica gel before the dust filter. Use a cylinder which is capable of withstanding a pressure of 1.2 MPa or higher to fill activated carbon or silica gel. The connection is shown in the figure below. Use the standard accessory tube for dilution gas with dust filter. Connect the outlet of the dust filter (30 cm tube attached) to the DILUTION GAS (dilution gas inlet) of the Permeater. The fitting of the DILUTION GAS (dilution gas inlet) is Swagelok® type. Follow the procedure below.

①Tighten the female nut on the short end of the tube to the male thread of the DILUTION GAS (dilution gas inlet) until it can be turned fully by hand.

②Use a 14mm spanner or the like to tighten the nut about 1/4 more.

③ Make sure that the nut is securely tightened and the tube is held.

Connect the inlet of the dust filter (with a 200cm tube) to the outlet of the silica gel filled cylinder.
The hose to be connected to the silica gel filled cylinder is φ6 (outer diameter) × φ4 (inner diameter). Use a fitting that fits this size.
Activated carbon and silica gel should be replaced in a timely manner as they become contaminated with long-term use. Replace the dust filter if it is blocked.


*Example of connection

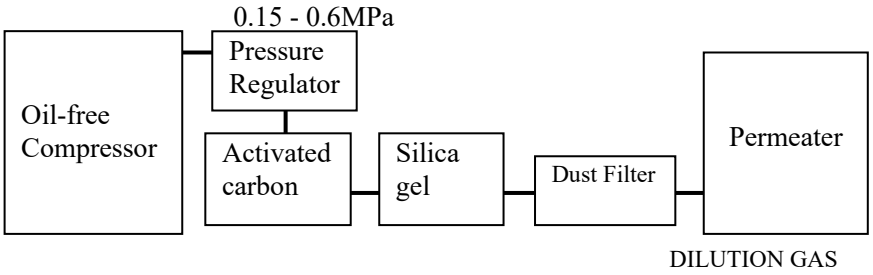
⚠Warning

When using air compressed by an oilless compressor for dilution gas, remove airborne contaminants through an activated carbon or silica gel before the dust filter.

- Use a cylinder which is capable of withstanding a pressure of 1.2 MPa or higher to fill activated carbon or silica gel.
- Activated carbon and silica gel should be replaced in a timely manner as they become contaminated with long-term use.

△Note:

Do not use oil-cooled compressors to supply dilution gas.

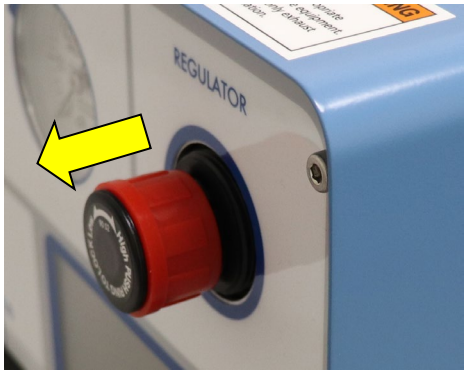


*An example of a compressor connection

6.3 Adjustment of the dilution gas pressure

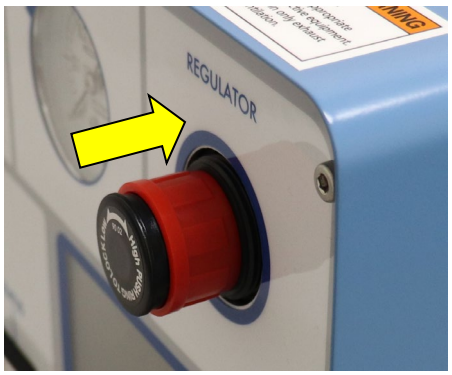
Supply dilution gas, adjusting the PD-1C PRESSURE GAUGE indication to 0.15 to 0.3 MPa (in the range of the blue band).

Pull the red lock ring on the PD-1C REGURATOR toward you to unlock it.



Turning the lock ring clockwise increases the pressure and turning it counterclockwise decreases it.

After adjustment, push in and lock the lock ring.



△**Note:**

When the regulator in PD-1C is pressurized to a pressure greater than 0.4 Mpa, the safety valve works to release the dilution gas into the main unit case. During the release of the dilution gas, a leakage sound of dilution gas is heard.

6.4 Connecting tubes at the outlets of the calibration gas

There are two CALIBRATION GAS outlets, which are connected inside. One is connected to the supplied FEP tube (O.D. 6 mm x I.D. 4 mm, tube without dust filter) for use of calibration gas. Connect the FEP tube to the other outlet. Follow the connection procedure below.

① Loosen the tube-fixing nut attached to CALIBRATION GAS (calibration gas outlet).

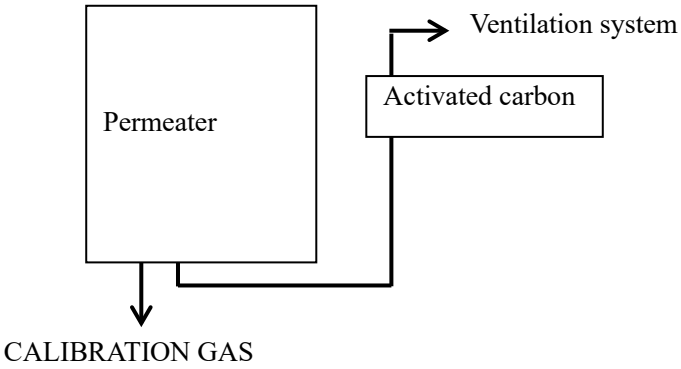
② Insert the FEP tube into the nipple.

③ Tighten the nut to hold the FEP tube.

④Check that the FEP tube does not come out easily by pulling gently.

⑤ When removing the FEP tube and connecting it again to CALIBRATION GAS (calibration gas outlet), cut approximately 10mm of the tube end and re-attach it.

When discharging the calibration gas, remove the toxic substances by a pressure-free method before discharging them outdoors.
(A pressure-free removal method is to pass the used calibration gases through pipes filled with activated carbon with a particle diameter of 2 mm or more and a pipe diameter of 50 mm or more.)



Example of filtering gas

⚠Warning

- ■ Position the instrument and connect tubes so that the CALIBRATION GAS (calibration gas outlet) is away from the breathing zone when use.
- ■ If only one CALIBRATION GAS outlet is used, close the other outlet. If it is left open, calibration gas will come out.

6.5 Connecting the Earth and Power Cord

Use a power supply that meets the following specifications.

・100-240V AC 50-60Hz 160W

Connect the 3-pin connector of the power cord to the power inlet of the main unit.

Insert the plug into a power outlet with protective ground connection.
If the power outlet does not have a protective ground connection, connect the protective earth to the GND terminal on the backside of the main unit.

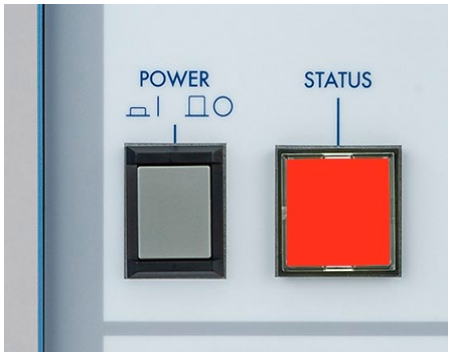
Turn on the earth leakage breaker on the rear panel.

⚠Warning

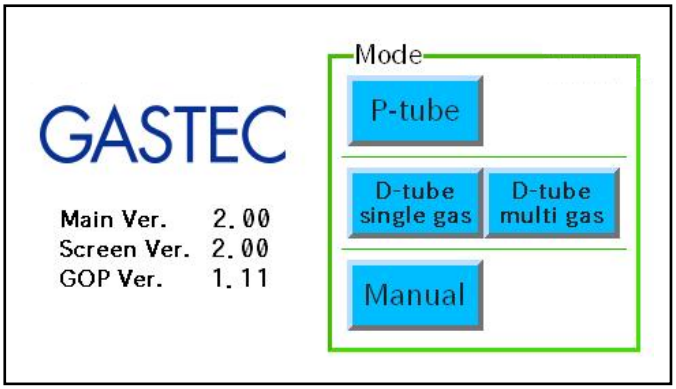
To prevent electrical shock, use a power outlet with a protective ground connection. If the power cord does not connect to protective earth, connect the GND terminal on the backside of the main unit to protective earth.

6.6 Filling water into the constant temperature water bath

① Check the water level sensor before filling the water bath. Press the POWER button to turn on the PD-1C, and STATUS lights up in red. (If the power does not turn on, check the leakage breaker on the rear panel.)

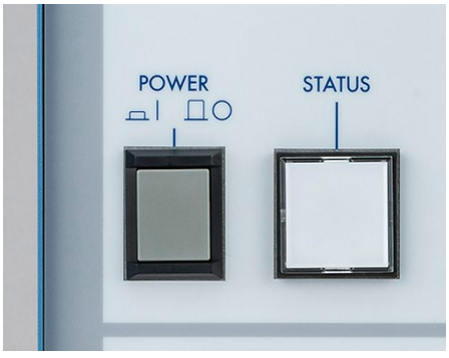


②After about 10 seconds, the buzzer sounds and the touch screen displays the start screen.



Press "P-tube" or "D-tube" to open the main window.
Check that the buzzer sounds intermittently and that "WARNING040: Low water level" is displayed on the touchscreen. If the buzzer does not sound and no warning is displayed, the water level sensor is faulty. Refer to Section 12.10 'Repair' and have the main unit serviced.

③ Turn off the power.



④Prepare 1.5L of clean water.

⑤Check the WATER DRAIN (temperature water tank drain port) is closed.

⑥ Open WATER INLET (water filling port of the constant temperature water bath) and insert a funnel.

⑦ Make sure the inlet you are pouring water is WATER INLET. Watch the WATER gauge and pour water between levels H and L. Overflow may occur due to slow response of the WATER gauge. If level L is exceeded, pour water slowly.

⑧When the appropriate water level is reached, finish pouring and close the WATER INLET lid.

⚠Warning

- ■ Do not fill water exceeding “H” marking. If it exceeds the upper limit, overflow may be caused during operation.
- ■ To prevent electric shock and malfunctions, take care not to spill the water when pouring it into the temperature water bath.

△**Note:**

- If water is added during operation, the temperature may drop and cause a "Heating/Cooling error". If this happens, turn the power OFF, and restart the main unit.
- When pouring water, reconfirm that the inlet is the WATER INLET. Pouring water into the TUBE HOLDER may cause it to malfunction.
- The "WARNING040: Low water level" message may appear even though the water gauge display is normal. In this case, drain about half (0.7 L) of the water and fill the water tank to the normal level again. (When filling the water tank for the first time or after it has been empty for a long period of time, air bubbles may stick to the water level sensor.)

When draining water for periodic replacement of water or moving this instrument, refer to "12.1 Replacing and Draining Water in the Constant Temperature Chamber".

7.Start

⚠Warning

① Since many of the calibration gases prepared by this system are toxic, skin corrosive, hazardous to health, or harmful to the environment, they should be used in a local exhaust ventilation system or in a place with sufficient indoor ventilation.

② When handling P-tubes and D-tubes, be sure to wear appropriate protective equipment such as protective glasses, impervious protective clothing, protective gloves or footwear.

③ Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.

④ This instrument is not explosion-proof. Do not allow calibration gas to come in contact with any part other than the calibration gas path.

⑤ P-tubes are sealed in intermediate packaging and storage(inner) packaging. To prevent inhalation of toxic gases, the intermediate packaging and storage(inner) packaging of the P-tube should be opened in a local exhaust ventilation system.

⑥ Always work inside a local exhaust ventilation system and wear appropriate protective equipment such as protective glasses, impervious protective clothing, protective gloves or footwear when charging liquid sample into the D-tube.

⑦ If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion. The temperature setting of PD-1C should be set below the "maximum temperature" on the P-tube storage container label.

⑧ If the temperature inside the TUBE HOLDER exceeds the "maximum temperature" on the P-tube storage container label, immediately switch to the clean-up mode with the TUBE HOLDER lid closed. Do not open the lid of the TUBE HOLDER because high concentration of gas may be accumulated in the TUBE HOLDER. Remove and Dispose of the P-tube after 24 hours of dilution gas flow.

⑨ After use, P-tubes should be disposed of properly in accordance with the "Operation Manual for Permeation Tube"

⑩ Once the P-tube has exceeded the "maximum temperature" on the P-tube storage container label, do not reuse it.

⑪ Do not apply external pressure or shock to the P-tube, or do not scratch or cut the P-tube. The internal liquefied gas may be gushed out. Gas pressure may remain even when there is no liquid remaining in the P-tube, such as when disposing of the P-tube.

⑫ If any abnormality is found in the appearance of the P-tube, corrosion of the stainless steel crimps, or cracks in the fluoroplastic tubing, immediately discontinue use and discard the P-tube.

⑬ Remove the P-tube when the PD-1C is not in use. If the P-tube is left in the TUBE HOLDER with the dilution gas stopped, a high concentration of gas will accumulate.

⑭ Do not open the TUBE HOLDER when a power failure occurs with P-tube or D-tube in it, as highly concentrated gas will accumulate in the TUBE HOLDER. P-tube and D-tube should be removed after at least 30 minutes of dilution gas flow.

⑮ P-tubes and D-tubes should be loaded into and removed from the TUBE HOLDER with the dilution gas always flowing. If the dilution gas is stopped, highly concentrated gas will be generated.

⑯ To prevent electrical shock, use a power outlet with a protective ground connection. If the power cord does

not connect to protective earth, connect the GND terminal on the backside of the main unit to protective earth.

⑰ □ To prevent electric shock and malfunctions, take care not to spill the water when pouring it into the temperature water bath. Do not fill water exceeding H of WATER gauge. (During water injection, the water level gauge may not respond quickly to the water injection speed and may overflow. When water level exceeds the lower limit level L of WATER gauge, pour water slowly while looking at the WATER gauge.) If water is spilled, immediately unplug the power cord and wipe off the water.

⑱ Do not use the instrument under abnormal conditions such as unusual smells or noises. Doing so may cause electric shock, fire, or gas leakage.

⑲ If the power cannot be turned off using the power switch due to a switch malfunction or other reason, pull the power cord out of the AC INLET or unplug it from the power outlet.

△Note:

① Set the water temperature at room temperature plus 5°C or higher.

② When running the calibration gas, do not cause pressure fluctuations in the flow path. The flowmeter is calibrated with the outlet open. If pressure is applied to the outlet, the true flow rate cannot be obtained.

③ Calibration gas is supplied from two outlets. If pressure is applied to one of the outlets, the calibration gas may flow to one of the outlets without load, and the gas may not be led to the other outlet. When using the calibration gas, do not apply pressure to the outlet. Conversely, if a flow rate greater than the set flow rate is taken from one outlet, the atmosphere will be drawn in from the other unloaded outlet. Calibration gas should be taken within the set flow rate.

④ To concentrate the set flow rate to one CALIBRATION GAS (calibration gas outlet), make sure that there is no pressure fluctuation inside the instrument when the other outlet is blocked. When one of the CALIBRATION GAS (calibration gas outlets) is closed, make sure that there is no pressure fluctuations inside the flow path.

⑤ When opening the closed CALIBRATION GAS (calibration gas outlet), be careful because the gas that has accumulated in the internal gas pathway will come out. The concentration of the accumulated gas may have changed.

⑥ A mass flow controller is used to control the dilution gas, and the flow rate is a value converted to 25° C, 1 atm. Flow rate accuracy is guaranteed only for nitrogen and air.

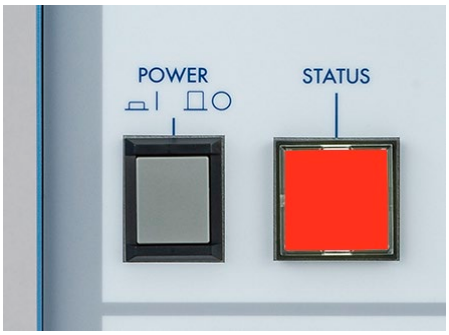
⑦ To maintain temperature uniformity in the TUBE HOLDER, make sure that the water level is always within the H to L level of the WATER during use, and pour water when the water level is near the L level. During use, the water level will gradually decrease.

⚠Warning

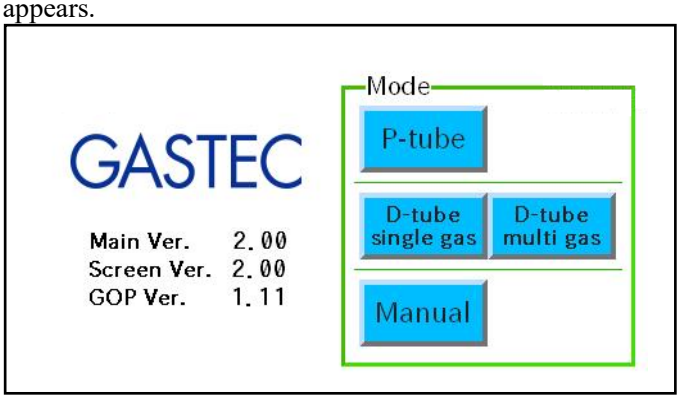
Do not load the P-tube/D-tube into the TUBE HOLDER immediately after startup. Wait at least 30 minutes after the dilution gas has flowed before loading. If the P-tube/D-tube has not been removed after the last use, there is a possibility that highly concentrated gas may remain.

7.1 Start screen

Press the POWER button to turn on the PD-1C, and STATUS lights up in red. (If the power does not turn on, check the leakage breaker on the rear panel.)



After about 10 seconds, the buzzer sounds, the STATUS turns orange, and the start screen shown below appears.



The power unit fan starts. Meanwhile, the flow controller and the temperature controller are stopped. Touching "P-tube" or "D-tube single gas" or "D-tube multi gas" or "Manual" displays the main screen for each mode. Descriptions of each mode are given in the following paragraphs.

- **P-tube mode (7.2)**
  This mode uses a P-tube to prepare calibration gas.
- **D-tube single gas mode (7.3)**
  This mode uses a D-tube to prepare single calibration gas.
- **D-tube multi gas mode (7.4)**
  This mode uses a D-tube to prepare multiple calibration gas mixture.
- **Manual mode (7.5)**
  This mode uses P-tube/D-tube to prepare calibration gas. In this mode, the automatic calculation function is not used, but the temperature and flow rate required for the desired calibration gas are calculated and set manually. Use this mode when the settings cannot be made in the above three modes, such as when using a P-tube to prepare multiple types of calibration gases.

7.2 P-tube mode

The status "STAND BY" is displayed in the upper part of the LCD touch screen.
The operation mode "P-tube" is displayed below the status display.
To use another operation mode, touch "Menu" in the lower right corner, then refer to section 7.9.
The following parameters are set in P-tube mode. See "7.6 Setting ranges for parameters " for the range in which each parameter can be set.

- K: Coefficient for volume conversion of gas mass (L/g)
- Pr1 - Pr10: Permeation rate (ng/min/cm) (Max. 10 tubes)
- L1 - L10: Effective length of tube (cm) (Max. 10 tubes)
- Temp : Temperature (℃)
- Flow: Flow of dilution gas (L/min)
- Conc: Calibration gas concentration (ppm)

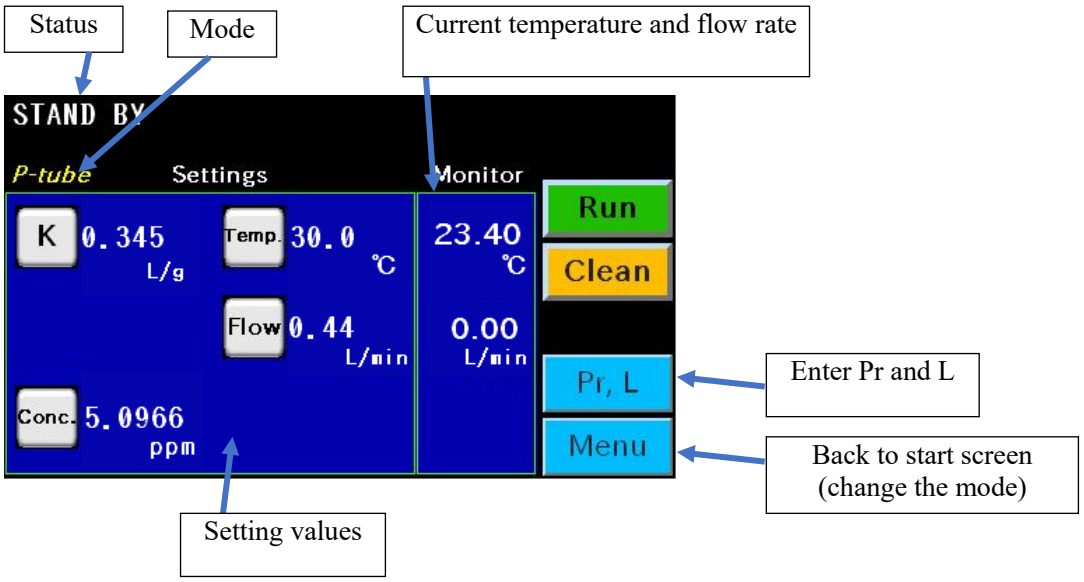
Permeation rate means a weight of gas that permeates and diffuses from a 1cm portion of permeating part (effective length) of the P-tube that is held at a constant temperature. Actual measured permeation rates at different temperatures are indicated on each P-tube and use the appropriate Pr value for calculation.
The effective length L of the P-tube means a length along which a liquefied gas permeates. Each P-tube indicates its effective length and this L value shall be used for calculation.

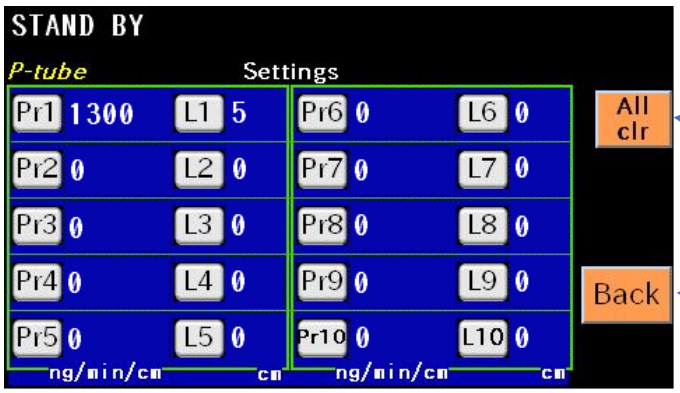
The value of one P-tube should be set to the same numbered parameter (Pr1 and L1, Pr7 and L7, etc.).
If the number of P-tubes is less than 10, set "0" to either or both Pr and L of the unused number. It is not necessary to set them in order of number.

When K, Pr1-Pr10, L1-L10, or Flow is entered, Conc is automatically calculated.
When Conc is entered, Flow is automatically calculated. From the Flow obtained by this calculation, an approximate Conc is automatically calculated and used. This is because there is a limit to the minimum volume of Flow that the mass flow controller can control, so a rounding process is necessary.

The accuracy of the calibration gas concentration is better when a larger Flow is set than when a smaller Flow is set.

The P-tube must be kept at a stable temperature for approximately 24 hours for the permeation rate to stabilize. At this time, the dilution gas must continue to run to prevent gas accumulation. If need to save dilution gas, minimize consumption by setting the flow rate to a minimum of 0.2L/min while waiting for the permeation rate to stabilize. Five minutes before using the calibration gas, change the flow rate setting to prepare the required gas concentration.

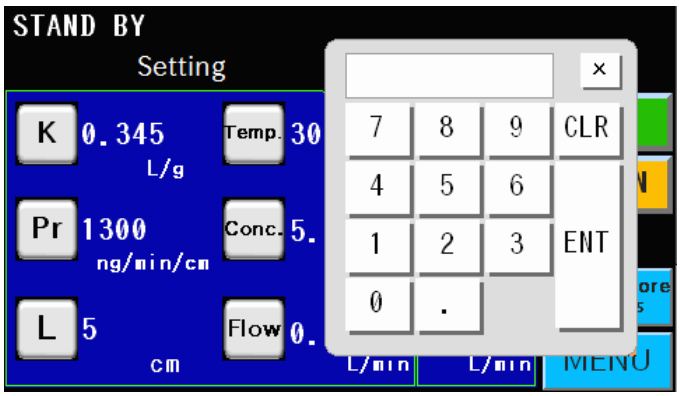




Reset all setting values to zero

Back to the previous screen

Touch the button (K, Flow, etc.) or the parameter value to be set to display the keypad. Enter the value to be set.



