Technical Information

FLEXA Series Conductivity/Inductive Conductivity Analyzer Guide

TI 12D08A01-01E

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1. Introduction

Yokogawa's Technical Information Conductivity Analyzer Guide provides you, whether a first-time user of or an expert on a conductivity analyzer, with a convenient source of information, basic conductivity theory; measurement methods; applications; and product features necessary for the proper equipment selection.

Conductivity is one of the key measurement parameters used by industries for monitoring and control of various kinds of water usage, such as boiler feed water and water for injection (WFI). Conductivity is also the most stable and cost effective parameter available when the measurement of percent concentration of a specific chemical is required.

2. Conductivity

Conductivity is the parameter used to measure a solution's ability to conduct an electric current. The term "Conductivity" is derived from Ohm's Law which is defined as: E = I • R, where E is voltage applied between the two "plates" (shown in Figure 2.1), and an electrical current I will flow which is dependent on the resistance R of the conductor. Therefore, conductivity is defined as the reciprocal of resistance of a solution between two electrodes and it can be expressed as: G = I/R.

The basic unit of conductivity is the siemen (S), formerly called the mho. Since the cell geometry determines the conductivity value it can be used to measure, standardized measurements are expressed in specific conductivity units to compensate for variations in the electrode dimensions. Specific conductivity is calculated by multiplying the measured conductivity (G) by the electrode's cell constant. The cell constant is determined by the formula L/A; where L is the length of the column of liquid between the electrodes and A is the area of the electrodes: C = G x (L/A)

Conductivity measurements cover a wide range of solution conductivity from pure water at less than 1×10^{-7} S/cm to values greater than 1 S/cm for concentrated solutions. Conductivity is a measure of the purity of water or the concentration of ionized chemicals in water. However, it is a nonspecific measurement, unable to distinguish between different types of ions, giving instead a reading that is proportional to the combined effect of all the ions present.

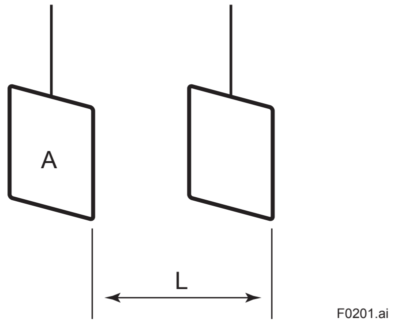


Figure 2.1 Measurement Principle

2.1 Conductivity versus Percent Concentration

Conductivity is a common measurement used to determine the percent concentration of a chemical (electrolyte). The conductivity of a chemical increases as the percent concentration increases (see Figure 2.2) while the amount of dissolution (percent values) are small. However, when the concentration of the electrolyte increases a point will be reached where the degree of disassociation (ease of ionization) decreases, and the increase in conductivity tends to level off or begin to decrease. The graphs in Figure 2.3 show the relationships between the percent concentration value and the conductivity value of common chemicals used in industry.

The relationship is indeed very complex where there can be more than one percent concentration value having the same conductivity value. Note the graphs for sulfuric acid (H_2SO_4), and sodium chloride (NaCl). This is an important point to note when planning to control the concentration of solutions with a conductivity analyzer.

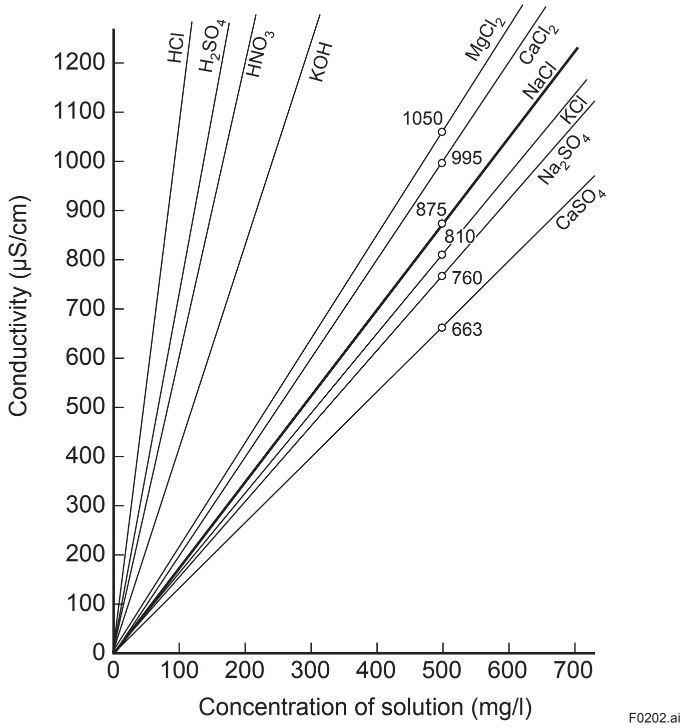


Figure 2.2 Relationship between Concentration of Solutions and Conductivity (at 18°C)

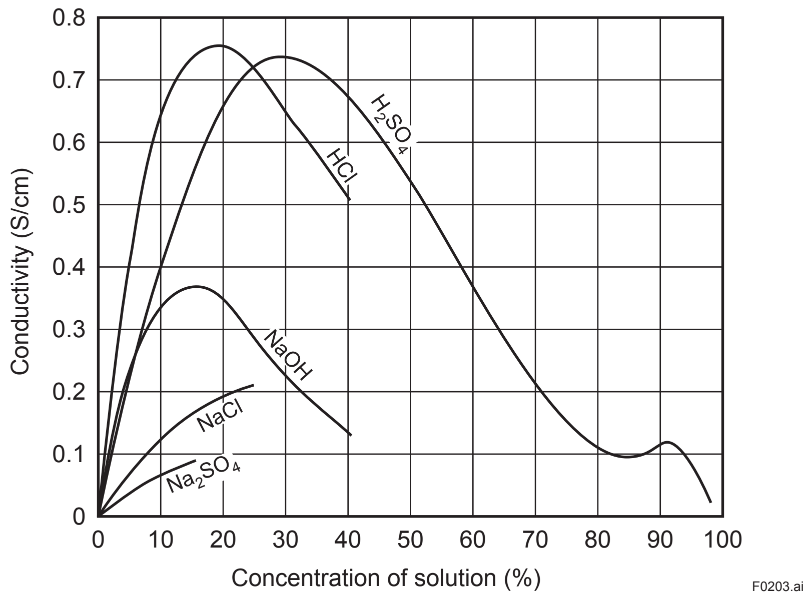


Figure 2.3 Relationship between Concentration of Solutions and Conductivity (at 18°C)

2.2 Temperature Coefficient

The conductivity of a chemical or solution is significantly affected by changes in temperature. Most fluids will increase in conductivity as the temperature increases. For example, ionic solutions increasing about 2% for each 1°C increase in temperature. So, it is impossible to obtain the true value of a liquid by measuring only the conductivity. The temperature of the liquid must also be measured.

Industrial equipment adjusts the conductivity value based on a Temperature Compensator and displays a value that is corrected, or normalized to 25°C. The instrument automatically adjusts the reading as if the sample was at 25°C, no matter what the actual temperature is.

The following formulas help to shown the relationship of temperature to conductivity measurements and how the rate of change is different for different electrolytes.

When the liquid temperature changes from t_1 to t_2, and the conductivity changes from K_1 to K_2, the temperature coefficient α of that liquid is represented by the equation (2.1).

$$\alpha = \frac{1}{K_1} \bullet \frac{K_2 - K_1}{t_2 - t_1} \quad \text{------------------------} \quad (2.1)$$

In some instances, the value of conductivity in a certain temperature range includes a secondary coefficient β which can be calculated by equation (2.2).

$$K_t = K_{ts} \{1 + \alpha (t - t_s) + \beta (t - t_s)^2\} \quad \text{------------} \quad (2.2)$$

Where; t_s : Reference temperature

K_{ts} : Conductivity at reference temperature

K_t : Conductivity at temperature t°C

$$K_t = K_{ts} \{1 + \alpha (t - t_s) + \beta (t - t_s)^2\} \qquad (2.2)$$

Where

t_s: Reference temperature

K_{ts}: Conductivity at reference temperature

K_t: Conductivity at temperature t°C

Temperature coefficients will vary depending on the type and percent concentration of the solution. Table 2.1 shows temperature coefficients of typical solutions at a temperature range of about 0 to 30°C.

Table 2.1 Temperature Coefficients of Electrolyte Solutions

Dissolved substance	α	β
NaCl	226×10^{-4}	84×10^{-6}
KCl	217×10^{-4}	67×10^{-6}
$NaNO_3$	220×10^{-4}	75×10^{-6}
$CaCO_3$	229×10^{-4}	—
Na_2CO_3	261×10^{-4}	151×10^{-6}
$MgSO_4$	238×10^{-4}	95×10^{-6}
$MgCl_2$	254×10^{-4}	—
$CuSO_4$	232×10^{-4}	—
HCl	164×10^{-4}	-15×10^{-6}
H_2SO_4	165×10^{-4}	-16×10^{-6}
H_3PO_4	169×10^{-4}	-1×10^{-6}
HNO_3	163×10^{-4}	-16×10^{-6}
KOH	190×10^{-4}	32×10^{-6}

Diluted NaCl solution. This temperature coefficient is based on the IEC table (IEC 60746-3) (see Table 2.2).

