Conductivity

Contacting Conductivity sensor selection guide

Contents

1. Introduction

Over the last few decades, measuring the conductivity of liquids has become more and more important in the process industry.

Conductivity is used to determine the purity or composition of a solution but is also used to monitor cooling systems for leak detection and blow-down control. in cooling towers and steam generation.

Conductivity analyzers are also perfectly suited to track process changes, on account of their fast direct measurement, but also because the total quantity of ions present in the solution are measured without differentiating the type of ion.

Unlike sometimes slower ion-selective measurements (pH, pCl, pNa, etc.) where the activity of specific ions is determined e.g., hydrogen ions, chloride ions, or sodium ions, conductivity measurements are non-specific and so can track very well process changes and/or total quantity of ions in any given solution

This technical information briefly describes the principles of contacting conductivity measurements followed by describing the factors that influence a measurement range and how one can determine the measurement ranges of a measurement loop consisting of an analyzer and sensor.

NOTE

1.1 Introduction to Conductivity

The industrial applications for conductivity measurements vary from simple determination of salinity to more complex quality measurements and control. Some examples are:
- Chemical concentration measurement
- CIP system monitoring
- Product detection
- Product quality
- Heat exchanger breakthrough
- Liquor applications (P&P)
- Boiler-feed water quality
- Water For Injection quality (WFI)
- Specialty Chemicals
- pH calculation by differential conductivity (VGB)
- Surface water protection

The main reasons why conductivity measurements are used in these applications are to:
- Produce products with consistent, well-defined properties
- Efficiently produce products at optimal cost
- Avoid unexpected shutdowns
- Ensure a safe working environment
- Fulfill environmental regulations

1.2 What is conductivity?

In an aqueous solution, Conductivity is defined as "the measure of the solutions ability to conduct or carry an electric current.

In a solution, electrical current is carried by free-moving charged ions. These ions are either positively charged (cations) or negatively charged (anions). They are formed by dissolving soluble salts, acids, and alkali into a polar solvent (in this context, water).
For liquids, the presence of ions is necessary as they are the "carriers" of the current flowing through the solution. If there are NO IONS present in the liquid, such as with ultrapure water, then NO CURRENT can flow, and the solution is NOT CONDUCTIVE.

The term "Conductivity" is derived from Ohm's Law which is defined as $E = I \times R$
Where E is the voltage applied between two "plates" (shown in Figure 1), electrical current I will flow dependent on the resistance R of the conductor. In this case the conductor is water.

Figure 1: Conductivity measurement sensor

Therefore, conductivity is defined as the reciprocal of resistance of a solution between two electrodes and it can be expressed as $G = 1 / R$.

The basic unit of conductivity is Siemens (S), formerly called the mho. The cell geometry determines the effective measuring range of the sensor.

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 calculated by the formula L/A; where L is the distance between the electrodes and A is the area of the electrodes: $C = G \times (L/A)$.

1.3 What influences the conductivity?

1. The number of ions in a solution

The conductivity will increase as the ion concentration increases until the point where the density of ions starts to restrict movement. For this reason, concentration to conductivity curves usually start rising together at first and then reverse, going back down again (see figure 2). Therefore, it is essential when using conductivity in concentration applications to check that the measurement range is within a linear part of the curve.

2. Ion mobility

Different ions move at different speeds. This means that conductivity is dependent on ion type.
For example, at a 10% concentration, Sodium Hydroxide (NaOH) conductivity is 140mS/cm, but a at 10% concentration, Hydrochloric Acid has a conductivity of 700mS/cm.

3. Temperature effect

Temperature significantly affects the conductivity of a solution -as much as 10% per °C or °F.
There are two effects that can be distinguished.
The first temperature effect is usually caused by increasing temperature, causing the ions to move faster. This typically results in a 1 to 3% effect on conductivity per °C or °F.

A second cause, which is only significant in pure waters where there are very few ions in solution. The number of water molecules dissociating into H+ and OH- ions (and hence the number of ions in solution) is a function of the temperature. This effect is nonlinear and can be as much as 10% per °C or °F. Therefore, the temperature is very important for ultra-pure water conductivity measurements.

Because of this immense effect of the temperature on the conductivity, most analyzers will have temperature compensation curves pre-programmed in the analyzer. Selecting this curve is part of the initial setup of the measurement. Usually, a reference temperature of 25°C (77°F) is set. The analyzer will always show the conductivity of the process is at this temperature and not at the process temperature, which might be fluctuating.

It is important to note that the NaCl compensation curves in the Yokogawa analyzers take into account the effects of dissociation and speed of ionic travel. That means this temperature compensation curve, will work well from ultra-pure water up to concentrated (salt) solutions.
Several other temperature curves are pre-programmed in the Yokogawa analyzers. In table 1 is an example of the FLXA402.

Table 1:Ready-made temperature compensation matrixes FLXA402

Select matrix	Compound to be measured	Concentration (*)	Temperature	Details
NH3 0..50 ppb	Ammonia	0 to 50 ppb	0 to 90°C	Table A
NH3 15..30 %	Ammonia	15 to 30 w/w%	10 to 50°C	Table B
Morpholine 0..500 ppb	Morpholine	0 to 500 ppb	0 to 90°C	Table C
NaOH 1..5 %	NaOH	1 to 5 w/w%	0 to 100°C	Table D
NaOH 0..15 %	NaOH	0 to 15 w/w%	0 to 100°C	Table E
H2SO4 1..5 %	H_2SO_4	0.5 to 5.0 w/w%	-1.1 to 98.9°C	Table F
H2SO4 0..27 %	H2SO4	0 to 27 w/w%	-1.1 to 98.9°C	Table G
HCl 0..200 ppb	HCl	0 to 200 ppb	0 to 100°C	Table H
HCl 0..5 %	HCl	0.37 to 5.5 w/v%	0 to 65°C	Table I
HCl 0..18 %	HCl	0 to 18.2 w/v%	-10 to 65°C	Table J
HNO$_3$ 1..5 %	H2SO4	1 to 5 w/w%	0 to 80°C	Table K
HNO3 0..25 %	H2SO4	0 to 24.8 w/w%	0 to 80°C	Table L

