User's Manual

Model FLXA402 4-Wire Converter Operation of DO

IM 12A01F05-01EN

YOKOGAWA

Yokogawa Electric Corporation

IM 12A01F05-01EN
3rd Edition

Introduction

Thank you for purchasing the FLXA™402 4-Wire Converter.

This Instructor's Manual contains all essential information for the user to make full use of FLXA402.

Please read the following respective documents before installing and using the FLXA402.

The related documents are listed as follows.

General Specifications

Contents	Document number	Note
FLXA402 4-Wire Converter	GS 12A01F01-01EN	Online manual

"EN" in the document number is the language code.

User's Manual

Contents	Document number	Note
FLXA402 4-Wire Converter Start-up and Safety Precautions	IM 12A01F01-01EN	Attached to the product (printed manual)
FLXA402 4-Wire Converter Installation and Wiring	IM 12A01F01-02EN	Online manual
FLXA402 4-Wire Converter Operation of Converter	IM 12A01F01-03EN	Online manual
FLXA402 4-Wire Converter Operation of pH/ORP	IM 12A01F02-01EN	Online manual
FLXA402 4-Wire Converter Operation of SC	IM 12A01F03-01EN	Online manual
FLXA402 4-Wire Converter Operation of ISC	IM 12A01F04-01EN	Online manual
FLXA402 4-Wire Converter Operation of DO	IM 12A01F05-01EN	Online manual (This manual)

"EN" in the document number is the language code.

An exclusive User's Manual might be attached to the products whose suffix codes or option codes contain the code "Z" (made to customers' specifications). Please read it along with this manual.

Technical Information

Contents	Document number	Note
FLXA402 4-Wire Converter HART communication	TI 12A01F01-61EN	Online manual
FLXA402 4-Wire Converter Modbus communication	TI 12A01F01-62EN	Online manual

"EN" in the document number is the language code.

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Notes on Handling User's Manuals

- Please provide the user's manuals to your end users so that they can keep the user's manuals for convenient reference.
- Please read the information thoroughly before using the product.
- The purpose of these user's manuals is not to warrant that the product is well suited to any particular purpose but rather to describe the functional details of the product.
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- If you have any questions, or you find mistakes or omissions in the user's manuals, please contact our sales representative or your local distributor.

Drawing Conventions

Some drawings may be partially emphasized, simplified, or omitted, for the convenience of description.

Some screen images depicted in the user's manual may have different display positions or character types (e.g., the upper / lower case). Also note that some of the images contained in this user's manual are display examples.

Composition of this User's Manual

FLXA402, a modular-designed converter, is a multi- parameter instrument offering a wide range of measurement choices; such as: pH/ORP (oxidation-reduction potential), Resistivity/ Conductivity (SC), Inductive conductivity (ISC), Dissolved Oxygen (DO) – with the respective sensor module.

For specification of DO, see GS 12A01F01-01EN.

This user's manual contains general description and precautions of the instrument.

The table below shows user's manuals to read concerning the instrument's operation, configuration, or calibration, which vary depending on its installation, wiring, and specification of each instrument.

Contents	pH/ORP SENCOM™ SA	Contacting conductivity (SC) SENCOM SA	Inductive conductivity (ISC)	Dissolved oxygen (DO)
Introduction and general description	IM 12A01F01-02EN			
Wiring and installation	IM 12A01F01-02EN			
Converter operation (Setting, Calibration) Maintenance, Troubleshooting	IM 12A01F01-03EN			
Sensor operation (Setting, Calibration)	IM 12A01F02-01EN	IM 12A01F03-01EN	IM 12A01F04-01EN	IM 12A01F05-01EN

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Terminology

sensor(s):	sensors, sensors with SA11, sensor module(s)
SENCOM SA	SA11, SENCOM Smart Adapter or “-S5” (SENCOM SA) of 1st or 2nd input
analog sensor (module)	selectable sensors when -P1/-C1/-C5/-D1 is specified for 1st or 2nd input, e.g. DO30G.
Optical DO Sensor, DO70G	“-D5” (Digital sensor) for 1st input
Optical DO Sensor, DO71, DO72	“-D6” (Digital sensor) for 1st input
NE107:	NAMUR NE107 see Section 4.7 Error settings in IM 12A01F01-03EN Operation of Converter

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Model FLXA402
4-Wire Converter
Operation of DO

IM 12A01F05-01EN 3rd Edition

CONTENTS

1. Sensor Menu Outline

Main/Home screen > MENU "Sensor menu". > "Detail" / "Calibration" / "Setting"

The operation is secured by password. See the section 5.4 in IM 12A01F01-03EN Operation of Converter.

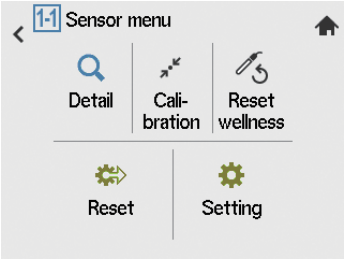


Figure 1.1 Sample image of "Sensor menu"

Sensor detail

On Sensor menu, tap "Detail". Read "2.1 Detail".

Figure 1.2 Sample image of "Detail"(Sensor menu>Detail)

Calibration

On Home/Main screen, tap CAL. On Sensor menu, tap for calibration of sensors.

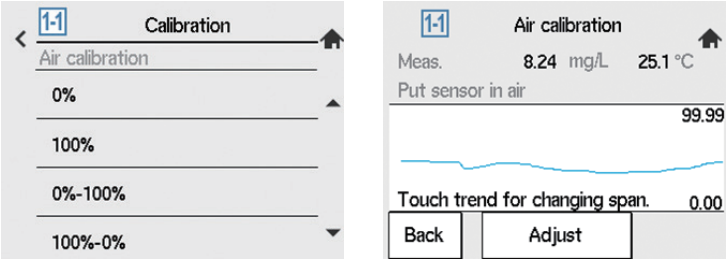


Figure 1.3 Sample images of pH Calibration

For further information read "4. Calibration DO".

Wellness reset

Go to Sensor menu> tap . Read "2.3 Reset wellness".

Sensor reset

On Sensor menu, tap . Read "2.4 Reset".

Configure sensor

Converter menu or Sensor menu > ⚙ “Setting”

Go to Converter menu to configure the setting of converter such as mA output, display setting.

Go to Sensor menu to configure the sensor setting such as calibration setting.

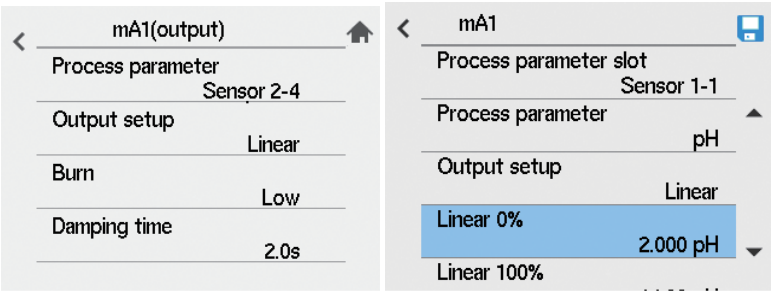


Figure 1.4 Sensor configuration (parameter list)

Select a parameter to change. The parameter becomes highlighted. To overwrite the data, tap 💾

Read “3. Sensor setting” about sensor configuration.

2 Sensor menu

Main screen MENU > Sensor menu

The following operation are available.

Detail (details on sensors)

Calibration (sensor calibration)

Setting (sensor setting)

etc.