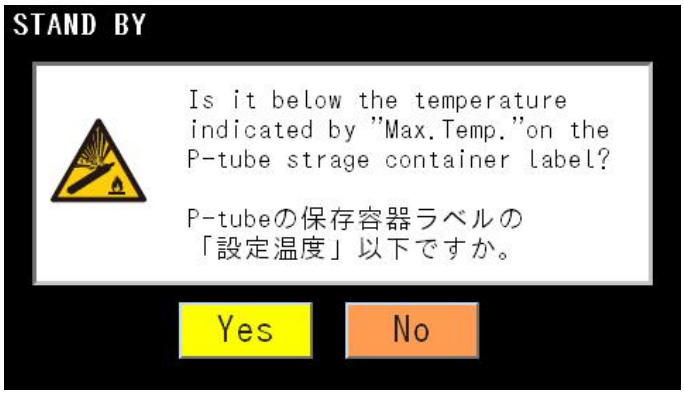
⚠Warning

The temperature setting of the P-tube should be set below the maximum temperature setting on the label of the P-tube storage container. If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion.

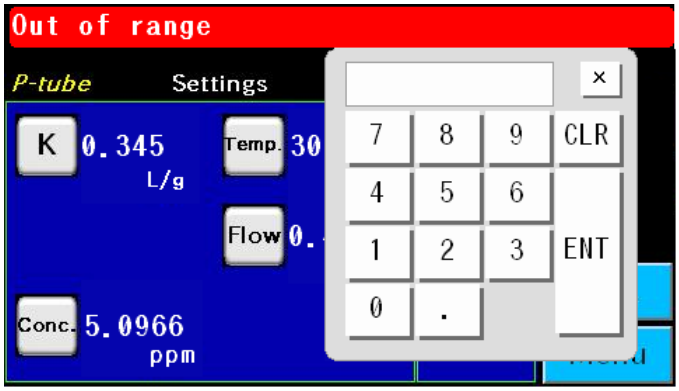
If a value of 35.1°C or higher is entered for the temperature, a confirmation screen will be displayed.

If the entered temperature is below the maximum temperature setting on the label of the P-tube storage container, touch Yes. The entered value is set.

If the entered temperature is above the maximum temperature setting on the label of the P-tube storage container, touch No. The display returns to the screen showing the previous keyboard. Enter a value less than or equal to the maximum temperature setting on the label.



If a value out of the settable range is entered, or if the automatic calculation results in a concentration or required dilution gas flow rate out of the specification range, "Out of range" is displayed.



Check that each parameter is set correctly before starting the run.

△Note

Make sure Conc. is set correctly; Conc. changes when other parameters are entered.

After confirming the set values, start the run. Proceed to 7.7.

7.3 D-tube single gas mode

The status "STAND BY" is displayed in the upper part of the LCD touch screen.
The operation mode "D-tube single gas" is displayed below the status display.
To use another operation mode, touch "Menu" in the lower right corner, then refer to section 7.9.
The following parameters are set in D-tube single gas mode. See "7.6 Setting ranges for parameters " for the range in which each parameter can be set.

- K: Coefficient for volume conversion of gas mass (L/g)
- Dr1 – Dr4: Diffusion rate (μ g/min) (Max. 4 tubes)
- Temp : Temperature (℃)
- Flow: Flow of dilution gas (L/min)
- AmbP: Ambient pressure (hPa)
- Conc: Calibration gas concentration (ppm)

Diffusion rate (Dr) is the mass of gas that diffuses per minute from a D-tube held at a constant temperature. The diffusion rate depends on the size of the D-tube and the temperature.
When using diffusion tube set No. 3100, use the Diffusion Rate data table in the catalog or diffusion tube set instruction manual for K and Dr values.
When using multi-component diffusion tube set No. 3200, use the Diffusion Rate data table supplied with the tube 3200.

This instrument does not control the pressure in the tube holder. The pressure around the D-tube is the same as the pressure at the calibration gas outlet, so set AmbP to the value of the ambient pressure sensor readout indicated in "Monitor" on the touch screen.
Refer to "8.2 Calculation for D-tube " for AmbP setting when using actual measurement of Diffusion Rate Dr or when there is a flow resistance at the calibration gas outlet.

The Diffusion Rate data tables in the catalogs, diffusion tube instruction manuals, and multi-component diffusion tube instruction manual are our actual or estimated values. For higher accuracy, or for substances not listed in the table, it is recommended to measure the Diffusion Rate under the actual conditions of use.
For the actual measurement of Diffusion Rate, refer to "8.2 Calculation for D-tube ".

If the number of D-tubes used is less than 4, enter "0" for the unused Dr.

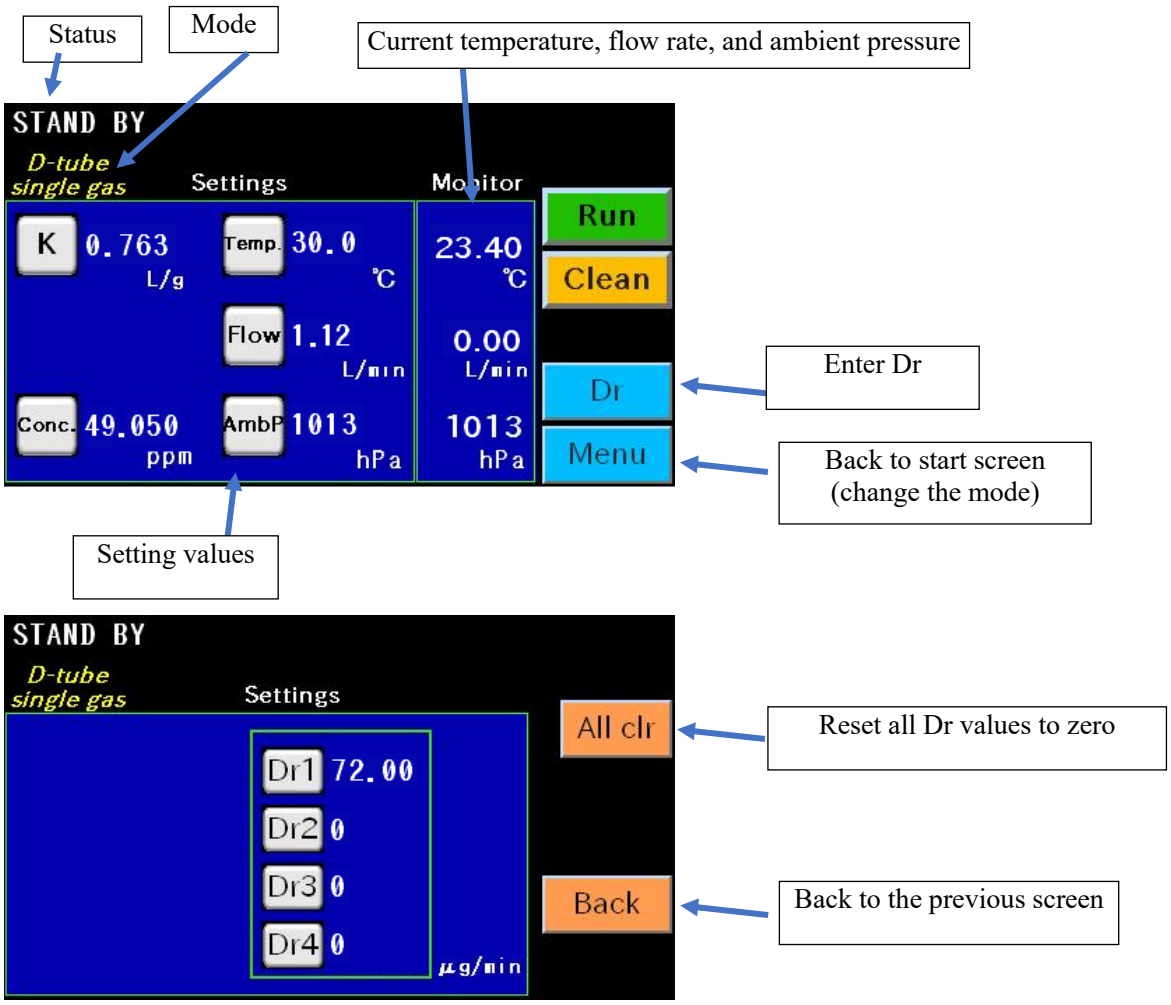
When K, Dr1-Dr4, AmbP, or Flow is entered, Conc is automatically calculated.
When Conc is entered, Flow is automatically calculated. From the Flow obtained by this calculation, an approximate Conc is automatically calculated and used. This is because there is a limit to the minimum volume of Flow that the mass flow controller can control, so a rounding process is necessary.

The accuracy of the calibration gas concentration is better when a larger Flow is set than when a smaller Flow is set.

△Note

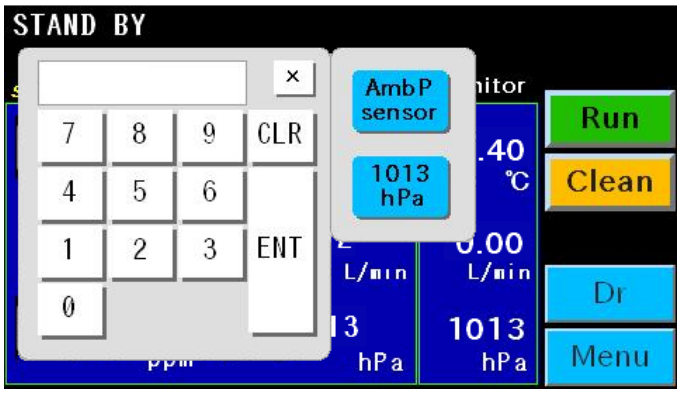
When using D-tube, the dilution gas flow rate should be in the range of 0.20 to 8.00 L/min. If the flow rate exceeds 8.00 L/min, the Diffusion Rate may become unstable.

The D-tube must be kept at a stable temperature for 30 minutes to 24 hours (depending on Dr, see instruction manual of diffusion tube for the details) for the Diffusion Rate to stabilize. At this time, the dilution gas must continue to run to prevent gas accumulation. If need to save dilution gas, minimize consumption by setting the flow rate to a minimum of 0.2L/min while waiting for the permeation rate to stabilize. Five minutes before using the calibration gas, change the flow rate setting to prepare the required gas concentration.



Touch the button (K, Flow, etc.) or the parameter value to be set to display the keypad. Enter the value to be set.
To set ambient pressure, touch the "AmbP" button. The keypad, "AmbP sensor" button, and "1013hPa" button will appear.

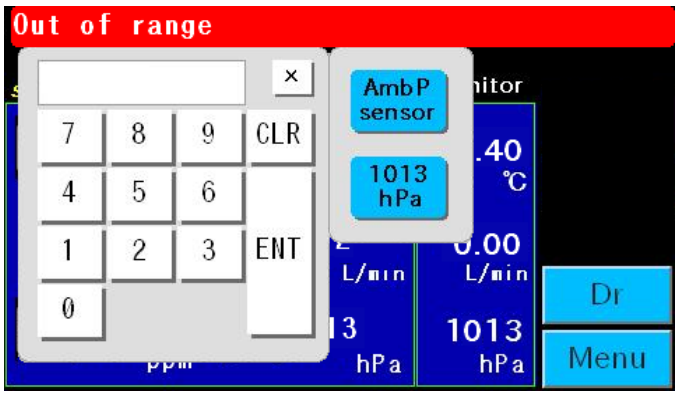
- To apply the value of the built-in ambient pressure sensor, touch the "AmbP sensor" button.
- If pressure correction is not used, touch "1013hPa" button to set the pressure to 1013hPa.
- To set the pressure to a desired value, use the keypad to set the value. (The pressure should be within the range of ambient pressure ±150 hPa.)



△NOTE

The ambient pressure setpoint is changed only when the above settings are made. Even if the ambient pressure changes during operation, the set value does not change automatically.

If a value out of the settable range is entered, or if the automatic calculation results in a concentration or required dilution gas flow rate out of the specification range, "Out of range" is displayed.



Check that each parameter is set correctly before starting the run.

△Note

Make sure Conc. is set correctly; Conc. changes when other parameters are entered.

After confirming the set values, start the run. Proceed to 7.7.

7.4 D-tube multi gas mode

The status "STAND BY" is displayed in the upper part of the LCD touch screen.
The operation mode "D-tube multi gas" is displayed below the status display.
To use another operation mode, touch "Menu" in the lower right corner, then refer to section 7.9.

The following parameters are set in D-tube single gas mode. See "7.6 Setting ranges for parameters " for the range in which each parameter can be set.

- K 1 - 4: Coefficient for volume conversion of gas mass (L/g) (Max. 4 tubes)
- Dr1 – Dr4: Diffusion rate (μ g/min) (Max. 4 tubes)
- Temp : Temperature (℃)
- Flow: Flow of dilution gas (L/min)
- AmbP: Ambient pressure (hPa)
- Conc 1 - 4: Calibration gas concentration (ppm) (Max. 4 substances)

Diffusion rate (Dr) is the mass of gas that diffuses per minute from a D-tube held at a constant temperature. The diffusion rate depends on the size of the D-tube and the temperature.
When using diffusion tube set No. 3100, use the Diffusion Rate data table in the catalog or diffusion tube set instruction manual for K and Dr values.
When using multi-component diffusion tube set No. 3200, use the Diffusion Rate data table supplied with the tube 3200. With No. 3200, a four-calibration gas mixture can be prepared.

This instrument does not control the pressure in the tube holder. The pressure around the D-tube is the same as the pressure at the calibration gas outlet, so set AmbP to the value of the atmospheric pressure sensor readout indicated in "Monitor" on the touch screen.
Refer to "8.2 Calculation for D-tube " for AmbP setting when using actual measurement of Diffusion Rate Dr or when there is a flow resistance at the calibration gas outlet.

The Diffusion Rate data tables in the catalogs, diffusion tube instruction manuals, and multi-component diffusion tube instruction manual are our actual or estimated values. For higher accuracy, or for substances not listed in the table, it is recommended to measure the Diffusion Rate under the actual conditions of use.
For the actual measurement of Diffusion Rate, refer to "8.2 Calculation for D-tube ".

The value of one D-tube should be set to the same numbered parameter (e.g., K1 and Dr1, K3 and Dr3, etc.).

If the number of D-tubes used is less than 4, enter "0" for the unused Dr.

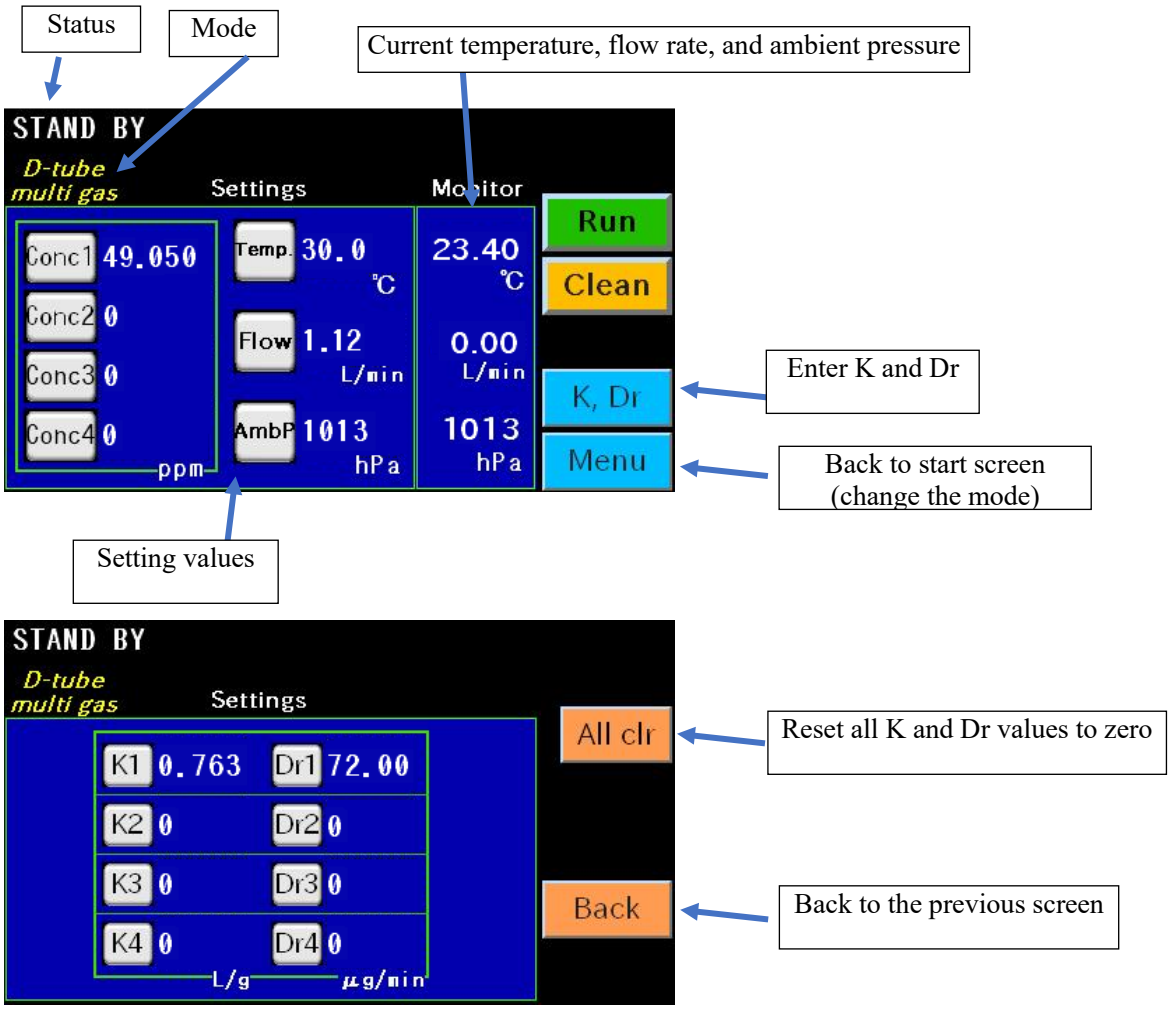
When K1-K4, Dr1-Dr4, AmbP, or Flow is entered, Conc1-4 are automatically calculated.
When Conc1-4 are entered, Flow is automatically calculated. From the Flow obtained by this calculation, an approximate Conc1-4 are automatically calculated and used. This is because there is a limit to the minimum volume of Flow that the mass flow controller can control, so a rounding process is necessary.

The accuracy of the calibration gas concentration is better when a larger Flow is set than when a smaller Flow is set.

△Note

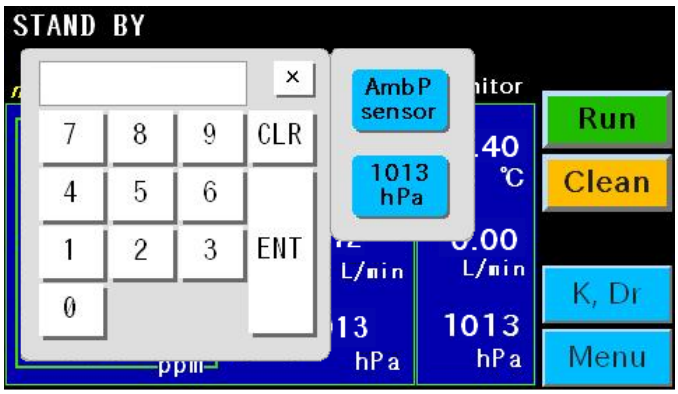
When using D-tube, the dilution gas flow rate should be in the range of 0.20 to 8.00 L/min. If the flow rate exceeds 8.00 L/min, the Diffusion Rate may become unstable.

The D-tube must be kept at a stable temperature for 30 minutes to 24 hours (depending on Dr, see instruction manual of diffusion tube for the details) for the Diffusion Rate to stabilize. At this time, the dilution gas must continue to run to prevent gas accumulation. If need to save dilution gas, minimize consumption by setting the flow rate to a minimum of 0.2L/min while waiting for the permeation rate to stabilize. Five minutes before using the calibration gas, change the flow rate setting to prepare the required gas concentration.



Touch the button (K, Flow, etc.) or the parameter value to be set to display the keypad. Enter the value to be set.
To set ambient pressure, touch the "AmbP" button. The keypad, "AmbP sensor" button, and "1013hPa" button will appear.

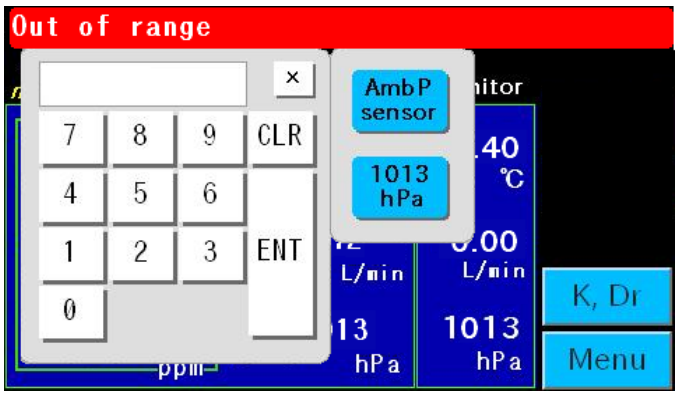
- To apply the value of the built-in atmospheric pressure sensor, touch the "AmbP sensor" button.
- If pressure correction is not used, touch "1013hPa" button to set the pressure to 1013hPa.
- To set the pressure to a desired value, use the keypad to set the value. (The pressure should be within the range of ambient atmospheric pressure ±150 hPa.)



△NOTE

The ambient pressure setpoint is changed only when the above settings are made. Even if the ambient pressure changes during operation, the set value does not change automatically.

If a value out of the settable range is entered, or if the automatic calculation results in a concentration or required dilution gas flow rate out of the specification range, "Out of range" is displayed.



Check that each parameter is set correctly before starting the run.

△Note

Make sure Conc.1 - 4 are set correctly; Conc. 1 - 4 change when other parameters are entered.

After confirming the set values, start the run. Proceed to 7.7.

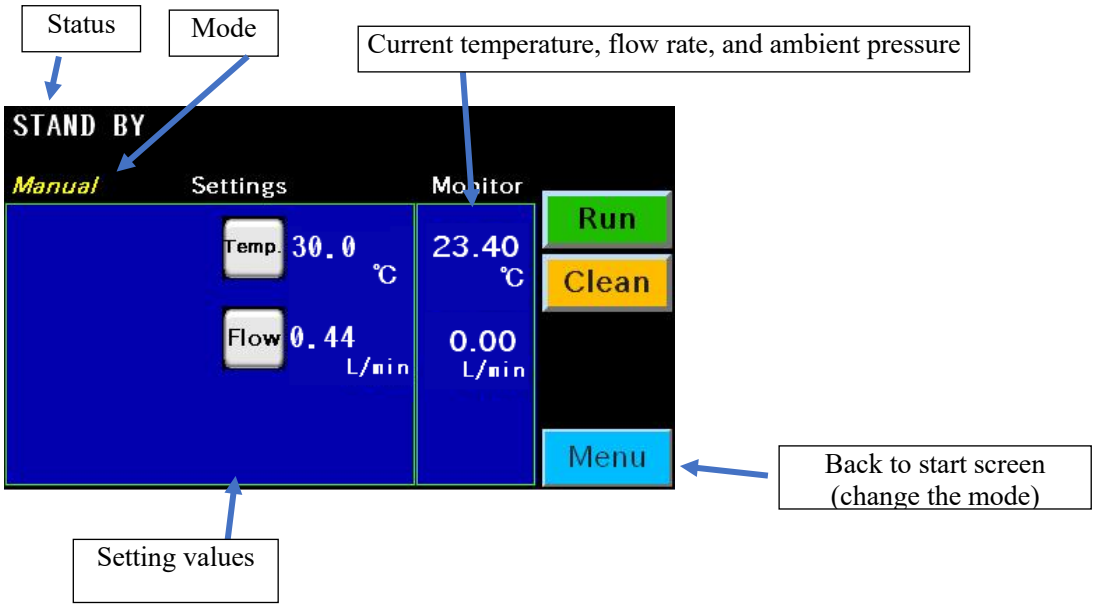
7.5 Manual mode

The status "STAND BY" is displayed in the upper part of the LCD touch screen.
The operation mode "Manual" is displayed below the status display.
To use another operation mode, touch "Menu" in the lower right corner, then refer to section 7.9.