If the temperature coefficient of the actual measurement solution is significantly different from that of the diluted NaCl solution, you will need to calculate and program the proper coefficient manually in order to have an accurate conductivity or percent concentration measurement.

Table 2.2 NaCl Compensation Compliant with IEC 60746-3 (at Reference Temperature of 25°C)

T (°C)	K_t	α	T (°C)	K_t	α
0	0.54	1.8	100	2.68	2.2
10	0.72	1.9	110	2.90	2.2
20	0.90	2.0	120	3.12	2.2
25	1.0		130	3.34	2.2
30	1.10	2.0	140	3.56	2.2
40	1.31	2.0	150	3.79	2.2
50	1.53	2.1	160	4.03	2.2
60	1.76	2.2	170	4.23	2.2
70	1.99	2.2	180	4.42	2.2
80	2.22	2.2	190	4.61	2.2
90	2.45	2.2	200	4.78	2.2

α: Temperature compensation coefficient (%/°C)
T: Solution temperature (°C)
K_t: Conductivity value at temperature T

3. Conductivity - Measurement Methods

The two most common methods used to measure conductivity are: (1) Contacting; and (2) Inductive, also known as Toroidal. The measuring elements (plates or electrodes) of Contacting sensors, as the name implies, come in direct contact with the process. The inductive method uses electromagnet coils that are encased in a chemically resistant plastic to keep them from direct contact with the process. So they are suitable for measurement of highly-concentrated acid and alkali solutions or heavily polluted waste water.

3.1 Contacting Electrode Method

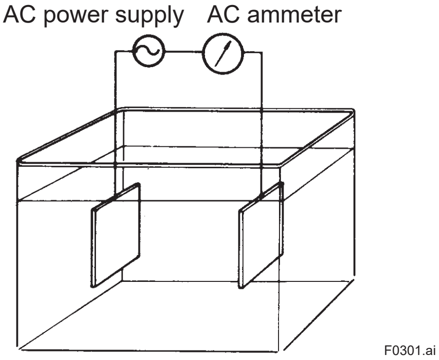


Figure 3.1 Principle of Contacting Conductivity Measurement

When two metal plates are placed in a solution as electrodes as shown in Figure 3.1, and an AC voltage is applied across these plates, the electric current that flows between the plates is proportional to the resistance (or conductivity) of the solution they are in. The equation is:

$$I = \frac{E}{R_C} \quad \text{-------------------} \quad (1)$$

Where R_c represents an electrical resistance of solution between the electrodes. The following equation represents the relationship between Rc and the conductivity K of the solution.

$$R_C = J \cdot \frac{1}{K} \quad \text{-------------------} \quad (2)$$

Where J is a constant that is determined by the distance shape of the electrodes and the distance between them. This is called the cell constant. Take a look at the following equations.

$$I = \frac{E}{J} \cdot K \quad \text{or} \quad K = \frac{J}{E} \cdot I$$

E and J are fixed values, so conductivity K can be obtained by measuring current I.

If the measurement solution is highly conductive, or contains contaminating components, polarization of the sensor elements will occur and a correct measurement cannot be obtained. In such cases, it is recommended to use a four-electrode sensor to reduce the influence of contamination and polarization. Using an Inductive sensor is another option.

Figure 3.2 shows the principle of the four-electrode measurement.

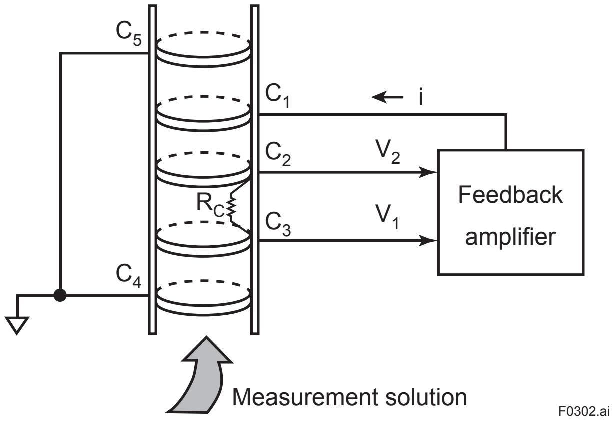
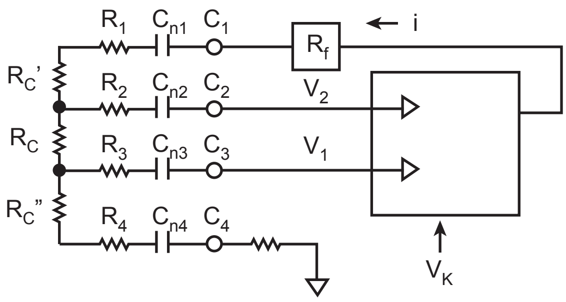


Figure 3.2 Principle of Four-Electrode Measurement

The four-electrode design reduces the effect of polarization and fouling of the electrode. An AC alternating current is applied only to the outer pair of rings C_4 and C_5. The voltage is measured on the inner rings without polarization effects because no current flows in the measuring circuit. This type of probe is superior to two electrode contacting sensors in function for most solutions and covers nearly the whole conductivity range with one or two cell constants.



C_{nx} : Capacity between electrodes (C_1 to C_4) and solution

R_n : Resistance to fouling

R_C : Cell resistance = $\frac{K}{J}$

K : Cell constant (cm^{-1})

J : Conductivity (S/cm)

V_K : Reference voltage

Figure 3.3 Equivalent Circuit Schematic

If the electric current flowing between the measurement electrodes is greater than the geometry of the electrodes can accept, polarization occurs at the electrodes causing the measurement to be incorrect. In the case of a four-electrode sensor, the current does not flow through the actual measurement electrodes C_2 and C_3, so polarization does not occur. In addition, the square-wave feedback amplifier makes sure the voltage potential $|V_2| - |V_1|$ between the electrodes is kept constant, so that high conductivity values can be measured. See Figure 3.3.

$$V_1 = (R_C" + R_4)\, i$$

$$V_2 = (R_C + R_C" + R_4)\, i$$

$$|V_2| - |V_1| = R_C \cdot i = V_K$$

Therefore,

$$i = \frac{V_K}{R_C}$$

Accordingly, the method is immune to the influence of resistance R_n to fouling.

3.2 Inductive Method

Unlike contacting sensors (2 or 4-electrode), the inductive method, measures conductivity without any contact between the electrodes and the process fluid. The measurement is based on inductive coupling of 2 ring transformers (toroids) by the liquid being measured. The transformers are incased in a chemically resistant plastic to protect them from the process. Figure 3.4 shows the structure of the sensor.

Figure 3.5 is a diagram showing the principle of operation. The analyzer supplies a reference voltage at a high frequency to the drive coil (T_1) and a strong electromagnetic field is generated in the toroid. The liquid passes through the hole in the toroid and can be considered as a “one turn” secondary winding (C_2). The magnetic field induces a voltage in this liquid winding that is proportional to the conductivity of the solution. In turn, the resultant voltage is inducted in the Receiver coli (T_2) and this output voltage is proportional to the specific conductivity of the solution.

Inductive sensors are well suited for measuring high-conductivity solutions as they are not susceptible to polarization like contacting sensors, and have excellent corrosion resistance, as there are no metal parts in contact with the solution. They are simpler to maintain and therefore suitable for measurement of strong acidic (H_2SO_4) or caustic (NaOH) solutions.

However, inductive sensors are not as accurate below 50μS and are not suited for measuring low-conductivity water solutions such as pure water.

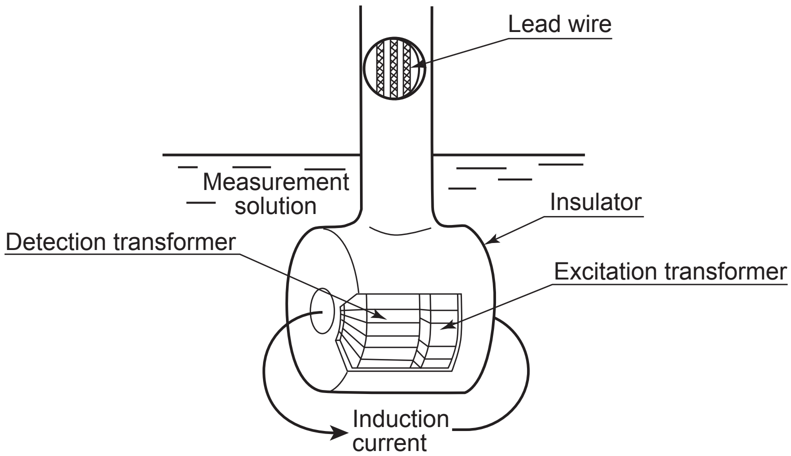


Figure 3.4 Structure Diagram (Cross-section view with outer wall removed)

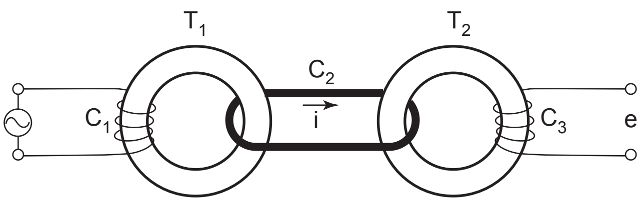


Figure 3.5 Principle Diagram

4. Calibration

There is no global organization (or standard) that defines or certifies standard calibration solutions and procedures for the calibration of conductivity process loops. The most common calibration method is to use locally obtainable conductivity calibration solutions as the standard for adjusting the conductivity analyzer – sensor loop.