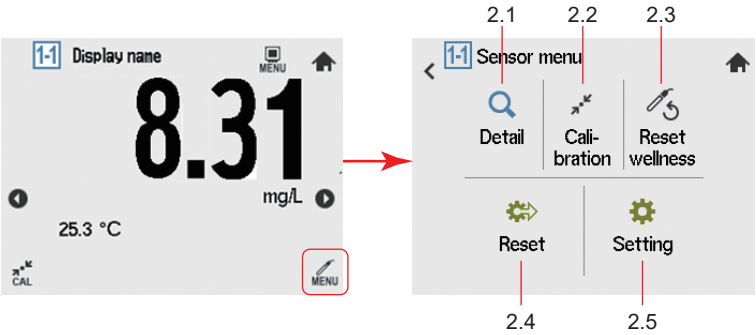


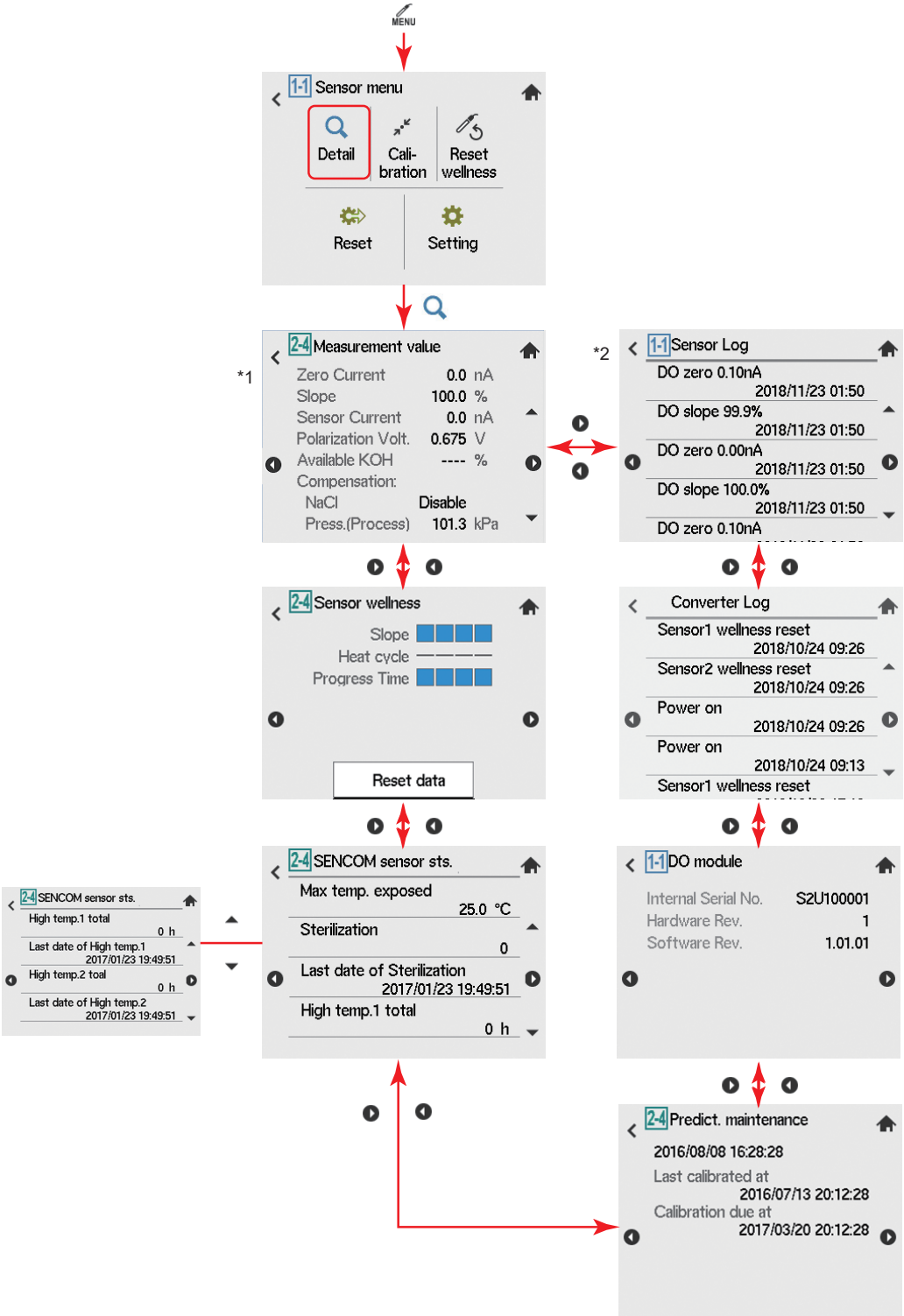
Figure 2.1 Sensor menu (sample)

When Optical DO Sensor is used, “Reset wellness” is not available.

2.1 Detail

Go to Sensor menu > “Detail” to check details (setup, sensor diagnosis, calibration, and module production number). (“2.2 Calibration”)

In case of trouble, when you contact Yokogawa service, please inform us of the module and FLXA402 software revision displayed on the Detail and module production number, revision number indicated on the nameplate attached to the instrument.



*1: “----”is displayed, depending on a process or sensor configuration when Optical DO Sensor is used.
*2: The number of log page goes as many as the connected sensors.

Figure 2.2 Sensor menu flow chart

NOTE

When Optical DO Sensor is used, “Sensor wellness”, “SENCOM sensor sts.”, “Predict maintenance” are not available.

Measurement value

Zero Current

The offset value of a calibrated sensor. This is the offset of the sensor and sensor circuit in the zero oxygen condition. When Optical DO Sensor is used, the value is 0 (fixed).

Slope

This parameter indicates the sensitivity of the sensor after calibration. It is indicated as a percentage of the reference sensitivity based on the selection of the sensor or that has been entered. When Optical DO Sensor is used, the value is 100 (fixed).

Sensor Current

The raw output of the sensor before it is calibrated and temperature compensated. When Optical DO Sensor is used, “----” is displayed.

Polarization volt

Appears only when “Sensor type” is “Polarographic”. To set, go to sensor menu > Sensor configure > Polarographic > Polarization Voltage

Available KOH

For the parameter, go to Sensor menu > Configure sensor > Wellness settings > Check KOH residue > Sensor type :DO30G (for “Others” ” a bar (----) is displayed.)

This parameter indicates the amount of available KOH remaining in the sensor. This amount is calculated from the amount of KOH consumed by dissolved oxygen measurements.

When replacing the solution in the sensor, calibration should be made to reset (clear) diagnostic sensor data.

Compensation

For compensation of measured value, salinity compensation, Pressure comp. (measure), and Pressure Comp. (Cal) are available. The salinity compensation shows the current setting. When Pressure comp. (measure) is set to “manual”, Pressure level (process) calculates, when Pressure comp. (measure) is set to “External input”, mA input and low/high limit value calculates the pressure. As for Pressure comp. (Cal), a setting value is displayed.

The salinity compensation of DO70G, DO71 and DO72 are always functionally Enabled although the display on NaCl of Measurement value-Compensation is “Disable”.

■ Sensor wellness

Sensor wellness shows the soundness of a module. The larger number of ■ appears in each gauge, the more sound the parameter concerned is. A gauge is indicated for only those parameters whose sensor wellness setting is “enabled, “while a bar (----) is displayed if the sensor wellness setting is “disabled.”

For Sensor wellness, go to Sensor menu > Configure sensor > Wellness settings

See Section “3.4 Wellness settings” for the details.

When a sensor or an electrode is replaced, sensor wellness data should be reset. Use Reset wellness in Sensor menu. See Section “2.3 Reset wellness”. When Optical DO Sensor is used, this function is not available and a bar (----) is displayed.

■ SENCOM Sensor status

The status of the sensor is displayed. When Optical DO Sensor is used, this function is not available.

● Max temp. exposed

Displays the maximum temperature, which is automatically updated every time a higher temperature is measured.

● Sterilization

Displays the number of times the temperature remains above the preset value for at least the prescribed time period (min.). (Figure 2.3)
Go to Sensor menu > Configure sensor > Wellness settings > Define SENCOM status

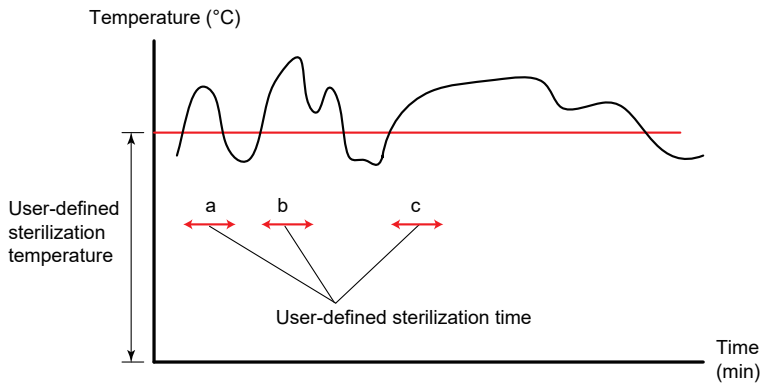


Figure 2.3 Sterilization

a: does not count, because the length of time that the temperature exceeds the sterilization temperature is shorter than the length of sterilization time.

b: counts, because the length of time that the temperature exceeds the sterilization temperature is longer than the length of sterilization time.

c: counts, because the length of time that the temperature exceeds the sterilization temperature is longer than the length of sterilization time.

If the temperature exceeds the sterilization temperature longer than the length of sterilization time consecutively, the event counts as one.

The last time when the event counts is displayed as a last sterilization date/time.
Counter indicates a maximum of 9999. After the counter reaches the maximum, if the requirements to count is satisfied, the data of last sterilization date and time is updated.

High temp 1 total, Last date of High temp1, High temp 2 total

To define the temperature of “High temp 1” and “High temp 2”, go to Sensor menu > Configure sensor > Wellness settings > Define Sencom status

The total length of time that the measured temperature exceeds the defined High temp 1 or High temp 2.

Displays the total time during which the temperature remains over the high temperature 1 or 2. The last date and time (the end of high-temperature condition) is displayed as the “last date. “Up to 10 years (87600 hours) can be counted. Even after that, the “last date” is updated if the event meets the conditions.

Predict. maintenance

When Optical DO Sensor is used, this function is not available.

Last calibrated at

Date on which the last sensor calibration was performed. The displayed value of the Zero is the result of this calibration. The displayed value of Slope was calibrated on this date only if the last calibration was a 2-point calibration.

Calibration due at

Date when the calibration must be done next according to the settings of the calibration interval. To set the calibration intervals, go to Sensor menu > Calibration settings > Limits and timing >Calib. interval. For details see Section “3.3 Calibration settings”.

DO module

The contents displayed on the details screen are as follows.

Detail	Analog sensor	DO70G	DO71, DO72
Serial number	Serial number	Device no. *1	Serial number of DO71, DO72
Hardware Rev.	Module Hardware Rev.	Module Hardware Rev.	1.01.01 (fixed)
Software Rev.	Module Software Rev.	Module Software Rev.*2	DO71, DO72 Firmware Rev.