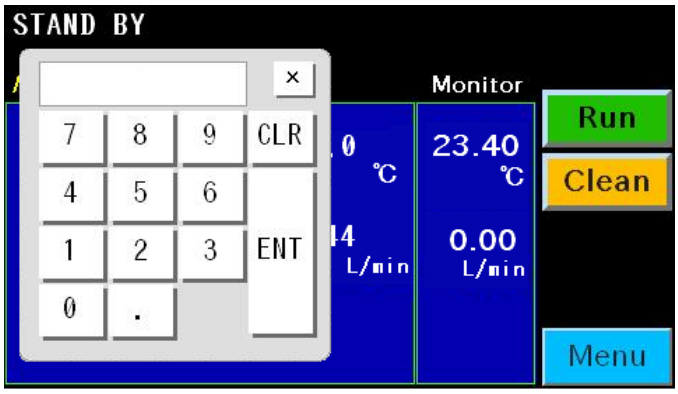
In Manual mode, only temperature and flow rate are set for use. See "7.6 Setting ranges for parameters " for the setting ranges.

Temperature and flow rate are determined by calculation. See Section 8 for the calculation method.
The accuracy of the calibration gas concentration is better when a larger Flow is set than when a smaller Flow is set.
Check that each parameter is set correctly.

The D-tube and P-tube must be kept at a stable temperature for 30 minutes to 24 hours (depending on application) for the Diffusion Rate or Permeation Rate to stabilize. At this time, the dilution gas must continue to run to prevent gas accumulation. If need to save dilution gas, minimize consumption by setting the flow rate to a minimum of 0.2L/min while waiting for the permeation rate to stabilize. Five minutes before using the calibration gas, change the flow rate setting to prepare the required gas concentration.



Touch the button (Temp, Flow) or the parameter value to be set to display the keypad. Enter the value to be set.



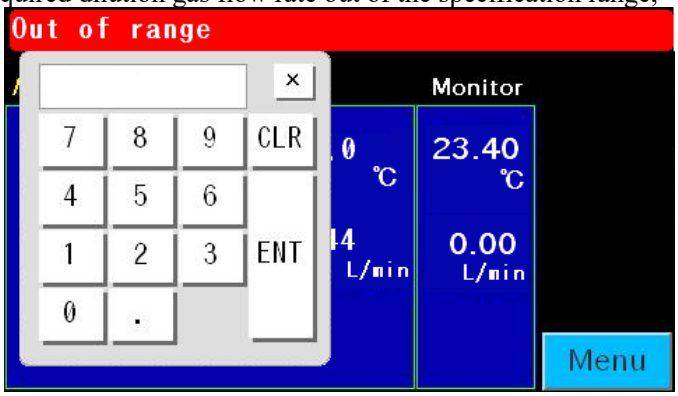
⚠Warning

The temperature setting of the P-tube should be set below the maximum temperature setting on the label of the P-tube storage container. If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion.

△Note

When using D-tube, the dilution gas flow rate should be in the range of 0.20 to 8.00 L/min. If the flow rate exceeds 8.00 L/min, the Diffusion Rate may become unstable.

If a value out of the settable range is entered, or if the automatic calculation results in a concentration or required dilution gas flow rate out of the specification range, "Out of range" is displayed.



After confirming the set values, start the run. Proceed to 7.7.

7.6 Setting ranges for parameters

Parameter	Setting range	Values to be entered	Increment/decrement
Coefficient of conversion of mass of the gas into volume K (L/g)	0.050 - 1.700	0.050 - 1.700	0.001
Permeation rate Pr (ng/min/cm)	1.00 - 990000 *1	1.00 - 9.99	0.01
		10.00 - 99.99	0.01
		100.0 - 999.9	0.1
		1000 - 9999	1
		10000 - 99999	1
		100000 - 990000	1
Diffugion rate Dr (µg/min)	0.010 – 99000 *2	0.010 - 9.999	0.001
		10.00 - 99.99	0.01
		100.0 - 999.9	0.1
		1000 - 9999	1
		10000 - 99000	1
Effective length L (cm)	1 – 100 *1	1 - 9	1
		10 - 99	1
		100	1
Temperature Temp (℃)	10.0-50.0	10.0 – 50.0	0.1
Concentration Conc (ppm)	0.0010 - 99000	0.0010 - 9.9999	0.0001
		10.000 - 99.999	0.001
		100.00 - 999.99	0.01
		1000.0 - 9999.9	0.1
		10000 - 99000	1
Dilution gas flow rate Flow (L/min)	0.20 - 10.00	0.20 - 9.99	0.01
		10.00	0.01
Ambient pressure AmbP (hPa)	500 - 1200	500 - 999	1
		1000 - 1200	1

*1
- The sum of L1 to L10 must be less than or equal to 100.
- The sum of (Pr1 x L1) - (Pr10 x L10) must be less than 990000.

*2
- In case of D-tube single gas mode, the sum of Dr1 to Dr4 must be less than 99000.

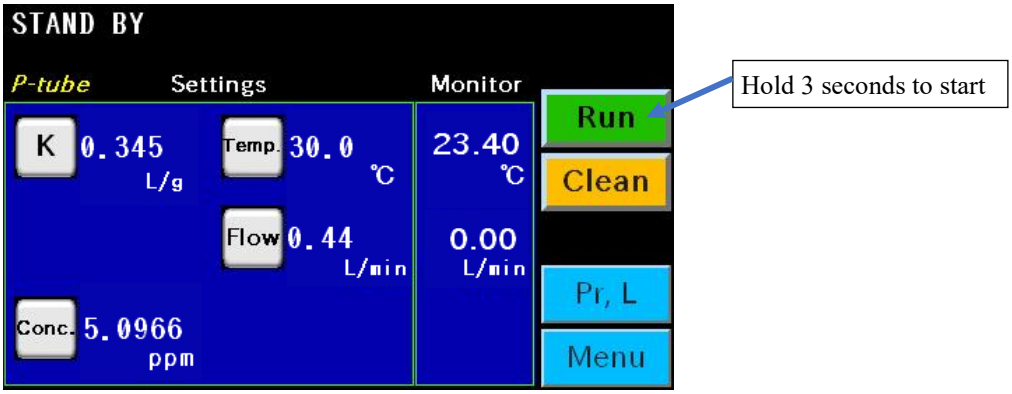
When Pr x L of 10 P-tubes are measured together, they can be entered together in one Pr1 and L1. For example, if any of the following combinations of Pr and L are used, the calculation result is the same in all cases.
Pr1= 9900, L1= 100
Pr1= 99000, L1= 10
Pr1= 990000, L1= 1

7.7 Start

⚠Warning

Before opening the TUBE HOLDER, allow the dilution gas to flow for at least 30 minutes. If the P-tube or D-tube used last time remains in the TUBE HOLDER, highly concentrated gas may have accumulated inside the TUBE HOLDER.

Before starting, make sure that each tube connection is fastened and that there are no leaks on the gas flow path, ensuring that the gas is led to an appropriate ventilation system or hazardous substance filtering system. Hold the "RUN" button for 3 seconds to start the gas flow controller, the temperature controller, and the water pump. The STATUS lamp turns green and the working status "RUNNING" is displayed on the screen. The green light illuminates when the temperature of the water bath is set at less than 35.1°C, and the green light blinks when at 35.1°C and more. It may take 1 to 2 hours for the water temperature to stabilize at the setpoint. The set point can be changed during the operation.



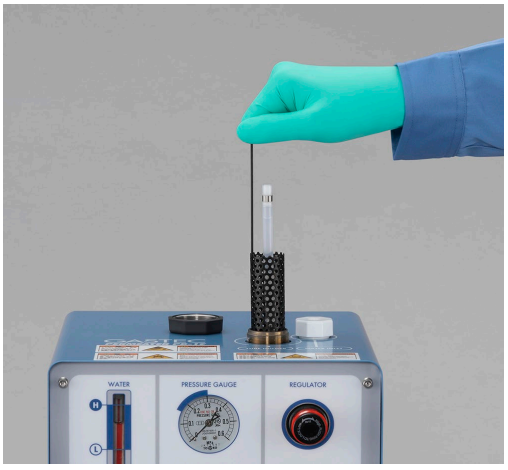
△Note

- ■When "RUNNING" and "STAND BY" are switched by pressing RUN and STOP for 3 seconds (when operation is started or stopped), the settings at that time are stored. The next time the power is turned on, the settings used the last time are automatically set.
- ■When in the "RUNNING" state, the power supply fan may repeatedly run and stop, which is normal operation.
- ■Although the temperature of the water may move in opposite directions from the set point within one minute after holding "RUN" button, that is the normal operation. The temperature changes toward the set point later.

Allow the dilution gas to flow and wait at least 30 minutes.

When using the D-tube to prepare calibration gas, refer to the instruction manual of the diffusion tube kit and load the liquid sample into the D-tube.

Place the P-tube or D-tube to be used in the tube holding cage. Open the TUBE HOLDER, place the tube holding cage, make sure the bottom of the cage touches the bottom of the TUBE HOLDER, and then release your hand.



Close the TUBE HOLDER firmly.

⚠Warning

- ■ Always work inside a local exhaust ventilation system when loading liquid samples into the D-tube.
- ■ When handling P-tube/D-tube, be sure to use appropriate protective equipment such as protective glasses, chemical protective clothing, protective gloves or footwear, etc. because of the toxicity and irritating odor.
- ■ TUBE HOLDER must be opened with dilution gas flowing.

△Note

- ■ Use the supplied tube holding cage when loading the P-tube or D-tube in the TUBE HOLDER. If not using it, the P-tube or D-tube cannot be taken out of the TUBE HOLDER. The use of the cage can also prevent the P-tube or D-tube from falling introduced in the temperature water bath by mistake.

About 24 hours (regarding the P-tube) or 30 minutes (regarding the D-tube) for equilibrium is required to obtain the stable permeation or diffusion rate after loading them in the TUBE HOLDER.

When running with a lower dilution gas flow rate during equilibrium, revert to the flow rate corresponding to the desired concentration after equilibrium. The prepared gas can be used after 5 minutes of stabilization.

The concentration of the calibration gas can be changed by the following operations.

a. Changing the dilution gas flow rate *F*.
After the flow rate is changed, it takes about 5 minutes for the concentration to stabilize.

b. Reduce effective length L. (Use fewer P-tubes)
If two or more P-tubes are used, the concentration can be reduced by reducing the number of P-tubes. After removing unnecessary P-tubes, the calibration gas concentration will stabilize in 5 minutes.

c. Increase the effective length L. (Use more P-tubes)
The concentration of the calibration gas can be increased by adding a P-tube. 24 hours are required for the calibration gas concentration to stabilize after the addition of a P-tube.

d. Changing the size of the D-tube
The concentration of the calibration gas can be changed by changing the size of the D-tube. When the D-tube is changed, the concentration of the calibration gas stabilizes 30 minutes after the temperature stabilizes.

e. Changing the temperature of the water bath
When P-tube is used, it takes 24 hours for the calibration gas concentration to stabilize. When D-tube is used, it takes 30 minutes for the calibration gas concentration to stabilize.

△Note

- ■ When using a dilution gas other than nitrogen or air, the flow controller must be calibrated with that gas.
- ■ The PRESSURE GAUGE indication swings toward zero as the flow rate is increased.

7.8 After use

After use, open the TUBE HOLDER and remove the tube holding cage while keeping the dilution gas flowing.

⚠Warning

- ■ Remove P-tube/D-tube from PD-1C when not in use. High concentrations of gas will accumulate.
- ■ TUBE HOLDER must be opened with dilution gas flowing. High concentrations of hazardous substances may remain in the TUBE HOLDER.

P-tubes are sealed and stored in the storage container provided with the P-tube.

The minimum temperature for storing P-tubes is -25°C. The maximum temperature for storage is indicated on the label of the storage container provided with the P-tube.

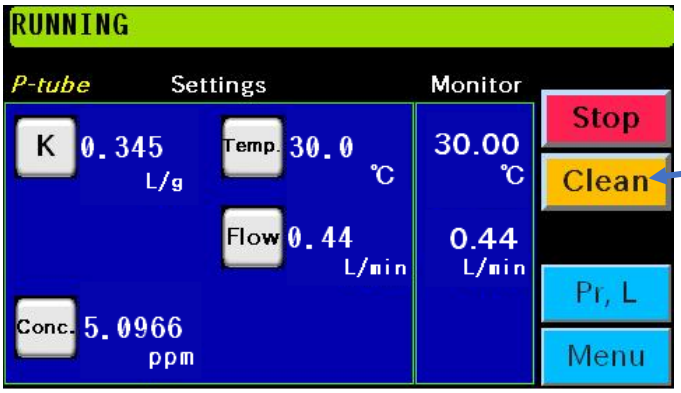
⚠Warning

- ■ The minimum storage temperature for P-tubes is -25°C. If P-tubes are stored at temperatures lower than -25°C, there is a possibility of temporary leakage of filling gas due to the difference in expansion coefficients of the tubes, metal parts, etc. when they are returned to room temperature.
- ■ The maximum storage temperature depends on the type of P-tube; check the label on the storage container that comes with the P-tube: "Below -5°C" or "Below 25°C".

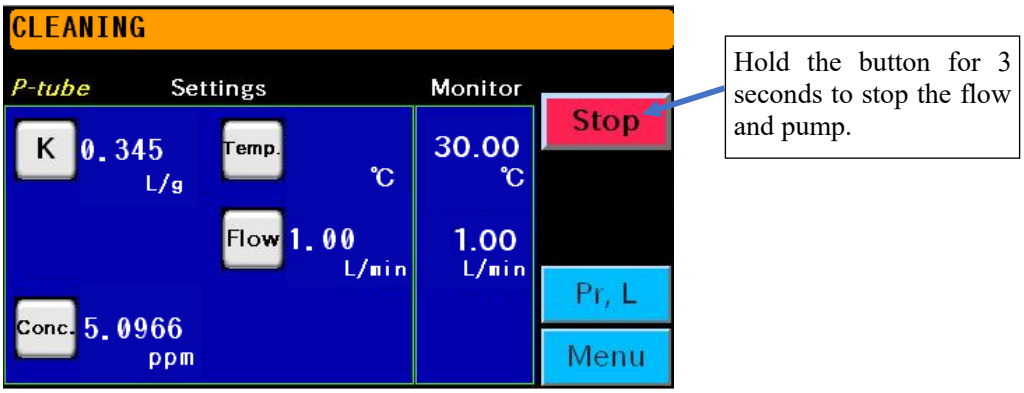
After using the D-tube, allow the liquid sample to evaporate completely in the local exhaust ventilation system or permeator. Alternatively, the liquid sample is impregnated with activated charcoal. Used activated carbon should be properly disposed of as industrial waste or incinerated. When incinerating, some hazardous gases may be generated. Use a chemical waste incinerator equipped with an exhaust gas treatment system.

If a high boiling point substance or a highly viscous substance is used, wash it several times with a volatile solvent such as alcohol or toluene, and then dry it.

After removing the tube holding cage, touch and hold the "CLEAN" for 3 seconds to clean up the inside of the flow path. (The flow rate is 1 L/min, the temperature controller is turned OFF, and the pump is turned ON.) The status display on the screen will change to "CLEANING" and the STATUS lamp will light up orange.



After 30 minutes or more, touch and hold the "STOP" button on the screen for 3 seconds to stop the flow controller and the pump. The status display on the screen will change to "STAND BY" and the STATUS lamp will light up orange. Press the POWER button to turn off the PD-1C.



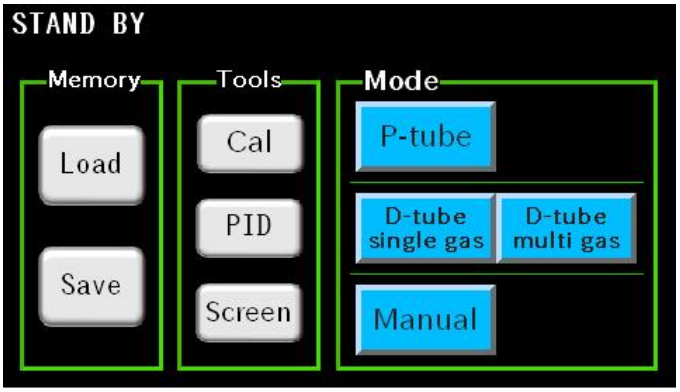
△Note

When the RUN/STOP button is touched to switch between "RUNNING" and "STAND BY," the settings at that time are stored in the memory of this instrunent. The next time the power is turned on, the stored value is set. (The settings at the start of cleanup are stored.)

7.9 Menu screen

Touching the "MENU" button on the main screen of each operation mode displays the menu screen. The following functions are available.

Mode "P-tube", "D-tube single gas", "D-tube multi gas", "Manual": Switching the operation mode (7.2) (7.3) (7.4) (7.5)
Memory "Load" and "Save": Save and recall parameter settings (7.10)
Tools "Cal": Calibration (flow rate, temperature, atmospheric pressure) (9)
Tools "PID": PID auto-tuning of temperature controller (10.2)
Tools "Screen": Screen brightness, timeout setting, touch screen setting (10.1)

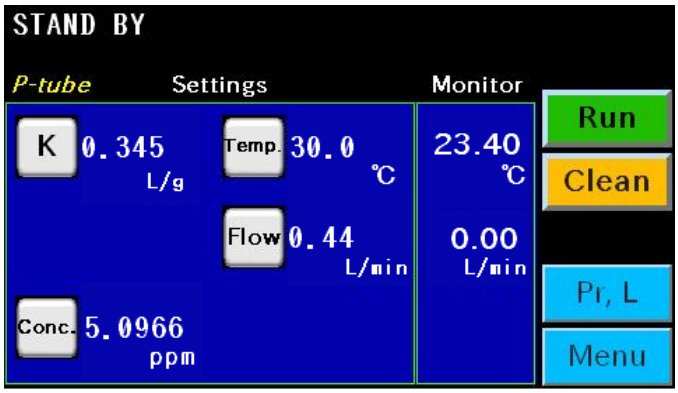


7.10 Memory function

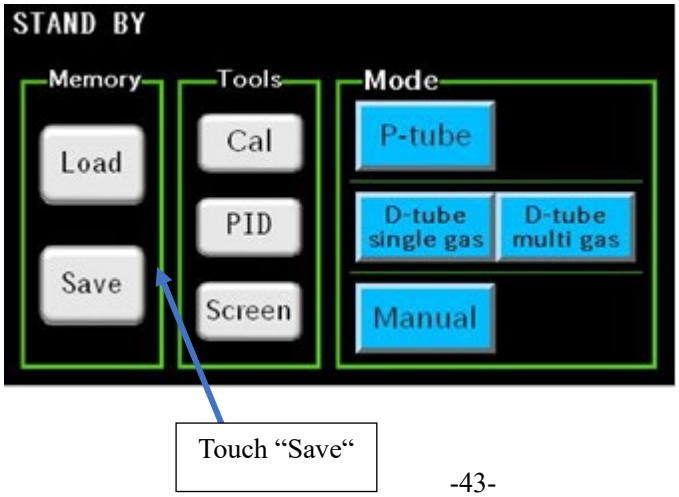
Settings made on the main screen can be named and saved, and the saved settings can be recalled on the main screen.

Saving the setting

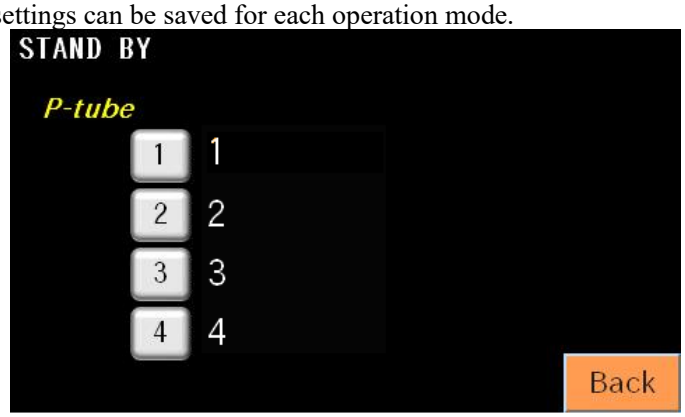
① Set parameters on the main screen of the operation mode to be saved, and touch the "MENU" button.



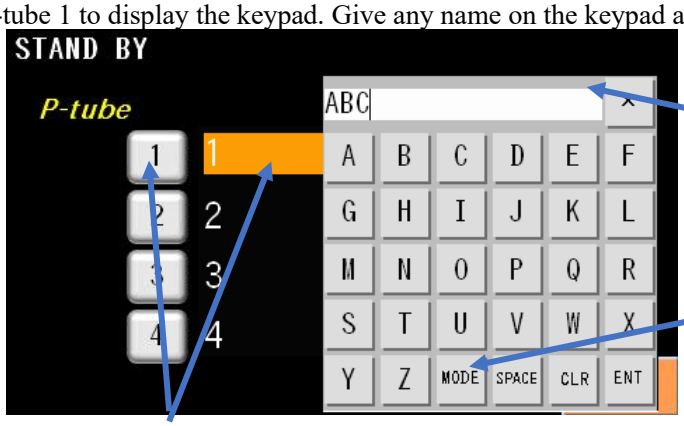
② Touch "Save" on the MENU screen.



③ The save screen is displayed. The memory list of the previous operation mode is selected. Four settings can be saved for each operation mode.



④Here is an example of how to save the settings in P-tube 1. Touch the number or the letter part of P-tube 1 to display the keypad. Give any name on the keypad and touch "ENT".

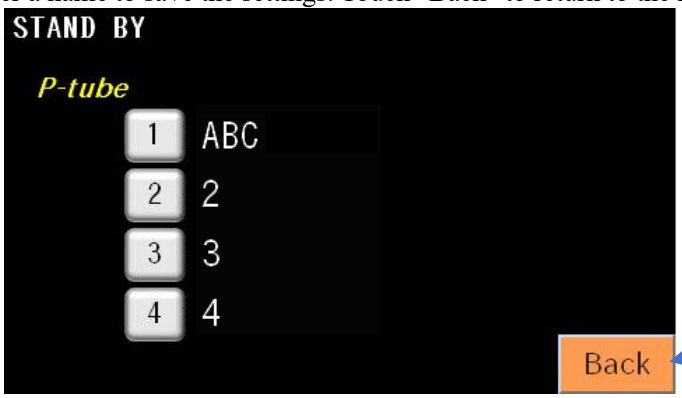


Upper and lower case alphabet, numbers and symbols can be entered.

Touching the MODE key toggles the type of character to be entered

Touch a number or a letter to display the keypad.

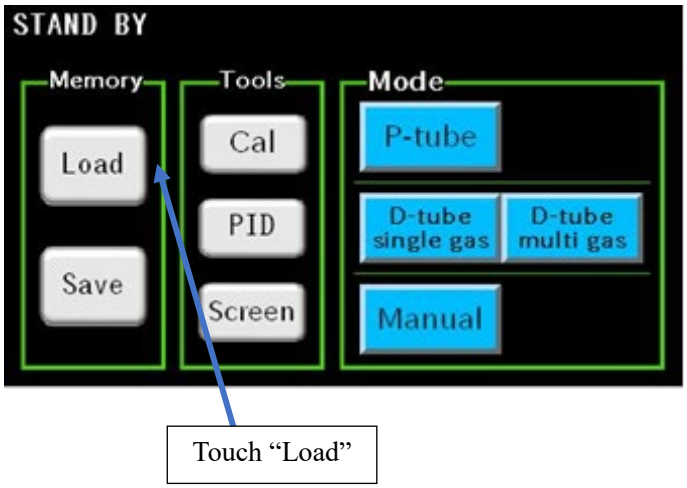
⑤Enter a name to save the settings. Touch "Back" to return to the menu screen.



To the MENU screen.