*   w/w%:   solution weight (g)/solution weight (g) x 100
    w/v%:   solution weight (g)/solution volume (mL) x 100

1.4 Conductivity versus Concentration Curves

Another important industrial application for conductivity measurement is in processes with higher conductivity values. In these applications often the concentration of the chemicals is determined, e.g.
- The strength of a scrubber solution: enough NaOH present to still be effective
- The concentration of a solution for example when producing Hydrochloric Acid (HCl)

In order to achieve the best, most accurate and reliable measurement from conductivity it is worth keeping the following in mind:
1. Each chemical responds differently from the next, converting its conductivity value versus percent concentration level. Often the difference is significant, but sometimes it is not. These differences have to do with the size and mobility of the ion of each chemical (chapter 1.3).
2. Conductivity is a non-specific measurement and will measure all ions present in a solution.
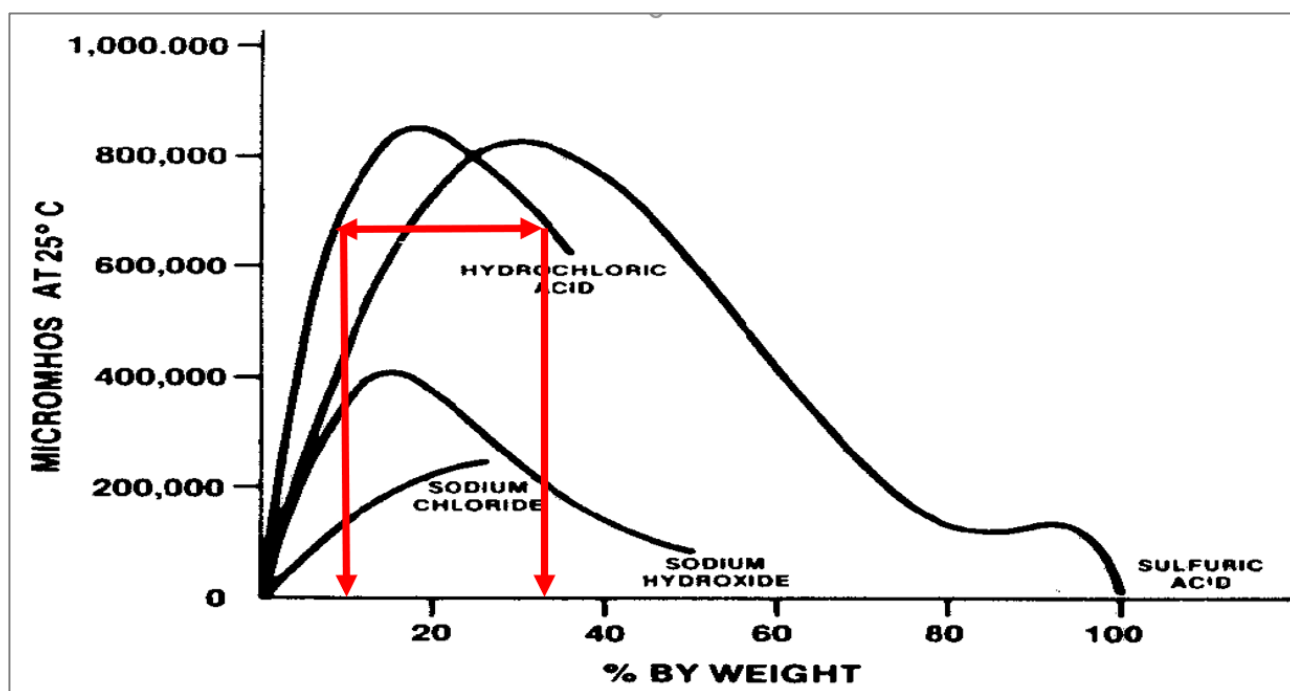3. Temperature affects all conductivity measurements.

Figure 2:Conductivity versus % Weight graphs of various solutions

The first factor is illustrated in figure 2. The effect is demonstrated between the different sized ions of each chemical reflected in their different curves for conductivity versus % concentration. The four chemicals shown all respond differently. It demonstrates how important it is that the analyzer is set up with the correct curve information for the specific chemical being measured, or the results will be useless. Many analyzers have built-in tables for conductivity versus % concentration to select from and also the capability to enter a "user-defined" table.

In figure 2, it can also be seen that the continued rise in the percent concentration results in a decrease in the conductivity value at a certain point. This is due to the increasing number of ions in the solution interfering with one another causing the mobility of the ions, and therefore the conductance of the solution to decrease. This change in direction could be a problem should the measurement range include that part of the curve where the changes occurs, such as 18 – 50% Sulfuric Acid, or 10 – 30% Hydrochloric Acid.

The issue is that there will be one conductivity value that represents two different percent concentrations. At 18% and 50% Sulfuric Acid, the conductivity value is about 600,000 µS. Just reading the conductivity will not clearly state what percent concentration is being measured. It is essential to then be aware of which side of the curve the measurement is currently.

