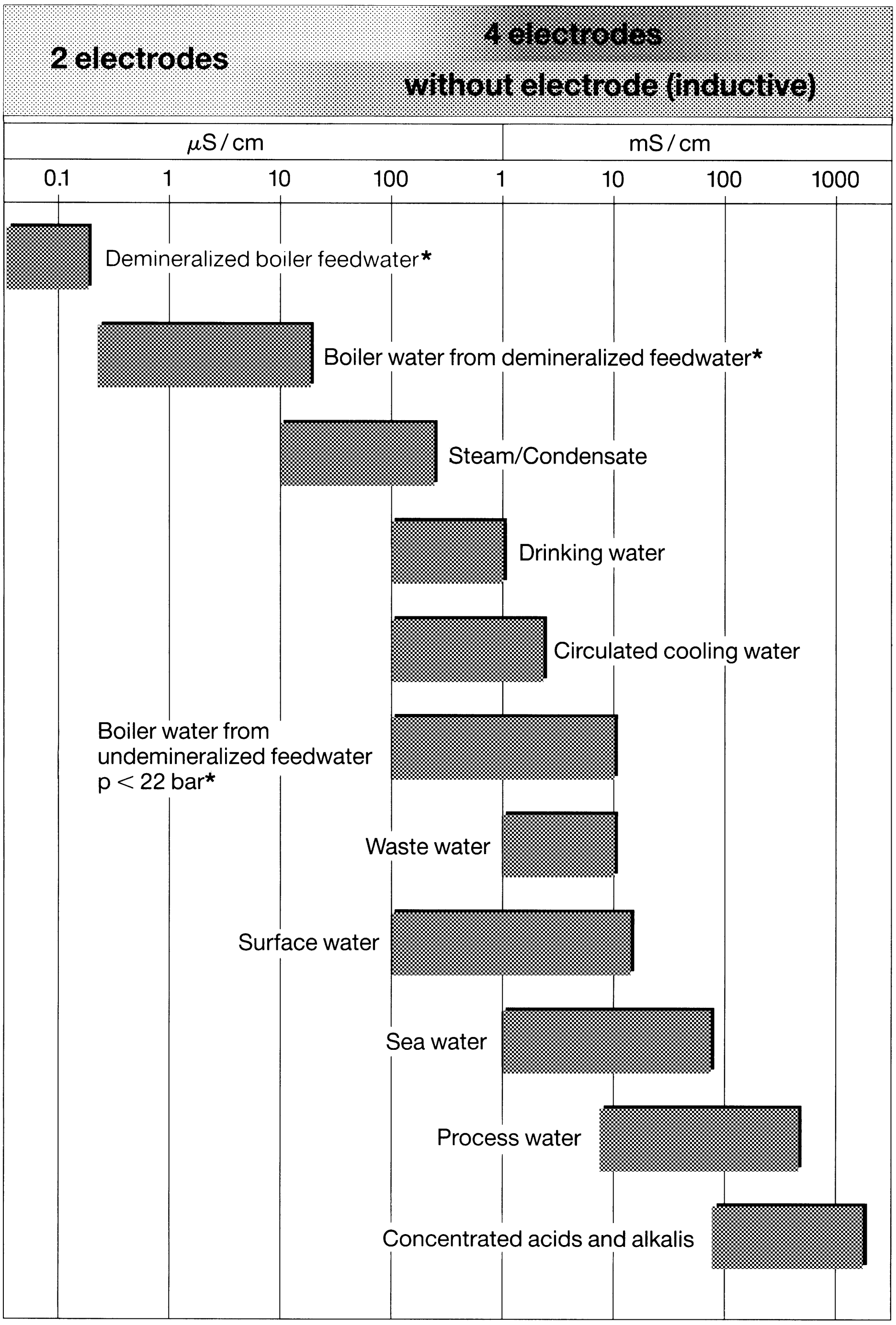
GESTRA® **Information B 1.4**

Issue Date 11/01

Reliable Methods for Electrolytic Conductivity Measurement



*Standard values in acc. with TRD 611 — 1 $\mu S/cm \hat{=} \sim 0.5$ ppm

Fig. 1: *Preferred measuring range of various measuring systems*

Data acquisition systems with real time indication are increasingly required by plant managers in order to make all process information instantly available. At the same time the standards required of the measuring instruments grow. Higher standards imply, however, that the advantages and limits of the various systems should be known and weighed against each other.