*1: You cannot confirm the serial number.
*2: “ODOUM042” or later is supported. Neither ODOUM040 nor ODOUM041 is supported.

Converter log, Sensor log

Same display as on the converter “Detail”.

See Section 3.1 in IM 12A01F01-03EN Operation of Converter.

2.2 Calibration

Sensor menu > Calibration . See Section “4. Calibration DO”.

Figure 2.4 Calibration selection

If you have a password, a prompt dialog box appears to input your password. After the password is verified, the page shifts to Calibration.

For password, see Section 5.4 in IM 12A01F01-03EN Operation of Converter.

2.3 Reset wellness

Sensor menu > Reset wellness

A dialog box appears to ask if you want to reset sensor wellness data.

Yes: the wellness is reset

No: the reset will not take place. The page returns to Sensor menu.

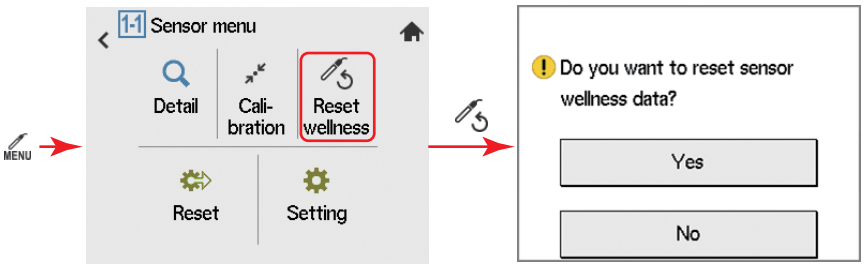


Figure 2.5 Reset wellness and dialog

If you created a password, a prompt dialog box appears to input your password. After the password is verified, a dialog appears to confirm if you want to reset.

For password, see 5.4 in IM 12A01F01-03EN Operation of Converter.

When Optical DO Sensor is used, this function is not available.

2.4 Reset

Sensor menu > Reset

The screen jumps to Load PH config. File screen, where you can reset parameters of analog sensor module, SENCOM SA.

While Wash is in progress, “Reset” is invalid. Even if you tap the icon, you will not jump to the sensor reset screen.

Figure 2.6 Reset in sensor menu (DO)

In the box of File name, name of defined sensor config. file to load is displayed, after sensors connected are automatically detected. You cannot change the file name.

If you tap “Execute”, the loading starts. When the loading ends, you will return to Sensor menu.

If you create a password, a prompt dialog box appears to enter the password. After the password is verified, Sensor reset screen appears.

For password, see 5.4 in IM 12A01F01-03EN Operation of Converter.

If you go to Sensor reset screen, mA output becomes HOLD, and contact output keeps the current status.

2.5 Sensor settings

Sensor menu > Setting > Sensor setting

When Wash is in progress, the character row is displayed in color. You cannot move to Sensor settings.

For further information on sensor settings, read “3. Sensor setting”.

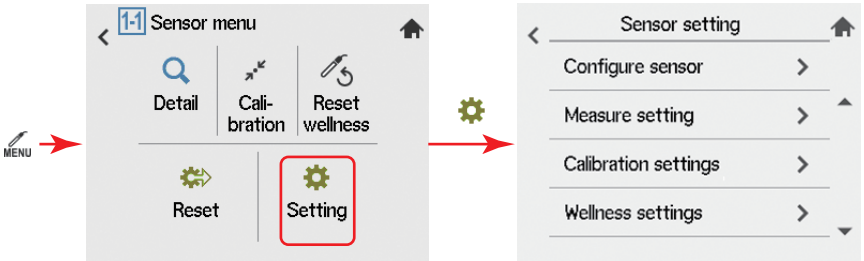


Figure 2.7 Sensor setting

If you create a password, a prompt dialog box appears to enter the password. After the password is verified, Sensor setting is displayed.

For password, see Section 5.4 in IM 12A01F01-03EN Operation of Converter.

If you go to Sensor setting, the mA output becomes HOLD, and contact output keeps the current status.

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3. Sensor setting

When you configure each setting, fill in User setting table we provide, and keep it in safe place.

Download the user setting table from our website below.

http://www.yokogawa.com/an/flxa402/download/

Configure sensor setting

Go to Main screen > Sensor menu > Sensor setting

You can confirm or edit the setting. When you go to Sensor setting, mA output becomes HOLD, and contact output keeps the current status.

Figure 3.1 Sensor menu to Sensor setting

To know how to confirm or edit the settings with parameters, refer IM 12A01F01-03EN Operation of Converter.

CAUTION

Among the Measure setting parameters (next page), only parameters with ∗ (asterisk) apply to Optical DO Sensor.

Some of these parameters may set to high/low limit when a fail value that exceeds high/low limit is entered instead of issuing an alarm.

When you configure sensor setting and save the data, a dialog box appears to notify the operation is in progress. If you succeed the configuration, you will return to parameter list, and if fail, a fail dialog appears.

The setting list of the analog sensor, DO70G, DO71, and DO72 is as follows:

○: Settable
×: Cannot be set

Sensor setting menu			Analog sensor	DO70G, DO71, DO72	
Configure sensor		Sensor type	○	×	
	Temperature settings	Temp. element (A)	○	×	
	Galvanic	Sensor sensitivity / User defined	○	×	
	Polargraphic	Sensor sensitivity / polarization voltage	○	×	
	Others	MODBUS address (S)	○	×	
Measure setting	DO settings	Unit *	○	○	
	Temperature settings	Unit	×	×	*1
	Temp compensation	Compensation / Manual temp.	○	×	
	Salinity comp.	Compensation	○	×	*2
		Salinity value *	○	○	
	Pressure comp. (Measure)	Compensation	○	×	*3
		Pressure level (Calibration) *	○	○	
		Unit of pressure	×	×	*1
	High/Low alarm setting		○	×	
Calibration settings	Limits and timing (Galvanic)	Zero High / Low limit	○	×	
		Slope High / Low limit	○	×	
	Limits and timing (Polargraphic)	Zero High / Low limit	○	×	
		Slope High / Low limit	○	×	
	Zero / Slope (Galvanic)	Zero current / Slope	○	×	
	Zero / Slope (Polargraphic)	Zero current / Slope	○	×	
	Pressure Comp. (Cal)	Pressure level	○	×	
	Step range	Zero / Span	○	×	
	Cal. Set others	Stabilization time / Calibr. interval	○	×	
	Cal. set temperature	Temp.offset	○	×	
Wellness settings	Progress time	Progress time / BAD Limit	○	×	
	Heat cycle	Heat cycle/Heat cycle temperature / Heat cycle time / BAD Limit	○	×	
	Check KOH residue	Sensor type	○	×	
	Define SENCOM status	Sterilization temperature / Sterilization time / High temp 1 / High temp 2	○	×	

*1: Go to Converter menu to set. Refer to section 4.6 of the "Model FLXA402 4-Wire Converter Operation of Converter" (IM 12A01F01-03EN).
*2: Salinity compensation of DO70G, DO71, DO72 are always Enabled, but are displayed “Disable” in the setting screen.
*3: Go to Converter menu to configure DO70G, DO71, DO72. Refer to section 4.1 of the "Model FLXA402 4-Wire Converter Operation of Converter" (IM 12A01F01-03EN).

3.1 Configure sensor

Configure the setting of sensors (analog sensors).

■ Sensor type

Select a sensor type from Galvanic or Polarographic. Care about which one is compatible with sensors being connected.

3.1.1 Galvanic

Select a Sensor sensitivity among “0.45μA/ppm” / “0.90μA/ppm” / “Others.”

If you select “Others”, enter a numeric value on “Sensor sensitivity (User defined)”.

3.1.2 Polarographic

Enter a numeric value of sensor sensitivity. You can define a polarization voltage recommended for the sensor

3.1.3 Temperature settings

Only for analog sensors.

■ Temp. element (A)

Select the temperature element used for compensation from among Pt1000, NTC2k. Select the same type of temperature element as is actually connected.

3.1.4 Others

■ MODBUS address (S)

You can change MODBUS address only when SENCOM SA is in use.

3.2 Measure setting

Set parameters for measurement.

3.2.1 DO settings

■ Unit

Select DO unit from “mg/L” / “ppm” / “ppb” / “%SAT”.

3.2.2 Temperature settings

■ Unit

Displays the unit for temperature. You cannot change the setting here.

To change the setting, go to

Converter menu > Setting> Advanced setting > Other

3.2.3 Temp compensation

■ Compensation

Methods: Automatic, Manual, External input

Automatic:	when a temperature element is used,
Manual:	when a manually set temperature is used.
External input:	when mA input to the converter is used. Go to Converter menu > Converter setting > mA input setting (Ad) : Temperature The setting must be specification of the device to use as an external input.

NOTE

When Manual is selected on the Temperature compensation, a process temperature should be set in the “Manual temp. Home/Main screen displays the temperature you set here.

■ Manual temp.

When you select Manual, you must enter process temperature.

3.2.4 Salinity comp.

This function is used to measure sample water containing salt such as sea water.

The dissolved oxygen in a solution is affected by salinity. Therefore, to conduct accurate measurements, it is necessary to compensate the influence of the salinity of the sample solution.

To make salinity compensation, select “Enabled” for “Compensation.”

