BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXVI No. 4/2014	47 - 52	Seria Tehnică

Advances in Automation of Two-Phase Separators

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Abstract

The paper approaches automation problems associated with two-phase separators from oil rigs. Two-phase separators issues and conventional automation were analyzed. There were studied the trends and progresses in the field of two-phase separators automation. In addition to monitoring and control classical structures, the systems which estimate the water content in oil are of present interest. This paper critically examines the systems that perform on-line measurement of the amount of water in oil. The investigated device is EASZ-1 Water in Oil Monitor, from EESIFLO. There are evaluated the performance of both the transducer and the effects of its use in the oil industry.

Key words: *two-phase separator, water content in oil, capacitive transducer, homogenous mixture*

Introduction

The first operation performed on the mixture of fluids extracted from the wells (oil, gas and water) is their separation. Usually, the separation facilities are equipped with metal vessels which have technological connections for fittings and measurement and control instrumentation, manholes and unit support [1]. According to the number of separated phases, the separators can be:

- two-phase separators, used for separation of the gas from the mixture of fluids from the wells (gas, oil, water);
- three-phase separators, for separation of all three phases.

Two-phase separators require less investments but they do not separate water and oil. Until a few years ago, the automation of two-phase separators was quite simple, based on pneumatic equipment and on/off control [2, 3].

Current trends regarding two-phase separators indicate the necessity of accurate measurement of liquid phase flowrate and estimation of water content in oil, and of oil content in the liquid phase.

Present paper presents the authors' researches regarding the trends in automation of two-phase separators from oil well parks.

Use of Two-Phase Separators in Oil Industry

In the case of the two-phase separator are obtain a liquid phase and a gaseous phase. The liquid phase consists of pure oil, emulsified oil and free water and is sent directly to storage tanks and subsequently to treatment facilities. The gas phase is collected and transported separately to the oil rig or the gasoline recovery units. The automation structure of the two-phase separator is presented in figure 1 [3]. This structure contains a pressure control system, a level control system (usually with an on/off controller) and a temperature control system (in most cases provided with an on/off controller).

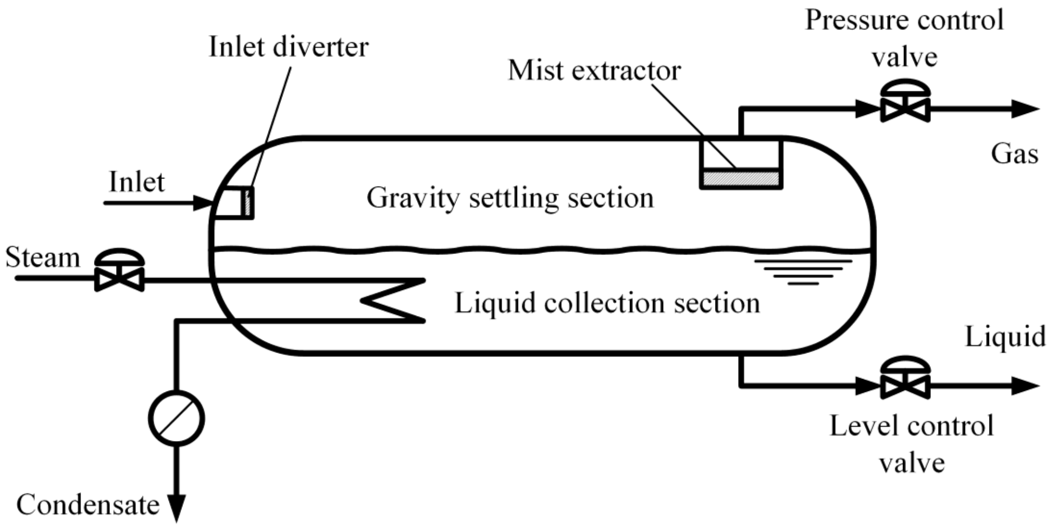


Fig 1. Structure of a two-phase separator.

The kinetic aspects of separation of two immiscible liquid phases indicated a laminar flow of the water particles in the continuous oil phase. It is considered that the size of the water particles is 500 µm, which would result in water content in oil of 5-10%. Separation of oil particles from water is much easier, since the viscosity of the oil is 5 to 20 times higher than that of the water. This is justified by the oil content in water, which is comprised between 100 and 2000 mg/l. Therefore, in the case of the two-phase separator, the water from the liquid phase can be found in the following conditions: bottom water, water dissolved in oil and water-in-oil emulsion. The on-line determination of the water content in oil is done using EASZ-1 **W**ater in **O**il **M**onitor (water cut) produced by firma EESIFLO [4, 5].