4.1 Calibration of Electrode Contacting Sensor

Yokogawa's contacting conductivity sensors are factory calibrated using standard calibration solutions before they are shipped.

Periodic re-calibration of conductivity sensors is not usually required unless the sensors become worn, corroded, or coated by the process. These affects can cause the cell constant to change resulting in an inaccurate measurement. There are two basic calibration methods used.

(1) Calibration can be performed by adjusting the analyzer/transmitter to a known conductivity solution at a known temperature. Specific calibration procedures are described in the user's manual for FLXA402 4-Wire Converter Operation of SC (IM 12A01F03-01EN), and/or for FLXA202/FLXA21 2-Wire Analyzer (IM 12A01A02-01E).

Conductivity solutions are commercially available in liquid and powder form. The powder form is usually prepared in the plant laboratory assuring it is fresh and accurate. In Section 4.3 are two reference Tables, one using NaCl (Table 4.1) and one using KCl (Table 4.2) that show the conductivity values of several concentrations of these salt solutions.

(2) Calibration can also be performed by adjusting the process loop to the values measured with an independent conductivity analyzer used at the laboratory. In this case, the Lab analyzer should have traceable periodic calibrations to assure its accuracy. Also, the calibration of the process loop using the laboratory loop must be done at the same temperature to eliminate any possible error due to the instruments temperature compensation circuitry.

4.2 Calibration of Inductive Sensor

Calibration of inductive conductivity sensors are only required upon initial installation or when the installation location is changed as the sensor is unaffected by corrosion or coating like contacting sensor are.

The cell factor of a inductive conductivity sensor is affected by the proximity of the sensor to the wall of the pipe or tank in which it is installed. Therefore, it necessary to perform a calibration if the location of the sensor is changed. It is best to perform the calibration with the sensor actually installed so that the proximity to the process wall can be taken into account. The specific procedure is described in the user's manual for FLXA402 4-Wire Converter Operation of ISC (IM 12A01F04-01EN), and/or for FLXA202/FLXA21 2-Wire Analyzer (IM 12A01A02-01E).

4.3 Typical Calibration Solutions

Tables 4.1 and 4.2 show the typical values of sodium chloride (NaCl) and potassium chloride (KCl) solutions.

Table 4.1 Conductivity Values of NaCl Solution at Temperature of 25°C (IEC 60746-3)

%	mg/kg	Conductivity
0.001	10	21.4 μS/cm
0.003	30	64.0 μS/cm
0.005	50	106 μS/cm
0.01	100	210 μS/cm
0.03	300	617 μS/cm
0.05	500	1.03 mS/cm
0.1	1000	1.99 mS/cm
0.3	3000	5.69 mS/cm
0.5	5000	9.48 mS/cm
1	10000	17.6 mS/cm
3	30000	48.6 mS/cm
5	50000	81.0 mS/cm
10	100000	140 mS/cm

Table 4.2 Conductivity of KCl Solution at Temperature of 25°C

mol/l	mg/kg	Conductivity
0.001	74.66	0.1469 mS/cm
0.002	149.32	0.2916 mS/cm
0.005	373.29	0.7182 mS/cm
0.01	745.263	1.4083 mS/cm
0.1	7419.13	12.852 mS/cm
1.0	71135.2	111.31 mS/cm

Reference: International Recommendation No. 56, International Organization of Legal Metrology (OIML)

5. Conductivity Sensor

Yokogawa offers a wide variety of contacting and inductive conductivity sensors designed to meet the varied requirements of industrial process applications.

5.1 Measurement Methods and Applications

- **Two-Electrode Method**

This contacting conductivity sensor and is most suitable for low-conductivity applications for pure and ultra-pure water such as demineralizers and boiler water in Power Plants.

- **Four-Electrode Method**

This contacting conductivity sensor can be used for moderate to high-conductivity applications where polarization may be a problem.

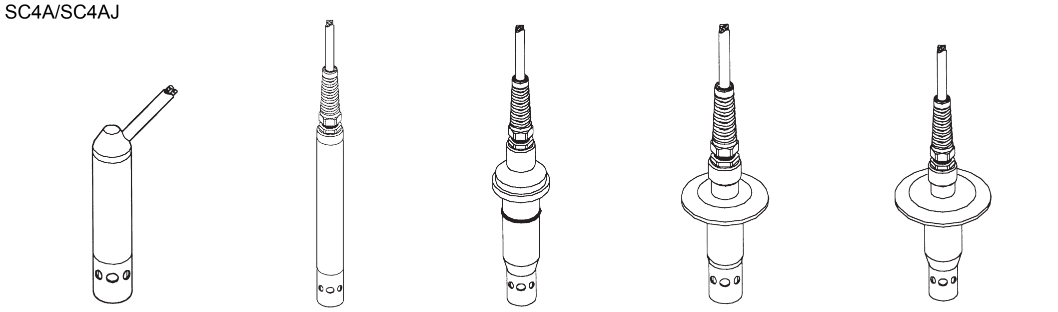
- **Inductive Method**

The Inductive sensor is not affected by polarization problems and is suitable for all applications with a conductivity value greater than 50μS.

5.2 Conductivity Sensors and Selection Criteria

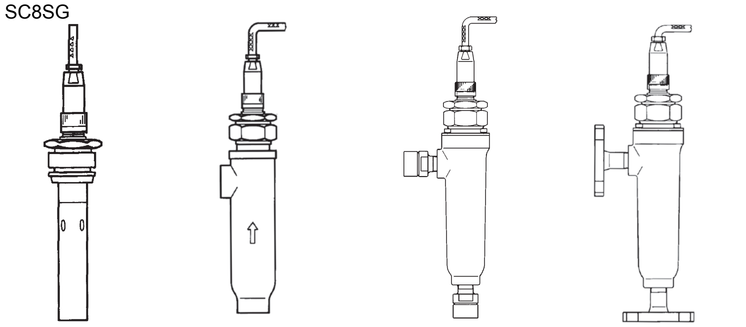
Two-Electrode Method

SC4A/SC4AJ



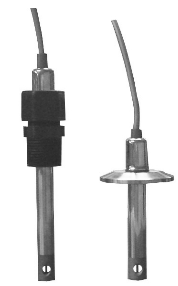
-AD-09 Adapter mounting (Electrode length: 9 cm) | -AD-15 Adapter mounting (Electrode length: 15 cm) | -SA Welding socket mounting | -SB 1- or 1.5-inch clamp mounting | -SC 2-inch clamp mounting

SC8SG



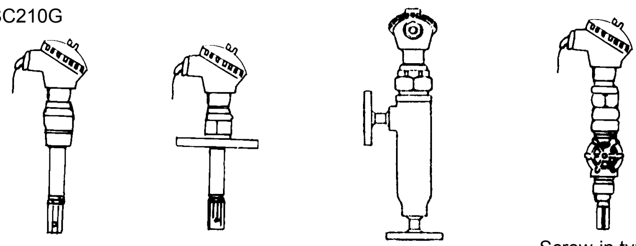
Screw-in type | Flow-through type (screw connection) Chamber material: SCS14 | Flow-through type (screw connection) Chamber material: PP | Flow-through type (flange connection)

SC42



Direct Insertion, Sanitary Fitting

SC210G



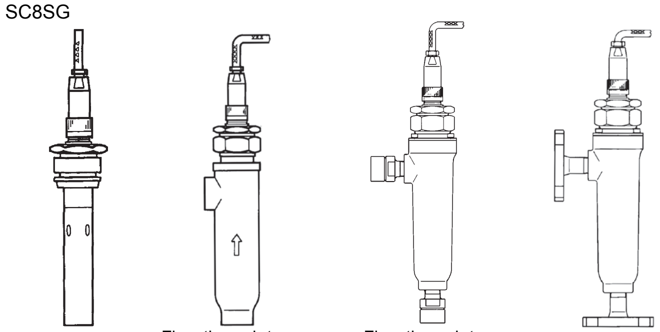
Screw-in type | Flange type | Flow-through type | Screw-in type with gate valve

SX42

Screw-in type, Flange type

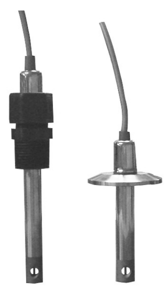
Four-Electrode Method

SC8SG



Screw-in type | Flow-through type (screw connection) Chamber material: SCS14 | Flow-through type (screw connection) Chamber material: PP | Flow-through type (flange connection)