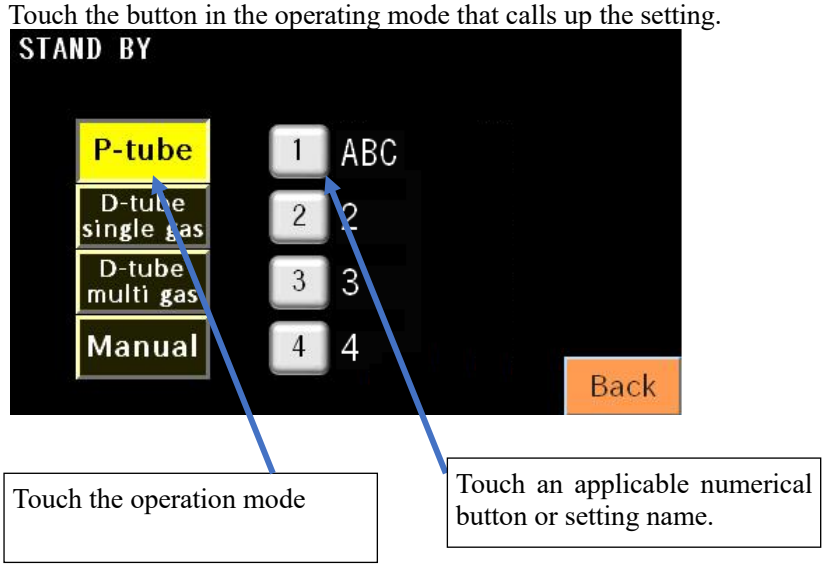
Recalling saved settings

① Touch "Load" button on the MENU screen.



② Touch the button in the operation mode that calls up the setting.

③ Touch the button in the operating mode that calls up the setting.



7.11 Action to be taken if the P-tube exceeds the "maximum temperature" on the P-tube storage container label

⚠Warning

If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion. If the temperature inside the TUBE HOLDER exceeds the "maximum temperature" on the P-tube storage container label, take the following measures.

- Immediately switch to the clean-up mode with the TUBE HOLDER lid closed
- Do not open the lid of the TUBE HOLDER because high concentration of gas may be accumulated in the TUBE HOLDER.
- Remove and Dispose of the P-tube after 24 hours of dilution gas flow. For disposal of P-tubes, refer to Instruction Manual for Permeation Tube

8. Calculation of conditions for preparation of calibration gas

The PD-1C automatically calculates the preparation parameters. On the other hand, the setting temperature of the water bath and the diluent gas flow rate can also be calculated using equations described in this section.

When simultaneously preparing more than two different kinds of gases, make sure that they do not react each other.

The accuracy of the prepared gas concentration will be improved when setting the dilution gas flow rate to a higher value. This is due to the characteristics of the gas flow controller.

Pr /*Dr* values can also be determined by weighing the P-tube/D-tube. For higher accuracy, we recommend weighing the P-tube/D-tube under the actual conditions of operating environment.

8.1 Calculation for P-tube

The label on the P-tube storage container supplied with the P-tube provides the permeation rate at each set temperature, the effective length of the P-tube and the *K* value. Preparation conditions are determined using those values with the calculation.

・The calibration gas concentration can be calculated with the formula (1) below:

$$C = \frac{K \times Pr \times L}{F \times 1000} \qquad (1)$$

C: Calibration gas concentration (ppm)
Pr: Permeation rate (ng/min/cm)
L: Effective length of tube (cm)
F: Flow rate of dilution gas (L/min)
K: Coefficient for converting a gas weight into a volume (L/g)

The permeate rate is the mass of gas that permeates from 1 cm of the permeating part of the P-tube in one minute from the liquefied gas in the P-tube held at a constant temperature. The actual measured value of the permeation rate at each temperature is indicated on the label of the storage container supplied with the P-tube for each bottle; use this *Pr* value for the calculation.

The effective length of a P-tube is the length of the part through which liquefied gas permeates; the label on the storage container supplied with the P-tube indicates the effective length for each P-tube, so use this *L* value for calculations.

The *K* value represents the volume of 1 g mass of the substance in the P-tube when it becomes a gas. This value is calculated at 25 °C and 1 atm.

$$K = \frac{22.4}{M} \times \left(\frac{298}{273}\right) \qquad (2)$$

M: Molecular weight of the substance in the P-tube

A mass flow controller is used to control the dilution gas flow rate, and the flow rate is displayed/controlled at 25°C and 1 atm conditions.
The actual volume flow rate varies with changes in ambient temperature and ambient pressure. However, the volume of the generated gas and dilution gas change at the same rate. Therefore, the volume concentration does not change.
In a strict sense, the volume of 1 mol of gas in the standard state (STP) varies depending on the type of gas. Also, a more accurate *K* value can be obtained by using the molar mass instead of the molecular weight in Equation (2).

<Calculation Example>

Obtain the dilution gas flow rate F for the preparation of Sulphur Dioxide 1.00 ppm and 0.20 ppm with the temperature set to 35 °C.

The label on the P-tube storage container supplied with the SO_2 P-tube indicates the following information. Use these values for the calculation.

Effective length	K value	Permeation rate Pr (ng/min/cm)	
5cm	0.382	30°C: 310	35°C: 430

Equation (1) is transformed to obtain Equation (3).

$$F = \frac{K \times Pr \times L}{C \times 1000} \qquad (3)$$

$$= \frac{0.382 \times 430 \times 5}{C \times 1000} = \frac{0.8213}{C}$$

From the above equation, to prepare C = 1.00 ppm, set the temperature to 35 °C and the dilution gas flow rate F to 0.82 L/min.
To prepare C = 0.20 ppm, set the dilution gas flow rate F to 4.11 L/min at a temperature setting of 35 °C.

・The calibration gas concentration when using two P-tubes is calculated using the following equation.

$$C = \frac{K \times (Pr_1 \times L_1 + Pr_2 \times L_2)}{F} \qquad (4)$$

Pr_1: Permeation rate of the first tube (ng/min/cm)
L_1: Effective length of the first tube (cm)
Pr_2: Permeation rate of the second tube (ng/min/cm)
L_2: Effective length of the second tube (cm)

・Calculations to estimate Pr values at temperatures not listed on the label of the P-tube storage container
The Pr at a given temperature can be simply calculated from the Pr value indicated on the label of the storage container supplied with the P-tube. Only the lower to upper range of temperatures indicated on the label is applicable.
For more accurate Pr values, see "Methods for measuring permeation rate Pr values".

If the temperature difference between the two Pr values indicated on the label is 5°C,

$$Pr_T = Pr_L \times \left(\frac{Pr_H}{Pr_L}\right)^{\frac{T-T_L}{5}} \qquad (5)$$

Pr_T : Pr to be estimated
T : Temperature of Pr_T (°C)
T_L : Lower temperature of 5°C interval setting indicated on the label (°C)*
Pr_L : Pr values for the lower 5°C intervals indicated on the label
Pr_H : Pr values for the higher 5°C intervals indicated on the label

* When T is between 25°C and 30°C, T_L is 25°C. When T is between 30°C and 35°C, T_L is 30°C. When T is between 35°C and 40°C, T_L is 35°C.

If the temperature difference between the two Pr values indicated on the label is 15°C (The error tends to be larger than when the temperature difference is 5°C),

$$Pr_T = Pr_L \times \left(\frac{Pr_H}{Pr_L}\right)^{\frac{T-T_L}{10}} \qquad (6)$$

T_L : Lower temperature of 15°C interval setting indicated on the label (°C)

When T is between 35°C and 50°C, T_L is 35°C.

⚠Warning

The above Equations (5) and (6) are applicable only in the temperature range from the lower to the upper limit of the temperature indicated on the label of the storage container supplied with the P-tube. Temperatures outside this range may cause the P-tube to rupture.

・Methods for calculating mass concentration

From the equation for volume concentration, exclude the coefficient K value for converting mass to volume and add corrections for temperature and atmospheric pressure. The volume concentration is calculated with 25 °C and 1 atm, so it can be converted using the following equation.

$$C_g = \frac{Pr \times L}{F \times 1000} \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right) \quad (7)$$

$$F = \frac{Pr \times L}{C_g \times 1000} \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right) \quad (8)$$

C_g : Calibration gas concentration (mg/m^3)
T : Ambient temperature (°C)
P : Ambient pressure (hPa)
P_0 : Standard atmosphere (hPa)

・Methods for measuring permeation rate Pr values

Pr values can be determined by actual measurement. For higher accuracy, it is recommended to measure the actual values under the actual conditions of use.

The operation mode of this instrunment is set to “Manual” and only temperature and flow rate are displayed.

Place the P-tube in the TUBE HOLDER. Maintain a constant temperature while dilution gas is flowing (> 0.2 L/min). After about 24 hours, remove the P-tube and weigh it on a balance with a minimum unit of 0.1-0.01 mg. Record the time by minute. Immediately after weighing, return the P-tube to TUBE HOLDER to continue gas generation.

For balances with [minimum limit 0.01 mg, repeatability ≤ 0.015 mg], repeat the weighing at intervals at which its decrease is 15 mg or more (1-10 days) until a reliable Pr value is obtained. The approximate weighing interval is determined by Equation (9) and the Pr value by Equation (10).

$$\text{Weighing interval (Day)} = \frac{1 \times 10^4}{Pr \times L} \quad (9)$$

$$\text{Permeation rate } Pr = \frac{m \times 10^6}{L \times T} \quad (10)$$

Pr : Permeation rate (ng/min/cm)
L : Effective length of the P-tube (cm)
M: P-tube Decrease (mg)
T : Weighing interval (min)

For information on how to determine the uncertainty of the prepared gas concentration, refer to Section 11 "Uncertainty of the prepared gas concentration".

8.2 Calculation for D-tube

When using the No.3100 Diffusion tube set, use the K value and the diffusion rate described in the catalogue of the Permeater or in the table of the diffusion rate in the instruction manual for Diffusion tube.

When using the No.3200 Diffusion tube set for the multi-component diffusion tube, use the diffusion rate described in the No.3200 technical document attached to No.3200 Diffusion tube set.

The No.3200 Diffusion tube set allows simultaneous preparation of gases for four-species.

The calibration gas concentration can be calculated with the following formula:

$$C_0 = \frac{K \times Dr}{F} \qquad (11)$$

C: Calibration gas concentration (ppm) No atmospheric pressure compensation
Dr: Diffusion rate (μg/min)
F: Flow rate of dilution gas (L/min)
K: Coefficient for converting a gas weight into a volume (L/g)

When using D-tube, the dilution gas flow rate should be in the range of 0.2 to 8.0 L/min.
If the flow rate is greater than 8.0 L/min, a stable diffusion rate may not be obtained.

In the case of D-tube, *Dr* value is affected by ambient pressure, so correction by formula (12) is necessary.

$$C = C_0 \times \frac{P_0}{P} \qquad (12)$$

C: Calibration gas concentration (ppm)
C_0 : Calibration gas concentration at standard atmospheric pressure (ppm)
P: Ambient pressure (hPa)
P_0 : Standard atmospheric pressure (hPa)

The *K* value represents the volume of 1 g mass of the substance in the D-tube when it becomes a gas. This value is calculated at 25 °C and 1 atm.

$$K = \frac{22.4}{M} \times \left(\frac{298}{273}\right) \qquad (13)$$

M: Molecular weight of the substance in the D-tube

A mass flow controller is used to control the dilution gas flow rate, and the flow rate is displayed/controlled at 25°C and 1 atm conditions.
The actual volume flow rate varies with changes in ambient temperature and ambient pressure. However, when PD-1C is used, the volume of the generated gas and dilution gas change at the same rate. Therefore, the *K* value does not change.
In a strict sense, the volume of 1 mol of gas in the standard state (STP) varies depending on the type of gas. Also, a more accurate *K* value can be obtained by using the molar mass instead of the molecular weight in equation (13).

<Calculation example> 5.0 ppm Benzene at standard atmospheric pressure

The following diffusion rates are obtained from the catalogue of the Permeator or the instruction manual for Diffusion tube.

Diffusion rate at 30 °C	D-10 :	31.0 μg/min
	D-20 :	75.0 μg/min
	D-30 :	215.0 μg/min
	K value :	0.313

Equation (11) is transformed to obtain Equation (14).
The calculation for the use of a D-10 type D-tube is as follows

$$F = \frac{K \times Dr}{C} \qquad (14)$$

$$= \frac{0.313 \times 31.0}{5.0} = 1.94$$

To prepare C=5.0 ppm, set the water bath temperature to 30 °C, use D-10 type D-tube, and set the

dilution gas flow rate F to 1.94 L/min.

・The calibration gas concentration when using two D-tubes can be calculated with the following formula:

$$C_0 = \frac{K \times (Dr_1 + Dr_2)}{F}$$

Dr_1: Diffusion rate of the first tube (μg/min)
Dr_2: Diffusion rate of the second tube (μg/min)

・Calculations to estimate Dr values not described in the catalogue of Permeator, the instruction manual for the Diffusion tube or the No. 3200 technical documents

The Dr at a given temperature can be simply calculated from the Dr value indicated on those documents. Only the lower to upper range of temperatures indicated on those documents is applicable. For more accurate Dr values, see "Methods for measuring diffusion rate Dr values".

If the temperature difference between the two Dr values given in the documents is 5°C, the Dr at a temperature between those Dr values can be estimated using the following equation.

$$Dr_T = Dr_L \times \left(\frac{Dr_H}{Dr_L}\right)^{\frac{T-T_L}{5}}$$

Dr_T : Dr to be estimated
T : Temperature of Dr_T
T_L : Lower temperature of 5°C interval setting in the documents (°C)*
Dr_L : Dr values for the lower 5°C intervals indicated in the documents
Dr_H : Dr values for the higher 5°C intervals indicated in the documents

*When T is between 30°C and 35°C, T_L is 30°C. When T is between 35°C and 40°C, T_L is 35°C.

If the temperature difference between the two Dr values given in the documents is 10°C, the Dr at a temperature between those Dr values can be estimated using the following equation.

$$Dr_T = Dr_L \times \left(\frac{Dr_H}{Dr_L}\right)^{\frac{T-T_L}{10}}$$

T_L : Lower temperature of 10°C interval setting in the documents (°C)
When T is between 40°C and 50°C, T_L is 40°C.

・Methods for calculating mass concentration

From the equation for volume concentration, exclude the coefficient K value for converting mass to volume and add a correction for atmospheric pressure for the Dr value and a correction for temperature and atmospheric pressure for the volume. The formula for volume concentration is calculated at 25 °C and 1 atm, so it can be converted using the following equation.

$$C_g = \frac{Dr}{F} \times \left(\frac{P_0}{P}\right) \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right)$$
$$= \frac{Dr}{F} \times \left(\frac{298}{273+T}\right) \qquad (15)$$
$$F = \frac{Dr}{C_g} \times \left(\frac{P_0}{P}\right) \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right)$$
$$= \frac{Dr}{C_g} \times \left(\frac{298}{273+T}\right) \qquad (16)$$

C_g : Calibration gas concentration (mg/m^3)
T : Ambient temperature
P : Ambient pressure (hPa)
P_0: Standard atmosphere

・Methods for measuring diffusion rate *Dr* values

Dr values can be determined by actual measurement. For higher accuracy or for substances not listed in the tables, it is recommended to measure the actual values under the actual conditions of use.
Fill the D-tube with the specified amount of sample liquid and place it in the TUBE HOLDER. Maintain a constant temperature while dilution gas is flowing (> 0.2 L/min).
After at least about 30 minutes, remove the D-tube and weigh it on a balance with a minimum unit of 0.1-0.01 mg. Record the time by minute. Immediately place the D-tube in the TUBE HOLDER and maintain it at a constant temperature with dilution gas flowing.
Repeat the weighing at equal intervals and calculate the diffusion rate at that temperature from equation (17). As the diffusion rate is reproducible, the value can be used repeatedly for the same D-tube.
For balances with [minimum limit 0.01 mg, repeatability ≤ 0.015 mg], repeat the weighing at intervals of at least 15 mg decrease until a reliable Dr value is obtained. The approximate weighing interval is determined by equation (18).

$$Dr = \frac{m \times 10^6}{T} \qquad (17)$$

$$T = \frac{m \times 10^6}{Dr} \qquad (18)$$

Dr : Diffusion rate (μg/min)
m : D-tube decrease (g)
T : Weighing interval (min)

For actual measurement, a weighing interval of at least 1 day for a *Dr* value = 10, 2.5 hours for a *Dr* value = 100, and 30 minutes for a *Dr* value = 500 is recommended.
The operation mode of this instrument is set to “Manual” and only temperature and flow rate are displayed.
When measuring the actual diffusion rate, increasing the holding temperature of the D-tube from 30 °C to 50 °C will approximately triple the *Dr* value. At the same temperature, the diffusion rate is approximately 2.5 times higher with D-20 and approximately 7.2 times higher with D-30 than with D-10 diffusion tubes.
Make sure that the vapor pressure of the sample liquid is within the range 5 - 400 mmHg. For substances out of this range, a stable diffusion rate may not be obtained.

The diffusion rate *Dr* listed in the catalogue, the instruction manual for the diffusion tube or the No.3200 technical document for the multi-component diffusion tube is the value under the standard atmospheric pressure. In the PD-1C, the pressure around the D-tube is the same as the pressure at the calibration gas outlet. Therefore, if the pressure at the calibration gas outlet is different from the ambient pressure, the diffusion rate must be corrected by the pressure at the calibration gas outlet.
Although the PD-1C is basically handled with no flow load (the same as ambient pressure), the dilution gas flow may be overloaded (the pressure different from ambient pressure) when a humidifying cylinder, filter, or other object is connected to the calibration gas outlet.
An absolute or differential pressure gauge (separately prepared) is used for checking whether overloading is occurring. The pressure should be measured with only dilution gas flowing since calibration gas may damage the pressure gauge. Measure the absolute pressure at the outlet of the calibration gas with an absolute pressure gauge. (If cannot, measure the differential pressure at the outlet of the calibration gas with a differential pressure gauge, and add the measured value to the value of the built-in ambient pressure sensor of the PD-1C.)
The value of deviation of concentration due to differences in pressure without correction is referred by the formula (12).
Refer to the table below for the settings of the PD-1C.

	Without flow-overloading (Normal case)	Flow-overloading
When using the *Dr* listed in the catalogue, the instruction manual for the diffusion tube or the No.3200 technical document for the multi-component diffusion tube	Correction for atmospheric pressure is necessary. Touch the "AmbP sensor" button. The value of the built-in ambient pressure sensor will be set.	Set the measured value of the absolute pressure gauge using the keypad.
When measuring the *Dr*, (There is a possibility that pressure at the outlet of the calibration gas changes between the time of the *Dr* measurement and that of gas generation.)	① Calculate the *Dr* value under the standard atmospheric pressure from the measured *Dr* value. (Set the calculated *Dr* value.) ② Correction for atmospheric pressure is necessary when preparing the calibration gas. Touch the "AmbP sensor" button. The value of the built-in ambient pressure sensor will be set.	①Calculate the *Dr* value under the standard atmospheric pressure from the measured *Dr* value. (Set the calculated *Dr* value.) ② Correction for atmospheric pressure is necessary when preparing the calibration gas. Set the measured value of the absolute pressure gauge using the keypad.
When measuring the *Dr*, (The pressure at the calibration gas outlet does not change between the time of *Dr* value measurement and that of gas generation.)	① The measured *Dr* value is not corrected for pressure. (The pressure at the time the *Dr* value is measured is treated as the value at the outlet of the calibration gas at the time of calibration gas preparation.) ② Atmospheric pressure correction is not necessary. Touch the "1013hPa" button. The value of "1013" is set to "AmbP" and the correction is invalidated. (The correction factor is "1013/1013 = 1".)	③ The measured *Dr* value is not corrected for pressure. (The pressure at the time the *Dr* value is measured is treated as the value at the outlet of the calibration gas at the time of calibration gas preparation.) ④ Atmospheric pressure correction is not necessary. Touch the "1013hPa" button. The value of "1013" is set to "AmbP" and the correction is invalidated. (The correction factor is "1013/1013 = 1".)

※When setting the pressure using the keypad, the value should be within the range of ambient pressure ±150 hPa.

For information on how to determine the uncertainty of the prepared gas concentration, refer to Section 11 "Uncertainty of the prepared gas concentration".

9. Calibration for flow rate, temperature and atmospheric pressure

This section describes the calibration of flow rate and temperature. For calibration of atmospheric pressure, please contact Gastec or your Gastec representative. (Refer to Section 12.10 "Repair".)

9.1 Flow rate calibration (recommended every year)

① Remove the P-tube/D-tube from the TUBE HOLDER.

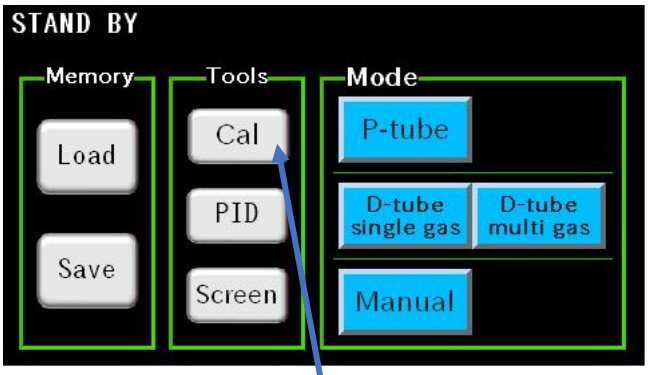
② Check that the water temperature in the constant temperature water bath is within ±3°C of the ambient temperature. When the water temperature differs significantly from the ambient temperature, the calibration gas temperature will be unstable after the calibration gas is discharged from the outlet, so the readings of the standard flowmeter may not be accurate.

③ The flow rate of PD-1C is displayed/controlled at 25°C and 1 atm conditions. Therefore, set the environmental conditions of the standard flowmeter (separately prepared) to 25°C, 1 atm.

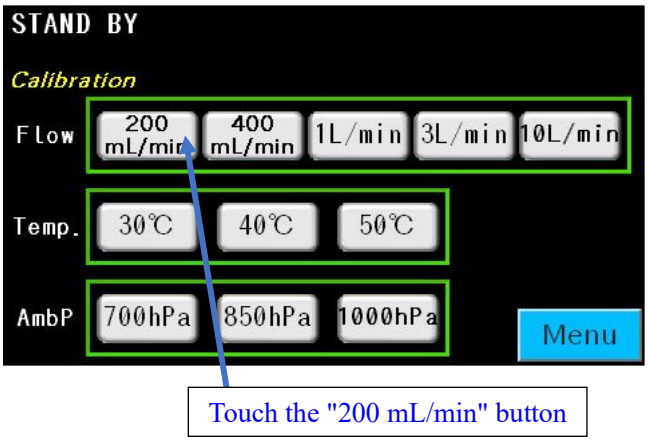
④ Connect the inlet of the standard flowmeter to one side of the CALIBRATION GAS (outlet) on the front panel of PD-1C, and close the other side of CALIBRATION GAS.

⑤ Set the measurement range of the standard flowmeter to the range that includes the calibration flow rate of 200 mL/min.

⑥ Touch the "Cal" button on the menu screen.

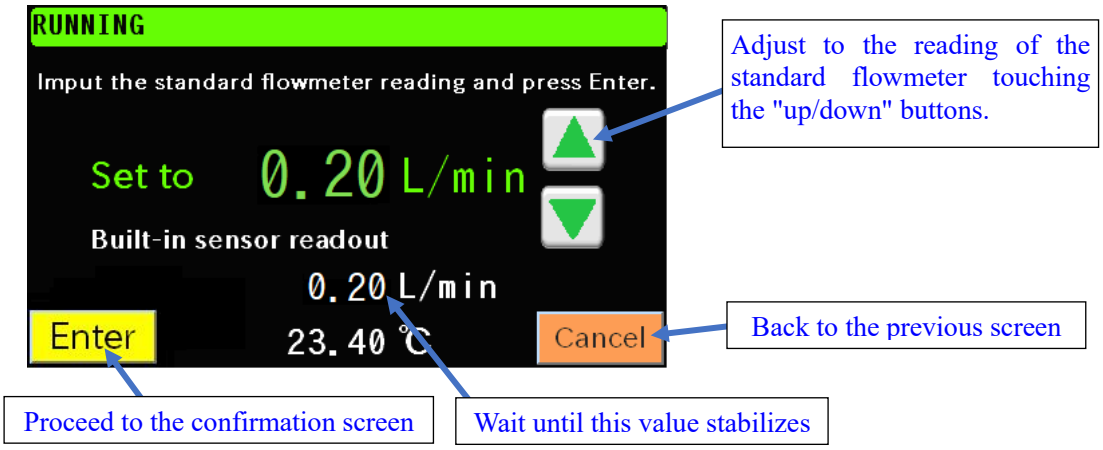


⑦ The calibration point selection screen appears. Select the flow rate "200mL/min" to be calibrated.