Electrical conductivity depends to quite a considerable extent on the fluid temperature at the time of the measurement (in the technical literature and recommendations usually a basis temperature of 25 °C is therefore used for conductivity data).

An indication of the effect of temperature on the conductivity is the alpha value (% per °C) which in turn depends on the constituents of the fluid to the measured.

For natural water (ground, well or surface water) a correction factor of 2.1 % per °C has been agreed upon and most portable measuring instruments are adjusted to this figure. The temperature influence for other fluids has, however, to be determined from tables in the technical literature, manufacturers' specifications etc. or by tests (see DIN 38404, part 8, for example).

Besides temperature, the so-called polarization effect plays an important part when selecting the equipment to be used.

A unidirectional current in an electrolyte always implies galvanic corrosion. The ions depositing on the electrodes and the change in concentration of the solution at the electrodes produce an opposing electromotive force which reduces the current flow and gives a false result.

The influence of polarization and consequently the inaccuracy of measurement can be reduced:

- by applying an a.c. voltage with a higher frequency, e.g. measurement with 1000 Hz instead of 50 Hz mains frequency,
- by increasing the electrode surface area or decreasing the current density,
- by the selection of appropriate electrode material.

The measurement inaccuracy can be completely eliminated by the use of sensors without an electrode.

In the field of continuous measured-value acquisition – different from limit value or trend monitoring often previously regarded as sufficient – high accuracy should be considered right from the beginning and a suitable method of measurement selected.

Before dealing with the different methods of measurement, we want to consider the conductivities of various fluids and the preferred measuring-range limits of the various systems.

As can be seen from the graph, Fig. 1, the two-electrode measuring system is mainly used for low conductivities (up to approx. 1000 μS/cm). The sensors (conductivity electrodes) consist, as a rule, of two metal or graphite measuring tips which are either concentrically arranged, or are beside one another, or which use the vessel wall (boiler etc). as the earth electrode.

An a.c. voltage (to avoid serious polarization) with constant amplitude is connected to the two sensors. The current flowing through the liquid is inversely proportional to the resistance of the liquid volume between the electrodes and consequently directly proportional to the specific conductivity.

$$I = U/R \implies R = 1/\sigma \implies I = U \times \sigma$$

This linearity requires, however, an exact definition of the geometry of the measuring surface and a corresponding design of the electronic control unit. To be able to cover the complete spectrum of the measuring range of two-conductor electrodes with a sufficient accuracy, the electrodes are manufactured with measuring surfaces (CELL CONSTANT) of different dimensions.

Fig. 2: *Two-electrode measuring system*

The two-electrode system is used, for example, in water-treatment plants, for feedwater, condensate and boiler-water monitoring and in drinking-water treatment plants.

Practice has shown that, due to the polarization effect at the electrode measuring surface, for conductivity ranges above 1000 μS/cm the two-electrode system could in many cases no longer provide the required accuracy. For this application up to approx. 500 mS/cm the four-electrode system has proved successful.

For this measuring system the current-carrying electrodes are separated from the voltage-carrying ones; a similar method is applied in the case of four-wire circuitry for measuring ohmic resistances.

The polarization at the current-carrying electrodes, which in the case of a two-electrode system would lead to an inaccuracy of measurement, no longer influences the measuring result, as the voltage at the voltage electrodes is measured without current and consequently free from polarization.