SC42



Direct Insertion, Sanitary Fitting

Conductive Method

ISC40G/ISC40GJ, ISC40S/ ISC40SJ

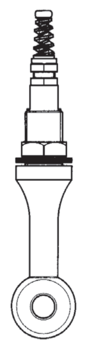
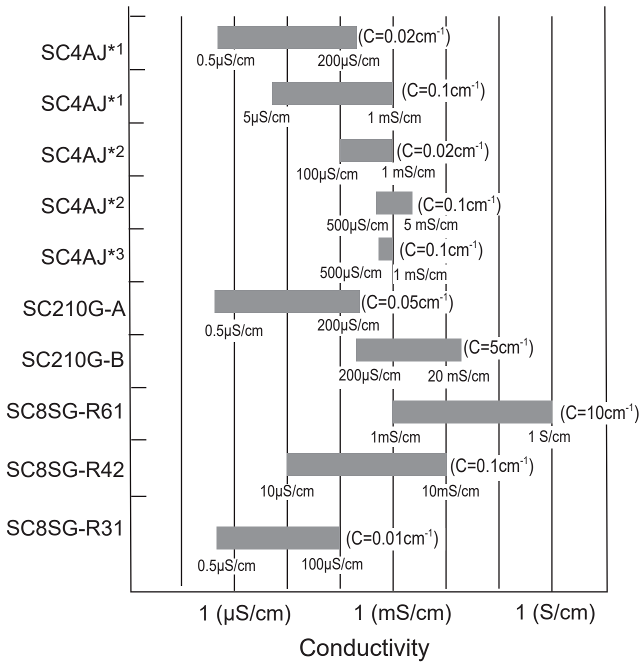


Table 5.1 List of Types of Sensors and Combination with Converter/Transmitter

Measurement method	Sensor model	Cell constant
Two-electrode method	SC4A/SC4AJ- □ - □□-□□ -002	0.02 cm^{-1}
	SC4A/SC4AJ- □ - □□-□□ -010	0.1 cm^{-1}
	SC8SG-R31-T	0.01 cm^{-1}
	SC8SG-R42-T	0.1 cm^{-1}
	SC8SG-R61-T	10 cm^{-1}
	SC210G-C	0.05 cm^{-1}
	SC210G-D	5 cm^{-1}
	SC42-SP34, -SV34	0.01 cm^{-1}
	SC42-SP24, -SV24	0.1 cm^{-1}
	SC42-EP14, -EP15, -SP16	1.0 cm^{-1}
	SC42-EP04	10.0 cm^{-1}
	SX42-SX34	0.01 cm^{-1}
	SX42-SX24	0.1 cm^{-1}
Four-electrode method	SC8SG-R61-F	10 cm^{-1}
	SC42-EP18	1.0 cm^{-1}
	SC42-EP08, -FP08, -TP08, -FV08, -TV08	10.0 cm^{-1}
Inductive method	ISC40G/ISC40GJ	
	ISC40S/ISC40SJ	

(*) The ISC402J is combined with the ISC202SJ.



NOTE:
The bar graph at the left shows the range of the upper range limit of each sensor. For example, in the case of SC8SG-R61, the measuring range is from 0-1 mS/cm to 0-1 S/cm.
In measurement in high conductivity range, polluted solution may affect measured values of any sensors.
C represents cell constant.

Note that when used in combination with the SC100 converter, the SC4AJ sensor has different measuring range depending on the material and so forth.

*1 : In case of the combination with the SC202G, or SC202SJ
*2 : In case of the combination with the SC100 (Titanium)
*3 : In case of the combination with the SC100 (SUS)

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Figure 5.1 Range ability of conductivity sensors

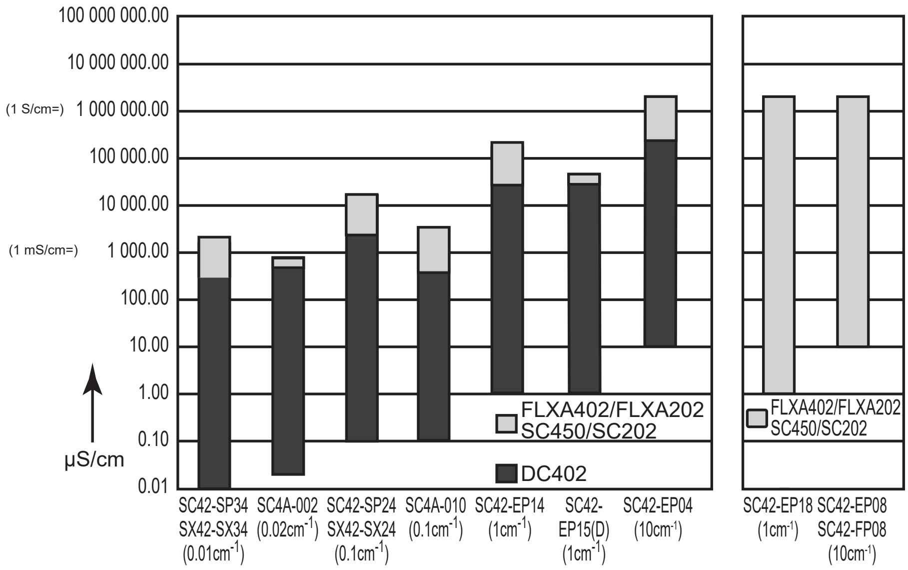


Figure 5.2 Range ability of conductivity sensors (For excluding Japan)

NOTE: In case of using other sensors, measurement upper limit is also 200 mS x (Cell constant) (Upper limit 2000 mS/cm).

5.3 Sensor Installation Issues

5.3.1 Contacting Sensor Installations

Air bubbles in the process will interfere with the continuity between the sensor electrodes causing a noisy and erroneous measurement. Care should be taken to eliminate these air bubbles by proper installation of the sensor or additional measures such as providing an overflow tank, as shown in Figure 5.3.

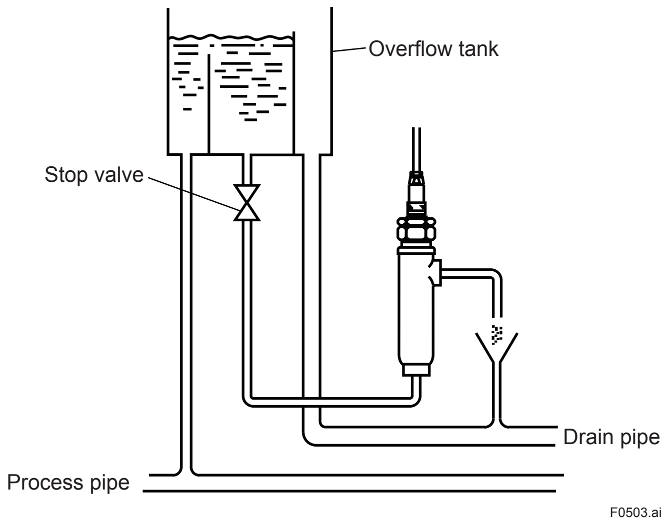


Figure 5.3 Example of Piping for the Case where Many Air Bubbles are Contained in Measurement Solution

5.3.2 Inductive Sensor Installation

An inductive conductivity sensor is donut-shaped sensor and function best when installed with the donut at a right angle to the direction of the process flow (see Figure 5.4).

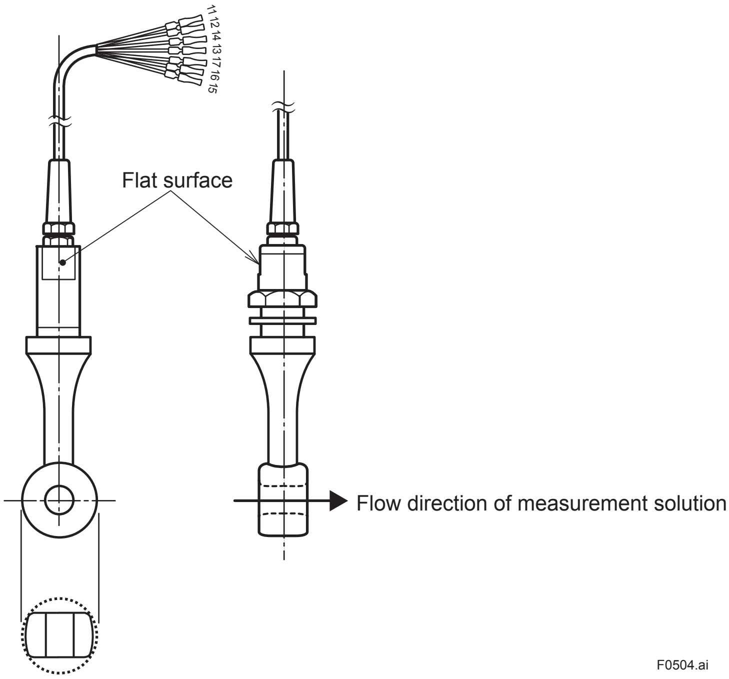
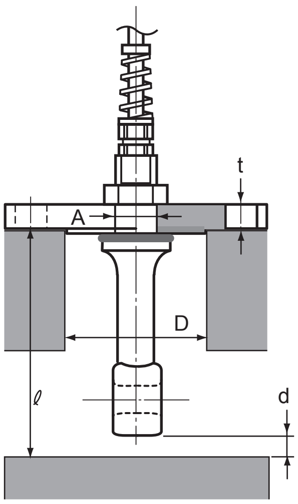


Figure 5.4 Installation Direction of Sensor

The distance (d) between the sensor and the pipe wall shall be at least 30 mm (see Figure 5.5). If this requirement cannot be met for the distance (d), see “Adjusting Cell Constant” below.