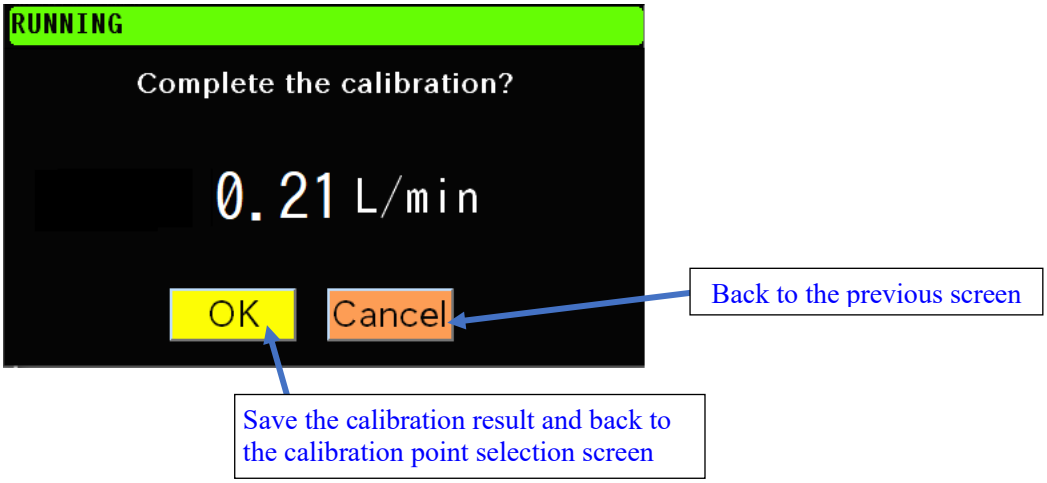


⑧ The flow rate of the "Built-in sensor readout" displayed on the screen changes. Wait until both the "Built-in sensor readout" value and the reading of the standard flowmeter stabilize near the calibration point.

⑨ Adjust the "Set to" value to the reading of the standard flowmeter touching the "up/down" buttons, then touch the "Enter" button to proceed to the confirmation screen. To cancel, touch the "Cancel" button.



⑩ The confirmation screen appears. Check again that the displayed value agrees with the reading of the standard flowmeter, and if it does, touch the "OK" button, saving the calibration result and returning to the calibration point selection screen. If it is different, touch the "Cancel" button to return to the previous screen and adjust the value to the reading of the standard flowmeter again.



⑪ Calibrate the flow rate at the calibration points of 400 mL/min, 1 L/min, 3 L/min, and 10 L/min in the same manner.

⑫ Remove the standard flowmeter.

9.2 Temperature calibration (recommended every year)

Prepare a standard thermometer with its sensor part of approximately 6 mm in outer diameter.

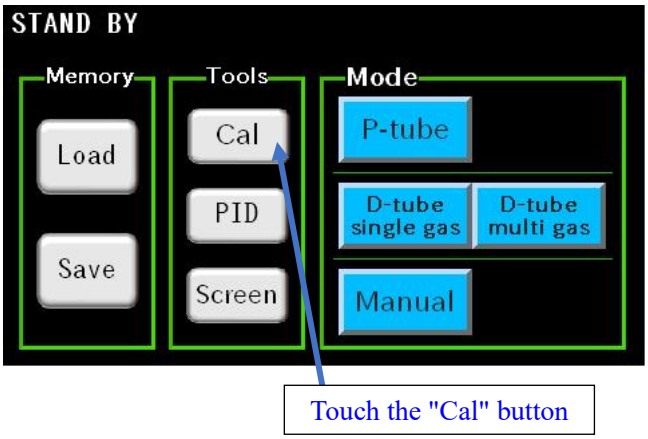
① Remove the P-tube/D-tube from the TUBE HOLDER.

② Remove the WATER INLET lid.

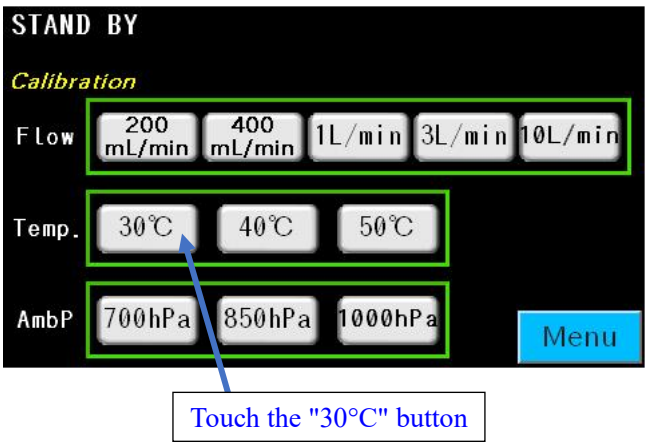
③ Insert the standard thermometer into the supplied rubber stopper until the tip of the thermometer (sensor part) is about 16.5 cm from the rubber stopper. (This is approximately 16.5 cm from the top of the WATER INLET.)

④ Insert the standard thermometer with the rubber stopper into the constant temperature water bath and fix it.

⑤ Touch the "Cal" button on the menu screen.

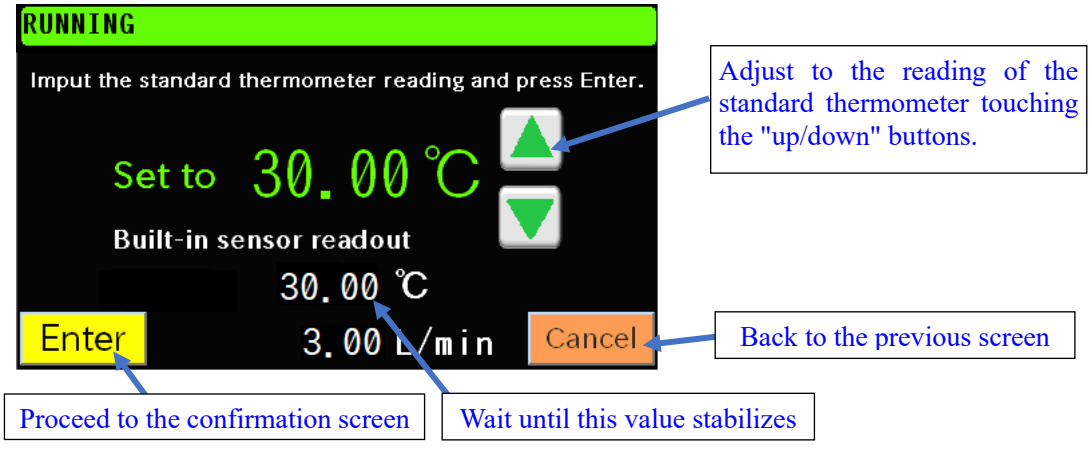


⑥ The calibration point selection screen appears. Select the temperature "30°C" to be calibrated.

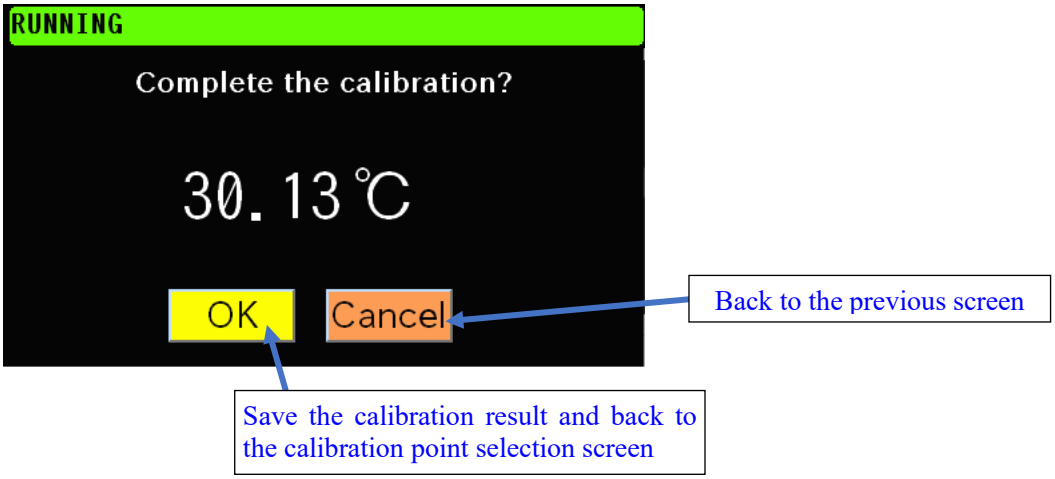


⑦ The temperature of the constant temperature water bath changes, and that of the "Built-in sensor readout" displayed on the screen changes. Wait until both the "Built-in sensor readout" value and the reading of the standard thermometer stabilize near the calibration point.

⑧ Adjust the "Set to" value to the reading of the standard thermometer touching the "up/down" buttons, then touch the "Enter" button to proceed to the confirmation screen. To cancel, touch the "Cancel" button.



⑨ The confirmation screen appears. Check again that the displayed value agrees with the reading of the standard thermometer, and if it does, touch the "OK" button, saving the calibration result and returning to the calibration point selection screen. If it is different, touch the "Cancel" button to return to the previous screen and adjust the value to the reading of the standard thermometer again.



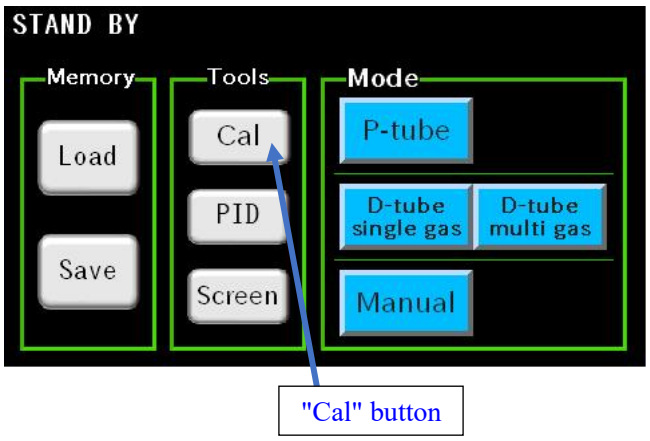
⑩ Calibrate the temperature at the calibration points of 40°C and 50°C in the same manner.

⑪ Remove the standard thermometer with the rubber stopper, and close the WATER INLET lid.

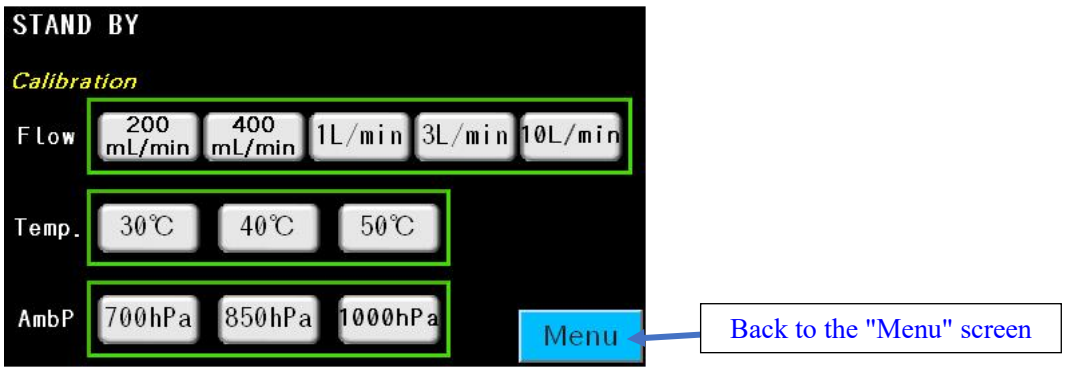
9.3 Atmospheric pressure calibration

Please contact Gastec or your Gastec representative for the calibration. The calibration by the customer is not included in the operation of the PD-1C.

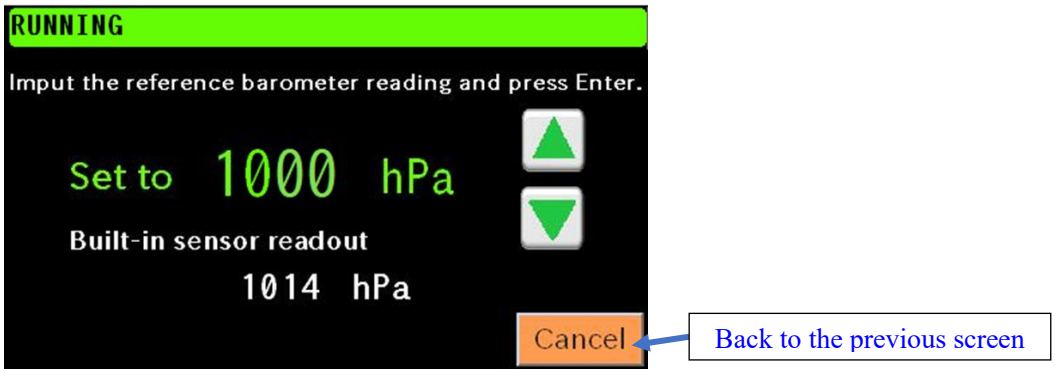
The calibration point selection screen appears touching the "Cal" button on the menu screen.



The calibration point selection screen appears. Select "1000 hPa".



The screen for inputting a calibration value appears, but the values cannot be confirmed.
Touch the "Cancel" button to return to the previous screen.

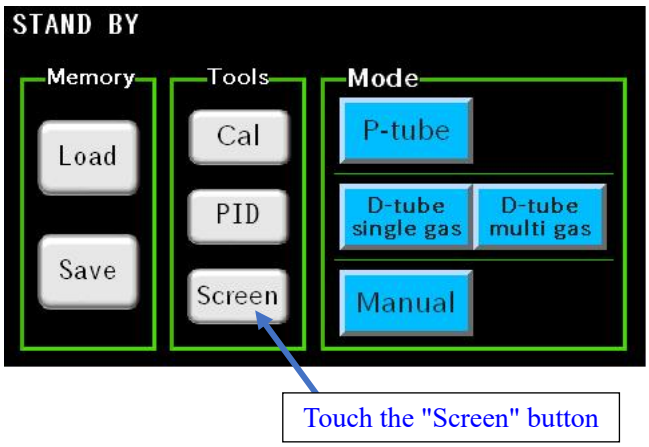


10. Other settings

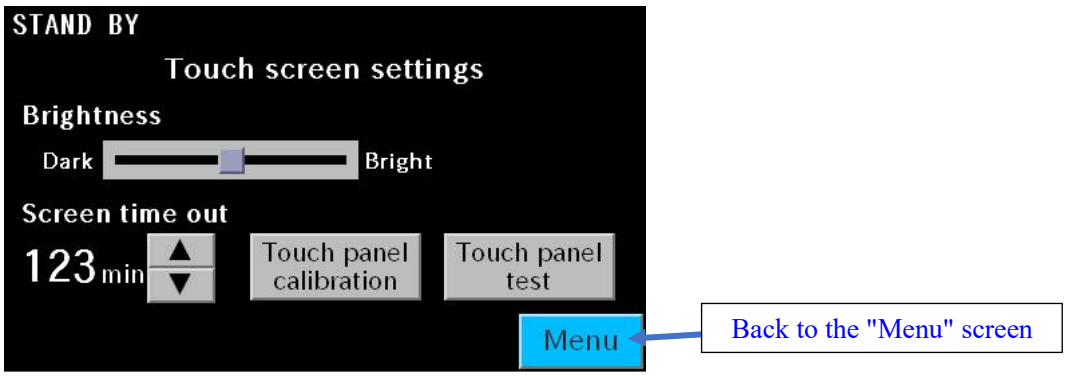
10.1 Screen Settings

Screen brightness, timeout, and touch panel can be adjusted.

① Touch the "Screen" button on the menu screen.



② The setup screen appears.



- "Brightness": Adjustment of screen brightness
- "Screen time out": Time until the screen goes off. If set to "0 min", the light does not turn off.
- "Touch panel calibration": Adjustment of touch panel detection position
- "Touch panel test": Checking of the detection position of the touch panel

We recommend a screen brightness near the center and a timeout of 10 minutes. Brighter screens or no timeout (setting to "0 min") will shorten the life of the backlight.

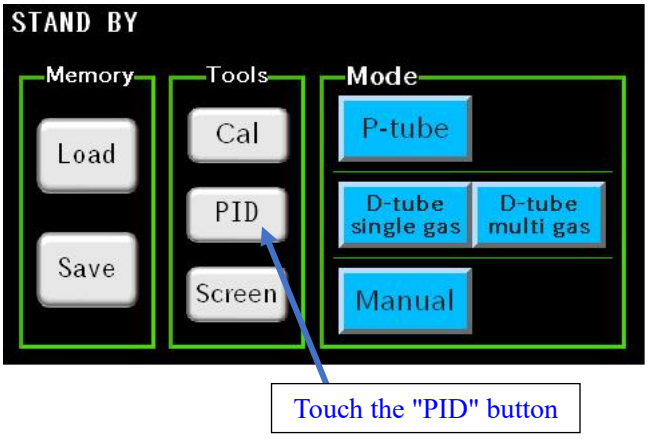
"Touch panel test" allows to check the detection position of the touch panel. If the screen is out of the correct position, adjust the detection position with "Touch panel calibration".
Touching the "OK" button or not operating for one minute when the "Touch panel test" screen or "Touch panel calibration" screen is displayed will return to the above setting screen.
For the "Touch panel test" screen and "Touch panel calibration" screen, we recommend using a commercially available stylus pen for touch panels.

10.2 Auto-tuning of temperature controller with PID control

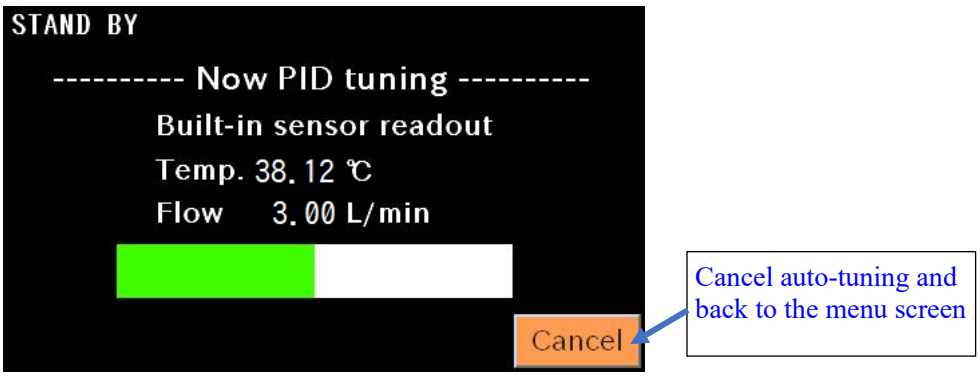
Temperature fluctuations associated with temperature control can be reduced. This is done at the time of our inspection and is usually not required.

① Remove the P-tube/D-tube from the TUBE HOLDER.

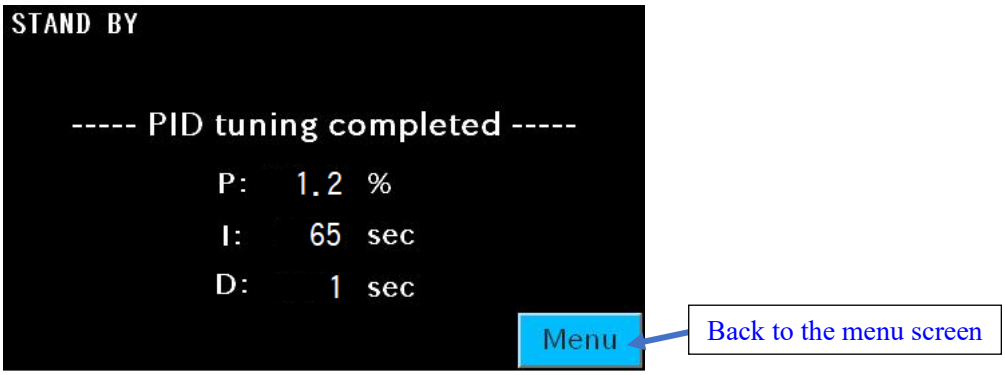
② Touch the "PID" button on the menu screen.



③ The temperature automatically rises and falls, and auto-tuning is performed. The progress is displayed as a bar graph. To cancel auto-tuning, touch "Cancel" button.



④ After about 1 hour, the result will be displayed. It is normal if "P: 0.8 to 1.4%", "I: 55 to 80 sec", and "D: 0 to 3 sec". Touch the "Menu" button to return to the menu screen.



11. Uncertainty of prepared gas concentrations

Uncertainty is one of the quantitative measures of the degree of variation in measured values. Uncertainty is expressed as the width of the interval in which the final measurement value would be included with approximately 95% probability in many cases where the measurement values follow a normal distribution. (This means that the measured value falls within the indicated width with a probability of 95%.) In this case, the coverage factor k=2 is noted together.

The uncertainty of the prepared gas concentration is calculated based on the uncertainties of the built-in instruments in the PD-1C and the external instruments that calibrate them, and the repeatability of the permeation rate *Pr*/diffusion rate *Dr*, meaning the deviation of *Pr*/*Dr* obtained by measuring *Pr*/*Dr* multiple times in advance. An examples calculation is given below.

≪Example 1≫

When calculating the gas concentration using the permeation rate listed on the label of the P-tube storage container

Given:

- Gas/ Concentration: Hydrogen Sulfide/ Approximately 0.5 ppm
- P-tube: P-4 (1 tube) (Effective length 10 cm)
- Temperature: 35°C
- *Pr* (listed on the label): 454.0 ng/min/cm
- *K*: 0.718 L/g
- Dilution gas flow rate (Setting value): 6.52 L/min $\because \frac{0.718 \times 454.0 \times 10}{0.5 \times 1000} = 6.52\ \mathrm{L/min}$

Formula for calculating gas concentration is (Refer to Section 8.1)

$$C = \frac{K \times Pr \times L}{F \times 1000}$$

C: Calibration gas concentration (ppm)
Pr: Permeation rate (ng/min/cm)
L: Effective length of tube (cm)
F: Flow rate of dilution gas (L/min)
K: Coefficient for converting a gas weight into a volume at 25°C (L/g)

On the right side of the above equation, the parameters with uncertainty are *Pr* and *F*.

※ Since the volume of the permeated gas and the dilution gas change at the same rate when ambient temperature and pressure change, temperature and pressure corrections are not required for the *K* value, and there is no uncertainty resulting from this. (Refer to Section 8.1)

※ *L* is the same as the value by which the mass loss is divided when determining *Pr*. When calculating the gas concentration, this value (effective length, fixed) is multiplied by *Pr*, so there is no uncertainty regarding length.

※ *Pr* is not affected by ambient pressure, and there is no pressure-induced uncertainty regarding *Pr*.

Factors of uncertainty

Repeatability of measurements for the permeation rate: Pr_v

Our repeated measurements of *Pr* have shown that the maximum relative standard deviation is 3.0%. Therefore, the standard uncertainty ($u(Pr_v)$) of Pr listed on the label is 0.03 and the relative standard uncertainty ($u(Pr_v)/Pr_v$) is below.

$$\left(\frac{u(Pr_v)}{Pr_v}\right) = \frac{0.03}{1} = 0.03$$

Temperature variation in permeation rate: Pr_t

Since the temperature variation of the TUBE HOLDER is ±0.15°C* and the sensitivity coefficient of *Pr* is about 1% per 0.1°C, *Pr* may vary up to ±1.5% due to temperature variation. Assuming that this standard uncertainty follows a rectangular distribution, the standard uncertainty ($u(Pr_t)$) and the relative standard uncertainty ($u(Pr_t)/Pr_t$) are as follows:

*Cited from Section 13 (Calculated based on the repeatability and resolution of the built-in measuring instruments and the uncertainty of the external measuring instruments.)

$$u(Pr_t) = \frac{454.0 \times 0.015}{\sqrt{3}} = 3.93\ \mathrm{ng/min/cm} \qquad \frac{u(Pr_t)}{Pr_t} = \frac{3.93}{454.0} = 0.0087 \qquad \left(\frac{0.015}{\sqrt{3}} = 0.0087\right)$$

※ The time, which is one of the parameters in the calculation of *Pr*, was omitted because the uncertainty is very small.