The easiest solution to this problem would be to ensure the range is set up so that it never crosses that peak point. However, there may be occasions where this is not possible, and the measurement becomes more complicated. One solution is to use a secondary device (such as a flow meter or density meter) which can work in tandem with the conductivity analyzer. This allows validation on which side of the curve the measurement is happening. Usually, a switch is required to change the output from the first analyzer to the second once the peak of the curve is reached the measurement could be made (and vice versa).

2. Conductivity measuring ranges

Determining the suitable sensor for a particular application depends on several factors.
The main factors that influence a measurement range are the measuring loop: analyzer, cable, sensor, and optional fitting.

Figure 3: Measurement loop components example

Function of each component:

1. **The analyzer interprets and relays**
   - Signal and displays measured values
   - Generates analogue & digital outputs
   - Performs calculations to transform measurements into meaningful data
     - e.g. temperature compensation, concentration calculations
   - Enables Validation and Calibration

2. **The cable connects and transfers**
   - Connects the sensor with the analyzer
   - Transfers electric signal
   - Transfers power

3. **The sensor senses**
   - Measures the resistance of a solution

4. **Fitting for installation in the process**
   - Fit the sensor in the most suitable location in the process for optimized process control

Each of these components also influences the measuring range of the loop. The analyzer has a maximum and minimum input range based on the conductivity. The sensor should be selected to fit within the range of the analyzer.

In the following paragraph this is explained in detail with examples.

2.1 The analyzer

Each analyzer has its own measuring range. The operating range of an analyzer is, in principle, expressed in Ohms (resistance). For all our analyzers (EXA series, FLEXA Series and SENCOM), the minimum operating range is 5 ohms, and the maximum is 1 Mohm.

2.1.1 Measurement range

The measurement range of an analyzer is determined by the hardware components and limitations such as the range of insulation, measurement voltage and frequency it operates at. In each range, different combinations of voltage and frequency are required for optimal measurement.

Simplified: at an ohmic resistance lower than 5 ohms, transition resistances in the electronics of the analyzer affect the accuracy. At a higher resistance than 1Mohm, insulation plays a vital role in the measurement accuracy. That means there are limitations for the input range of the hardware.
In table 2, an overview is given of the different analyzers and their input ranges.

INPUT RANGE (Ω)	EXA SERIES	FLEXA SERIES	SA11 SMART ADAPTER	UM33A	
1	under range	out of range	out of range	out of range	
3	under range	out of range	under range	under range	
4	under range	under range	under range	under range	
5					
10					
100					Linear range
1000					
10000					
100000					
1000000					
10000000	overrange	overrange	overrange	overrange	

Table 2 Input ranges Yokogawa analyzers:

2.1.2 How is the measurement range calculated?

The conductivity is expressed in Siemens (S), milli Siemens (mS), or micro-Siemens (µS) and is the reciprocal value of the resistance:
Conductivity = 1 / resistance (Ω).

With this calculation, it is possible to calculate the measurement range of the analyzer.

For example (use yellow part in table 2)
- input from sensor is 5Ω
- conductivity = 1 / 5Ω
- Conductivity = 0.20 Siemens

To convert this to milli Siemens:
- 0.20 * 1000 = 200 mS

To convert this to micro Siemens:
- 200 * 1000 = 200,000 µS

INPUT (Ω)	SIEMENS (S)	MILLI SIEMENS (mS)	MICRO SIEMENS (µS)
1	1	1000	100000
3	0.33	3333	333333
4	0.25	250	250000
5	0.20	200	200000
10	0.10	100	100000
100	0.01	10	10000
1000	0.001	1	1000
10000	0.0001	0.1	100
100000	0.00001	0.01	10
1000000	0.000001	0.001	1
10000000	0.0000001	0.0001	0.1
CONDUCTIVITY= 1 / RESISTANCE (Ω)			

Table 3: Input range and corresponding conductivity values

2.2 The sensor

2.2.1 General

One of the most important features of a conductivity sensor is that it remains unchanged over time, even under arduous conditions of high and variable temperatures and pressures.

Contacting conductivity sensors consist of two contacting electrodes (plates) and a temperature sensor. Between the two electrodes is an insulator piece to guarantee a proper measurement.

Figure 4 gives an overview of the main conductivity sensor models sold by Yokogawa. There are two different types of models: a two-electrode and a four-electrode type.

The two-electrode type sensor is the standard sensor with two metal plates. The 4-electrode sensor has two additional electrodes that slightly increase the range of the sensor making it less susceptible to fouling and polarization (see also chapter 2.3.1).

CELL CONSTANT			
0.01, 0.02 cm^{-1}	**0.1 cm^{-1}**	**1 cm^{-1}**	**10 cm^{-1}**
• SC42-SP34	• SC42-SP24	• SC42-EP14 (EP18)	• SC42-FP08
• SC42-SV34	• SC42-SV24	• SC42-EP15 (EP16)	• SC42-FV08
• SC4A-002	• SC4A-010	• SC42-EV15 (EP16)	• SC42-TP08
			• SC42-TV08

CONTACTING CONDUCTIVITY

Figure 4: Overview Yokogawa models and related cell constants

When selecting the correct sensor, four factors must be considered:

1. Sensor material

Sensor materials are very significant: The insulator between the two electrodes must not deteriorate over time. For example, when measuring in Ultra-Pure Water (UPW) is being made at 18MΩ: any of the insulation degradation would result in higher than actual conductivity measurement.

2. Compatibility with the process

All the materials must be compatible with the process. They must not rust, swell, shrink etc.

3. Robustness

The sensor must be as strong and robust as possible. The geometric dimensions between the two electrodes are critical: any change will significantly impact the conductivity reading.

4. Temperature sensor accuracy

The temperature sensor must be of high quality: a one °C error could result in a 10% conductivity error.