A = mounting hole: 27 mm	
t = thickness	10 to 30 mm
d = distance	30 mm or more
D = insert hole size	50 mm or more
ℓ = insert length	150 mm or more

Figure 5.5 Flange Mounting Example

Adjusting Cell Factor

Inductive sensors do not have a cell constant in the same sense as a contacting sensor does. Instead, it is manufactured with a nominal cell factor of 1.88 cm^{-1}. This factor is affected by the material of the process pipe or tank and how close the “donut” is mounted to the wall of the pipe or tank. If a distance of 30 mm is possible, then the cell factor is unaffected. It this distance cannot be met, an on-line calibration must be performed allowing the inductive conductivity converter (or transmitter) to calculate a new cell factor based on the installation conditions. This new factor is used to perform conductivity measurement.

If on-line calibration is not possible, input a cell factor in the converter (or transmitter) in accordance with the instructions described below.

- If the sensor is to be installed in the standard stainless steel holder (ISC40FF-S), the cell factor will be about 7% less. Input a value that is 7% less than the value indicated on the label of the sensor cable.
- If the sensor is to be installed in the standard polypropylene holder (ISC40FF-P), the cell factor is about 1% greater. Input a value that is 1% greater than the value indicated on the label of the sensor cable.
- If the sensor is to be installed in a pipe (conductive or non-conductive), mount it in the direction as shown in Figure 5.6 and use the graph to determine the cell factor to be programmed in the converter (transmitter).

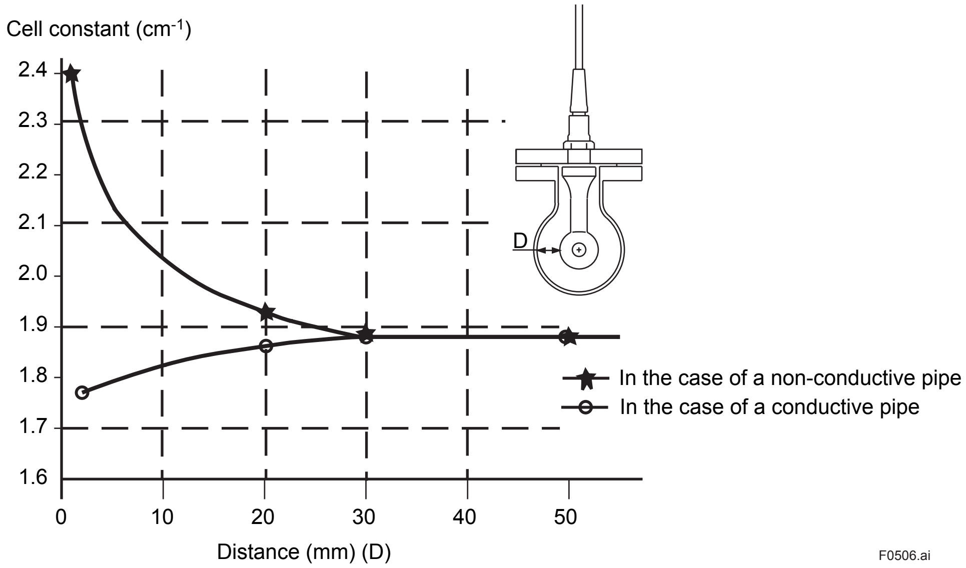


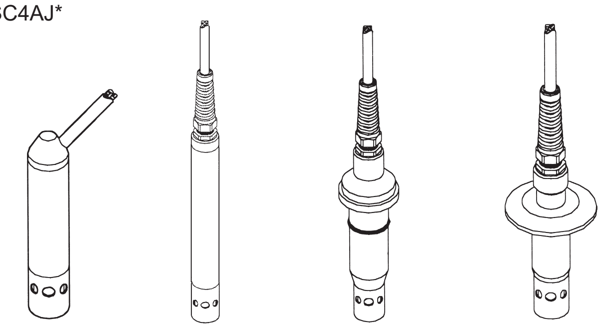
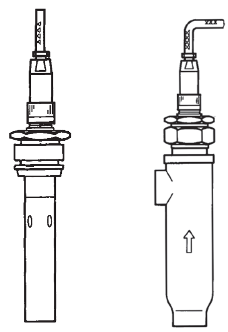
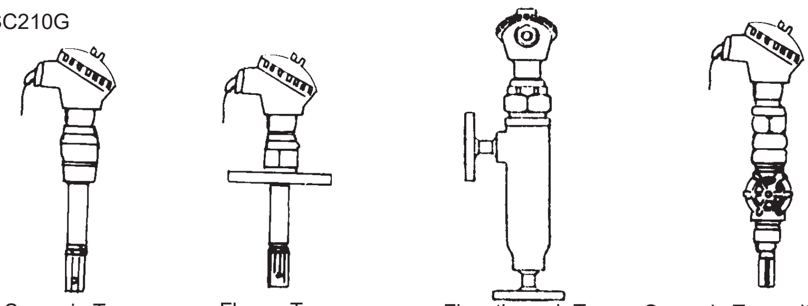
Figure 5.6 Cell Constant when Installing on Pipe (reference value)

6. System Configuration of Contacting Conductivity Analyzers

There are two standard contacting conductivity instruments versions used for process control.

- "Four-wire" (mains powered, 90-264 VAC) conductivity converter system with 4-20mA outputs and dry alarm contacts. This version comes in both ½ DIN and ¼ DIN configurations for wall, pipe and panel mounting.
- "Two-wire" (24 VDC, loop powered) conductivity field transmitter suitable for general purpose, Class 1, Div 2 or Class 1 Div 1 areas. Comes in 4-20mA, HART, Foundation Fieldbus or Profibus versions.

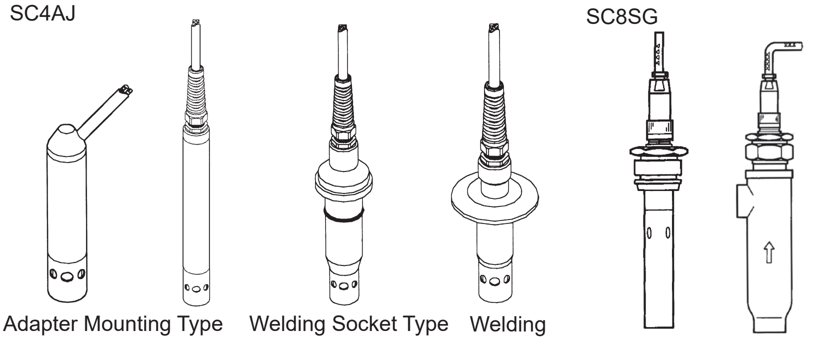
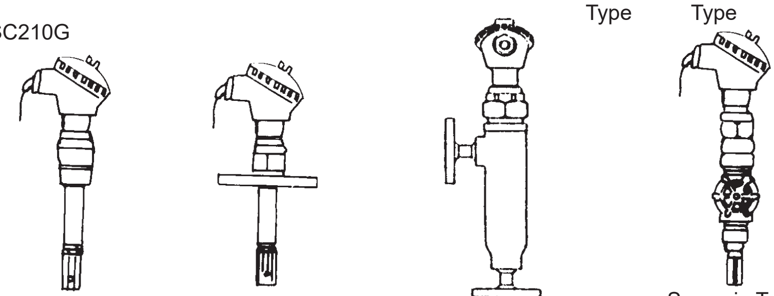
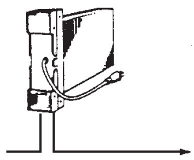
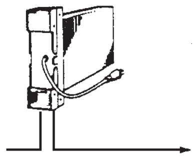
■ Four-wire Conductivity / Resistivity Analyzers

Conductivity Sensors	Conductivity Converter
SC4AJ*  Adapter Mounting Type · Welding Socket Type · Welding Clamp Type SC8SG*  Screw-in Type · Flow-through Type SC210G  Screw-in Type · Flange Type · Flow-through Type · Screw-in Type with Gate Valve	FLXA402 4-Wire Converter 