Dilution gas flow rate: *F*

The flow rate variation of the mass flow controller at a flow rate of 6.52 L/min is ±3.7%**. Assuming that this standard uncertainty follows a rectangular distribution, the standard uncertainty ($u(F)$) and the relative standard uncertainty ($u(F)/F$) are as follows:

**Cited from Section 13 (Calculated based on the repeatability and resolution of the built-in measuring instruments and the uncertainty of the external measuring instruments.)

$$u(F) = \frac{6.52 \times 0.037}{\sqrt{3}} = 0.139 \text{ L/min} \qquad \frac{u(F)}{F} = \frac{0.139}{6.52} = 0.021 \qquad \left(\frac{0.037}{\sqrt{3}} = 0.021\right)$$

From the above, the combined relative standard uncertainty ($u(C)/C$) is

$$\frac{u(C)}{C} = \sqrt{\left(\frac{u(Pr_v)}{Pr_v}\right)^2 + \left(\frac{u(Pr_t)}{Pr_t}\right)^2 + \left(\frac{u(F)}{F}\right)^2} = \sqrt{0.03^2 + 0.0087^2 + 0.021^2} = 0.038$$

The gas concentration (C) is given by $\dfrac{0.718 \times 454.0 \times 10}{6.52 \times 1000} = 0.500$ ppm

Thus, the combined standard uncertainty ($u(C)$) is $0.500 \times 0.038 = 0.019$ ppm

Since the expanded uncertainty ($U(C)$) is obtained by multiplying the combined standard uncertainty by the coverage factor of 2, the expanded uncertainty is

$$U(C) = 0.019 \times 2 = 0.038 \text{ ppm}$$

Consequently, 0.500 ± 0.038 ppm$(k = 2)$ (Percentage is ±7.6%.)

The parameters and uncertainties required for the calculation can be summarized as follows:

Symbol	Parameter		Value X	Standard uncertainty $u(x)$	Relative standard uncertainty $u(x)/x$
Pr_v	Permeation rate [ng/min/cm]	Repeatability	1	0.03	0.03
Pr_t		Temperature fluctuation	454.0 ng/min/cm	3.93 ng/min/cm	0.0087
F	Dilution gas flow rate [L/min]		6.52 L/min	0.139 L/min	0.021

≪Example 2≫

When calculating the gas concentration using actual measured diffusion rate

Given:

- Gas/ Concentration: Acetone/ Approximately 500 ppm
- D-tube: D-30
- Temperature: 35°C
- *Dr* (Measured): 667.2 µg/min*
- *K*: 0.421 L/g
- Dilution gas flow rate (Setting value): 0.56 L/min $\because \dfrac{0.421 \times 667.2}{500} = 0.562$ L/min

*From the weighing data, the weighing interval was 1,020 minutes and the weight loss was 0.69073 g.

$$Dr = \frac{0.69073 \times 10^6}{1020} = 667.2 \text{ µg/min}$$

Formula for calculating gas concentration is (Refer to Section 8.2)

$$C_0 = \frac{K \times Dr}{F}$$

C_0: Calibration gas concentration (ppm)
Dr: Diffusion rate (µg/min)
F: Flow rate of dilution gas (L/min)
K: Coefficient for converting a gas weight into a volume at 25°C (L/g)

On the right side of the above equation, the parameters with uncertainty are *Dr* and *F*.

※ When weighing a diffusion tube to determine the *Dr* value, if the ambient pressure fluctuates only slightly between the two weighing points, no correction of *Dr* by atmospheric pressure is required and the calculation of uncertainty of *Dr* regarding atmospheric pressure is not necessary.

※ Since the volume of the diffused gas and the dilution gas change at the same rate when ambient temperature and pressure change, temperature and pressure corrections are not required for the *K* value, and there is no uncertainty resulting from this. (Refer to Section 8.2)

Factors of uncertainty

Measurement of diffusion rate: Dr_m

The uncertainty of the mass measurement of the diffusion tube is estimated referring to the uncertainty of the electronic balance in use, listed on its calibration certificate issued by the manufacturer. For example, assume that the uncertainty per weighing is estimated to be 0.05 mg when measuring an object weighing approximately 20 g using an electronic balance with a minimum display of 0.01 mg. In this case, considering that the weighing is done twice in total before and after the weighing interval, the standard uncertainty (u (Dr_m)) is calculated as follows:

$$u(Dr_m) = \sqrt{2 \times (0.05 \times 10^{-3})^2} = 0.000071\text{g}$$

The relative standard uncertainty ($u(Dr_m)/Dr_m$) is

$$\frac{u(Dr_m)}{Dr_m} = \frac{0.000071}{0.69073} = 0.00010$$

Temperature variation in permeation rate: Dr_t

Since the temperature variation of the TUBE HOLDER is ±0.15°C*** and the sensitivity coefficient of Dr is about 0.8% per 0.1°C, Dr may vary up to ±1.2% due to temperature variation. Assuming that this standard uncertainty follows a rectangular distribution, the standard uncertainty ($u(Dr_t)$) and the relative standard uncertainty ($u(Dr_t)/Dr_t$) are as follows:

***Cited from Section 13 (Calculated based on the repeatability and resolution of the built-in measuring instruments and the uncertainty of the external measuring instruments.)

$$u(Dr_t) = \frac{667.2 \times 0.012}{\sqrt{3}} = 4.62\ \mu\text{g/min} \qquad \frac{u(Dr_t)}{Dr_t} = \frac{4.62}{667.2} = 0.0069 \quad \left(\frac{0.012}{\sqrt{3}} = 0.0069\right)$$

※ The time, which is one of the parameters in the calculation of Dr, was omitted because the uncertainty is very small.

Dilution gas flow rate: F

The flow rate variation of the mass flow controller at a flow rate of 0.56 L/min is ±7.0%****. Assuming that this standard uncertainty follows a rectangular distribution, the standard uncertainty ($u(F)$) and the relative standard uncertainty ($u(F)/F$) are as follows:

****Cited from Section 13 (Calculated based on the repeatability and resolution of the built-in measuring instruments and the uncertainty of the external measuring instruments.)

$$u(F) = \frac{0.56 \times 0.070}{\sqrt{3}} = 0.0226\ \text{L/min} \qquad \frac{u(F)}{F} = \frac{0.0226}{0.56} = 0.040 \qquad \left(\frac{0.070}{\sqrt{3}} = 0.040\right)$$

From the above, the combined relative standard uncertainty ($u(C_0)/C_0$) is

$$\frac{u(C_0)}{C_0} = \sqrt{\left(\frac{u(Dr_m)}{Dr_m}\right)^2 + \left(\frac{u(Dr_t)}{Dr_t}\right)^2 + \left(\frac{u(F)}{F}\right)^2} = \sqrt{0.0001^2 + 0.0069^2 + 0.040^2} = 0.041$$

The gas concentration (C_0) is given by $\dfrac{0.421 \times 667.2}{0.56} = 501.6\ \text{ppm}$

Thus, the combined standard uncertainty ($u(C_0)$) is $501.6 \times 0.041 = 20.6\ \text{ppm}$

Since the expanded uncertainty ($U(C_0)$) is obtained by multiplying the combined standard uncertainty by the coverage factor of 2, the expanded uncertainty is

$$U(C_0) = 20.6 \times 2 = 41.2\ \text{ppm}$$

Consequently, $501.6 \pm 41.2\ \text{ppm}\ (k = 2)$ (Percentage is ±8.2%.)

The parameters and uncertainties required for the calculation can be summarized as follows:

Symbol	Parameter		Value X	Standard uncertainty $u(x)$	Relative standard uncertainty $u(x)/x$
Dr_m	Diffusion rate [µg/min]	Mass loss	0.69073 g	0.000071 g	0.00010
Dr_t		Temperature fluctuation	667.2 µg/min	4.62 µg/min	0.0069
F	Dilution gas flow rate [L/min]		0.56 L/min	0.0226 L/min	0.040

12. Maintenance and Inspection

⚠Warning

Do not open the case of the main unit. There is a risk of electric shock due to the 100-240 V AC wiring inside the main unit.

12.1 Replacement/drainage of water in the constant temperature water bath

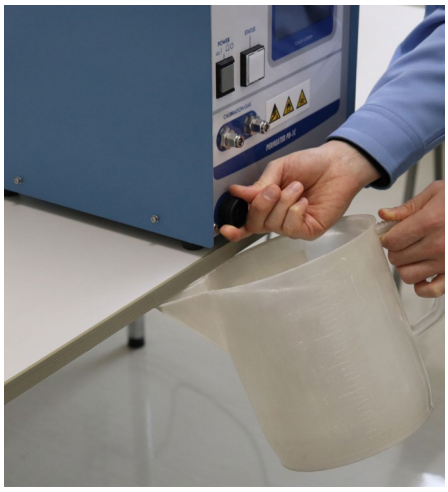
Even when this instrument is not in use, water should be changed at least once every three months.Water should also be changed if the water level gauge is dirty or if the water visible through the window of the water level gauge is dirty. Using dirty water may shorten the life of the pump and heater or cause the water level sensor to malfunction and fail to detect a drop in the water level. If the water level drops, the heater will run dry and fail. Drain the water when moving this instrument or when the instrument will not be used for a long period of time.

When draining water for periodic water changes or when moving the main unit, follow the procedure below.

①Prepare a container with a capacity of at least 2 L with a large opening.

②Open the WATER INLET and bring the container as close to WATER DRAIN as possible.

③Open WATER DRAIN.



④After draining, close WATER DRAIN.

⑤Close WATER INLET.

Refer to "6. Installation and Preparation of Permeaters" for water injection.

12.2 Replacement of Activated Carbon and Silica Gel for Purification of Diluting Gas

When compressor air is used as dilution gas, it must be purified with activated carbon and silica gel. Activated carbon and silica gel should be replaced in a timely manner, as they become contaminated after long-term use.

⚠Warning

Use a cylinder which is capable of withstanding a pressure of 1.2 MPa or higher to fill activated carbon or silica gel.

12.3 Replacement of the dust filter

The dilution gas must be filtered through a dust filter (capable of withstanding a pressure of 1.2 MPa or higher, and collect particle size of 100μm). The dust filter should be replaced in a timely manner as it may be blocked after prolonged use.

⚠Warning

Use a dust filter which is capable of withstanding a pressure of 1.2 MPa or higher.

12.4 Checking the Earth Leakage Breaker/Replacing the Fuse

If the power does not turn on, check in the order shown below.

①Check the power cord connections
(If there is no problem found, proceed to ②).

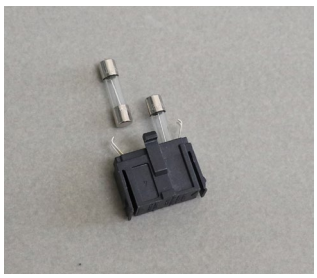
②Check the earth leakage breaker
Check that there is no leakage and turn the leakage breaker OFF and then ON.
(If there is no problem found, proceed to ③. If the earth leakage breaker detects leakage again, unplug the power cord and request repair.)

③Replacing the Fuse
Fuse box is incorporated in AC INLET.

A) Unplug the power cord from AC INLET.

B) Hold both ends of the fuse holder to release the latches and pull it out.

C)Replace the two fuses.
(The unbroken fuse is also likely to be damaged, so replace both fuses.)
Fuse rating: Size 5×20mm 10A/250V AC time-lag type
Use Littlefuse 0218010.MXP or equivalent.



D)Push in the fuse holder until it latches securely.

E) Plug the power cord into the AC INLET.
(If the fuse blows again, unplug the power cord and contact your distributor for repair.)

⚠Warning

- ■Replace the fuse with the power cord unplugged from AC INLET. Failure to do so may cause electric shock.
- ■Do not use fuses of different ratings. Failure to do so may result in electric shock, fire, or malfunction.

12.5 Calibration

The built-in flowmeter, thermometer, and barometer should be calibrated periodically. Recommended calibration intervals are shown in the table below.

No.	Item	Interval
1	Flow meter	1 year
2	Thermometer (water temperature)	1 year
3	Barometer (atmospheric pressure)	2 years

For the calibration procedures, refer to "9. Flow Rate Calibration, Temperature Calibration, and Atmospheric Pressure Calibration."

For atmospheric pressure calibration, contact your distributor.

12.6 Service and maintenance

Periodical maintenance and service are recommended in order to detect faults at an early stage and prevent breakdowns. For more information on periodic inspections, please contact your distributor.

12.7 Lifetimes of the parts

The parts listed in the table below will need to be replaced. The recommended replacement times are shown in the table below, but the time of failure may vary depending on the frequency of use and environment.

No.	Parts	Recommended replacement time
1	Power supply unit	10 years
2	Power supply unit fan	10 years
3	Main unit	10 years
4	Water pump	5 years
5	Heater	5 years
6	Pressure Regulator	10 years
7	Temperature controller	10 years
8	Gas flow controller	10 years
9	LCD touchscreen	10 years

12.8 Trouble shooting

Try checking again, referring to the table below, before servicing.

Troubles	Possible causes / statues	Actions to be taken
PD-1C does not turn on	The power cord is unplugged.	・Plug the power cord
	The earth leakage breaker is OFF.	・Check that there is no electric leakage, and turn the leakage breaker OFF once and then ON.
	The fuse is blown.	・Replace the fuse (Section 12.4).
Even though the water level is appropriate "WARNING040: Low water level" is displayed.	Air bubbles may stick to the water level sensor when the tank is used for the first time or when it is filled after a long period of time without water in it.	Drain about half (0.7 L) of the water and pour water to the normal level.
Temperature error in the constant temperature water bath	The set temperature is different from the actual temperature.	・Set the temperature again ・Check the status indication, release the error, and turn OFF-ON the power. ・ Remove any blockage from the ventilation holes on the rear and the bottom. ・ Set the temperature at room temperature +5°C or higher.
	Temperature changes in the opposite direction from the set point for about 1 minute after RUNNING starts.	・ This is normal operation. The temperature will change toward the set value.
	Adding water during operation causes a 'Heating/Cooling error'.	・ This is normal operation. Turn OFF-ON the power and press RUN to restart.
	Temperature control is not working.	・Press RUNNING to turn on. ・Request for repair
Dilution gas pressure does not increase	The dilution gas supply is not connected.	・Connect the tubes ・Check the status indication, release the error, and turn OFF-ON the power.
	Insufficient pressure of the dilution gas supplied to the instrument.	・Use dilution gas at 0.15-0.6 MPa.
	REGULATOR is not set correctly.	・Set REGURATOR to the specified pressure 0.15 to 0.3 MPa.
	The dust filter is blocked.	・Replace the dust filter
	There is a leak in the piping inside the instrument.	・Contact your distributor
Abnormal flow rate	Dilution gas does not flow. Flow rate is incorrect.	・Connect the dilution gas tubes ・Set the flow rate again ・Check the status indication, release the error, and turn OFF-ON the power.
	The dust filter is blocked.	・Replace the dust filter
	The gas flow controller is not working	・Press RUNNING to turn on ・Contact your distributor
The status indicator turns orange, and the warning message is displayed on the touch screen.	A warning is generated.	Refer to "12.9 Status Display List" to resolve the problem.
The status indicator turns red, and the error message is displayed on the touch screen.	An error is occurring.	Refer to "12.9 Status Display List" to solve the problem. If required, OFF-ON the power and clear the fault.
Unusual mechanical noise	Water pump failure	・Contact your distributor
	Cooling fan failure	・Contact your distributor

12.9 Status Display List

Normal operation

Message on LCD touchscreen	Status	Operating status				To release the error	Automatic stop				Start operation	Start Cleaning
		PO	SB	RN	CL		PM	HT	GF	FN		
STAND BY	Waiting	-	✓	-	-		-	-	-	-	Possible	Possible
RUNNING	In operation	-	-	✓	-		-	-	-	-		Possible
CLEANING	Cleaning	-	-	-	✓		-	-	-	-	Not possible	
Out of range	An invalid value is entered.	-	✓	✓	✓	Enter the valid value. /Close the keypad.	-	-	-	-	Not possible	Not possible

※Occurrence conditions... PO: when power is on SB: when stand by RN: when running CL: when cleaning
※Automatic stop ••••• PM: Pump HT: Heater GF: Gas flow controller FN: Power supply unit fan

Error/Warning Display classification

The errors and warnings are classed into three categories according to severity:
① Error
② Warning "AmbP sensor" "Low water level"
③ Warning "Temp correction" "Flow correction" "AmbP correction" "Corrections"
The order of severity is ①-②-③, from highest to lowest.

Errors/Warnings are not cleared by other errors/warnings.
The message is rewritten to a new one when an error/warning of equal or greater severity occurs.
The water level error is cleared when the water level reaches the appropriate level.
Errors other than Water Level Error can only be cleared by turning the power off.
Warnings are released when the cause is cleared. When a warning is released, the warning with the highest severity among the remaining warnings is displayed. (Warnings of the same severity are not specified in the order of display).

・Errors

Code	Message on LCD touchscreen	Name	Cause of the error	Operating status when the error occurs				Action to release the error	Automatic stop				Starting calibration gas running
				PO	SB	RN	CL		PM	HT	GF	FN	
100	Power supply unit	Power supply voltage error	Abnormality in 24V system voltage	-	✓	✓	✓	Power OFF	✓	✓	✓	-	Not possible
101	Temp in the housing	High temperature Error	High temperature inside PD-1C	-	✓	✓	✓	Power OFF	✓	✓	✓	-	Not possible
102	Power supply unit fan	Power supply unit fan error	Power supply unit fan failure	-	✓	✓	✓	Power OFF	✓	✓	✓	✓	Not possible
104	Low water level	Water level error	Low water level continues for more than 1 hour	-	✓	✓	✓	Raise the water level	✓	✓	-	-	Not possible
105	Water pump	Pump error	Water pump failure	-	-	✓	✓	Power OFF	✓	✓	-	-	Not possible
107	Temp control (main sensor)	Temperature control error (main sensor)	Main temperature sensor of the water temperature controller failure	-	-	✓	-	Power OFF	✓	✓	-	-	Not possible
108	Air flow	Flow error	Abnormal gas flow rate	-	-	✓	✓	Power OFF	✓	✓	✓	-	Not possible
117	Comm with LCD	LCD communication error	Communication failure with the LCD	-	✓	✓	✓	Power OFF	✓	✓	✓	-	Not possible
118	Comm with temp controller	Temperature controller communication error	Communication failure with the temperature controller	-	✓	✓	✓	Power OFF	✓	✓	-	-	Not possible
119	Temp control (sub sensor)	Temperature control error (sub-sensor)	The temperature of the outer wall of the water bath is abnormal (sub-sensor)	-	✓	✓	✓	Power OFF	✓	✓	-	-	Not possible
120	Temp sensor	Temperature sensor error	Abnormal relationship between temperature controller and sub temperature sensor values	-	✓	✓	✓	Power OFF	✓	✓	-	-	Not possible
121	Comm with flow controller	Gas flow controller communication error	Communication failure with the gas flow controller	-	✓	✓	✓	Power OFF	✓	✓	✓	-	Not possible

※Operating status... PO: when power is on SB: when stand by RN: when running CL: when cleaning

※Automatic stop: PM: Pump HT: Heater GF: Gas flow controller FN: Power supply unit fan

・Warnings

Code	Message on LCD touchscreen	Name	Cause of the warning	Operating status when the warning occurs				Action to release the warning	Automatic stop				Starting calibration gas running
				PO	SB	RN	CL		PM	HT	GF	FN	
003	Temp correction	Temperature correction value load warning	Abnormal temperature compensation value	✓	-	-	-	Temperature calibration	-	-	-	-	Possible
004	Flow correction	Flow correction value load warning	Abnormal flow correction value	✓	-	-	-	Flow calibration	-	-	-	-	Possible
005	AmbP correction	Ambient Pressure correction value load warning	Abnormal atmospheric pressure correction value	✓	-	-	-	Atmospheric pressure calibration	-	-	-	-	Possible
008	Corrections	Correction-value load-warning	More than one correction value is abnormal	✓	-	-	-	Correction value calibration	-	-	-	-	Possible
040	Low water level	Water level warning	Low water level	-	✓	✓	✓	Raise the water level	-	-	-	-	Not possible
042	AmbP sensor	Pressure sensor warning	Pressure sensor error	-	✓	✓	✓	Enter atmospheric pressure manually /Atmospheric pressure calibration	-	-	-	-	Not possible

※Operating status... PO: when power is on SB: when stand by RN: when running CL: when cleaning
※Automatic stop: PM: Pump HT: Heater GF: Gas flow controller FN: Power supply unit fan

When in the 003 to 008 warning states, it is possible to start running calibration gas. The LCD touchscreen, buzzer, and status lamps operate as shown in the table below.

Status	LCD touchscreen	Buzzer	Lamp
Standby state after power-on	○○Correction Value Load Warning	Beep	Red
Running	RUNNING	Stop	Green
Cleaning	CLEANING	Stop	Orange
Standby state after stop	○○Correction Value Load Warning	Stop	Red

12.10 Repair

For repairs, please contact the distributor where you purchased the product or Gastec Corporation.

⚠Warning

- When transporting or carrying the PD-1C, remove the P-tube/D-tube from the TUBE HOLDER. If the P-tube/D-tube is left in the TUBE HOLDER with the dilution gas stopped, a high concentration of gas will accumulate.
- When transporting or carrying the PD-1C, drain the water from the temperature water bath. Do not move the PD-1C lying sideways or upside down. Incorrect transport may cause malfunctions.
- When removing P-tube/D-tube, TUBE HOLDER must be opened with dilution gas flowing. High concentrations of hazardous substances may remain in the TUBE HOLDER.

13. Specifications

Calibration gas channel: 1

Gases to be prepared

Permeation tube method

SO_2, H_2S, NH_3, Cl_2, C_3H_8, CH_2CHCl, CH_3SH, $(CH_2)_2S$, C_2H_5SH, CH_2CCl_2, etc. The gas has a boiling point in the range of -60 to +30°C and is a stable high-purity substance.

Diffusion tube method

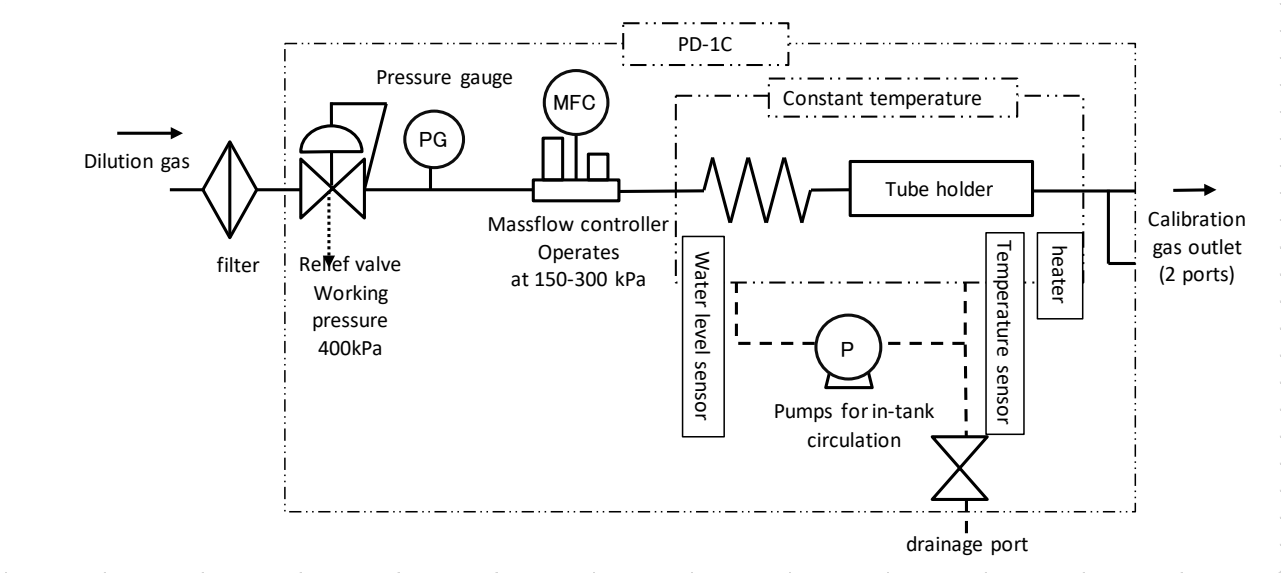
A liquid has a vapour pressure of 5-400 mmHg at 30-50°C and a stable, high-purity substance.