Calculate the saturated concentration value from the salinity and temperature of the actual sample water based on Table 1 in Appendix (Solubility of oxygen in water as a function of temperature and salinity) and enter the value.

The salinity compensation of DO70G, DO71 and DO72 are always functionally Enabled although the measure setting screen shows the compensation is “Disable”.

NOTE

Set up the conductivity value (mS/cm) at 20°C. Refer to Appendix.

3.2.5 Pressure comp. (Measure)

Dissolved oxygen concentration varies depending on changes in the process pressure or air pressure. To compensate this, enter a value of pressure (air pressure).

Compensation has two options, “Manual” or “External input”.

To program freely selected pressure value, choose “Manual” and enter the pressure value on “Pressure level (process)*”. For further information, see Table 2, Table 3 in Appendix.

If you use mA input corresponding to measured value of pressure from external devices, select “External input”.

To use the mA input, go to Converter menu > Setting > mA input settings (Ad) > Type > Pressure.

You can confirm the unit of pressure but not change the setup on this mode.

To setup, go to Converter menu > Setting > Advanced setting > Other settings

NOTE

When Optical DO Sensor is used, the conpensation settings cannot be chaged from “Manual” to “External input”.

To compensate pressure by the external input, instead of using this function, go to Converter menu,

Converter menu > Setting > mA input settings (Ad) > Pressure > Pressure Comp. * > select “Enable”.

If you select “Disable”, the compensation is implemented by the value on Pressure level (process) *

3.2.6 High/Low alarm setting

Alarms from sensors are sorted out to “Device fail”, “Device status”, “Measure alarm”, “Sensor status”. Setup High/Low alarm setting of main measurement value on Measure alarm.

For details on alarms, see Section 4.7 in IM 12A01F01-03EN Operation of converter.

Parameter	Reason for alarm	Setting range	Default
Temp. warning high limit	Temp. is too high	-20.0 to 150.0 [°C]	150.0 [°C]
Temp. warning low limit	Temp. is too low	-20.0 to 150.0 [°C]	-20.0 [°C]
DO warning high limit(mg/l)	DO is too high	0.00 to 99.99 [mg/L]	99.99 [mg/L]
DO warning low limit(mg/l)	DO is too low	0.00 to 99.99 [mg/L]	0.0 [mg/L]
DO warning high limit(ppm)	DO is too low	0.00 to 99.99 [ppm]	99.99 [ppm]
DO warning low limit(ppm)	DO is too high	0.00 to 99.99 [ppm]	0.00 [ppm]
DO warning high limit(ppb)	DO is too high	0.0 to 9999 [ppb]	9999 [ppb]
DO warning low limit(ppb)	DO is too low	0.0 to 9999 [ppb]	0.0 [ppb]
DO warning high limit(%SAT)	DO is too low	0.0 to 100.0 [%SAT]	100.0 [%SAT]
DO warning low limit(%SAT)	DO is too high	0.0 to 100.0 [%SAT]	0.0 [%SAT]

NOTE

When Optical DO Sensor is used, High/Low alarm is not issued and this setting is not available.

When measured temperature exceeds

high limit: 60.0 [°C] or low limit: -20.0 [°C]

the value is recognized as fail of temperature element then issues

“temp. resistivity too high (fail)” or “temp. resistivity too low (fail)”

Temperature can be measured within the range of specification: -40.0 to 140.0 [°C] which is specification of DO70G, but DO value is displayed as “----”.

Temperature can be measured within the range of specification: -40.0 to 100.0 [°C] which is specification of DO71/DO72, but DO value is displayed as “----”.

When DO value exceeds

high limit: 300.0 [%SAT] or low limit: 0.0 [%SAT]

the value is recognized as sensor fail, issuing

“mA input too high (fail)” or “mA input too low (fail)”.

If the version of DO70G is ODOUM042, the alarms might not be detected depending on the situation.

3.3 Calibration settings

3.3.1 Limits and timing

Set limits and timing on every type of analog sensors (galvanic or polarographic) respectively.

■ Zero high / low limit

Set the high and low limits of Zero. During calibration, it is checked whether the new zero exceeds these high and low limits. Narrowing the band will prevent bad calibration procedures and calibration of bad sensors, which results in higher accuracy. The default values should be adjusted to suit the application and the “users” criterion.

■ Slope high/low limit

Set the high and low limits of Slope (sensitivity). During calibration, it is checked whether the new slope exceeds these high and low limits. Narrowing the band will prevent bad calibration procedures and calibration of bad sensors, which results in higher accuracy. The default values should be adjusted to suit the application and the “users” criterion.

3.3.2 Zero/Slope

■ Zero/Slope

You can directly enter the value “Zero current”, “Slope”. You can configure each one on type of analog sensors (“Galvanic”, or “Polarographic”) respectively.

3.3.3 Pressure Comp. (Cal)

■ Pressure level (Calibration)

You can directly enter the value of “Pressure level” (Calibration).

This parameter is used only for calibration. Enter the pressure at calibration.

Neither “Pressure comp. (Measure)” nor “Salinity comp.” applies to calibration.

(Note) “Pressure comp. (Measure)” and “Salinity comp.” are applied for calibration when using DO70G, DO71, and DO72.

3.3.4 Step range

You can define a step range. When a measured value fluctuates within the step range, it implies the measuring is stabilized. Define step range on each DO measuring unit of both zero and slope, “mg/L, “ppm”, “ppb”, “%SAT” respectively.

3.3.5 Cal. Set others

Stabilization time

During calibration, the stability of the ORP value is constantly monitored. When variations of the measured value are within the preset Step Range, the value is regarded as being stable. If the measured value does not stabilize within 60 minutes, calibration is aborted.

Calibr. interval

Set the interval in which a new calibration must take place. If the interval set here is exceeded, the instrument will be notified according to the setting in “Calib. time exceeded” in the error configuration.

3.3.6 Cal. set temperature

Temp.offset

You can enter directly Temp. offset value here.

Input the temperature-corrected offset value based on the next equation.

Y= A-(B-C)

where Y=Temp.offset
A= actual value
B= displayed temperature value
C=current temperature offset

Note
- Check A (actual value) on other devices.
- B is a value displayed on FLXA402 process.
- C (current temperature offset) is confirmed on Temp. offset screen.

NOTE

When you renew Temp. offset value on FLXA402 by calibration, you don’t need to input Temp. offset value directly. Enter the value directly when calibration is not implementable.

3.4 Wellness settings

This screen is used to set items relating to sensor diagnostics displayed on the Sensor wellness.

Gauges are displayed for only parameters that have been enabled in “Wellness settings”. ”Parameters set to Disable are provided with a bar display.

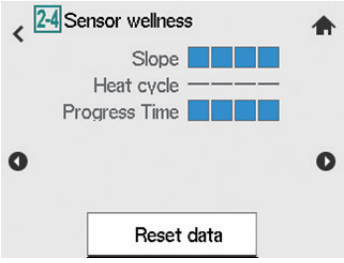

Figure 3.2 Sensor wellness

The setting parameters include “Progress Time”, “Heat cycle” “Check KOH residue”.

Progress time: “Progress time”, and “BAD Limit”.

Heat cycle: “Heat cycle temperature”, “Heat cycle time”, “BAD Limit”.

To enable “Available KOH” appear on the sensor “Measurement value” screen, go to “Check KOH residue” > “Sensor type

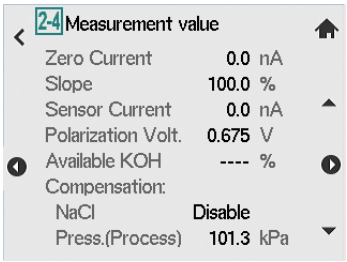

Figure 3.3 Measurement value

Define SENCOM status

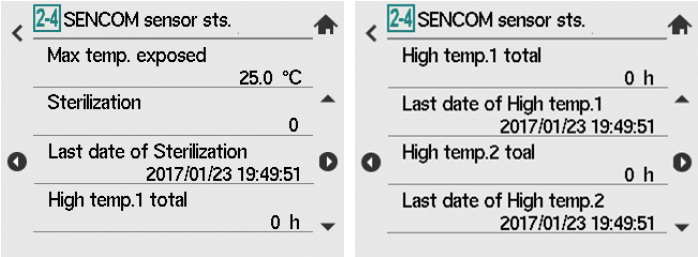

Figure 3.4 SENCOM sensor status

The parameters are “Sterilized temp.”, “Sterilized time”, “High temp.1”, “High temp.2”. For further information on sensor status, see Section “2.1 Detail”

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4. Calibration DO

Calibration of the dissolved oxygen analyzer is performed in the following situations:

- When a new dissolved oxygen sensor is installed.
- When the membrane is replaced and/or the electrolyte solution is replaced

There are three methods for calibration : Air calibration, Water calibration and Manual calibration

air calibration: the most common and easiest method.
water calibration: features higher accuracy than the air calibration
manual calibration: analyzes a sample solution or gas manually and then calibrate the sensor to adjust to this value.