The Operating Principle of EASZ-1 Water in Oil Monitor

The measurement of water content in oil is based on the capacitance variation of the dielectric composed of the water – oil mixture. In this respect, the EASZ-1 is a precise measuring device for capacitance. For transformation of primary information about the capacitance of the mixture in information on the water content in oil, the device must match the measured capacitance (at a certain temperature) with the actual content of water in oil.

Relative dielectric constant varies significantly between oil and water. A typical value for water is 80, and for oil or other petroleum products is about 2. Because of this difference is possible to accurately measure water content. Figure 2 shows the variation of capacitance according to the amount of water in the water - oil mixture at a constant reference temperature [4]. The device is built in such that the oil – water mixture flows through an ensemble of two electrodes. This enables the measurement of the dielectric constant of the mixture as a variable capacitance across the electrode.

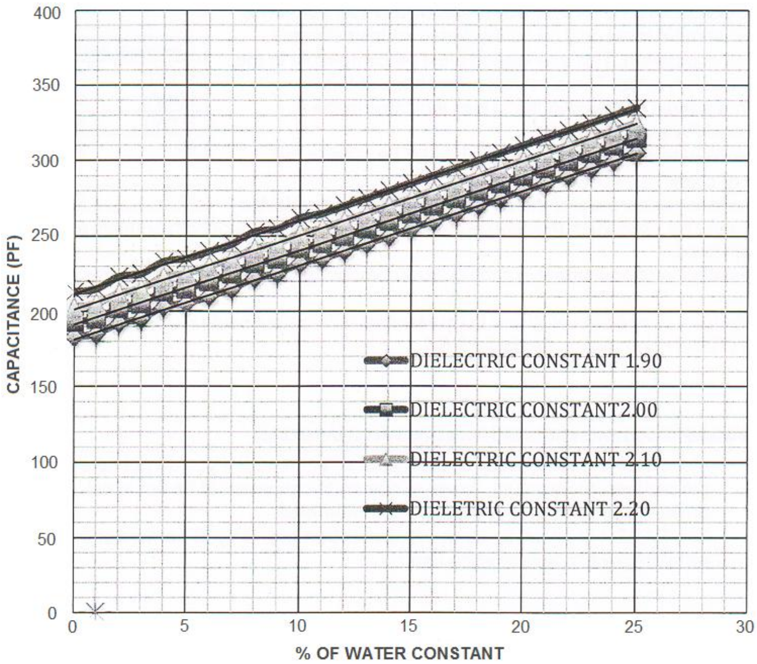


Fig. 2. Capacitance variation of the water-oil mixture with the water content in oil, at reference temperature [4].

Restrictions on EASZ-1 Usage

EASZ-1 is a capacitive transducer, therefore it obeys the laws of physics associated to capacitors. A brief investigation related to the series connection of capacitors reveals one of the main limitations of using this transducer.

Assuming that the liquid phase is separated equally into an aqueous phase, characterized by $\varepsilon_{water} = 80$, and crude oil, with $\varepsilon_{crude} = 2$, the electric circuit of the transducer will measure the equivalent capacitance of the series connection

$$\frac{1}{C_{equiv}} = \frac{1}{C_{water}} + \frac{1}{C_{crude}}, \tag{1}$$

where the electric capacitance is calculated with the relation

$$C = \varepsilon\, C_0, \tag{2}$$

with ε the relative dielectric constant, and C_0 – dielectric constant of vacuum.

Combining relations (1) and (2) it is obtain successively

$$\frac{1}{C_{equiv}} = \frac{1}{\varepsilon_{water}\, C_0} + \frac{1}{\varepsilon_{crude}\, C_0};$$

$$\varepsilon_{equiv} = \frac{\varepsilon_{water}\, \varepsilon_{crude}}{\varepsilon_{water} + \varepsilon_{crude}}. \tag{3}$$

Taking into account the previously mentioned values of the relative capacitances, the equivalent capacitance of the series connection is $C_{equiv} = \frac{80 \times 2}{80 + 2} = \frac{160}{82} = 1.91$, which fully corresponds to the oil phase although the two phases are equal.