Dilution gas	Nitrogen or air	
Dilution gas pressure	0.15 - 0.6MPa	
Flow rate setting range	0.20 – 10.00L/min	
Operation temp. range	10.0 - 50.0℃	
Temperature control range	(Ambient temperature +5°C) to 50°C	
Flow rate setting accuracy	Flow range 1.00 - 10.00L/min ±3.7% s.p. Flow range 0.40 – 1.00L/min ±7.0% s.p. Flow range 0.20 - 0.40L/min ±13.2% s.p.	
Temperature setting accuracy	±0.15℃	
Atmospheric pressure measurement accuracy	±7.0hPa	
Tubes for Dilution/calibration gas	O.D. 6mm I.D. 4mm	
TUBE HOLDER capacity	P-tube standard-size x 10 tubes H size x 5 tubes	
	D-tube single component x 1 tube multiple components x 4 tubes	
Operating temperature range	15°C to 30°C (can operate 10°C to 15°C, but is accuracy not guaranteed)	
Operating humidity range	10 to 90%RH (non-condensing)	
Overvoltage category	Category II	
Pollution degree	Pollution degree 2	
Location of use	Indoors	
Usable altitude	2000 m or below	
Dimensions and weight	250(W) ×340 (H) ×315 (D) mm 14kg (without	
Power supply and maximum power consumption	100-240V AC 50-60Hz 160W	
Power cord	Connector IEC60320-C13 7A or higher	
POWER SUPPLY INLET	IEC60320-C14	
Fuse rating	Size 5×20mm 10A/250V AC time lag type Equivalent to Littlefuse 0218010.MXP	
Standards/Directives	Low Voltage Directive	EU: EN61010-1:2010/A1:2019
	EMC	EU:EN61326-1:2021 (For use in industrial locations)
	RoHS	EU:EN IEC63000:2018

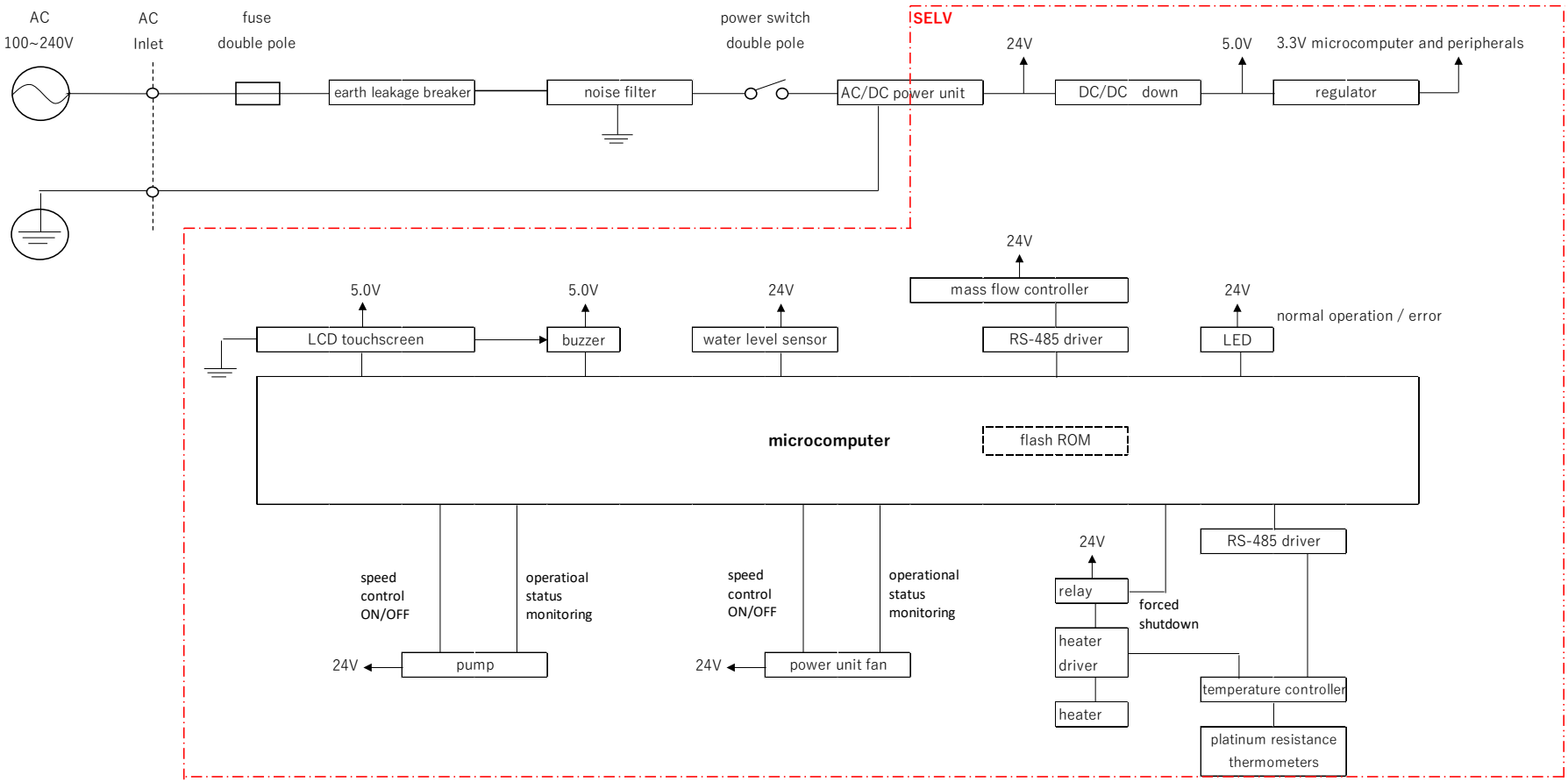
⚠Warning

- ■ Use a power cord that complies with the laws and regulations of the country/region where this instrument is used and meets the safety requirements of that country/region.
- ■ Do not use fuses of differing ratings. Failure to do so may cause an electric shock, fire or malfunction.

14. Flow Path Diagram



15. Block Diagram of Electronic Components



Product Warranty and disclaimer

Gastec warrants that its products are free from defects in design, material, and workmanship and will comply with the specifications established by Gastec for a period of one year from the date of purchase. With respect to any defective product to which this Warranty applies, Gastec shall, at its sole option, either replace the defective product with a new product or refund the purchase price of the defective product. THIS REPLACEMENT OR REFUND REMEDY SHALL BE THE CUSTOMER'S OR END USER'S SOLE AND EXCLUSIVE REMEDY FOR DEFECTIVE PRODUCTS. THE AGGREGATE LIABILITY THAT GASTEC SHALL HAVE WITH RESPECT TO PRODUCTS SHALL BE LIMITED TO THE AMOUNT ACTUALLY PAID BY THE CUSTOMER OR END USER FOR THE PRODUCT THAT IS THE SUBJECT OF THE PARTICULAR CLAIM.

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This Warranty shall not apply if: (a) the product is modified, tampered with or altered by anyone other than Gastec after leaving Gastec's control, unless authorized by Gastec in writing; (b) Gastec is not notified in writing of the loss, claim or product nonconformity within 365 days after purchase; (c) the product is not distributed, stored, used, maintained, and/or repaired in accordance with all applicable instructions, guidelines, warnings, laws, standards and product literature; (d) the product is subjected to abuse, accident, misuse, neglect, inadequate protection against shock, vibration, excessively high or low temperatures or overpressure, or unauthorized repair, testing, storage, shipping or handling; (e) the loss, claim, product nonconformity, or damage to the product is caused by a combination of the product with any items not supplied by Gastec, or by the use of the product with any other Gastec product contrary to Gastec's instructions, guidelines, and warnings; (f) the product is beyond its expiration date, tube shelf life, maximum storage period, or maximum refrigerated storage period; (g) the product was purchased or acquired through a source other than an authorized Gastec or its authorized distributor or reseller; or (h) the loss, claim, product nonconformity, or damage to the product was the result of any cause beyond Gastec's control, including natural disaster, fire, flood, or other force majeure.

The Warranty shall not apply to consumable products, parts, or components.

The Warranty shall be voided if the product is used by persons untrained and unfamiliar with the proper use and application of the products, particularly those used with hazardous or toxic substances.

This Warranty may not be modified, expanded, or altered in any way except in a writing signed by a fully authorized representative of Gastec.

For any questions, please contact: international@gastec.co.jp

CE

GASTEC

EU DECLARATION OF CONFORMITY (No.GDOC1006CE-0)

1. Apparatus model/Product:

   PD-1C / Calibration gas generation system Permeater

2. Name and address of the manufacturer:

   GASTEC CORPORATION

   8-8-6 Fukayanaka, Ayase-City, Kanagawa 252-1195, Japan

3. This declaration of conformity is issued under the sole responsibility of the manufacturer

4. Object of the declaration:

5. The object of the declaration described above is in conformity with the requirements of the following EU legislation and harmonized standards:

Council Directives		Applicable standards
RoHS Directive	**2011/65/EU, (EU)2015/863**	EN IEC63000 : 2018
EMC Directive	**2014/30/EU**	EN 61326-1:2021
LVD Directive	**2014/35/EU**	EN 61010-1:2010/A1:2019

6. Notified Body involved:

   -

7. Additional information:

   -

(place and date of issue): **Ayase-City, Kanagawa,Japan 27 Nov. 2023**

(name, function)(signature): **YUICHIRO KAIFUKU Director of Quality Assurance**

Yuichiro Kaifuku

GCG323-R010

Instruction Manual for Permeation Tube

Foreword

This instruction manual describes how to operate the permeation tube that is to be used together with Gastec calibration gas generator (PERMEATER, models PD-1B, PD-1B-2, and PD-1C).
Please read this instruction manual and enclosed SDS carefully and fully understand the contents therein before using this unit. We also recommend keeping this manual on hand while you use this unit.

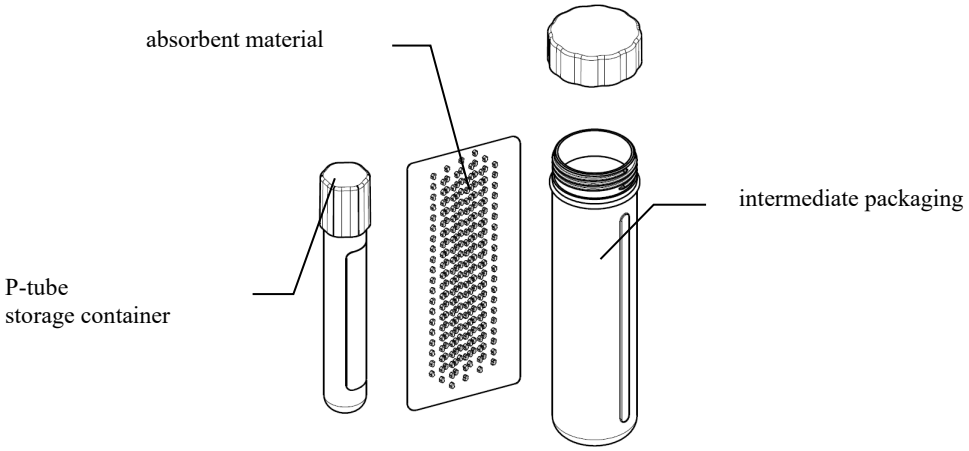
Be sure to observe any safety precautions to assure safe and proper use of the permeation tube (hereafter, “P-tube”). The following symbols are used in this manual to assure safe operation of this unit.

WARNING This symbol indicates a potentially hazardous situation that, if not avoided, will result in death or serious injury to the operator.

CAUTION This symbol indicates a potentially hazardous situation that, if not avoided, will result in minor or moderate injury to the operator.

WARNING

- The product you have purchased contains an intermediate packaging, instruction manual, and SDS in the outer packaging. The P-tube is packaged in a storage container in the intermediate packaging with absorbent material.



- When handling P-tubes, be sure to wear appropriate protective equipment such as protective glasses, impervious protective clothing, protective gloves or footwear.
- P-tubes are sealed in intermediate packaging and storage(inner) packaging. To prevent inhalation of toxic gases, the intermediate packaging and storage(inner) packaging of the P-tube should be opened in a local exhaust ventilation system.
- Most of the calibration gases prepared by this product are toxic, so Position equipment and connect pipework so that the CALIBRATION GAS (calibration gas outlet) is away from the breathing zone when use. Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.
- If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion. The temperature setting of the calibration gas generator should be set below the "maximum temperature" on the P-tube storage container label.
- If the temperature inside the TUBE HOLDER exceeds the "maximum temperature" on the P-tube storage container label, immediately switch to the clean-up mode with the TUBE HOLDER lid closed (when using PD-1C). If PD-1B or PD-1B-2 is used, switch off the power supply immediately. Do not open the lid of the TUBE HOLDER because high concentration of gas may be accumulated in the TUBE HOLDER. Remove and Dispose of the P-tube after 24 hours of dilution gas flow.
- Once the P-tube has exceeded the "maximum temperature" on the P-tube storage container label, do not reuse it.
- Do not apply external pressure or shock to the P-tube, or do not scratch or cut the P-tube. The internal liquefied gas may be gushed out. Gas pressure may remain even when there is no liquid remaining in the P-tube, such as when disposing of the P-tube.
- If any abnormality is found in the appearance of the P-tube, corrosion of the stainless steel crimps, or cracks in the fluoroplastic tubing, immediately discontinue use and discard the P-tube.

- P-tubes should be sealed and stored in the storage container provided with the P-tube. The maximum storage temperature is indicated on the P-tube storage container as "-5° C or lower" or "25° C or lower". The minimum storage temperature is -25° C. If P-tubes are stored at temperatures lower than -25°C, there is a possibility of temporary leakage of filling gas due to the difference in expansion coefficients of the tubes and crimps when they are returned to room temperature.

CAUTION

- Avoid direct hand contact with the surface of the effective part of P-tube. If the surface is contaminated, the specified permeation rate cannot be obtained.
- When loading P-tubes into the TUBE HOLDER, use the tube holding cage provided. If the tube holding cage is not used, the P-tube cannot be removed. Using the tube holding cage also prevents the P-tube from being incorrectly placed in the WATER INLET.

Preparation of a calibration gas using the permeation tube

1. Overview

Almost all of environmental measuring equipment or industrial measuring equipment for gas compositions use a calibration gas to calibrate their scales before measurement. This naturally means that a highly reliable calibration gas is needed to obtain highly reliable measured results. A calibration gas is also necessary for measuring bad odors using the olfactory sense, research for gas analysis techniques, tests of influences of gases on animals and plants, and tests of influences of specific gases to various materials.

There are two calibration gas generation methods, a static one and a dynamic one. The static method mixes gases in a container and the gaseous phase concentration may change over time due to the reaction with the container wall with a chemically active gas, or adsorption or condensation on the container wall from a decrease in the environmental temperature for an adsorptive gas or a condensable gas. Thus, while a static method only requires simpler devices and operations compared with a dynamic method, the types and the concentration range possible for generated gases are limited.

Dynamic methods represented by the P-tube method have superior features. They are less likely to be influenced from adsorption or condensation even with a chemically active gas or a condensable gas. They are able to generate gases even in low-concentration areas in which a static method cannot generate gases. Finally, they support preparations in a broader concentration range.

P-tube is a gas source for dynamic calibration and generates a low-concentration gas.
National Metrology Institute of Japan (NIMJ) adopted P-tube method as the source of reference gas mixture for Formaldehyde. And the National Institute of Standards and Technology (NIST) and the Environmental Protection Agency (EPA) adopted the calibration gas preparation method of P-tube as the standard method.

2. How to use the P-tube

The P-tube encapsulates a highly pure liquefied gas in a fluoride resin tube. The amount of liquefied gas that permeates and diffuses through the tube wall for a unit time will be stable when it is held at a specified temperature. Therefore, a calibration gas can be obtained by blending with a constant flow of a dilution gas. Calibration gas concentration as well as dilution gas flow calculation can be made from the www.gastec.co.jp website, go to technical information, then preparation conditions calculation for simple instructions.

This method of generating a calibration gas is highly reliable because it determines a gas concentration based on the measured difference in weight loss of the P-tube for a unit time (permeation rate) and the measured flow of the dilution gas.

1) Calculation of a calibration gas concentration
Calibration gas concentration (volume concentration) can be calculated with the equation below:

$$C = \frac{K \times Pr \times L}{F \times 1000} \qquad (1)$$

C: Calibration gas concentration (ppm)
Pr: Permeation rate (ng/min/cm)
L: Effective length of tube (cm)
F: Flow of dilution gas (mL/min)
K: Coefficient for converting a gas weight into a volume (L/g)

The permeate rate is the mass of gas that permeates from 1 cm of the permeating part of the P-tube in one minute from the liquefied gas in the P-tube held at a constant temperature. The actual measured

value of the permeation rate at each temperature is indicated on the label of the storage container supplied with the P-tube for each bottle; use this Pr value for the calculation.

The effective length of a P-tube is the length of the part through which liquefied gas permeates; the label on the storage container supplied with the P-tube indicates the effective length for each P-tube, so use this L value for calculations.

The K-value represents the volume of 1 g mass of the substance in the P-tube when it becomes a gas. This value is calculated at 25 °C and 1 atm.

$$K = \frac{22.4}{M} \times \left(\frac{298}{273}\right) \qquad (2)$$

M: Molecular weight of the substance in the P-tube

The actual volume flow rate varies with changes in ambient temperature and ambient pressure. However, when PD-1C is used, the volume of the generated gas and dilution gas change at the same rate. Therefore, the volume concentration does not change. In a strict sense, the volume of 1 mol of gas in the standard state (STP) varies depending on the type of gas. Also, a more accurate K value can be obtained by using the molar mass instead of the molecular weight in Equation (2).

<Calculation Example>
Obtain the dilution gas flow rate F for the preparation of Sulphur Dioxide 1.00 ppm and 0.20 ppm using Sulphur Dioxide P-tube P-5-5 with the temperature set to 35 °C.
The label on the storage container supplied with the SO 2 P-tube indicates the following information. Use these values for the calculation.

Effective length	*K* value	Permeation rate *Pr* (ng/min/cm)	
5 cm	0.382	30℃ : 310	35℃ : 430

Equation (1) is transformed to obtain Equation (3).

$$F = \frac{K \times Pr \times L}{C \times 1000} \qquad (3)$$

$$= \frac{0.382 \times 430 \times 5}{C \times 1000} = \frac{0.8213}{C}$$

From the above equation, to prepare C = 1.00 ppm, set the temperature setting to 35 °C and the dilution gas flow rate *F* to 0.82 L/min.
To prepare C = 0.20 ppm, set the dilution gas flow rate F to 4.11 L/min at a temperature setting of 35 °C (When using PD-1B and PD-1B-2, set to 4.2 L/min).

The calibration gas concentration when using two P-tubes is calculated using the following equation.

$$C = \frac{K \times (Pr_1 \times L_1 + Pr_2 \times L_2)}{F \times 1000} \qquad (4)$$

Pr_1: Permeation rate of the first tube (ng/min/cm)
L_1: Effective length of the first tube (cm)
Pr_2: Permeation rate of the second tube (ng/min/cm)
L_2: Effective length of the second tube (cm)

Calculations to estimate Pr values at temperatures not listed on the label. (only when PD-1C is used)

Within the temperature ranges listed on the label, the Pr at temperatures between the Pr values can be estimated in 1°C increments. Larger temperature differences between Pr values tend to increase the error in the estimated Pr. For more accurate Pr values, see “Methods for measuring permeation rate Pr values”.

If the temperature difference between the two Pr values indicated on the label is 5°C, the Pr at a temperature between those Pr values can be estimated using the following equation.

$$P_{rT} = P_{rL} \times \left(\frac{P_{rH}}{P_{rL}}\right)^{\frac{T-T_L}{5}} \qquad (5)$$

PrT : Pr to be estimated
T : Temperature of PrT (°C)
T_L : Lower temperature of 5°C interval setting indicated on the label (°C)*.
Pr_L : Pr values for the lower 5°C intervals indicated on the label
Pr_H : Pr values for the higher 5°C intervals indicated on the label

* When T is between 25°C and 30°C, T_L is 25°C. When T is between 30°C and 35°C, T_L is 30°C. When T is between 35°C and 40°C, T_L is 35°C.

If the temperature difference between the two Pr values indicated on the label is 15°C, the Pr at a temperature between those Pr values can be estimated using the following equation.

$$P_{rT} = P_{rL} \times \left(\frac{P_{rH}}{P_{rL}}\right)^{\frac{T-T_L}{15}} \qquad (6)$$

PrT : Pr to be estimated
T : Temperature of PrT (°C)
T_L : Lower temperature of 15°C interval setting indicated on the label (°C)*.
Pr_L : Pr values for the lower 15°C intervals indicated on the label
Pr_H : Pr values for the higher 15°C intervals indicated on the label

WARNING

The above Equations (5) and (6) are applicable only in the temperature range from the lower to the upper limit of the temperature indicated on the label of the storage container supplied with the P-tube. Temperatures outside this range may cause the P-tube to rupture.

Methods for calculating mass concentration

From the equation for volume concentration, exclude the coefficient K value for converting mass to volume and add corrections for temperature and atmospheric pressure. The volume concentration is calculated with 25 °C and 1 atm, so it can be converted using the following equation.

$$C_g = \frac{Pr \times L}{F \times 1000} \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right) \quad (7)$$

$$F = \frac{Pr \times L}{C_g \times 1000} \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right) \quad (8)$$

C_g : Calibration gas concentration (mg/m^3)
T : Ambient temperature
P : Ambient pressure
P_0 : Standard atmosphere

Methods for measuring permeation rate Pr values

Pr values can be determined by actual measurement. For higher accuracy, it is recommended to measure the actual values under the actual conditions of use.
When using the PD-1C, using the Manual mode will display only the temperature and flow rate on the main screen, making it ideal for measuring the diffusion rate Dr value.
Place the P-tube in the TUBE HOLDER of the PERMEATER. Maintain a constant temperature while dilution gas is flowing (> 0.2 L/min).
After about 24 hours, remove the P-tube and weigh it on a balance with a minimum unit of 0.1-0.01 mg. Record the time by minute. Immediately after weighing, return the P-tube to TUBE HOLDER to continue gas generation.
For balances with [minimum limit 0.01 mg, repeatability ≤ 0.015 mg], repeat the weighing at intervals at which its decrease is 15 mg or more (1-10 days) decrease until a reliable Pr value is obtained. The approximate weighing interval is determined by Equation (9) and the Pr value by Equation (10).

Weighing interval (day) $= \frac{1 \times 10^4}{Pr \times L}$ (9)

Permeation rate $Pr = \frac{m \times 10^6}{L \times T}$ (10)

Pr : Permeation rate (ng/min/cm)
L : Effective length of the P-tube (cm)
M: P-tube Decrease (mg)
T : Weighing interval (min)

2) To change the calibration gas concentration
① Change the dilution gas flow rate F.
After changing the flow rate, the concentration will stabilize when the residual gas in the gas flow path is replaced.
② Decrease the effective length L.
When two or more P-tubes are used, the concentration can be reduced by decreasing the number of P-tubes. After reducing the number of P-tubes and changing the flow setting, the concentration stabilizes when the residual gas in the gas flow path is replaced.
③ Increase the effective length L.
Concentration can be increased by increasing the number of P-tubes used. After adding a new P-tube, it takes 24 hours for the concentration to stabilize.
④ Change the temperature setting.
It takes 24 hours for the concentration to stabilize.

3) Time necessary for a P-tube to stabilization
It takes about 24 hours for the P-tube to reach the specified permeation rate after it is placed in the TUBE HOLDER. After this time has elapsed, prepare the calibration gas.

4) Procedures after use
After use, open the lid of the TUBE HOLDER with dilution gas flowing, and remove the tube holding cage. P-tubes should be sealed and stored in the storage container provided with the P-tubes. The minimum storage temperature is -25 °C. The maximum storage temperature is indicated on the label of the storage container supplied with the P-tube.