Table 4.1 Calibration of oxygen analyzer (analog sensor, DO sensors)

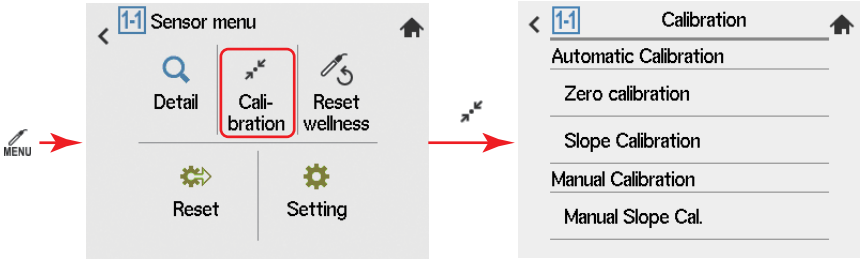
Para meter	Method	Sample	Analog sensors (galvanic, polarographic)		
			converter menu	Note	Rate (*1)
zero	zero	sodium sulfite solution water or N_2 gas *3	air -zero water -zero	rarely necessary (recommended for low concentration measurement)	(B)
span	air	the atmosphere (Humidity saturated atmosphere is best)	air -span	common, easiest	B
	water	air saturated water	water.-span	highest accuracy	A
	sample	solution with known-value of concentration *4	manual-slope	implement according to the necessity	N/A

Table 4.2 Calibration of dissolved oxygen analyzer (DO70G, DO71, DO72)

Para meter	Method	DO70G, DO71, DO72-W (Wide measuring range sensor)				DO72-T (Trace measuring range sensor)			
		Sample	converter menu	Note	Rate (*1)	Sample	converter menu	Note	Rate (*1)
zero	zero	sodium sulfite solution water or N_2 gas *3	Automatic calibration zero	always required	A	sodium sulfite solution water or N_2 gas *3	Automatic calibration zero	always required	A
span	air	the atmosphere (Humidity saturated atmosphere is best)	Automatic calibration auto air-span	easy, less accurate	C	the atmosphere (Humidity saturated atmosphere is best)	air-span	unsupported *2	
	water	air saturated water	Automatic calibration water-span	highest accuracy	A	air saturated water	span	unsupported *2	
	sample	solution with known-value of concentration *4	manual-slope	implement according to the necessity	N/A	1–2vol% O_2 gas (N_2 balance)	manual-slope	highest accuracy	A

*1: Rating of recommendation. In alphabetical order, A is the most recommended. (highlighted field is recommended)
*2: Do not select. If selected, “Failed” is displayed.
*3: Use N2 gas of 99.999% or more concentration.
*4: Use Sample to perform a calibration with salt water.

(1) Analog sensor (on display Zero: “0 %”, Span “100 %”)



(2) DO70G, DO71, DO72

Figure 4.1 Sensor menu to Calibration

For DO, Favorite Calibration is not available. Tap CAL on Home/Main screen, then you switch to calibration screen.

When analog sensor modules are used, “Air calibration”, “Water calibration”, “Manual Slope Cal.”, “Temperature calibration”, “Manual Offset Cal.” are available.

When DO70G, DO71, DO72 is used, Automatic Calibration (Zero Calibration, Air Calibration), Manual calibration (Manual Slope Cal.) are available.

“Air Calibration”, “Water Calibration”, “Manual Slope Cal.”, “Automatic Calibration shows” graphical data of calibration trend and verifies the stability of the calibration process.

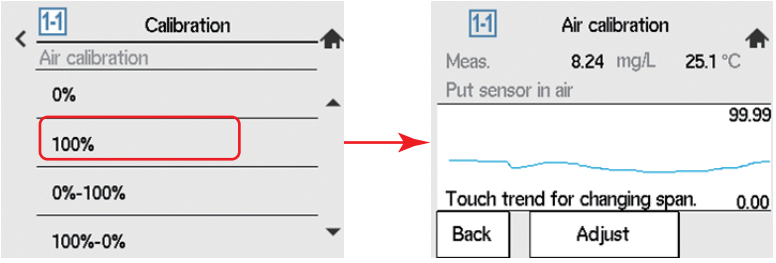


Figure 4.2 Calibration- trend sample (when air cal.is 100 %)

Follow steps to implement calibration being instructed on each screen. Each measuring point inspects stability of the calibration. After the value becomes stable, you can go to the next step.

NOTE

While “Checking stability” is on screen, the stability of current calibration value is being monitored automatically. When the inspection lasts longer than 60 minutes, the fail alarm occurs and the calibration is not implemented. If you need, edit “Stabilization time” and “Step range” and try again the calibration.

If FLXA402 detects any sensor fault such as damage on temperature electrode, no calibration is implemented.

CAUTION

When Optical DO Sensor is used, because no sensor status can be monitored, be sure that there is no damage on sensors before use.

NOTE

When a sensor or an electrode is replaced, sensor wellness data should be reset.

4.1 Air Calibration

Move the sensor to a maintenance site and wash off any dirt on the membrane. Lightly wipe off any remaining water from the membrane with a soft tissue.

Expose the sensor to the air in an environment where there is no temperature change and no wind. (A convenient way to accomplish this environment is to place the sensor in an empty bucket)

Oxygen partial pressure in the atmospheric gas is influenced by vapor saturation. The lower humidity drops, the higher the oxygen partial pressure rises. (influential rate of 2 to 3 % at maximum)

For suitable condition to perform calibration, the vapor level in the atmosphere requires approximately saturated (100 % of humidity) and the oxygen partial pressure should not fluctuate according to the change of humidity.

4.2 Water Calibration

Water calibration is a method of calibrating dissolved oxygen analyzers in a laboratory. Accurate results can be obtained if the span calibration is performed carefully in air-saturated water.

Although setting the Zero Calibration to “Enabled” allows 2-point calibration of Zero (0%) and Span (100%), the reading must have been stable before performing zero calibration. Therefore, zero calibration takes a relatively long time.

Conduct water calibration in fresh water. For zero calibration in salt water, perform it by manual calibration.

Set the sensor in the maintenance mode. Wash off any stain on the membrane and use a soft tissue to wipe off any remaining water from the membrane.

● Air-saturated water

Pour water (without salt content) into a beaker or other container, and place it on a magnetic stirrer or other agitator. Put a stirring bar in it and agitate the water, and send air from a pump (bubbling). It takes 15 to 30 minutes until the water is fully saturated. Then put the sensor in this water which is still agitated and bubbling, and calibrate it. Keep the sensor at least 3 cm above the bottom of the beaker to prevent the membrane from directly contacting the air bubbles.

● Water for zero calibration

When analog sensor is used, zero calibration takes a long time and normally there is no need to perform it. A clean sensor does not have a zero current and thus does not require zero calibration.

For the zero calibration water, dissolve 20 to 30 grams of sodium sulfite in 1 liter of desalinated water. For DO70G, DO71 or DO72, using a saturated solution of sodium sulfite delays response. The amount of sodium sulfite dissolved in the solution must be 20 to 30 grams in 1 liter of desalinated water.

NOTE

When analog sensor is used, Dissolve sodium sulfite in the water and wait until the reading becomes stable before calibrating the sensor. Even a healthy sensor needs 40 to 50 minutes. Leave the sensor in the solution.

NOTE

- When DO70G, DO71, DO72-W (general purpose) is used, you can select Span calibration or Air calibration from “Automatic calibration”.

  Air calibration adjust the span point (100%), Zero calibration adjust the zero point (0 %).

  Water calibration with saturated water enables you to gain an accurate result if you select span calibration on screen and follow the calibration procedure of Water calibration.

  It takes some time for water calibration to become stable. if you perform Zero calibration, follow the process of Water calibration.
- When DO72-T(trace range) is used, you cannot select Span calibration from “Automatic calibration”. Do not select Span calibration on the screen. If you need Span calibration for DO72-T(trace range), see Section “4.3 Manual slope calibration”.

4.3 Manual slope calibration

Analog sensor, DO70G, DO71, DO72-W (Wide measuring range sensor)

Calibrate the sensitivity of the sensor with a solution of known oxygen concentration.

First, analyze the oxygen concentration of a sample solution and then calibrate the sensor sensitivity to adjust to this value. From the actual measurement of salinity and temperature, obtain the dissolved oxygen concentration by referring to Table 1 on page App.-1 and enter it.

When salinity must be considered, perform the calibration manually.

Note the following:

- Quickly analyze the sample water to prevent the dissolved oxygen concentration or temperature from changing.
- Before analyzing the sample water, analyze the reference with a calibrated laboratory instrument.
- To eliminate any discrepancies, the laboratory instrument must have been calibrated with the same calibration data as specified in ISO 5814.

Confirm that the reading of the instrument is stable and the sensor is clean. If the reading remains unstable, set the sensor in the maintenance mode and wash off any stain on the sensor membrane. Return the sensor to the sample water and leave it until the reading becomes stable.

Salinity calibration using sample water with salt content

To make salinity compensation,

Sensor menu > Setting > Measure setting > Salinity comp. > select “Enabled” for “Compensation”.(see “3.2.4 Salinity comp.”)

Perform calibration by referring to Table 1 on page App.-1.

Example:

When the atmospheric pressure is 101.325 kPa, the solution temperature is 20.0°C, and the salinity (conductivity) is 9.1 mS/cm,

(1) Calculate the salinity from the conductivity.
According to Table 2 on page App.-2, the salinity is 6 (g/kg), 9.1 mS/cm

(2) Calculate the oxygen decrease by obtaining the difference of saturated dissolved oxygen level between two salinity points.