2.2.2 Cell Constant (CC)

The liquid to be measured may have an ohmic resistance outside the analyzer's measuring range. For this reason, there are sensors with different geometry available. These differences are expressed in the Cell Constant (CC).

The CC of a sensor is the ratio of distance and the surface area of two measuring plates (see figure 4).

Although the exact cell constant is specific for an individual sensor, they are grouped by nominal value: cell constants of 0.01, 0.02, 0.1, 1, 10 cm^{-1} are usual.
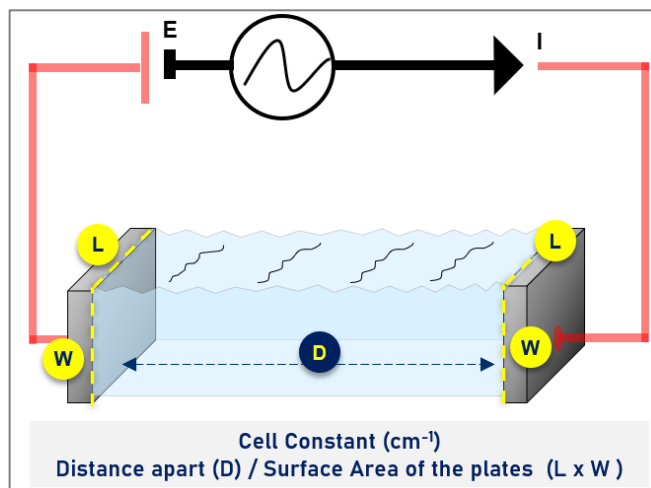

Figure 5: Cell Constant (CC) calculation

Measuring only specific conductivity, e.g., Siemens or µS, this does not give any information on the purity of the liquid. For this it is necessary to multiply by the cell constant (CC). This is the key point of conductivity measurement. The conductivity must be expressed per unit distance e.g., Siemens per cm (S/cm).

For example, if it is stated that the conductivity of a bottle of water is 10 µS. Then it is not possible to state whether the water is pure because it is not known how the measurement was made.
To explain this, an example will be used to calculate the specific conductivity of a solution:
- µS/cm = µS x CC

First, a sensor with cell constant 0.01 cm^{-1}:
- Sensor A CC= 0.01 cm^{-1}
- µS/cm = 10 * 0.01
- Specific conductivity of water = 0.1 µS/cm
- Conclusion: the water is pure

The second sensor has a cell constant of 10 cm^{-1}:
- Sensor B CC= 10 cm^{-1}
- µS/cm = 10 * 10
- Specific conductivity = 100 µS/cm
- Conclusion: the water is **not** pure

For small cell constants, the electrode surface must be large and/or the distance between the electrodes is short. This enables measurements in low conductive fluids / processes.
Typical applications are pure and ultra-pure water.

The measurement of high conductive fluids requires a large cell constant, which means small surfaces and/or a large distance between the electrodes.
Typical applications are concentration control, phase separation, water / wastewater.

When the distance between the plates is smaller, the analyzer will measure a lower resistance value.

This phenomenon makes it possible to bring the resistant measurement of a liquid within the measuring range of an analyzer. The difference in cell constants enables the extension of the measurement range of the analyzer (see figure 6).
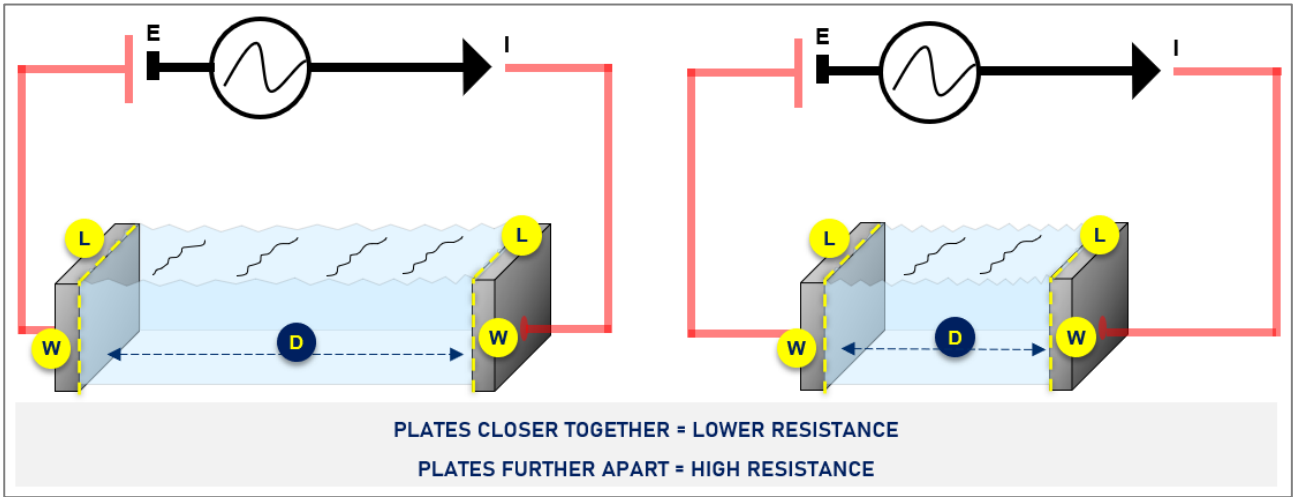
Figure 6: Bring the resistance measurement of a liquid into the measuring range of the analyzer

2.2.3 How to calculate the measurement range?

The following equation can calculate the measurement range:
Resistivity = input range analyzer/ CC
Conductivity = input range analyzer x CC