If the two phases are mixed, the mixture capacitance varies linearly and using the mentioned conditions, it can be obtained $\varepsilon_{mix} = 0.5\,\varepsilon_{water} + 0.5\,\varepsilon_{crude} = 0.5 \times 80 + 0.5 \times 2 = 41$, a completely different result to the previous.

In these circumstances it is imperative to have a homogenous mixture with one-phase. In order to achieve the homogenization of the mixture, an inline mixer may be used.

Mixers are becoming more important in the case of large pipes. In these cases, due to the gravity water can be separated into a distinct phase affecting the measurement process. Figure 3 presents a structure composed of a mixer and a watercut monitor used to accurately measure the water content from crude oil [4]. Of course, for this structure is necessary to ensure a minimum flow in the pipeline.

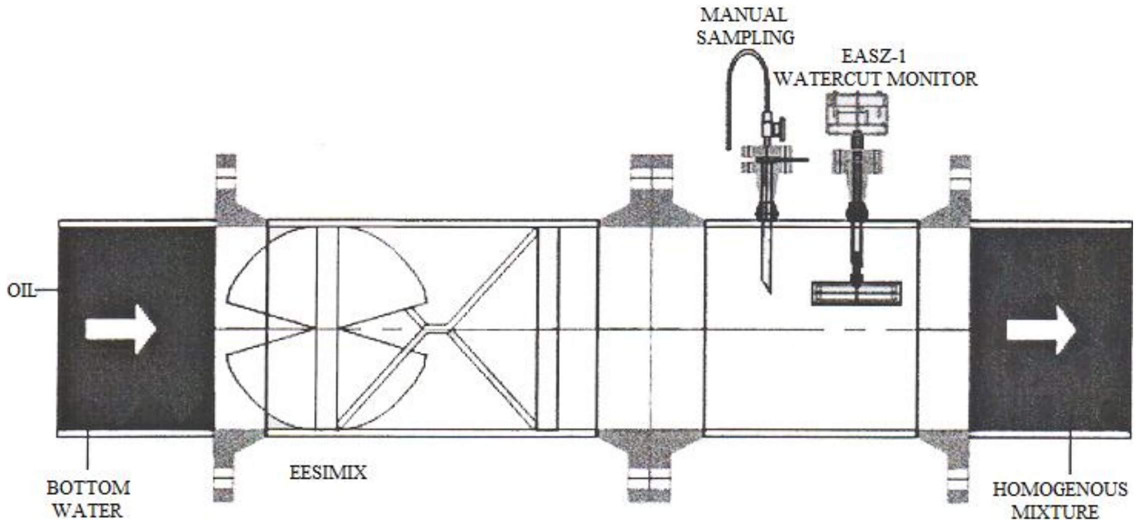


Fig. 3. Mixer – watercut structure [4].

Temperature Compensation

Water content in oil is determined from correlation in figure 2. Because this correlation is obtained for a reference temperature T_0, working temperature T is different from T_0 and electric capacitance of water and oil varies with temperature, it is necessary a numerical correction of measured capacitance.

EASZ-1 incorporates a sensor which measure the liquid phase temperature T, and the device software, using a temperature compensation factor f_T, corrects measured capacitance with relation

$$C = C_T - f_T\left(T - T_0\right). \tag{4}$$

Usually, factory values for f_T should not be changed. However, if from experiments it is find out that oil capacitance varies more than the estimated values, the coefficient can be calculated with relation

$$f_T = \frac{C_2 - C_1}{T_2 - T_1}, \tag{5}$$

where C_1 and C_2 are electric capacitances determined experimentally at T_1 and T_2 temperatures.

Configuration

EASZ-1 Monitor can be configured to measure different contents of water in oil. Measurement range can be set using HART protocol, by defining upper limit of the range [5]. After this setting, static characteristic of the device can be visualized and compared with an experimental one. The calibration of EASZ-1 includes a zero offset. This procedure involves the offset of the factory default ranges so that they are as close as possible to the experimental data for a certain oil or petroleum product. Figure 4 shows this philosophy.