According to the Table 1 on page App.-1

Salinity 0 at 20.0°C: 9.09 (mg/L), Salinity 9: 8.62 (mg/L)

(9.09 – 8.62)/9 = 0.052 [mg/L]

Therefore, the oxygen reduction per Salinity is 0.052 mg/L.

(3) Calculate the saturated concentration of the solution (for calibration) by subtracting the oxygen decrease value from the saturated oxygen concentration at Salinity0.

9.09–(0.052 × 6)=8.8 [mg/L]

Therefore, the saturated oxygen concentration of sea water (9.1 mS/cm) at 20.0°C is 8.8 (mg/L).

(4) Enter 8.8 mg/L to calibrate.

To compensate salinity with analog sensor, select “Enabled” in “Measurement setup” – “Salinity compensation” – “Compensation”

DO72-T (Trace measuring range sensor)

Calibrates the sensor sensitivity using gas of the known oxygen concentration in Use gas of 1 – 2 vol%O_2 (N_2 balance).

Figure 4.3 shows a piping example for calibration. Adjust the flow rate to the sensor to less than 0.5 L/min. After confirming that the reading is stabled, start the calibration. Use Table 5 on page App.-5 to find the concentration (mg / L) from the gas concentration (vol%) and temperature. Enter the value.

Note the following:

- Tee fitting should be supplied by the user. Sensor diameter is Ø12 mm.
- Do not use silicon tube because of its high oxygen permeability.
- Install piping of longer than 30 cm on the side of the joint where the atmosphere is released.

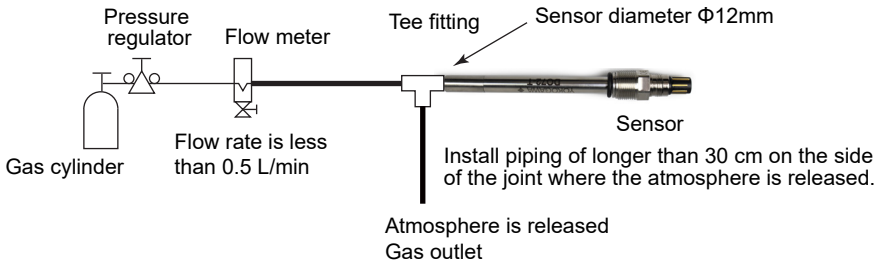


Figure 4.3 Outline of DO72-T Span calibration

WARNING

Ventilate this area to prevent suffocation.

4.4 Manual Offset Cal.

Analog sensor

Manual Offset calibration is to calibrate manually Zero Current of sensors. The measured value obtained in a laboratory is generally used as a reference.

4.5 Temperature Cal.

Analog sensor

For the most accurate measurements, it is important to have a precise temperature measurement. Measure the temperature with a high-precision thermometer and adjust the sensor reading accordingly. For best accuracy, this should be done as near to the normal operating temperature as possible.

4.6 Oxygen Exchange Cap

DO71, DO72

When using DO71 and DO72, you can check and enter calibration and factory adjustment values from the converter menu.

Converter menu > Setting > Others > Save/Load > Oxygen Exchange Cap setup

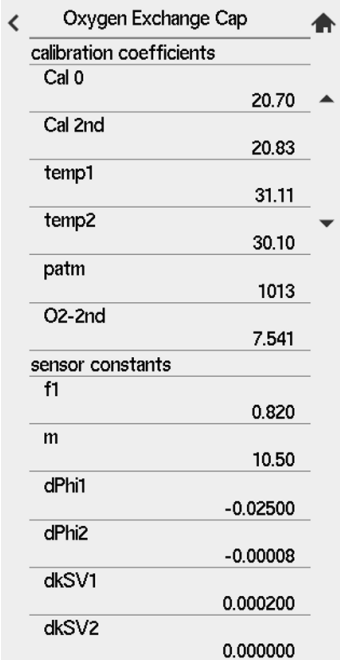


Figure 4.4 Screen example of Oxygen Exchange Cap

When replacing an Oxygen Exchange Cap, in order to make simple adjustment, enter the values for Cal 0, Cal 2nd, temp1, temp2, patm, O202nd, F1, m, dPhi1, dphi2, dKSV1 and dKSV2 on the Final Inspection Sheet attached to the new Oxygen Exchange Cap.

The Cal 0, Cal 2nd, temp1, temp2, patm and O2-2nd value are updated by calibrating.

For accurate measurements, be sure to calibrate.

Store the Final Inspection Sheet of the Oxygen Exchange Cap and the QIC (Test Certificate) of DO71/DO72 in a safe place.

Note

Before entering a value, go to “Measure setting” > “DO Unit”. Set the unit to “mg/L”. After the setting, return the DO Unit to the one you were using.

Appendix For DO (Dissolved Oxygen)

Dissolved oxygen

Dissolved oxygen means the oxygen dissolved in water.

Its concentration is expressed as the amount of oxygen per unit volume of water (mg/L or ppm).

The solubility of oxygen in water varies depending on water temperature, salinity, atmospheric pressure, etc.

The sensors used in FLXA402 employ the membrane electrode method and fluorescent method to measure the dissolved oxygen.

Two methods are available: galvanic cell method and polarographic method.

Compensation

There are three compensation methods for FLXA402: temperature compensation, salinity compensation, and process pressure compensation.

Salinity and temperature compensations meet ISO 5814 (see Table 1).

There is no need to change the setting for normal usage.

Use the salinity compensation when measuring a solution containing salt (see Section “3.2.4 Salinity comp.”).

For operation at high altitude, adjust the pressure value for the process pressure compensation (see Section “3.2.5 Pressure comp. (Measure)”).

Table 1 Solubility of oxygen in water as a function of temperature and salinity (*1)

Temperature (°C)	Salinity (‰) (*3)					Temperature (°C)	Salinity (‰) (*3)				
	0	9	18	27	36		0	9	18	27	36
	Solubility of oxygen in water (*2) (mg/l)						Solubility of oxygen in water (*2) (mg/l)				
0	14.62	13.73	12.89	12.11	11.37	23	8.58	8.14	7.73	7.34	6.97
1	14.22	13.36	12.55	11.79	11.08	24	8.42	8.00	7.59	7.21	6.85
2	13.83	13.00	12.22	11.49	10.80	25	8.26	7.85	7.46	7.09	6.73
3	13.46	12.66	11.91	11.20	10.54	26	8.11	7.71	7.33	6.97	6.62
4	13.11	12.34	11.61	10.93	10.28	27	7.97	7.58	7.20	6.85	6.51
5	12.77	12.03	11.33	10.66	10.04	28	7.83	7.45	7.08	6.73	6.40
6	12.45	11.73	11.05	10.41	9.81	29	7.69	7.32	6.96	6.62	6.30
7	12.14	11.44	10.79	10.17	9.58	30	7.56	7.20	6.85	6.52	6.20
8	11.84	11.17	10.54	9.94	9.37	31	7.43	7.07	6.74	6.41	6.10
9	11.56	10.91	10.29	9.71	9.16	32	7.31	6.96	6.63	6.31	6.01
10	11.29	10.66	10.06	9.50	8.97	33	7.18	6.84	6.52	6.21	5.92
11	11.03	10.42	9.84	9.29	8.78	34	7.07	6.73	6.42	6.11	5.83
12	10.78	10.19	9.63	9.09	8.59	35	6.95	6.63	6.32	6.02	5.74
13	10.54	9.96	9.42	8.90	8.42	36	6.84	6.52	6.22	5.93	5.65
14	10.31	9.75	9.22	8.72	8.25	37	6.73	6.42	6.12	5.84	5.57
15	10.08	9.54	9.03	8.55	8.09	38	6.62	6.32	6.03	5.75	5.48
16	9.87	9.35	8.85	8.38	7.93	39	6.52	6.22	5.93	5.66	5.40
17	9.67	9.15	8.67	8.21	7.78	40	6.41	6.12	5.84	5.58	5.32
18	9.47	8.97	8.50	8.05	7.63	41	6.31	6.03	5.75	5.50	5.25
19	9.28	8.79	8.34	7.90	7.49	42	6.21	5.94	5.67	5.41	5.17
20	9.09	8.62	8.18	7.75	7.35	43	6.12	5.84	5.58	5.33	5.09
21	8.92	8.46	8.02	7.61	7.22	44	6.02	5.75	5.50	5.25	5.02
22	8.74	8.30	7.88	7.47	7.09	45	5.93	5.67	5.42	5.18	4.95

*1: *ISO 5814: 2012 (E)*
*2: Solubility of oxygen in water in equilibrium with air at 101.325 kPa: unit at standard barometric pressure (normal atmospheric pressure at sea level): 101.325 kPa = 101.325 kN/m2 = 1 atm = 760 mmHg
*3: ‰ ≡ g/kg

Table 2 Relationship between conductivity and salinity at 20.0°C (‰ ≡ g/kg)

Conductivity (mS/cm)	Salinity (‰)	Conductivity (mS/cm)	Salinity (‰)	Conductivity (mS/cm)	Salinity (‰)
5	3	20	13	35	25
6	4	21	14	36	25
7	4	22	15	37	26
8	5	23	15	38	27
9	6	24	16	39	28
10	6	25	17	40	29
11	7	26	18	42	30
12	8	27	18	44	32
13	8	28	19	46	33
14	9	29	20	48	35
15	10	30	21	50	37
16	10	31	22	52	38
17	11	32	22	54	40
18	12	33	23		
19	13	34	24		