WARNING

- Remove the P-tube from the calibration gas generator when not in use. High concentrations of gas will accumulate.
- TUBE HOLDER must be opened with dilution gas flowing. High concentrations of hazardous substances may remain in the TUBE HOLDER.
- The minimum storage temperature is -25°C. If P-tubes are stored at temperatures lower than -25°C, there is a possibility of temporary leakage of filling gas due to the difference in expansion coefficients of the tubes and crimps when they are returned to room temperature.
- The maximum storage temperature depends on the type of P-tube; check the label on the storage container that comes with the P-tube. The maximum storage temperature is "-5 °C or lower" or "25 °C or lower".

3. Maintaining the accuracy of calibration gas concentrations

WARNING

- If the temperature of the P-tube becomes too high, the internal pressure will increase and there is a possibility of high gas concentration being released due to rupture/explosion. The temperature setting of the calibration gas generator should be set below the "maximum temperature" on the P-tube storage container label.
- Most of the calibration gases prepared by this product are toxic, so position the instrument and connect pipework so that the CALIBRATION GAS (calibration gas outlet) is away from the breathing zone when use. Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.
- Do not apply external pressure or shock to the P-tube, or do not scratch or cut the P-tube. The internal liquefied gas may be gushed out. Gas pressure may remain even when there is no liquid remaining in the P-tube, such as when disposing of the P-tube.
- If any abnormality is found in the appearance of the P-tube, corrosion of the stainless steel crimps, or cracks in the fluoroplastic tubing, immediately discontinue use and discard the P-tube.
- When handling P-tubes, be sure to wear appropriate protective equipment such as protective glasses, impervious protective clothing, protective gloves or footwear.

1) When using several P-tubes of different types in the TUBE HOLDER of a PERMEATER, make sure that the gases do not chemically react with each other.
2) Avoid direct hand contact with the surface of the effective length of the P-tube permeation area. If the surface is contaminated, the specified permeation rate cannot be obtained.
3) For highly corrosive Chlorine or Hydrogen Fluoride* P-tubes, wipe the metal crimps with a clean cloth as appropriate to prevent corrosion of the metal crimps during storage or use.
4) Corrosion of the metal crimps will be accelerated if the highly corrosive Hydrogen Fluoride P-tube*

is stored or used in the presence of moisture. If the crimps are corroded and deteriorates, the Pr value will be higher than the specified value. During storage, pay attention to the color of the absorbent (green gel) in the storage container and replace the green gel as necessary if the absorption capacity decreases. Also, use dry gas as the dilution gas during use. If humidification is necessary, mix the calibration gas supplied from the PERMEATER downstream with the dilution gas humidified by a humidifier or similar device.
5) NO_2 1 cm P-tube (P-9-1) * is equipped with a stainless steel tank. When placing the P-tube in the TUBE HOLDER of the PERMEATER, place the stainless steel tank on top.
6) Acetaldehyde 1 cm P-tube (P-92-1) is supplied with a glass tank; when placing the P-tube in the TUBE HOLDER of the PERMEATER, place the glass tank on top.
7) If air is used as dilution gas for the H_2S P-tube or if the H2S P-tube is exposed to air during storage, the oxygen in the air permeates back into the P-tube, releasing sulphur and causing the P-tube to become cloudy. The amount of liquefied gas cannot be seen, but the specified permeation rate is not affected. Nitrogen can be used as dilution gas to prevent cloudiness.
8) Trimethylamine 10 cm P-tubes (P-180-H) may rarely deposit a clear solid-like substance inside the P-tube, but this does not affect the specified permeation rate.
9) The dilution gas is Nitrogen or air purified with activated carbon and silica gel. Activated carbon and silica gel should be replaced in a timely manner as they become contaminated with long-term use.
10) When sampling the calibration gas, use a fluorocarbon resin tube at one outlet as short as possible (within a few metres), and sample at a flow rate within the dilution gas flow rate and without any pressure in the tube. Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.

*These P-tubes are not exported. They are for the Japanese market only.

4. P-tube handling instructions

1) Expiry date

①The expiry date of the permeation rate Pr is indicated on the storage container label of the P-tube.

②If the amount of liquefied gas in the P-tube decreases to about 10 % of the length of the permeation zone (effective length), the P-tube has reached the end of its service life even if it is still within the period of valid date.

2) Storage

CAUTION

- P-tubes should be sealed and stored in the storage container provided with the P-tube. The maximum storage temperature is indicated on the P-tube storage container as "-5°C or lower" or "25°C or lower". The minimum storage temperature is -25°C. If P-tubes are stored at temperatures lower than -25°C, there is a possibility of temporary leakage of filling gas due to the difference in expansion coefficients of the tubes and crimps when they are returned to room temperature.
- P-tubes are sealed in intermediate packaging and storage(inner) packaging. To prevent inhalation of toxic gases, the intermediate packaging and storage(inner) packaging of the P-tube should be opened in a local exhaust ventilation system.

3) Disposal instructions

Take out the adsorbent material from the intermediate packaging. With the P-tube in the storage container, fill it up to the opening of the container with the adsorbent. Seal the storage container with the cap. Store the P-tube at room temperature until the liquefied gas runs out. The adsorbing agent in the container will adsorb the gas. Dispose the vacant tube as plastic waste. The gas is toxic or can be

caustic when breathed. Perform the above procedures under a local exhaust ventilation system. When disposing of the adsorbent material, dispose it as industrial waste or incinerate it. Some may emit hazardous gas by incineration. In such cases, use a chemical incinerator which has flue gas treatment equipment.

For all types of gas and vapour SINCE 1970

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24G/MP

Operation Manual for Diffusion Tube

Foreword

This operation manual describes how to operate the diffusion tube, model No. 3100 that is to be used together with the calibration gas generation unit (PERMEATER, models PD-1B, PD-1B-2, and PD-1C). Please read this operation manual carefully and fully understand the contents therein before using this unit. We also recommend keeping this manual on hand while you use this unit.

Be sure to observe any safety precautions to assure safe and proper use of the diffusion tube (hereafter, "D-tube"). The following symbols are used in this manual to assure safe operation of this unit.

WARNING This symbol indicates a potentially hazardous situation that, if not avoided, will result in death or serious injury to the operator.

CAUTION This symbol indicates a potentially hazardous situation that, if not avoided, will result in minor or moderate injury to the operator.

WARNING

- When handling D-tubes, be sure to wear appropriate protective equipment such as protective glasses, impervious protective clothing, protective gloves or footwear.
- Always work inside a local exhaust ventilation system when loading liquid samples into the D-tube.
- D-tubes should be loaded into the TUBE HOLDER after at least 30 minutes of dilution gas flow. If the D-tube was not removed at the last time of use, there is a possibility that highly concentrated gas may have accumulated in the TUBE HOLDER.
- When loading D-tubes into the TUBE HOLDER, use the tube holding cage provided. If the tube holding cage is not used, the D-tube cannot be removed. Using the tube holding cage also prevents the D-tube from being incorrectly placed in the WATER INLET.
- Most of the calibration gases prepared by this product are toxic, so position the instrument and connect tubes so that the CALIBRATION GAS (calibration gas outlet) is away from the breathing zone when use. Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.

Preparation of a calibration gas using the diffusion tube

1. Overview

A diffusion tube is a glass container consisting of a diffusion tube and a liquid reservoir for continuously generating a constant vapour concentration, utilising the fact that the diffusion rate of vapour through a diffusion tube with a constant inner diameter is determined by the size and temperature of the diffusion tube. Calibration gas can therefore be obtained by keeping the D-tube at a constant temperature and feeding dilution gas at a constant flow rate.

This calibration gas generation method is highly reliable because the gas concentration is determined on the basis of the measurement of the physical quantity of the weight loss of the D-tube in unit time (diffusion rate) and the flow rate of dilution gas. Calibration gases over a wide concentration range can be generated continuously and stably over a long period of time by changing the diffusion rate by changing the holding temperature of the D-tube, by changing the flow rate of dilution gas, by changing the size (type) of the D-tube, etc.

The calibration gases that can be generated by the D-tube are stable, high-purity substances with a vapour pressure of 5-400 mmHg of the sample liquid at a temperature of 30-50 °C.

2. Calculation of a calibration gas concentration

The calibration gas concentration (volume concentration) can be calculated with the formula (1) below:

$$C_0 = \frac{K \times Dr}{F} \qquad (1)$$

C: Calibration gas concentration (ppm)　No atmospheric pressure compensation
Dr: Diffusion rate (μg/min)
F: Flow of dilution gas (mL/min)
K: Coefficient for converting a gas weight into a volume (L/g)

The diffusion rate is the weight of gas that evaporates and diffuses from a liquid in one minute from a D-tube held at a constant temperature. Refer to Tables 1 and 2 at the end of this document for the diffusion rate of D-tubes. The diffusion rate depends on the size of the D-tube and the temperature.
The diffusion rates listed in Tables 1 and 2 at the end of this document are the values actually measured by Gastec. For higher accuracy or for substances not listed in the table, it is recommended that actual measurements are carried out under the actual conditions of use. When using D-tube, the dilution gas flow rate should be in the range of 0.2 to 8.0 L/min.
If the flow rate is greater than 8.0 L/min, a stable diffusion rate may not be obtained.

In the case of D-tube, Dr value is affected by ambient pressure, so correction by formula (2) is necessary.

$$C = C_0 \times \frac{P_0}{P} \qquad (2)$$

C : Calibration gas concentration (ppm)
C_0 : Calibration gas concentration at standard atmospheric pressure (ppm)
P : Ambient pressure (hPa)
P_0 : Standard atmospheric pressure (hPa)

The K-value represents the volume of 1 g mass of the substance in the D-tube when it becomes a gas. This value is calculated at 25 °C and 1 atm.

$$K = \frac{22.4}{M} \times \left(\frac{298}{273}\right) \qquad (3)$$

M: Molecular weight of the substance in the D-tube

The actual volume flow rate varies with changes in ambient temperature and ambient pressure. However, when PD-1C is used, the volume of the generated gas and dilution gas change at the same rate. Therefore, the K value does not change.
In a strict sense, the volume of 1 mol of gas in the standard state (STP) varies depending on the type of gas. Also, a more accurate K value can be obtained by using the molar mass instead of the molecular weight in equation (3).

CAUTION

●Diffusion rate Dr values are affected by ambient pressure. The diffusion rates in Tables 1 and 2 are the values at standard atmospheric pressure, and should be corrected for atmospheric pressure if necessary.

<Calculation example> 5.0 ppm Benzene at standard atmospheric pressure (30°C)
The following diffusion rates are obtained from Table 2.

Diffusion rate 30 °C	D-10 :	31.0 (μg/min)
	D-20 :	75.0
D-30 :	215.0	
K value :	0.313	

Equation (1) is transformed to obtain Equation (4).

The calculation for the use of a D-10 type D-tube is as follows

$$F = \frac{K \times Dr}{C_0} \quad (4)$$

$$= \frac{0.313 \times 31.0}{5.0} = 1.94$$

To prepare C=5.0 ppm when using PD-1B series, set the water bath temperature to 30 °C, use D-10 type D-tube, and set the dilution gas flow rate F to 2.0 L/min. When using PD-1C, set the dilution gas flow rate F to 1.94 L/min.

Calculations to estimate Dr values at temperatures not in Tables 1 and 2. (only when PD-1C is used)

Within the temperature ranges listed in Tables 1 and 2, the Dr at temperatures between the Dr values can be estimated in 1°C increments. Larger temperature differences between Dr values tend to increase the error in the estimated Dr. For more accurate Dr values, see “Methods for measuring diffusion rate Dr values”.

If the temperature difference between the two Dr values given in the table is 5°C, the Dr at a temperature between those Dr values can be estimated using the following equation.

$$D_{rT} = D_{rL} \times \left(\frac{D_{rH}}{D_{rL}}\right)^{\frac{T-T_L}{5}} \quad (5)$$

Dr_T : Dr to be estimated
T : Temperature of Dr_T (°C)
T_L : Lower temperature of 5°C interval setting in Table 1 or 2(°C)*.
Dr_L : Dr values for the lower 5°C intervals indicated in Tables 1 or 2
Dr_H : Dr values for the higher 5°C intervals indicated in Tables 1 and 2

*When T is between 30°C and 35°C, T_L is 30°C. When T is between 35°C and 40°C, T_L is 35°C.

If the temperature difference between the two Dr values given in the table is 10°C, the Dr at a temperature between those Dr values can be estimated using the following equation.

$$D_{rT} = D_{rL} \times \left(\frac{D_{rH}}{D_{rL}}\right)^{\frac{T-T_L}{10}} \quad (6)$$

Dr_T : Dr to be estimated
T : Temperature of Dr_T (°C)
T_L : Lower temperature of 10°C interval setting in Table 1 or 2(°C)*.
Dr_L : Dr values for the lower 10°C intervals indicated in Tables 1 or 2
Dr_H : Dr values for the higher 10°C intervals indicated in Tables 1 and 2

*When T is between 40°C and 50°C, T_L is 40°C.

Methods for calculating mass concentration

From the equation for volume concentration, exclude the coefficient K value for converting mass to volume and add a correction for atmospheric pressure for the Dr value and a corrections for temperature and atmospheric pressure for the volume. The volume concentration is calculated with 25 °C and 1 atm, so it can be converted using the following equation.

$$C_g = \frac{Dr}{F} \times \left(\frac{P_0}{P}\right) \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right)$$
$$= \frac{Dr}{F} \times \left(\frac{298}{273+T}\right) \quad (7)$$
$$F = \frac{Dr}{C_g} \times \left(\frac{P_0}{P}\right) \times \left(\frac{298}{273+T}\right) \times \left(\frac{P}{P_0}\right)$$
$$= \frac{Dr}{C_g} \times \left(\frac{298}{273+T}\right) \quad (8)$$

C_g : Calibration gas concentration (mg/m^3)
T : Ambient temperature
P : Ambient pressure
P_0 : Standard atmosphere

Methods for measuring diffusion rate Dr values

Dr values can be determined by actual measurement. For higher accuracy or for substances not listed in the table 1 and 2, it is recommended to measure the actual values under the actual conditions of use.

When using the PD-1C, using the Manual mode will display only the temperature and flow rate on the main screen, making it ideal for measuring the diffusion rate Dr value.

Fill the D-tube with the specified amount of sample liquid and place it in the TUBE HOLDER of the permeator. Maintain a constant temperature while dilution gas is flowing (> 0.2 L/min).

After at least about 30 minutes, remove the D-tube and weigh it on a balance with a minimum unit of 0.1-0.01 mg. Record the time by minute. Immediately place the D-tube in the TUBE HOLDER and maintain it at a constant temperature with dilution gas flowing.

Repeat the weighing at equal intervals and calculate the diffusion rate at that temperature from equation (9). As the diffusion rate is reproducible, the value can be used repeatedly for the same D-tube.

For balances with [minimum limit 0.01 mg, repeatability ≤ 0.015 mg], repeat the weighing at intervals of at least 15 mg decrease until a reliable Dr value is obtained. The approximate weighing interval is determined by equation (10).

$$Dr = \frac{m \times 10^6}{T} \quad (9)$$
$$T = \frac{m \times 10^6}{Dr} \quad (10)$$

Dr : Diffusion rate (μ g/min)
m : D-tube decrease (g)
T : Weighing interval (min)

For actual measurement, a weighing interval of at least 1 day for a Dr value = 10, 2.5 hours for a Dr value = 100, and 30 minutes for a Dr value = 500 is recommended.

When measuring the actual diffusion rate, increasing the holding temperature of the D-tube from 30 °C to 50 °C will approximately triple the Dr value. At the same temperature, the diffusion rate is approximately 2.5 times higher with D-20 and approximately 7.2 times higher with D-30 than with D-10 diffusion tubes.

Make sure that the vapour pressure of the sample liquid is within the range 5-400 mmHg. For substances out of this range, a stable diffusion rate may not be obtained.

3. Maintaining the accuracy of calibration gas concentrations

CAUTION

- Most of the calibration gases prepared by this product are toxic, so position the instrument and connect tubes so that the CALIBRATION GAS (calibration gas outlet) is away from the breathing zone when use. Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or

a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.

1) When injecting the sample liquid into the D-tube, ensure that the liquid does not adhere to the inner walls.
2) The amount of sample liquid injected into the D-tube should be within the upper (upper level) and lower (lower level) lines marked on the D-tube. Outside this range, a stable diffusion rate may not be achieved.
3) The D-tube is placed in the TUBE HOLDER after the temperature of the water bath has been controlled to the set temperature and generates a gas concentration with the specified diffusion rate after at least 30 minutes.
4) Stable diffusion rates may not be achieved if liquid adheres to the inner wall of the D-tube. (If liquid adheres to the inner wall, a stabilisation time of about 30 minutes is recommended if the Dr value is 300 or higher, or 24 hours or longer if the Dr value is 10 or lower. If the Dr value is high, pay attention to the decrease of the sample in the D-tube. For example, in the case of benzene at 30 °C, D-30 and Dr = 215, all the sample will volatilise in about 7 days).
5) The dilution gas is Nitrogen or air purified with activated carbon and silica gel.
6) When sampling the calibration gas, use a fluorocarbon resin tube at one outlet as short as possible (within a few metres), and sample at a flow rate within the dilution gas flow rate and without any pressure in the tube. Before releasing the gas after use, remove the hazard by using a local exhaust ventilation system or a large-diameter activated carbon bed that does not cause backpressure. Then vent to the outdoors using a suitable ventilation system.

4. Cleaning the D-tube

After using high-boiling point substances or viscous liquids, flush the unit several times with a volatile solvent such as alcohol or acetone and then dry.

For all types of gas and vapour SINCE 1970
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Table 1. D-tube diffusion rate of organic solvents

Substance	K (25℃ 1atm)	Type of D-tube	D-10				D-20				D-30			
		Temp ℃	30	35	40	50	30	35	40	50	30	35	40	50
Acetone	0.421	*Dr*=	75	100	135	255	170	230	315	620	490	665	915	1830
Isobutyl Alcohol	0.330	*Dr*=	3.6	5.0	6.8	13	8.5	12	16	31	24	34	48	90
Isopropyl Alcohol	0.407	*Dr*=	13	17	23	42	29	40	54	100	85	115	160	290
Isopentyl Alcohol	0.277	*Dr*=	1.2	1.7	2.3	4.4	2.9	4.1	5.6	11	8.6	12	16	31
Ethyl Ether	0.330	*Dr*=	340				770				2210			
Ethylene Glycol Monoethyl Ether	0.271	*Dr*=	2.0	2.6	3.4	5.8	4.5	6.0	8.0	14	13	17	23	42
Ethylene Glycol Monoethyl Ether Acetate	0.185	*Dr*=	0.8	1.1	1.5	3.1	1.8	2.6	3.7	7.4	5.3	7.6	11	22
Ethylene Glycol Monobutyl Ether	0.207	*Dr*=	0.4	0.6	0.8	1.7	0.9	1.3	1.9	4.1	2.6	3.4	5.4	12
Ethylene Glycol Monomethyl Ether	0.321	*Dr*=	3.2	4.2	5.5	9.2	7.4	9.8	13	22	21	28	37	66
o-Dichlorobenzene	0.166	*Dr*=	0.7	0.9	1.2	2.2	1.6	2.2	3.0	5.4	4.8	6.5	8.8	16
Xylene	0.230	*Dr*=	3.3	4.1	5.2	7.1	7.3	9.1	12	18	21	26	32	50
o-Xylene	0.230	*Dr*=	2.5	3.3	4.2	7.1	5.7	7.5	10	17	16	21	29	50
m-Xylene	0.230	*Dr*=	2.8	3.7	4.8	8.0	6.5	8.6	11	19	19	25	33	56
p-Xylene	0.230	*Dr*=	3.0	3.9	5.0	8.2	6.9	9.1	12	20	20	27	35	58
Chlorobenzene	0.217	*Dr*=	4.6	6.0	7.9	14	11	15	19	33	32	43	55	94
Chloroform	0.205	*Dr*=	100	125	180	325	230	315	420	770	675	905	1220	2250
Isobutyl Acetate	0.210	*Dr*=	6.8	8.7	11	18	17	21	27	44	48	62	79	130
Isopropyl Acetate	0.239	*Dr*=	21	26	34	56	50	64	82	135	145	190	240	400
Isopentyl Acetate	0.188	*Dr*=	2.4	3.2	4.1	6.9	6.0	7.7	10	17	18	23	29	49
Ethyl Acetate	0.278	*Dr*=	33	43	57	97	78	100	130	225	225	290	380	650
Butyl Acetate	0.210	*Dr*=	4.1	5.5	7.5	14	8.8	12	17	33	24	34	49	97
Propyl Acetate	0.239	*Dr*=	13	16	21	33	31	39	49	80	91	115	145	235
Pentyl Acetate	0.188	*Dr*=	2.7	3.4	4.3	6.8	6.5	8.2	10	16	19	24	30	48
Methyl Acetate	0.330	*Dr*=	79	110	150	290	185	250	350	700	535	735	1010	2015

Table 2. D-tube diffusion rate of organic solvents

Substance	K (25℃ 1atm)	Type of D-tube	D-10				D-20				D-30			
		Temp℃	30	35	40	50	30	35	40	50	30	35	40	50
Carbon Tetrachloride	0.159	*Dr*=	65	84	110	175	155	195	255	410	445	570	680	1190
Cyclohexanol	0.244	*Dr*=	0.47	0.63	0.84	1.5	1.2	1.5	2.0	3.6	3.4	4.5	6.0	11
Cyclohexanone	0.249	*Dr*=	1.4	1.9	2.5	4.6	3.3	4.5	6.1	11	9.8	13	18	33
1,4-Dioxane	0.277	*Dr*=	13	17	22	36	31	40	51	85	89	115	150	250
1,2-Dichloroethane	0.247	*Dr*=	31	40	52	86	75	97	125	205	220	280	365	605
cis-1,2-dichloroethylene	0.252	*Dr*=	79	105	135	365	203	269	345	935	598	790	1013	2748
trans-1,2-dichloroethylene	0.252	*Dr*=	165	221	314		422	566	803		1241	1663	2360	
Dichloromethane	0.288	*Dr*=	230	355			545	855			1600	2500		
N,N-dimethylformamide	0.335	*Dr*=	1.3	1.8	2.4	4.3	2.9	4.2	5.7	10	8.5	12	17	30
Styrene	0.235	*Dr*=	2.3	3.0	3.9	6.7	5.3	6.9	9.1	16	15	20	26	44
1,1,2,2-Tetrachloroethane	0.146	*Dr*=	2.6	3.5	4.8	8.6	6.2	8.5	12	21	18	25	34	60
Tetrachloroethylene	0.147	*Dr*=	10	13	16	26	23	30	38	62	66	85	110	185
Tetrahydrofuran	0.339	*Dr*=	53	66	82	125	120	150	190	305	345	435	555	895
1,1-Trichloroethane	0.183	*Dr*=	56	73	94	160	130	170	220	370	380	485	620	1075
Trichloroethylene	0.186	*Dr*=	36	45	56	86	85	110	135	210	245	305	385	615
Toluene	0.265	*Dr*=	9.6	13	16	27	23	29	38	62	65	84	110	175
Carbon disulphide	0.321	*Dr*=	170	225	330		405	555	795		1180	1585	2320	
Normal hexane	0.284	*Dr*=	46	59	77	135	110	140	180	305	315	400	520	880
1-Butanol	0.330	*Dr*=	2.4	3.2	4.3	7.7	5.3	7.3	10	19	15	20	29	55
2-Butanol	0.330	*Dr*=	5.3	7.5	10	19	13	18	25	47	38	53	73	140
Methanol	0.763	*Dr*=	31	41	55	105	72	97	130	250	210	285	385	720
Methyl isobutyl ketone	0.244	*Dr*=	7.4	9.3	12	19	16	21	27	45	44	58	76	135
Methyl ethyl ketone	0.339	*Dr*=	27	35	46	77	64	83	105	180	185	240	310	525
Methylcyclohexanol	0.214	*Dr*=	0.33	0.44	0.56	0.92	0.83	1.1	1.4	2.2	2.4	3.1	4.0	6.5
Methylcyclohexanone	0.218	*Dr*=	1.0	1.3	1.7	2.9	2.4	3.2	4.2	7.3	6.9	9.2	12	21
Methyl butyl ketone	0.244	*Dr*=	4.3	5.5	6.9	11	11	13	17	26	31	39	49	77
Benzene	0.313	*Dr*=	31	40	52	86	75	95	124	206	215	281	361	598

24G/MP