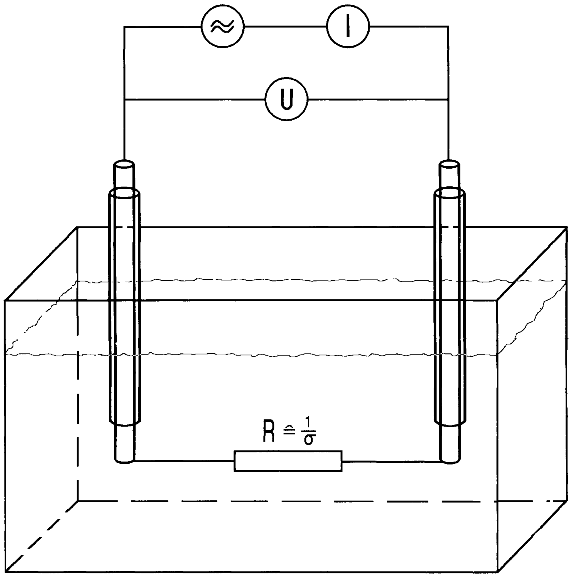


Fig. 3:
Schematic representation of two-electrode measuring system

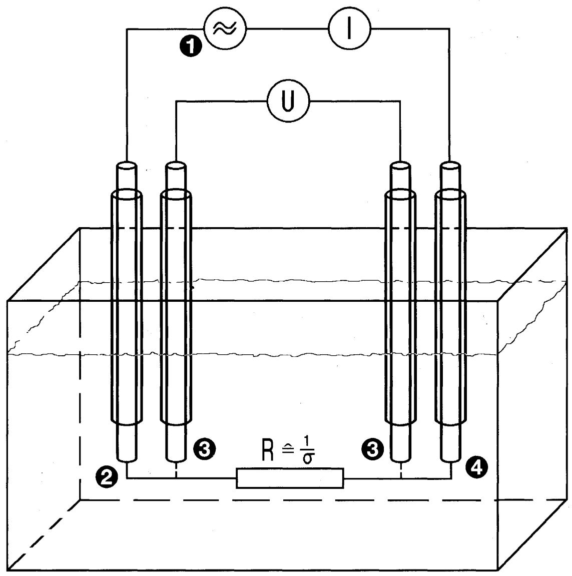


Fig. 4:
Schematic representation of four-electrode measuring system

The four-electrode measuring system operates as follows:

The measuring current "I" is flowing between power source (1) of electrode (2) through the fluid to electrode (4) and back to the power source forming an electric circuit. In the fluid to be measured there is a voltage drop between electrodes (2) and (4).

This voltage is measured at the two electrodes (3) and must correspond to a preset value. Deviations are balanced by a comparator in the electronic control unit which readjusts the current "I" until the voltage drop at the electrodes (3) has again reached the preset value, i.e. the current is proportional to the conductivity. Possible line resistances, polarization effects or dirt deposits on the electrodes are thus compensated for.

Four-electrode systems are offered in different patterns. Either rings arranged in parallel in a tube (e.g. of PVC) or in a cylindrical body are used or measuring tips fitted at equal distances in a body.

As this system is unaffected by contamination it covers a wide field of application ranging from process systems, boiler plants, the foodstuff industry to wastewater monitoring.

For high conductivities (above 2 S/cm) a measuring system operating without electrode is obviously the best solution in view of the unsatisfactory resistance of measuring tips in direct contact with the fluid.

If the fluid is in addition contaminated by oil, a system without electrode will become essential.

In comparison with the measuring systems described above, the inductive system is completely free from polarization as there are no electrodes in contact with the fluid.

Let us consider the **inductive measuring system** more closely:

The sensor (electrode for the other systems) consists of two high quality toroidal-core coils arranged concentrically or beside one another in a housing that is not electrically conductive. If the housing is designed so that part of the liquid can form a closed conductive current path through the concentric centre hole of the toroidal cores, the liquid can be considered as a common short-circuit loop of the toroidal cores.

Fig. 5: *Measuring system without electrode (inductive)*

The current "I1" generated in the excitation coil by the oscillator (constant a.c. voltage) is induced through the short-circuit loop and forms an output current on the measuring coil which is proportional to the conductivity.