This will result in the following measurement range per cell constant (CC) of 1, 10, and 0.01 cm^{-1}:

INPUT RANGE (Ω)	Measurement range with cell constant = 1.0		Measurement range with cell constant = 10		Measurement range with cell constant = 0.01	
	RESISTANCE (Ω)	Siemens (S)	RESISTANCE (Ω)	Siemens (S)	RESISTANCE (Ω)	Micro Siemens (µS)
5	5	0.20	0.5	2000	500	2000
10	10	0.10	1	1.0	1,000	1000
100	100	0.01	10	0.1	10,000	100
1,000	1000	0.001	100	0.01	100,000	10
10,000	10000	0.0001	1000	0.001	1,000000	1
100,000	100000	0.00001	10000	0.0001	10,000000	0.1
1,000000	1000000	0.000001	100000	0.00001	100,000000	0.01
10,000000	10000000	0.0000001	1000000	0.000001		0.001

Table 4: Comparison or measurement range of sensors with CC 1, 10 and 0.01 cm^{-1} (green shaded)

While the input range of the analyzer is fixed, choosing different cell constants will extend the measuring range of the analyzer from 0.5 Ohm*cm to 100Mohm*cm. Or when expressed in Siemens: 2.0 S/cm to 0.01µS/cm.

In the table above, different units have been used for the different cell constant to clarify readability. In appendix 1, the complete table is added to show the information expressed in multiple units.

2.3 Process liquid

A third important factor for determining the correct measurement combination is the behavior of the ions in the liquid, which is determined by the chemical composition.

2.3.1 Theory and practice of polarization

A low resistance of the liquid and, therefore high conductivity is caused by the presence of a large number of ions. Ions are charged particles in the liquid, which, in large numbers, can have a negative effect on the measurement.

The charged particles move from one plate to the other due to the applied measurement voltage by the electronics. If there are too many ions, they can get in each other's way or stop moving and stick to the sensor. Longer or opposite charged ions on the plate will result in a lower effective drive voltage. This behavior is called polarization.
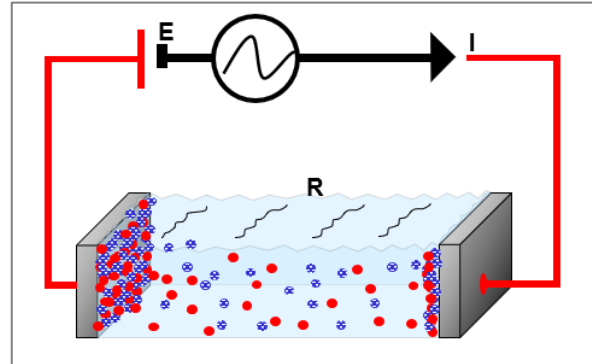

Figure 7: Example of polarization

This polarization depends on several factors, such as quantity and the size of the ions/molecules. Because each process differs in chemical composition, it is impossible to predict at what value this polarization phenomenon occurs in a process.

2.3.2 What does polarization mean in practical terms?

In a solution where the surface area is (too) small and the ions are sticking to the plates the sensor will become less and less responsive.
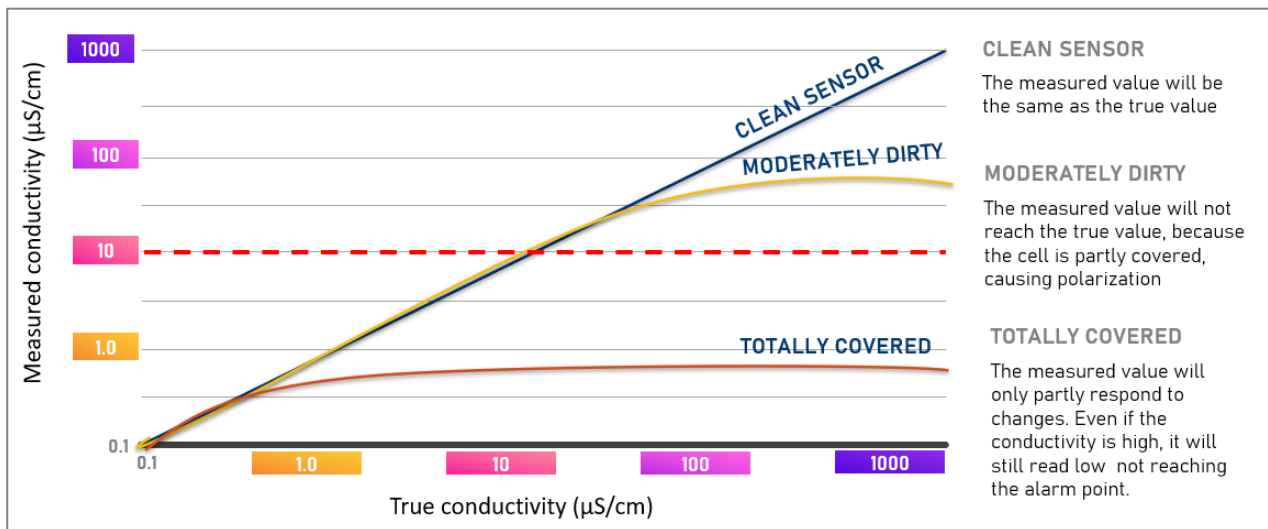The displayed conductivity value on the analyzer will be lower than what it is in reality.

Figure 8: The effects of polarization on a conductivity sensor

That is why all the Yokogawa analyzers are equipped with a Polarization check. This will indicate that the sensor needs to be cleaned, or that a sensor with a higher cell constant needs to be selected.

The selection of a sensor with the correct cell constant will minimize polarization problems.