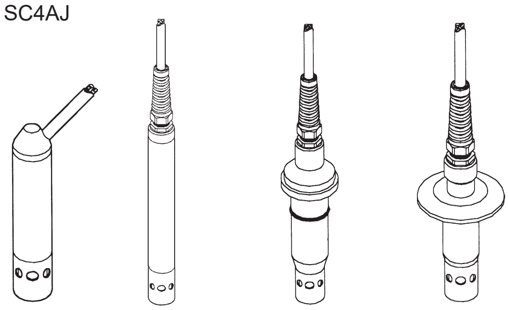
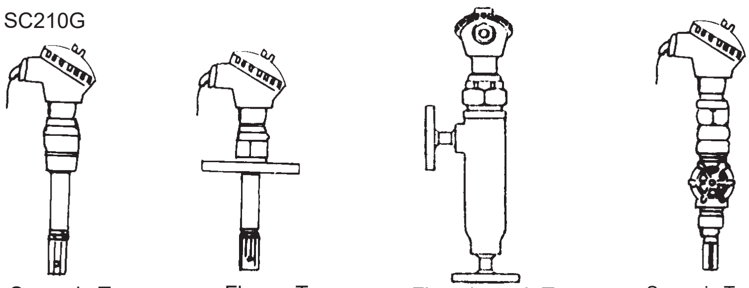
*: Applicable to SA11

Two-wire Conductivity / Resistivity Analyzers

System Configuration – Non-explosion protected type

Conductivity Sensors	Conductivity Converter	Distributor
SC4AJ SC8SG  Adapter Mounting Type / Welding Socket Type / Welding Clamp Type / Screw-in Type / Flow-through Type SC210G  Screw-in Type / Flange Type / Flow-through Type / Screw-in Type with Gate Valve	FLXA202 / FLXA21 	Dedicated Distributor PH201G  Analog output 1 to 5 V DC Output Failure contact output Maintenance contact output General Distributor SDBT, SDBS  Analog output 1 to 5 V DC Output

System Configuration – Explosion protected type

Conductivity Sensors	Conductivity Converter	Distributor Safety Barrier
SC4AJ  Adapter Mounting Type / Welding Socket Type / Welding Clamp Type SC210G  Screw-in Type / Flange Type / Flow-through Type / Screw-in Type with Gate Valve	FLXA202 / FLXA21 	Refer to TI 12A01A02-42EN FLXA202 Selection Guide for Intrinsic Safety-type Associated Apparatus. For FLXA21, use TI 12A01A02-42EN as a reference.

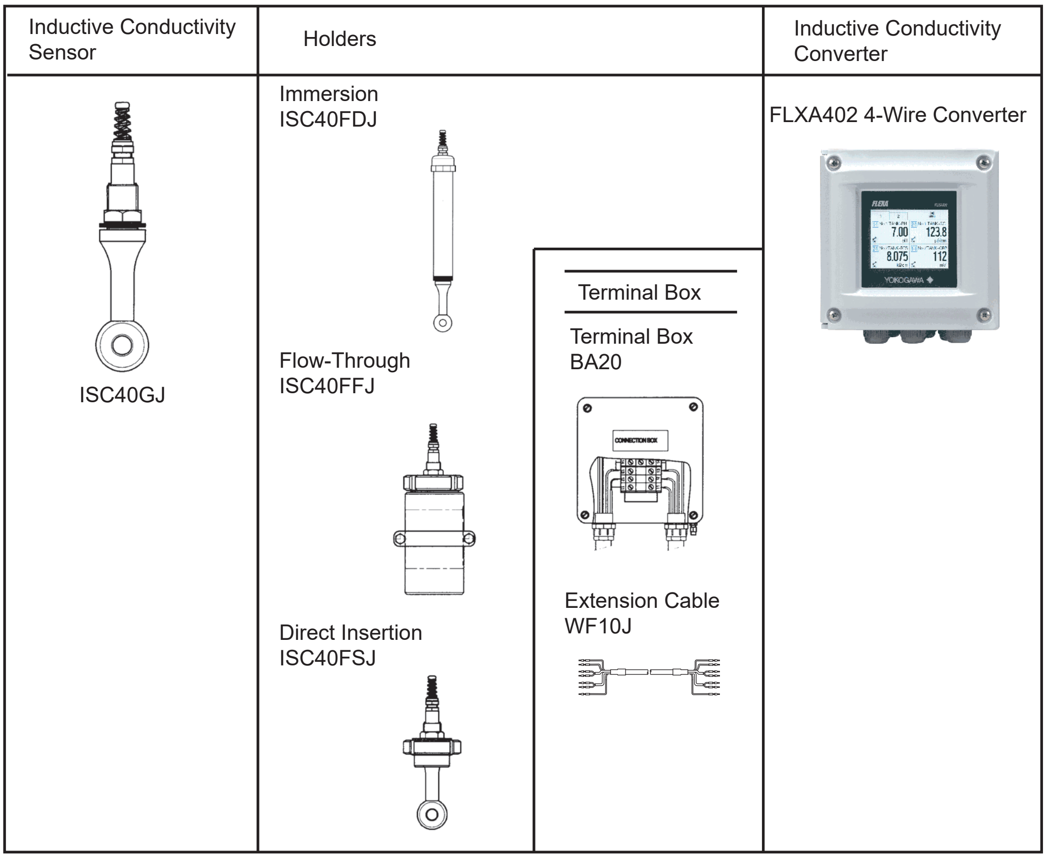
7. System Configuration of Inductive Conductivity Analyzers

There are two inductive conductivity analyzer systems for process control as follows.

- “Four-wire inductive conductivity transmitter system” for general conductivity measurement system
- “Two-wire inductive conductivity transmitter system” for conductivity measurement systemring large-scale instrumentation and explosion-proof protection

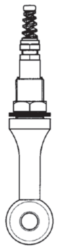
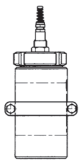
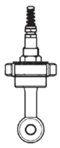
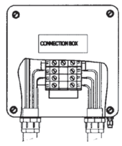
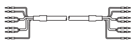
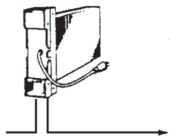
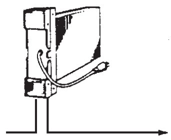
■ Four-wire Inductive Conductivity Analyzer

● System Configuration

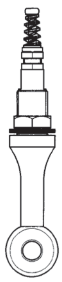
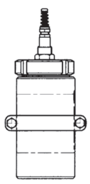
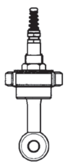


Two-wire Inductive Conductivity Analyzers

System Configuration – Non-explosion protected type

Inductive Conductivity Sensor	Holders	Inductive Conductivity Converter	Distributor
 ISC40GJ	Immersion ISC40FDJ  Flow-Through ISC40FFJ  Direct Insertion ISC40FSJ  Terminal Box Terminal Box BA20  Extension Cable WF10J 	FLXA202 / FLXA21 	Dedicated Distributor PH201G  Analog output 1 to 5 V DC Output Failure contact output Maintenance contact output General Distributor SDBT, SDBS  Analog output 1 to 5 V DC Output

System Configuration – Explosion protected type

Inductive Conductivity Sensor	Holders	Inductive Conductivity Converter	Distributor Safety Barrier
ISC40S 	Flow-Through ISC40FFJ  Direct Insertion ISC40FSJ 	FLXA202 / FLXA21 	Refer to TI 12A01A02-42EN FLXA202 Selection Guide for Intrinsic Safety-type Associated Apparatus. For FLXA21, use TI 12A01A02-42EN as a reference.

8. Maintenance

In practice, it has been seen that conductivity measuring cells seldom require attention and preventative maintenance is hardly necessary.

However, when the result of the conductivity measurement is unreliable, then two items must be considered:

A. Is the operation of the measuring converter correct?
B. Is the function of the conductivity measuring cell with connecting cable and/or the built-in temperature sensor correct?

The use of a Sensor Simulator (QT40) of Yokogawa makes it easier to check the measuring cell. In addition, the correctness of the cable and the temperature sensor can be determined.

A service handbook and accurate test equipment are required for a correct operating check of the measuring converter.

8.1 Calibration of the Measuring Cell

The cell constant is determined at a call resistance of 1000 Ohms. It is possible that slight variations in the cell constant may occur at other conductivity values. This possible error can be corrected by recalibrating with a solution of known conductivity value (according to DIN 53779).

NOTES

1. The specific conductivity value of the solution of known value must be near to the value of the liquid to be measured.
2. The specific conductivity value is highly dependent on temperature. Therefore, the temperature of the cell and the liquid should be allowed to equalize and should be accurately measured with a calibrated thermometer.

If no arrow is indicated on the text plate (see Figure 8.1 (a)), then the deviation from nominal cell constant value will be within ±2 % and no recalibration is required.

The arrow (see Figure 8.1 (b)) indicates the deviation from nominal cell constant value (-4 %). Individual cell calibration ensures maximum accuracy of the measurement (see instruction manual of the measuring converter).