The toroidal cores are mounted on PVC, PVDF, FEP or similar supporting materials. For systems with the liquid flowing through the sensor, materials such as PVC, PVDF, stainless steel etc. are used as the housing for the toroidal cores.

Due to the physical measuring principle, the low-maintenance inductive system is used mainly in the production and application of acids and alkalis, for monitoring oily water (e.g. in cooling towers), in the foodstuff industry (racking plants), in cleaning and pickling baths, washing and dry-cleaning plants etc.

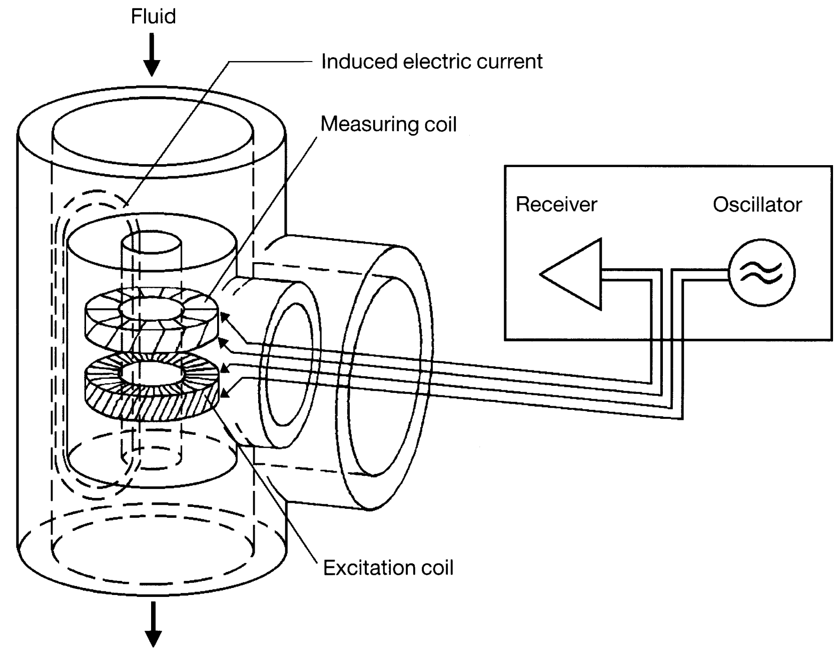


Fig. 7: *Schematic representation of inductive conductivity measurement*

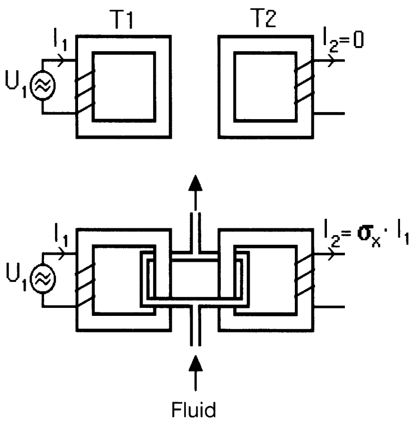


Fig. 6: *Diagrammatic representation of inductive conductivity measurement*

The special features of the inductive conductivity measurement systems can be summarized as follows:

- ❑ Operation without electrode, i.e. no measuring errors because of non-conductive deposits, polarization or galvanic corrosion.
- ❑ High degree of accuracy, low-maintenance continuous operation.
- ❑ No capacitance influence.
- ❑ Corrosion-resistant materials.
- ❑ Sensor with protective insulation, no earthing problems.

Final remark

With the measuring methods described above, reliable systems for determining electrolytic conductivity that can be adapted to the specific requirements of a process plant are today available. It is quite obvious that the temperature compensation as mentioned at the beginning of this article should not be forgotten.

GESTRA GmbH
P. O. Box 10 54 60, D-28054 Bremen • Münchener Str. 77, D-28215 Bremen
Tel. +49 (0) 421 35 03 - 0, Fax +49 (0) 421 35 03 - 393 • E-mail gestra.gmbh@gestra.de, Internet www.gestra.de
An Invensys company