From practical experience, it is known that an analyzer generally detects polarization when the input resistance is below 50 Ohm. When the analyzer measures less than 50 ohms, it is likely the polarization is occurring. With a sensor with a CC of 0.01 cm^{-1} this can be at a fluid value below 5000 Ohm (50 / 0.01).

Table 5 gives an overview from which process value and selected sensor polarization can be detected.

	Input range Ω	FLXA Series	Measurement range with CC 10 Ω	S	Measurement range with CC 0.1 Ω	mS	µS	Measurement range with CC 0.01 Ω	µS
5Ω	5		0.5	2.000	50	20	20000	500	2000
10Ω	10		1	1.000	100	10	10000	1000	1000
50Ω	50		5	0.2000	500	2	2000	5000	200
100Ω	100		10	0.1000	1000	1	1000	10000	100.0
1kΩ	1000		100	0.01000	10000	0.1	100	100000	10.00
10kΩ	10000		1000	0.00100	100000	0.01	10	1000000	1.000
100kΩ	100000		10000	0.00010	1000000	0.001	1	10000000	0.100
1MΩ	1000000		100000	0.00001	10000000	0.0001	0.1	100000000	0.010
10MΩ	10000000		1000000	0.000001	100000000	0.00001	0.01	1000000000	0.001

Table 5: Measurement range from which process value with the selected sensor can have polarization

2.3.3 Electrode system with 4 electrodes

Within the Yokogawa product range, sensors are available that have a 4-electrode system. This measuring principle ensures that certain polarization phenomena occur later or less.
In low ohmic liquids (high conductivity), a sensor with a Cell Constant of 10 cm^{-1} or 1 cm^{-1}is generally used. Yokogawa has this range of sensors in both a 2- electrode and a 4-electrode version.

2.3.4. Different constructions for different cell constants

Another effect that can influence the polarization, is the total surface area of a sensor.
An SC42-SP24 with a CC of 0,1 cm^{-1} is less sensitive to polarization than an SC4A with the same Cell Constant. This is because the SC4A is much smaller and the surface roughness much smoother resulting in a lower effective surface area than the SC42 sensors.
Figure 9 shows the measurement range of SC42 and SC4A with both the same Cell Constant
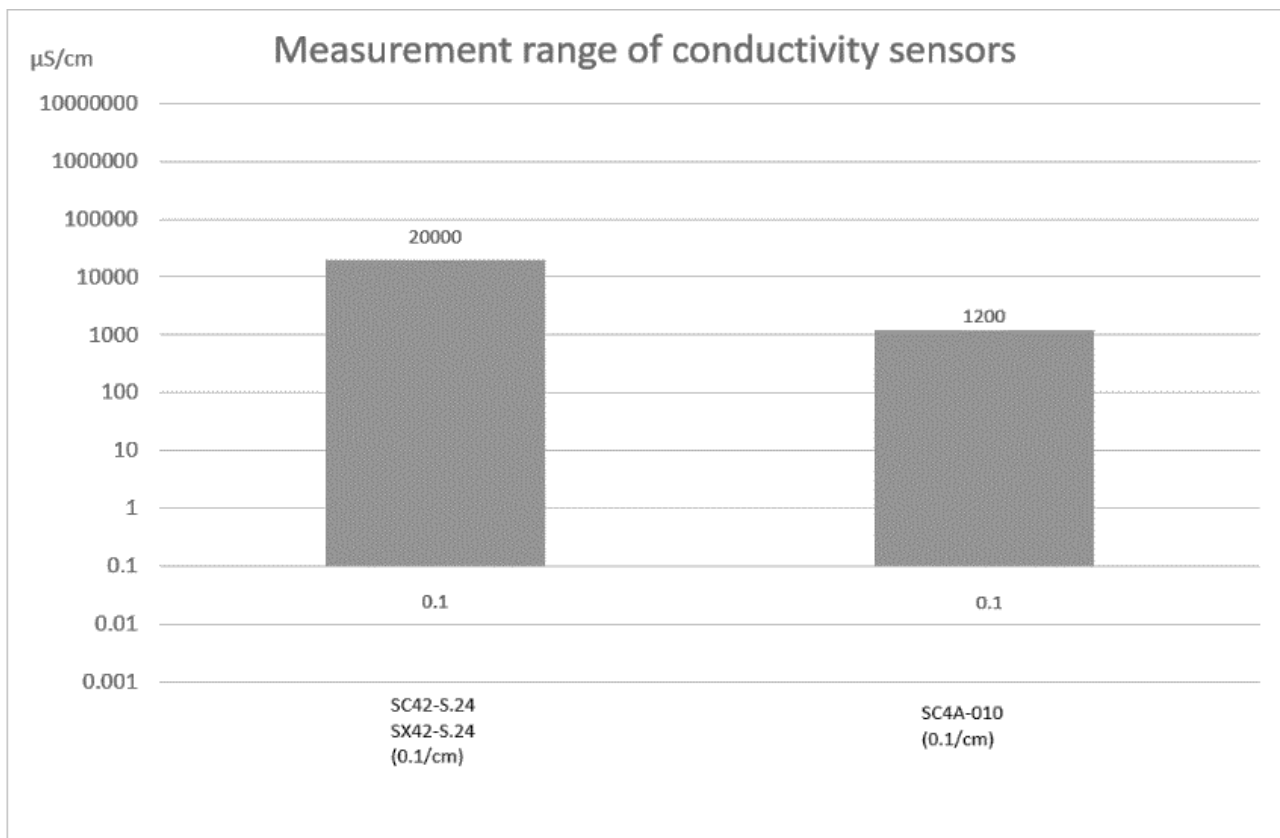

Figure 9: Measurement range SC42 and SC4A

Full chart of measurement ranges for our sensors written in Appendix 2

3. Sensor selection from application point of view

3.1 General selection guide

Figure 10 an overview is given of four types of general applications:
1. Low conductivity applications
2. Chemically Harsh applications
3. High temperature and/or high-pressure applications
4. High Conductivity
5.