Table 3 Solubility of oxygen in water as a function of temperature and pressure (*1)

Temperature (°C)	Pressure (kPa)													
	73.3	76.7	80.0	83.3	86.7	90.0	93.3	96.7	100.0	101.3	103.3	106.6	110.0	113.3
	Solubility (mg/l)													
0	10.56	11.04	11.53	12.01	12.49	12.98	13.46	13.94	14.43	14.62	14.91	15.39	15.88	16.36
1	10.27	10.74	11.21	11.68	12.15	12.62	13.09	13.56	14.03	14.22	14.5	14.97	15.44	15.91
2	9.98	10.44	10.9	11.36	11.82	12.27	12.73	13.19	13.65	13.83	14.1	14.56	15.02	15.48
3	9.72	10.16	10.61	11.05	11.5	11.94	12.39	12.84	13.28	13.46	13.73	14.17	14.62	15.06
4	9.46	9.89	10.33	10.76	11.2	11.63	12.06	12.5	12.93	13.11	13.37	13.8	14.24	14.67
5	9.21	9.64	10.06	10.48	10.91	11.33	11.75	12.18	12.6	12.77	13.02	13.45	13.87	14.29
6	8.98	9.39	9.8	10.22	10.63	11.04	11.46	11.87	12.28	12.45	12.69	13.11	13.52	13.93
7	8.75	9.16	9.56	9.96	10.37	10.77	11.17	11.57	11.98	12.14	12.38	12.78	13.19	13.59
8	8.54	8.93	9.33	9.72	10.11	10.51	10.9	11.29	11.69	11.84	12.08	12.47	12.87	13.26
9	8.33	8.72	9.1	9.48	9.87	10.25	10.64	11.02	11.41	11.56	11.79	12.17	12.56	12.94
10	8.13	8.51	8.88	9.26	9.64	10.01	10.39	10.76	11.14	11.29	11.51	11.89	12.26	12.64
11	7.94	8.31	8.68	9.04	9.41	9.78	10.15	10.51	10.88	11.03	11.25	11.61	11.98	12.35
12	7.76	8.12	8.48	8.84	9.2	9.56	9.92	10.27	10.63	10.78	10.99	11.35	11.71	12.07
13	7.58	7.94	8.29	8.64	8.99	9.34	9.69	10.04	10.4	10.54	10.75	11.1	11.45	11.8
14	7.41	7.76	8.1	8.45	8.79	9.14	9.48	9.82	10.17	10.31	10.51	10.86	11.2	11.54
15	7.25	7.59	7.93	8.26	8.6	8.94	9.28	9.61	9.95	10.08	10.29	10.62	10.96	11.3
16	7.1	7.43	7.76	8.09	8.42	8.75	9.08	9.41	9.74	9.87	10.07	10.4	10.73	11.06
17	6.94	7.27	7.59	7.92	8.24	8.56	8.89	9.21	9.54	9.67	9.86	10.18	10.51	10.83
18	6.8	7.12	7.43	7.75	8.07	8.39	8.7	9.02	9.34	9.47	9.66	9.98	10.29	10.61
19	6.66	6.97	7.28	7.59	7.91	8.22	8.53	8.84	9.15	9.28	9.46	9.77	10.09	10.4
20	6.52	6.83	7.13	7.44	7.75	8.05	8.36	8.66	8.97	9.09	9.28	9.58	9.89	10.19
21	6.39	6.69	6.99	7.29	7.59	7.89	8.19	8.49	8.79	8.92	9.1	9.4	9.7	10
22	6.26	6.56	6.85	7.15	7.45	7.74	8.04	8.33	8.63	8.74	8.92	9.21	9.51	9.8
23	6.14	6.43	6.72	7.01	7.3	7.59	7.88	8.17	8.46	8.58	8.75	9.04	9.33	9.62
24	6.02	6.31	6.59	6.88	7.16	7.45	7.73	8.02	8.3	8.42	8.59	8.87	9.16	9.44
25	5.91	6.19	6.47	6.75	7.03	7.31	7.59	7.87	8.15	8.26	8.43	8.71	8.99	9.27
26	5.8	6.07	6.35	6.62	6.9	7.18	7.45	7.73	8	8.11	8.28	8.55	8.83	9.11
27	5.69	5.96	6.23	6.5	6.77	7.05	7.32	7.59	7.86	7.97	8.13	8.4	8.67	8.94
28	5.58	5.85	6.12	6.38	6.65	6.92	7.19	7.45	7.72	7.83	7.99	8.25	8.52	8.79
29	5.48	5.74	6.01	6.27	6.53	6.8	7.06	7.32	7.59	7.69	7.85	8.11	8.37	8.64
30	5.38	5.64	5.9	6.16	6.42	6.68	6.94	7.2	7.46	7.56	7.71	7.97	8.23	8.49
31	5.28	5.54	5.8	6.05	6.31	6.56	6.82	7.07	7.33	7.43	7.58	7.84	8.09	8.35
32	5.19	5.44	5.69	5.95	6.2	6.45	6.7	6.95	7.2	7.31	7.46	7.71	7.96	8.21
33	5.1	5.35	5.59	5.84	6.09	6.34	6.59	6.84	7.08	7.18	7.33	7.58	7.83	8.08
34	5.01	5.25	5.5	5.74	5.99	6.23	6.48	6.72	6.97	7.07	7.21	7.46	7.7	7.95
35	4.92	5.16	5.4	5.64	5.89	6.13	6.37	6.61	6.85	6.95	7.09	7.34	7.58	7.82
36	4.83	5.07	5.31	5.55	5.79	6.03	6.26	6.5	6.74	6.84	6.98	7.22	7.46	7.7
37	4.75	4.98	5.22	5.46	5.69	5.93	6.16	6.4	6.63	6.73	6.87	7.1	7.34	7.57
38	4.67	4.9	5.13	5.36	5.6	5.83	6.06	6.29	6.53	6.62	6.76	6.99	7.22	7.46
39	4.58	4.81	5.04	5.27	5.5	5.73	5.96	6.19	6.42	6.52	6.65	6.88	7.11	7.34
40	4.5	4.73	4.96	5.19	5.41	5.64	5.87	6.09	6.32	6.41	6.55	6.78	7	7.23
41	4.43	4.65	4.88	5.1	5.32	5.55	5.77	6	6.22	6.31	6.45	6.67	6.9	7.12
42	4.35	4.57	4.79	5.01	5.24	5.46	5.68	5.9	6.12	6.21	6.35	6.57	6.79	7.01
43	4.27	4.49	4.71	4.93	5.15	5.37	5.59	5.81	6.03	6.12	6.25	6.47	6.69	6.91
44	4.2	4.41	4.63	4.85	5.07	5.28	5.5	—	—	—	—	—	—	—
45	4.12	4.34	4.55	4.77	4.98	5.2	5.41	—	—	—	—	—	—	—

*1: *ISO 5814: 2012 (E)*

Table 4 Variation of atmospheric pressure with respect to altitude (*1)

Altitude (m)	Atmospheric pressure (kPa)
0	101.3
150	99.5
300	97.9
450	96.0
600	94.3
750	92.6
900	91.0
1050	89.3
1200	87.7
1350	86.1
1500	84.6
1650	83.0
1800	81.5
1950	80.0
2100	78.5
2250	77.1
2400	75.6
2550	74.2
2700	72.8
2850	71.5
3000	70.1
3150	68.8
3300	67.5

*1: *ISO 5814: 2012 (E)*

Table 5 Relationship between vol% and mg/L at 101.3 kPa (Dry gas base)

