SENSOR FOR HIGH-FREQUENCY CONDUCTOMETRY UNDER FLOW CONDITIONS

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There are several descriptions in the literature of instruments and sensors for high-frequency conductometry, based on measurement of the high-frequency admittance of individual samples of the product to be monitored [1 to 3].

However, for continuous monitoring of a stream of product, it is necessary to use a high-frequency conductometric sensor designed for flow conditions. A change in the composition of the product, within acceptable technological limits, should then be accompanied by a change in the modulus of its high-frequency admittance. Such a sensor should give a stable and reproducible reading over a long time period, and should have adequate sensitivity, i.e., it should show a high ratio of the useful signal, produced by the change in high-frequency admittance of the product, to the noise. The noise may be associated with instability of the high-frequency oscillator, with the measuring circuit, with stray pickups, or with a change in the high-frequency admittance resulting from a change in the temperature of the product.

The requirements for high sensitivity and high stability are mutually exclusive, so that it is necessary to find a compromise, which is satisfactory for practical requirements.

A remote-reading sensor for high-frequency conductometry under flow conditions was developed at the Geochemical Institute of the Academy of Sciences of the USSR.* This consisted of a cylinder, 100 mm in diameter and 400 mm long, closed by sealed end caps, with collars for connection to the tubing carrying the product to be monitored. The internal diameter of the sensor tube was 32 mm. The sensor had an electric split joint, for bringing in the feed voltage, and for taking out the signal to a secondary instrument. Pretuning elements were distributed under the sealed cover, on the lateral surface of the sensor.

The sensor monitored the change in modulus of the high-frequency admittance of the product, produced by a change in its composition, regardless of whether this was due to a change in dielectric constant or in ionic conductance, or for another reason. The instrument was designed for monitoring aqueous solutions having a conductivity of not more than 10 Mmho/cm. Some of the resistors chould be changed for monitoring nonelectrolytes. Some of the sensor dimensions should also be changed if it is required to monitor nonelectrolytes with a low dielectric constant ($\varepsilon \leq 10$ to 20), or electrolytes with a conductivity > 20 Mmho/cm.

In order to increase the stability of operation, we used a transistorized high-frequency oscillator, whose parameters varied hardly at all with time. The power supply to the high-frequency oscillator stabilized. The flow-through cell was connected into the bridge of the measuring circuit. It is an advantage to arrange for temperature compensation in the measuring circuit, so as to reduce the effect of any change in the high-frequency admittance of the product, resulting from a change in temperature.

The sensor was intended for measuring the deviation of the high-frequency admittance of the product from a given value. It would show no deviation if there was a fault in the high-frequency oscillator. This could be erroneously interpreted as indicating that the product being monitored has certain properties, but in fact these properties may give any deviation. To avoid this uncertainty, a warning circuit was introduced which operated a needle

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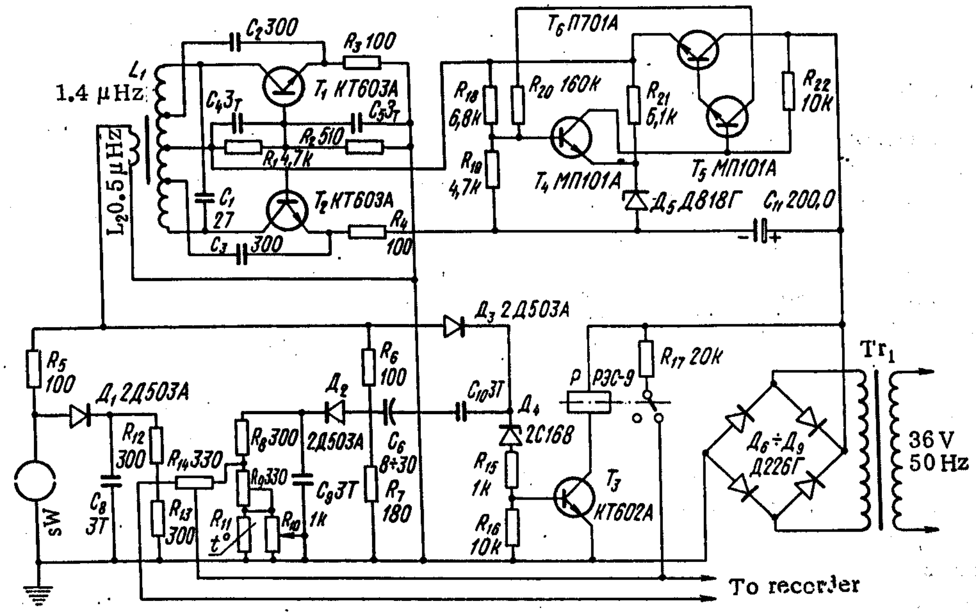

Fig. 1. Diagram of sensor.