Figure 10: Conductivity sensor selection guide

3.2 Sensors selection for chemical harsh applications

VERY HARSH

Available with SENCOM 4.0

SC42- TP/TV – GLASS-FILLED PTFE

Available with SENCOM 4.0

SC42- FP/FV – PVDF

LESS HARSH

SENCOM 4.0 compatibility Pending

SC42- EPOXY

Why use these sensors for harsh applications?

- High Chemical resistant body (Epoxy, Teflon and PFA)

- Measures accurately in high conductive solutions

- Fast temperature response

3.3 Sensor selection for (Ultra) pure water applications

Available with SENCOM 4.0

SX42 and SC42- S in Stainless Steel
SC4A- in Stainless steel or titanium

Why use these sensors for (U)PW applications?

- Large surface area

- High sensitivity in low conductive solutions

- UPS645 – Uncompensated conductivity

- Resolution ≥ 0.1µS/cm

3.4 Sensor selection matrix: specifications

Model	Cell constant (cm^{-1})	Material	Over pressure (barg)	Over pressure (psig)	Under pressure (barng)	Under pressure (psi)	Temp. (ºC)	Temp. (ºF)
SENSOR SPECIFICATIONS								
SC4A-002	0.02	SS or Ti	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 125*	32 - 257*
SC4A-01	0.1	SS or Ti	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 125*	32 - 257*
SC42-SP24/ SK24	0.1	SS	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 150	32 - 302
SC42-SV24/ SG24	0.1	SS	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 125	32 - 257
SC42-SP34/ SK4	0.01	SS	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 150	32 - 302
SC42-SV34/ SG34	0.01	SS	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 125	32 - 257
SC42-E*18, 15 and 16	1	Epoxy	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 110	32 - 230
SC42-E*08	10	Epoxy	0 - 10	7 - 145	0 - 0.5	0 - 7.3	0 - 110	32 - 230
SC42-F*08	10	PVDF	0 - 10 **	7 - 145	0 - 0.5	0 - 7.3	0 - 110	32 - 230
SC42-T*08	10	Teflon	0…10 **	7 - 145**	0 - 0.5	0 - 7.3	0 - 110	32 - 230
SX42-SX.4 -BS, -NS (thread)	0.1	SS	0 - 40	0 - 580	0 - 0.5	0 - 7.3	0 - 200	32 - 392
SX42-SX.4 -BV, -NV (thread)	0.1	SS	0 - 40	0 - 580	0 - 0.5	0 - 7.3	0 - 125	32 - 257
SX42-SX.4 -AF, -DF (flange)	0.01	SS	0 - 40	0 - 580	0 - 0.5	0 - 7.3	0 - 250	32 - 482
SX42-SX.4 -EF (flange)	0.01	SS	0 - 30	0 - 435	0 - 0.5	0 - 7.3	0 - 250	32 - 482

100°C / 212°F max. continuously for fixed cable types. For all types 135°C max. for a short period of time during sterilization.

** at Tmax 3 barg / 43.5 psig

Important note: for the latest information please check the relevant General Specifications sheets on our website.

3.5 Sensor and fitting selection guide

		FF20 3-hole	FS20 3-hole	FD40	FF40	FS40	PR10	K1598AB K1598AC	ISC40FD	ISC40FF	ISC40FS
		FITTINGS									
MATERIAL	PP	✓	✓		✓					✓	✓
	PVC			✓	✓	✓			✓		
	PVDF	✓	✓			✓				✓	✓
	SS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	PPS/Ryton										
MODELCODE	ISC40G						✓		✓	✓	✓
	ISC40S						✓		✓	✓	✓
	SC42 [4]			✓ not EP16	✓ not EP16	✓ not EP16					
	SC4A-E [4]							✓			
	SC4A-S-PR [4]						✓				
	SC4A-S-AD [4]							/PF /PS			
	SX42 [4]	see remark 1)	see remark 1)								