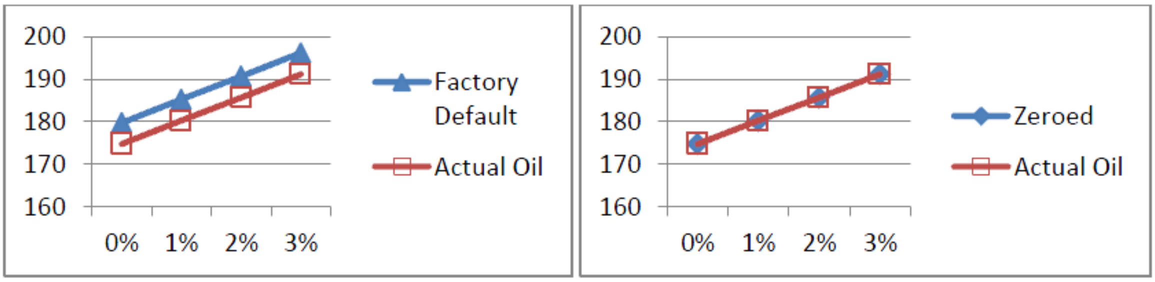


Fig. 4 Zero offset [5].

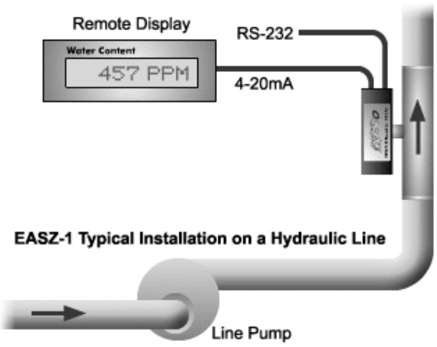
EASZ-1 Mounting

The mounting of EASZ-1 is dependent of the selected measurement range. There are three mounting solutions [4, 5]:

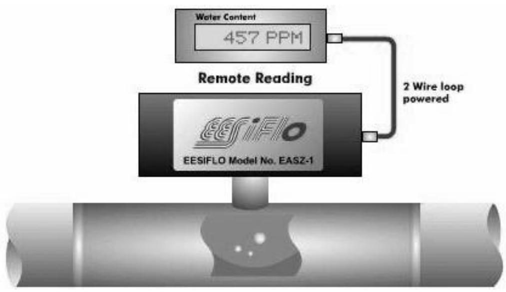
a) vertical position, with the flow going from down to up, recommended for measurement of fractions of percent of water in oil (ppm), Figure 5a;

b) horizontal position, as long as the pipe is always full, recommended for measurement of percentages of water in oil, Figure 5b;

c) horizontal position, as long as the mixture is homogenized using a mixer and the pipe is always full, recommended for measurement of higher percentages of water in oil, Figure 5c.



a



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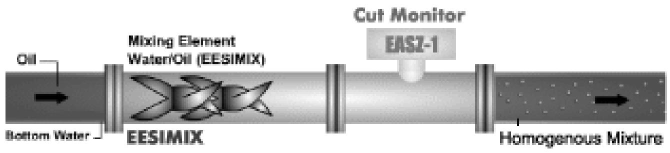

c

Fig. 5. Mounting possibilities: a – vertical position; b – horizontal position, measurement range - %; c – horizontal position, measurement range – tens of %.

Conclusions

This paper addressed a method to estimate the amount of water in oil, process related to two-phase separators in oil industry. The analyzed transducer was investigated in terms of its performance, its effects on the oil industry, and the restrictions of use. The analysis resulted in the following conclusions:

a) Due to the operating principle, the transducer can determine the water content in oil over a wide range, [0..100]%;

b) The transducer must be configured in close connection with the area of use;

c) The fluid through the transducer must have one phase. If this condition is not fulfilled, then it is mandatory the use of a mixer.

d) The flowrate of the flow through the transducer must have a small value, otherwise the flow is decomposed into two liquid phases (water and oil) and the measured value will be erroneous;

e) If the fluid is stationary in the pipeline for different periods of time, there is a separation of the two phases (water and oil) and the transducer cannot be used.

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Progrese în automatizarea separatoarelor bifazice

Rezumat

În lucrare sunt abordate probleme ale automatizare a separatoarelor bifazice utilizate în schelele petroliere. Autorii au analizat atât problematica separatoarelor bifazice cât şi a automatizării tradiţionale. În raport cu această ultimă variantă, autorii au studiat tendinţele şi progresele în domeniul automatizării separatoarelor bifazice. Astfel, pe lângă structurile clasice de reglare şi monitorizare sunt actuale şi sistemele de estimare a cantităţii de apă din ţiţei. Lucrarea analizează critic sistemele de măsurare a on-line cantităţii de apă din ţiţei. Traductorul investigat este EASZ-1, produs de firma EESIFLO. Sunt evaluate atât performanţele traductorului cât şi efectele utilizării acestuia în industria petrolieră.