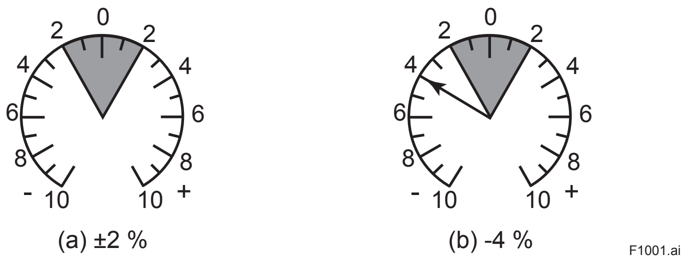


Figure 8.1 The deviation from the nominal value

8.2 Cleaning the Measuring Cell

In general conductivity/resitivity measurements do not need much periodic maintenance. If the EXA indicates an error in the measurement or in the calibration, some action may be needed. In case the sensor has become fouled an insulating layer mey be formed on the surface of the electrodes and consequently, an apparent increase in cell constant may occur, giving a measuring error. This error is:

$$2 \times \frac{R_V}{R_{cel}} \times 100 \quad (\%)$$

R_V : Resistance of the fouling layer

R_{cel} : Cell resistance

Note: Resistance due to fouling as well as to polarization does not effect the accuracy and operation of the four-electrode conductivity measuring system. If an apparent increase in cell constant occurs, cleaning the cell will restore accurate measuremet.

● Cleaning Methods

(1) For normal applications hot water with domestic washing-up liquid added will be effective.

(2) For lime, hydroxides etc. a 5 ... 10% solution of hydrochloric acid is recommended.

(3) Organic foulings (oils, fats, etc.) can be easily removed with acetone.

(4) For algae, bacteria or moulds, use a solution of domestic bleach (hypochlorite).

* Never use hydrochloric acid and bleaching liquid simultaneously. The very poisonous chlorine gas will result.

NOTES

1. Sharp objects must not be used on the surface of the electrodes. The paragraph about the decrease or preventation of polarization effects informs about a special layer (e.g. rhodium) to increase the electrode surface. The attack of this layer can give considerable increase of polarization and sonsequently, measuring errors.
2. The surface of the electrodes of f.i. stainless steel must not be polished. The special “ray patterned” electrode surface have an enlarge active surface to give a small current density. Polished electrodes give an increase to the polarization effect and consequently, measuring errors.

9. Applications

The industrial applications of conductivity measurements are numerous and vary from a simple determination of the salinity to more complex quality measurements and control.

A number of applications are listed below, some of which are described in detail.

Water quality treatment

- Conductivity measurement of pure water.
- Check and control of demine installations like caution exchanger protection, an-ion exchanger protection, mixing-basin exchanger protection.
- Boiler feed water protection.
- Condensate protection.
- Steam quality protection.
- Boiler blow-down control.
- Air-conditioning blow-down control.
- Hardness protection (e.g. laundries).
- Surface water protection.

Concentration measurements and control

- Sulphuric acid and oleum.
- Hydrochloric acid.
- Lye concentration control for generation of ions exchanger.
- Acid concentration control for regeneration of ions exchanger.
- Phosphate in boiler water.
- Ammonium and ammonia gas.
- Nitric acid for dairy cleaning.

Gas analysis

- Carbon dioxide in water.
- Sulphuric dioxide in water.

9.1 The Conductivity Measurement of Pure Water

The conductivity measurement in pure water needs a separate explanation.

The precise measurement of the specific conductivity of pure water is a complex subject.

In the conductivity measurement principles mentioned before, the starting point is that the concentration of ions in the dissolved solutions are much greater than the concentrations of the available H^+ and OH^- ions for the equilibrium.

In pure water the concentrations of H^+ and OH^- ions may not be neglected.

The specific conductivity of pure water equates to the sum of the specific conductivity values of the salts present and the dissociated H^+ and OH^- ions.

$$K = K_{water} + K_{salts}$$

The temperature influence differs for the two factors and cannot be compensated for by using one temperature coefficient based on NaCl. For pure water conductivity measurements, temperature compensation is made by utilizing two separate temperature sensors and electric circuits.

For dissolved salts a temperature coefficient of 2.16 %/°C is used.

The calculated curve for the temperature coefficient of the water equilibrium is added to the normal temperature correction requirements in an electronic circuit.

Figure 9.1 shows the temperature dependence of “pure” water at three conductivity values.

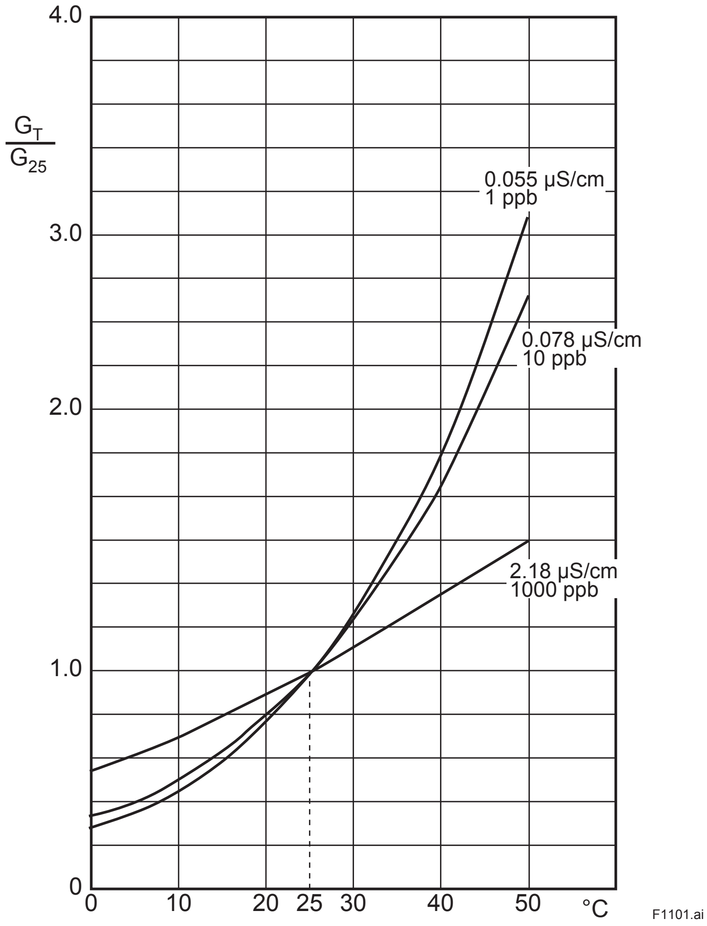


Figure 9.1 Conductivity of pure water with pollutions of resp. 1, 10 and 100 ppb.

Yokogawa has developed a special signal converter for measurements in pure water (low concentration converter). The measuring principle of this converter is similar to the two-electrode measuring principle.

However, the temperature compensation is made with two separate temperature sensors both mounted in the conductivity cell.

If the conductivity of the water is expected to be low, the low concentration principle for conductivity measurement is recommended. Generally, the accuracy of other measuring principles will be unacceptable.

9.2 Boiler Blow-off Control

A common application of conductivity measurement is blow-down or make-up control.

Industrial steam is used for a number of applications. The most important of which are energy generation in power stations and heating purposes.

Since the effect of boiler installation is pre-determined by the quality of the boiler feed water, it is important to monitor its quality.

The most usual method of maintaining the quality of the boiler water is by blow-down control based on the conductivity measurement.

A small sample is drawn continuously from the boiler and passed through a sample cooler. The conductivity of this sample is monitored and when it reaches an unacceptable level, a control value in the blow-down line is opened. The decrease in boiler level initiates through a level controller, the opening of a feed water valve. The conductivity controller of the control valve ensures that it only opens sufficiently to adjust the boiler water to the maximum permissable conductivity level.

Good blow-down control ensures that at the minimum loss of energy, in the form of heat, is coupled with minimum usage of make-up water.

9.3 Check on Condenser Performance

In the majority of chemical industries, steam is used to heat the process liquids.

The problem with this method is that the return condensate may be polluted by process liquid leaking into the steam tubes.

If this occurs, the return condensate must be prevented from returning directly to the boiler.

Figure 9.2 shows a typical control process circuit.

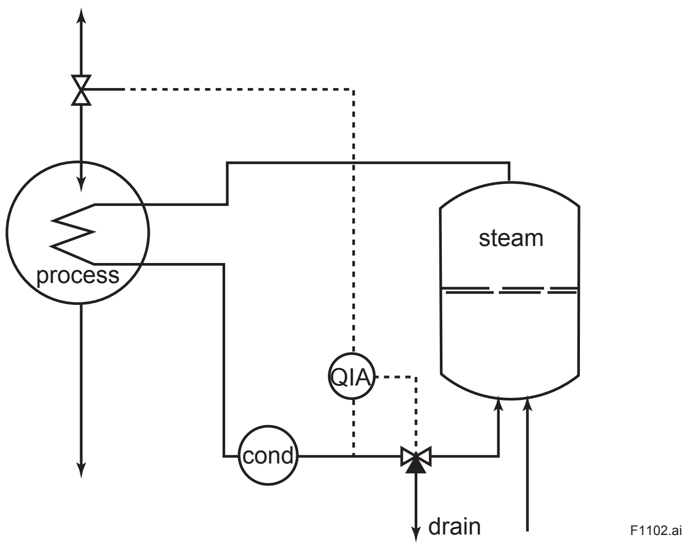


Figure 9.2 Return condensate

If the conductivity value of the condensate passes a preset-value, a valve in the return pipe to the boiler is closed and a blow-down valve is opened.