Remarks: 1) SX42-SX24-NS and SX42-SX24-NV fits in FF20-*3C and FS20-*3C fitting (for FU24, 1 mounting hole). Pressure and temperature are limited by the fitting specification.
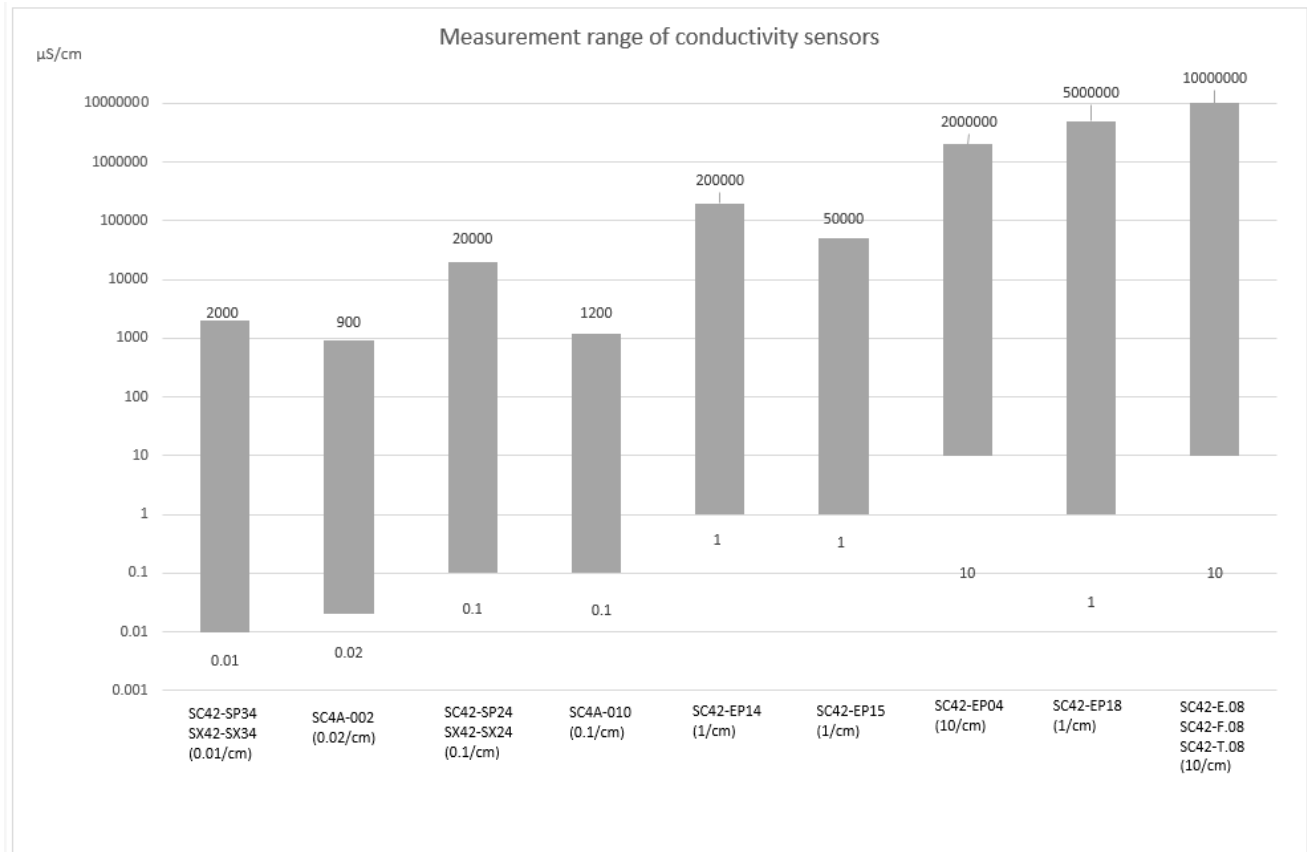2) SENCOM 4.0 sensor also fits in marked/footnoted YPA fitting (and applicable sparepart) with mounted SA11.

Appendix 1: Measurement range by Cell Constant (CC)

Measurement range with CC = 10

Input range Ω	FLXA Series	SxCC	mSxCC	mSxCC		Ω	S	mS	µS
5		0.2	200	200000		0.5	2.000	2000	2000000
10		0.1	100	100000		1	1.000	1000	1000000
50		0.02	20	20000		5	0.2000	200	200000
100		0.01	10	10000		10	0.1000	100	100000
1000		0.001	1	1000		100	0.01000	10	10000
10000		0.0001	0.1	100		1000	0.00100	1	1000
100000		0.00001	0.01	10		10000	0.00010	0.1	100
1000000		0.000001	0.001	1		100000	0.00001	0.01	10
10000000		0.0000001	0.0001	0.1		1000000	0.000001	0.001	1

Measurement range with CC = 1

Ω	S	mS	µS
5	0.2000	200	200000
10	0.1000	100	100000
50	0.0200	20	20000
100	0.0100	10	10000
1000	0.0010	1	1000
10000	0.0001	0.1	100
100000	0.00001	0.01	10
1000000	0.00000	0.001	1
10000000	0.000000	0.0001	0.1

Measurement range with CC = 0.1

Input range Ω	FLXA Series	SxCC	mSxCC	mSxCC		Ω	S	mS	µS
5		0.2	200	200000		50	0.0200	20	20000
10		0.1	100	100000		100	0.0100	10	10000
50		0.02	20	20000		500	0.0020	2	2000
100		0.01	10	10000		1000	0.0010	1	1000
1000		0.001	1	1000		10000	0.0001	0.1	100
10000		0.0001	0.1	100		100000	0.0000	0.01	10
100000		0.00001	0.01	10		1000000	0.00000	0.001	1
1000000		0.000001	0.001	1		10000000	0.00000	0.0001	0.1
10000000		0.0000001	0.0001	0.1		1E+08	0.000000	1E-05	0.01

Measurement range with CC = 0.01

Ω	S	mS	µS
500	0.0020	2	2000
1000	0.0010	1	1000
5000	0.0002	0.2	200
10000	0.0001	0.1	100.0
100000	0.0000	0.01	10.00
1000000	0.0000	0.001	1.000
10000000	0.00000	0.0001	0.100
100000000	0.00000	0.00001	0.010
1E+09	0.000000	1E-06	0.001

Appendix 2: measurement range of conductivity sensor

Measurement range of conductivity sensors

µS/cm

Sensor	Upper	Lower
SC42-SP34 SX42-SX34 (0.01/cm)	2000	0.01
SC4A-002 (0.02/cm)	900	0.02
SC42-SP24 SX42-SX24 (0.1/cm)	20000	0.1
SC4A-010 (0.1/cm)	1200	0.1
SC42-EP14 (1/cm)	200000	1
SC42-EP15 (1/cm)	50000	1
SC42-EP04 (10/cm)	2000000	10
SC42-EP18 (1/cm)	5000000	1
SC42-E.08 SC42-F.08 SC42-T.08 (10/cm)	10000000	10

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