Temperature (°C)	Gas concentration (vol%)										
	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04	1.05
	Oxygen density (mg/L)										
0	0.667	0.674	0.681	0.688	0.695	0.702	0.709	0.716	0.723	0.730	0.737
1	0.649	0.656	0.663	0.670	0.676	0.683	0.690	0.697	0.704	0.711	0.717
2	0.632	0.638	0.645	0.651	0.658	0.665	0.671	0.678	0.685	0.691	0.698
3	0.615	0.621	0.628	0.634	0.641	0.647	0.654	0.660	0.667	0.673	0.680
4	0.599	0.606	0.612	0.618	0.625	0.631	0.637	0.643	0.650	0.656	0.662
5	0.584	0.590	0.596	0.603	0.609	0.615	0.621	0.627	0.633	0.639	0.646
6	0.570	0.576	0.582	0.588	0.594	0.600	0.606	0.612	0.618	0.624	0.630
7	0.556	0.562	0.568	0.574	0.579	0.585	0.591	0.597	0.603	0.609	0.615
8	0.543	0.548	0.554	0.560	0.565	0.571	0.577	0.583	0.588	0.594	0.600
9	0.530	0.536	0.541	0.547	0.553	0.558	0.564	0.569	0.575	0.580	0.586
10	0.518	0.524	0.529	0.535	0.540	0.546	0.551	0.556	0.562	0.567	0.573
11	0.507	0.512	0.517	0.523	0.528	0.533	0.539	0.544	0.549	0.555	0.560
12	0.496	0.501	0.506	0.511	0.517	0.522	0.527	0.532	0.537	0.543	0.548
13	0.485	0.490	0.495	0.500	0.506	0.511	0.516	0.521	0.526	0.531	0.536
14	0.475	0.480	0.485	0.490	0.495	0.500	0.505	0.510	0.515	0.520	0.525
15	0.465	0.470	0.475	0.480	0.484	0.489	0.494	0.499	0.504	0.509	0.514
16	0.456	0.461	0.465	0.470	0.475	0.480	0.485	0.489	0.494	0.499	0.504
17	0.447	0.452	0.456	0.461	0.466	0.471	0.475	0.480	0.485	0.489	0.494
18	0.438	0.443	0.448	0.452	0.457	0.461	0.466	0.471	0.475	0.480	0.485
19	0.430	0.435	0.439	0.444	0.448	0.453	0.457	0.462	0.466	0.471	0.475
20	0.422	0.426	0.431	0.435	0.440	0.444	0.449	0.453	0.457	0.462	0.466
21	0.415	0.419	0.423	0.428	0.432	0.436	0.441	0.445	0.450	0.454	0.458
22	0.407	0.411	0.416	0.420	0.424	0.428	0.433	0.437	0.441	0.446	0.450
23	0.400	0.404	0.409	0.413	0.417	0.421	0.425	0.430	0.434	0.438	0.442
24	0.393	0.398	0.402	0.406	0.410	0.414	0.418	0.422	0.427	0.431	0.435
25	0.387	0.391	0.395	0.399	0.403	0.407	0.411	0.415	0.419	0.423	0.427
26	0.380	0.384	0.388	0.392	0.396	0.400	0.404	0.408	0.412	0.416	0.420
27	0.375	0.379	0.382	0.386	0.390	0.394	0.398	0.402	0.406	0.410	0.414
28	0.369	0.373	0.377	0.380	0.384	0.388	0.392	0.396	0.400	0.404	0.408
29	0.363	0.367	0.371	0.375	0.378	0.382	0.386	0.390	0.394	0.397	0.401
30	0.358	0.362	0.365	0.369	0.373	0.377	0.380	0.384	0.388	0.392	0.395
31	0.353	0.356	0.360	0.364	0.367	0.371	0.375	0.379	0.382	0.386	0.390
32	0.348	0.351	0.355	0.359	0.362	0.366	0.370	0.373	0.377	0.381	0.384
33	0.343	0.346	0.350	0.353	0.357	0.361	0.364	0.368	0.371	0.375	0.379
34	0.338	0.342	0.346	0.349	0.353	0.356	0.360	0.363	0.367	0.370	0.374
35	0.334	0.337	0.341	0.344	0.348	0.351	0.355	0.358	0.362	0.365	0.369
36	0.330	0.333	0.336	0.340	0.343	0.347	0.350	0.354	0.357	0.361	0.364
37	0.325	0.329	0.332	0.336	0.339	0.342	0.346	0.349	0.353	0.356	0.360
38	0.321	0.325	0.328	0.331	0.335	0.338	0.342	0.345	0.348	0.352	0.355
39	0.318	0.321	0.324	0.328	0.331	0.334	0.338	0.341	0.344	0.348	0.351
40	0.314	0.317	0.320	0.323	0.327	0.330	0.333	0.337	0.340	0.343	0.347
41	0.310	0.313	0.316	0.320	0.323	0.326	0.330	0.333	0.336	0.339	0.343
42	0.306	0.310	0.313	0.316	0.319	0.323	0.326	0.329	0.332	0.335	0.339
43	0.303	0.307	0.310	0.313	0.316	0.319	0.323	0.326	0.329	0.332	0.335
44	0.300	0.303	0.306	0.309	0.313	0.316	0.319	0.322	0.325	0.328	0.332
45	0.297	0.300	0.303	0.306	0.310	0.313	0.316	0.319	0.322	0.325	0.328

Temperature (°C)	Gas concentration (vol%)										
	1.95	1.96	1.97	1.98	1.99	2.00	2.01	2.02	2.03	2.04	2.05
	Oxygen density (mg/L)										
0	1.369	1.376	1.383	1.390	1.397	1.404	1.411	1.418	1.425	1.432	1.439
1	1.332	1.339	1.346	1.353	1.360	1.366	1.373	1.380	1.387	1.394	1.401
2	1.296	1.303	1.310	1.316	1.323	1.330	1.336	1.343	1.349	1.356	1.363
3	1.262	1.269	1.275	1.282	1.288	1.295	1.301	1.308	1.314	1.321	1.327
4	1.230	1.236	1.243	1.249	1.255	1.262	1.268	1.274	1.281	1.287	1.293
5	1.199	1.205	1.211	1.217	1.224	1.230	1.236	1.242	1.248	1.254	1.260
6	1.170	1.176	1.182	1.188	1.194	1.200	1.206	1.212	1.218	1.224	1.230
7	1.141	1.147	1.153	1.159	1.165	1.171	1.176	1.182	1.188	1.194	1.200
8	1.114	1.120	1.125	1.131	1.137	1.142	1.148	1.154	1.160	1.165	1.171
9	1.088	1.094	1.099	1.105	1.111	1.116	1.122	1.127	1.133	1.139	1.144
10	1.064	1.069	1.075	1.080	1.086	1.091	1.096	1.102	1.107	1.113	1.118
11	1.040	1.045	1.051	1.056	1.061	1.067	1.072	1.077	1.083	1.088	1.093
12	1.017	1.023	1.028	1.033	1.038	1.044	1.049	1.054	1.059	1.064	1.070
13	0.996	1.001	1.006	1.011	1.016	1.021	1.026	1.032	1.037	1.042	1.047
14	0.975	0.980	0.985	0.990	0.995	1.000	1.005	1.010	1.015	1.020	1.025
15	0.954	0.959	0.964	0.969	0.974	0.979	0.984	0.989	0.993	0.998	1.003
16	0.935	0.940	0.945	0.950	0.955	0.959	0.964	0.969	0.974	0.979	0.983
17	0.918	0.922	0.927	0.932	0.936	0.941	0.946	0.951	0.955	0.960	0.965
18	0.900	0.904	0.909	0.914	0.918	0.923	0.927	0.932	0.937	0.941	0.946
19	0.883	0.887	0.892	0.897	0.901	0.906	0.910	0.915	0.919	0.924	0.928
20	0.866	0.871	0.875	0.879	0.884	0.888	0.893	0.897	0.902	0.906	0.910
21	0.851	0.856	0.860	0.864	0.869	0.873	0.877	0.882	0.886	0.890	0.895
22	0.835	0.840	0.844	0.848	0.852	0.857	0.861	0.865	0.870	0.874	0.878
23	0.821	0.826	0.830	0.834	0.838	0.842	0.847	0.851	0.855	0.859	0.864
24	0.808	0.812	0.816	0.820	0.824	0.828	0.832	0.837	0.841	0.845	0.849
25	0.794	0.798	0.802	0.806	0.810	0.814	0.818	0.822	0.826	0.830	0.834
26	0.781	0.785	0.789	0.793	0.797	0.801	0.805	0.809	0.813	0.817	0.821
27	0.769	0.773	0.777	0.781	0.785	0.789	0.793	0.797	0.800	0.804	0.808
28	0.757	0.761	0.765	0.769	0.773	0.776	0.780	0.784	0.788	0.792	0.796
29	0.745	0.749	0.753	0.757	0.761	0.764	0.768	0.772	0.776	0.780	0.783
30	0.734	0.738	0.742	0.746	0.750	0.753	0.757	0.761	0.765	0.768	0.772
31	0.724	0.727	0.731	0.735	0.739	0.742	0.746	0.750	0.753	0.757	0.761
32	0.714	0.718	0.721	0.725	0.729	0.732	0.736	0.740	0.743	0.747	0.751
33	0.703	0.707	0.710	0.714	0.718	0.721	0.725	0.729	0.732	0.736	0.739
34	0.695	0.698	0.702	0.705	0.709	0.712	0.716	0.720	0.723	0.727	0.730
35	0.685	0.688	0.692	0.695	0.699	0.703	0.706	0.710	0.713	0.717	0.720
36	0.676	0.680	0.683	0.687	0.690	0.694	0.697	0.701	0.704	0.708	0.711
37	0.668	0.671	0.675	0.678	0.682	0.685	0.688	0.692	0.695	0.699	0.702
38	0.659	0.663	0.666	0.669	0.673	0.676	0.680	0.683	0.686	0.690	0.693
39	0.652	0.655	0.659	0.662	0.665	0.669	0.672	0.675	0.679	0.682	0.685
40	0.644	0.647	0.650	0.653	0.657	0.660	0.663	0.667	0.670	0.673	0.677
41	0.636	0.639	0.643	0.646	0.649	0.653	0.656	0.659	0.662	0.666	0.669
42	0.629	0.632	0.635	0.639	0.642	0.645	0.648	0.652	0.655	0.658	0.661
43	0.623	0.626	0.629	0.632	0.636	0.639	0.642	0.645	0.648	0.652	0.655
44	0.616	0.619	0.622	0.625	0.628	0.631	0.635	0.638	0.641	0.644	0.647
45	0.610	0.613	0.616	0.619	0.622	0.625	0.628	0.632	0.635	0.638	0.641

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Added description of DO71 and DO72, corrections (page. ii, 2-3, 2-6, 3-2, 3-3, 3-5 to 3-7, Chapter 4, Appendix)
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