This protection allows optimum quality of the condensate and process liquid leaks are avoided.

9.4 Blow-off Control of Cooling Towers or Open Cooling Systems

In a cooling system which includes an open cooler (e.g. cooling towers), the concentration of solids steadily increases due to evaporation losses. This is described as “increased thickening”.

An increase in solids in the water also leads to greater deposits in the piping system. The cooling capacity then suffers all the resultant consequences (over-heating, increased cooling, water consumption, etc.). To prevent the cooling water from becoming too thick, it is periodically drained.

The use of conductivity measurement to the degree of thickening can be measured and, if necessary, recorded.

When a preset conductivity value is exceeded, a blow-off valve is opened and the water is replaced by unpolluted water, through a make-up valve.

9.5 Conductivity Measurement as a Measurement or Control of Concentration

Many industrial processes use conductivity measurement to determine and control the concentration of dissolved solutions. In such applications it must be realized that all dissolved solutions contribute to the conductivity value to a greater or lesser degree.

Some examples are:

- The control of sulphuric acid concentration.

The control of sulphuric acid concentration during manufacturing (see Figure 9.3).

The concentration of sulphuric acid is usually between 60 and 99 % wt. (see Figure 9.4).

The relation between conductivity and concentration in this range is such that an increase of concentration gives a decrease of conductivity.

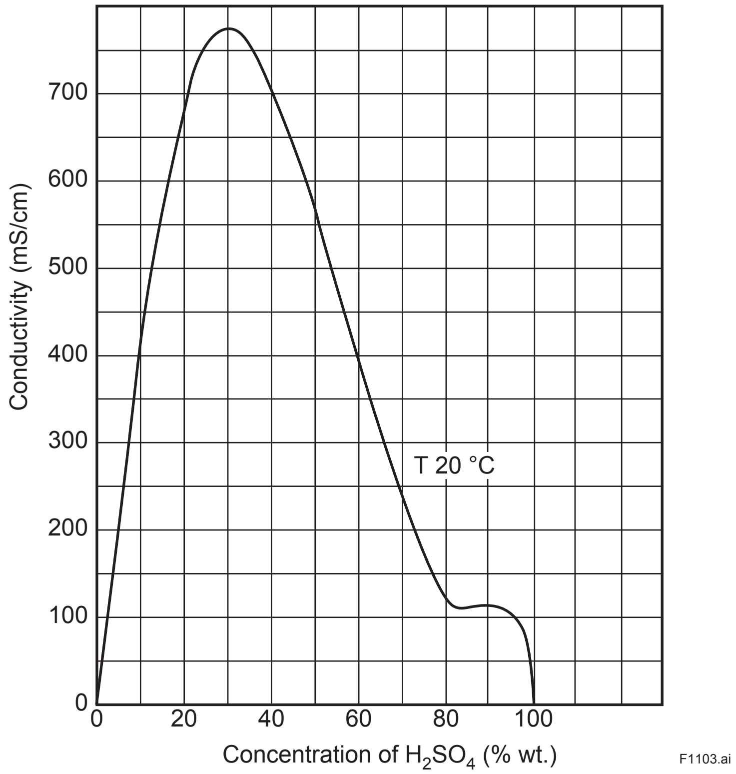


Figure 9.3 Conductivity of different sulphuric acid concentrations at 20°C.

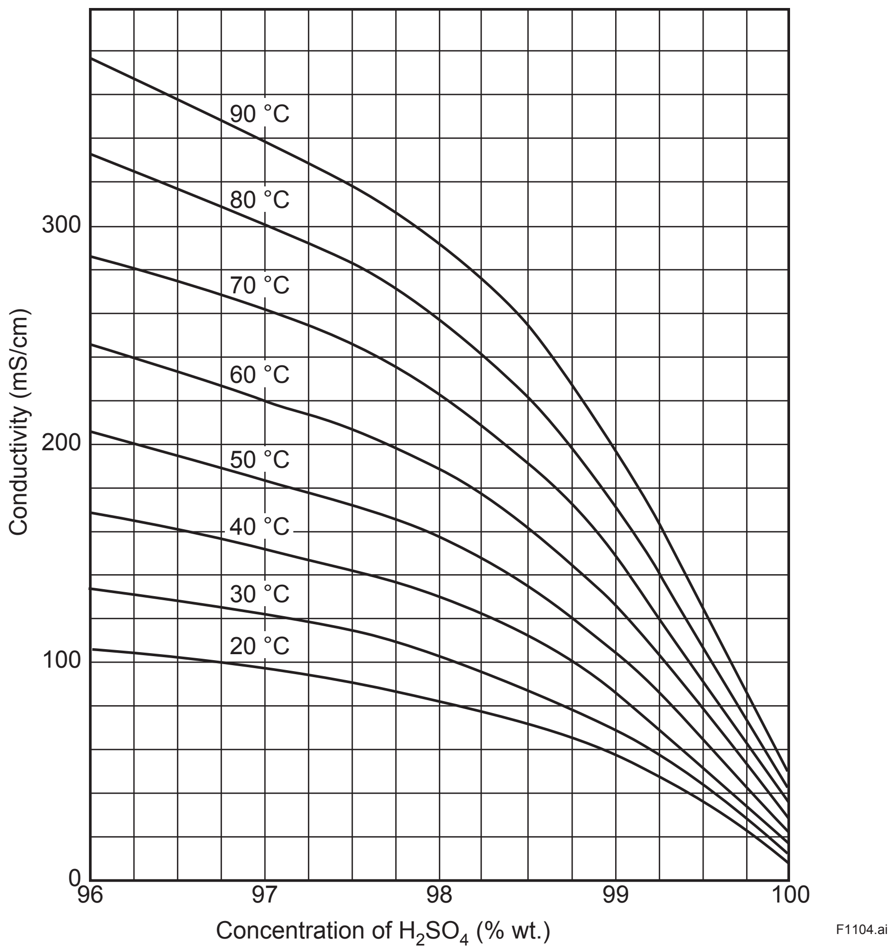


Figure 9.4 Conductivity of sulphuric acid with concentrations between 96 and 100 % wt.

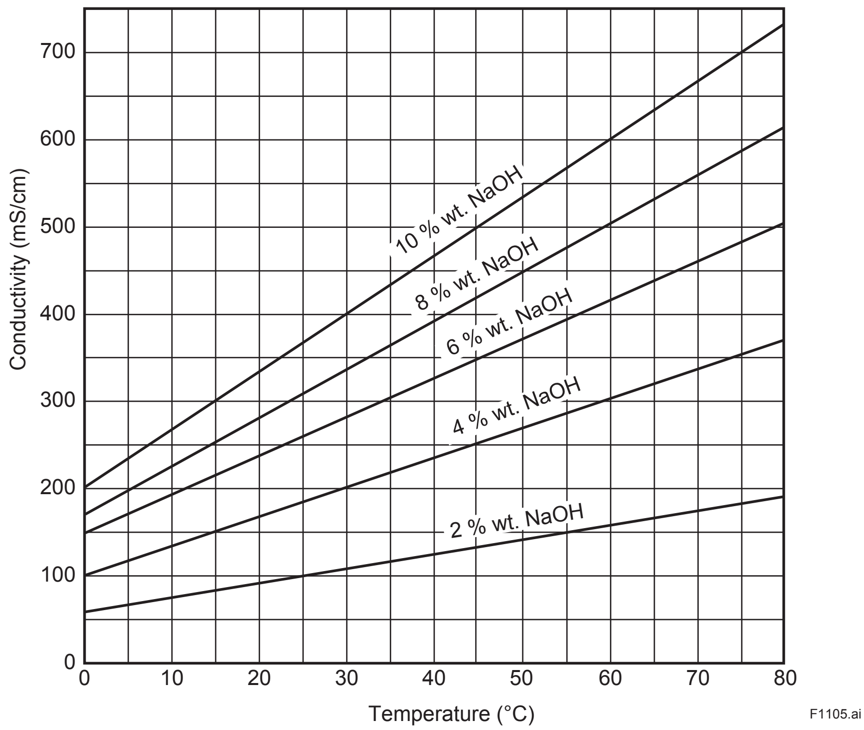


Figure 9.5 Conductivity of some NaOH concentrations at different temperatures.

- The measurement of alkaline concentration.

In a demineralising plant, the an-ions exchanges are regenerated with alkaline. That means the an-ions bound to the exchange resins are loosened by rinsing through with a concentrated alkaline solution. It is important that the alkali is used in the correct concentration and consequently, it is necessary to adjust this after each regeneration.

Non-optimum regeneration of an ions exchanger results in reduced operating cycle time and poorer water quality.

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