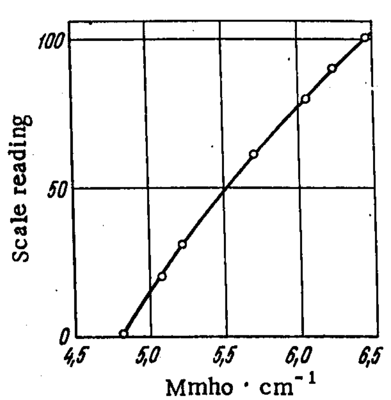

Fig. 2. Sensor calibration curve.

on a scale if the voltage supplied to the measuring bridge was too small, or absent altogether.

The sensor was enclosed in a sealed casing, which means that it could be used in a medium of high humidity or dust content, or in an explosive or aggressive atmosphere.

It was possible to monitor products at temperatures up to 80°C, and a temperature variation of 10 to 20°C did not introduce considerable errors. A PSR type of recorder was used as indicator; other types of recording or indicating instruments could be used.

Figure 1 shows a circuit of the sensor.

The transistors T_1 and T_2, working inpush-pull, operate the high-frequency oscillator. The circuit consisting of the inductance L_1 and the capacitor C_1 determines the oscillator frequency (25 MHz), and the resistors R_1 and R_4 and the capacitors C_2 to C_5 establish the operating point of the oscillator. The high-frequency voltage to be fed to the measuring circuit is taken off from the oscillator by means of the coupling coil L_2.

In the measuring circuit, thd resistors R_5 and R_6, the flow through cell II, and the R_7 and C_6 combination equivalent to a cell form a four-arm bridge.

The high-frequency voltages at the cell and the cell equivalent are rectified by the diodes D_1 and D_2 and filtered by the capacitors C_8 and C_9.

The constant voltage from the capacitor C_9 is fed to the temperature-dependent divider R_8 to R_{11}, which provides temperature compensation. The thermoresistor R_{11}, type KMT-12, is in thermal contact with the product to be monitored (it is attached to the external surface of the tube through which the product flows).

As the temperature of the product rises its electrical conductivity increases, so that there is a reduction in the high-frequency voltage across the cell, and a reduction in the voltages across the capacitor C_8 and the divider R_{12} to R_{13}. At the same time there is an increase in the temperature of the thermistor R_{11}. Its resistance decreases, and this leads to a reduction in the voltage taken from the temperature dependent divider R_8 to R_{11}.

With appropriate regulation of the resistors R_9 to R_{10}, the voltage difference, fed from the separators R_8 to R_{11} and R_{12} to R_{13} to the indicator, remains unchanged when the temperature of the product to be monitored varies by 10 to 20°C.

As well as being fed to the measuring circuit, the high-frequency voltage from the oscillator is also fed to the protective circuit. The diode D_3 rectifies this voltage. The direct voltage, developed across the capacitor C_{10}, unblocks the transistor T_3 through the stabilitron D_4 and this operates the relay P. If the high-frequency voltage feeding the measuring circuit falls below its assigned value for any reason, then the transistor T_3 is blocked, the relay P is de-energized, and one of the lead wires to the indicator is connected to the power supply via the resistor R_{17}. The voltage then fed to the indicator will be sufficient to deviate the indicator needle beyond the scale limit. This shows that the sensor is not operating satisfactorily.

The voltage stabilizer supplying the high-frequency oscillator is based on the transistors T_4 to T_6. The voltage at the stabilizer output is 24 V at a current of 40 mA. The voltage across the stabilitron D_5 (type D818Г) is used for reference. The sensor is connected to the indicator via a two-conductor shielded cable of practically unrestricted length. The sensor is powered by a 35 V ±25%, 50 cycle supply; the power required is about 3 W.

Before it is connected up for technological use, the sensor should be tuned with a known product so that variations in composition within premissible limits do not drive the needle beyond the scale limits, and so that the effect of the product temperature is minimal.

Figure 2 shows a calibration curve for the ratio between the indicator or recorder reading and the conductivity of a potassium chloride solution flowing past the sensor. The curve was obtained by changing the concentration of the solution in a thermostat at 30°C; the conductivity of the solution was checked by the normal conductometric method, to a precision of ± 0.1°C, The sensor was tuned so that the recorder pen moved from zero to full scale deflection for a change in specific conductivity from 4.8 to 6.5 Mmho/cm, and thermal compensation was provided for a solution temperature range from 25 to 35°C. Under these conditions the total error of the sensor did not exceed ± 1% in the course of three months' operation. No systematic error was detected.

The sensor was checked under semiproduction and under production conditions, and proved to be extremely useful. It could find application in petrochemical, medicinal, food, metallurgical, and other branches of industry.

LITERATURE CITED

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