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A Method for Automatic Measurement of Oil Flow Rate

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ABSTRACT

The article deals with a problem related to the oil industry, in particular to measuring equipment, and can be applied to centralized control systems measuring the flow rate of two-phase (oil and water) three-component output of a group of wells.

Keywords: oil well production rate measurement; oil fluid; oil density; oil flow rate; separator

INTRODUCTION

There is a method [1] for measuring the flow rate of oil wells implemented in the automated information system of oil field (AIS OF). A system of this type is designed for centralized control of the amount of fluid extracted from an oil formation over a given period of time and for measuring the current value of the flow rate for each well. Each well of this system is equipped with a pumpjack, a flow rate indicator (FRI) installed in the control unit (CU – 3) of the well, and a telemechanics system for transmitting data to the control station with further processing on a computer. The main functional units of the system of each well are the meter of active power consumed by the electric motor and the sensor gauging pressure developed by the electric drive of the downhole pump installed on the flowline of the well. The active power meter is a flow rate indicator that generates rate pulses in proportion to the measured power and transmits them to the CU. Determination (calculation) of the oil flow rate is carried out on the basis of the parameters obtained from the flow rate indicator and the pressure sensor using the developed computer software. This system makes it possible, by multiple comparison of the diagrams and characteristics obtained during operation with the nameplate data of the pumpjack, to determine the current value of the flow rate for each well and the formation flow rate for a given period of time and, if necessary, to stop or start the operation of the pumpjack.

The drawback of this method is that it, at best, indirectly repeats the operation of the system of remote control of downhole wells, which consists in taking diagrams. However, it is known that it is characteristic for all remote control systems, to one degree or another, that the diagram, even taken without distortion, does not give a complete picture of the well flow rate, i.e., of the main indicator of its performance. Therefore, correction factors have to be entered during each calculation. Another drawback of this method is a large error in measuring the well flow rate, which has to do with both not taking into account the gas factor and with a disproportional increase in the active power of the asynchronous electric motor of the pumpjack because of the asphalt and paraffin deposits on the rod string and the inner surface of the tubing.

There is a method [2] for measuring the flow rate of oil wells implemented in group measuring units such as AGM-3. The method involves measuring the level of the oil fluid in the separation measuring tank for a certain (given) time t3 using floats and a level sensor. The sensor converts the uniform movement of a magnetic indicator, which marks the water and oil levels by the position of special floats, into temporary current pulses. The obtained data are automatically recorded, and the flow rates of water and oil are calculated by one of the known algorithms, using laboratory data on the density of water and oil for each well. Well flow rate measurement is carried out by sequential (or out of sequence if necessary) cyclic connection of wells as preset. This method makes it possible to centrally control the two-component output of oil wells from the control unit.

The drawback of this method is that it allows calculating the flow rate for only two components, water and oil, does not take into account the amount of associated gas, and that the measurement process requires time for the settling of water, which increases the measurement time. Another drawback of the method is a large error in measuring the level of water and oil in the separation measuring tank. This error is caused by the level measuring system, which consists of two special floats and a level sensor. As a rule, a float placed on the water-oil interface becomes unable to reliably show the level of the water-oil interface over time due to asphalt, resin and paraffin oil components sticking to the float surface.

The known [3] method for automatic measurement of oil flow rate (and a device for its implementation) is the closest to the proposed method technically and in terms of the produced effect. The method includes measuring the formation water and the differential pressure between two points located in the lower part of the separator, the measured differential pressure is used to determine the moment of emptying the separator. The differential pressure created at the same heights between the piezometric columns of oil fluid and antifreeze placed in a special container is measured, and the oil and formation water flow rates are calculated from the stated formulas.

The drawback of this method is that it does not take into account the impact of the gas factor (GF) and the temperature of the extracted OF, because these parameters affect the values of oil density, and when the gas flow changes, the density of OF changes significantly.

The purpose of the article is to improve the accuracy and reliability of measuring the flow rate for a group of wells.

The essence of the article consists in a method for automatic measurement of oil flow rate, which involves measuring the pressure of a piezometric liquid column in the separator, the differential pressure between two points located in the lower part of the separator, the differential pressure created at equal heights between the piezometric columns of oil fluid and antifreeze placed in a special container and calculation of the oil and formation water flow rates; the temperature of the incoming oil fluid is measured, the gas factor is determine, and the flow rates of oil, formation water and oil fluid are calculated for each well from the formulas:

$$G_o = \frac{V_h \cdot 24}{\tau}(1 - W) \cdot \rho_o \cdot g$$

$$G_w = \frac{V_h \cdot 24}{\tau} \cdot W \cdot \rho_w \cdot g$$

$$G_{of} = G_o + G_w$$

$$\beta = G_g / G_{of}$$

$$W = \frac{\frac{\Delta P}{gh} - \rho_o - \beta\rho_g}{\rho_w - \rho_o - (\rho_w - \rho_o)\beta}$$

$$\rho_o = \rho_o^c(1 + \alpha(t - t_s))$$

where: $\rho_{o,}$ ρ_w, ρ_g are the density of oil, formation water and gas, respectively, g/cm^3
W is the content of water in the formation fluid (water cut), fractional;
G_{of}, G_o, G_w, G_g are the daily mass flow rate of oil fluid, oil, formation water and gas, t/day;
V_h, τ are the volume and the time of the filling of the separator to the level h, m^3
β is the gas factor, fractional;
t_s is the standard value of temperature (20^{0}C),
t is the current (measured) value of temperature, ^{0}C;
α is the coefficient A comparative analysis of the proposed method and the existing ones shows that the proposed method differs from the existing ones in measuring the temperature of the incoming flow of oil fluid, determining the gas factor and in the fact that the method is designed to calculate the flow rate not only for a single well, but for a group of wells.

The schematic of the device implementing the method is shown in Fig. 1. The device contains: 1 – pipeline, 2 – valve, 3 – measuring separator, 4 – pipeline, 5 – cylindrical vertical tank, 6 – common collector, 7 – control and display unit (CDU), 8 –actuator, 9 – differential pressure gauge, 10 – non-contact level switch, 11, 13, 22, 24 – separating vessels, 12 – sensor, 14 – sensor, 15, 25 – lines, 16, 17, 18 – valves, 19 – sensor, 20 – converter, 21 – differential pressure gauge, 23 – sensor.

The method is carried out as follows.

Through pipeline 1 through valve 2, oil fluid from the well containing formation water, oil and gas enters the measuring separator 3, where it is separated into gas and liquid phases.

At the same time, the timer is turned on, and the gas phase from the upper part of separator 3 through pipeline 4 enters the upper part of cylindrical vertical tank 5 and common collector 6, and the liquid phase accumulates in the separator.

Tank 5 is filled with antifreeze with a certain density ρ_w (ρ_w 〖>ρ〗_a), and the level of antifreeze in the tank is set equal to the height h. The moment the oil fluid enters separator 3 is recorded in control and display unit 7 (CDU). When the level of the oil fluid in the separator reaches the preset height h, then at the signal of the non-contact level switch 10, CDU 7 closes the access of the oil fluid through valve 2 of the filling line, and the clockwork is turned off. Then the differential pressure is measured between sensors 12 and 14 installed in the lower part of separator 3 and cylindrical vertical tank 5, the readings of which are transmitted through differential pressure gauge 9 to unit 7. Data on the density of water ρ_w, oil ρ_o and gas factor (β) are entered in unit 7 manually, and the mass flow rates of oil fluid, oil and formation water are determined from the calculation formulas.

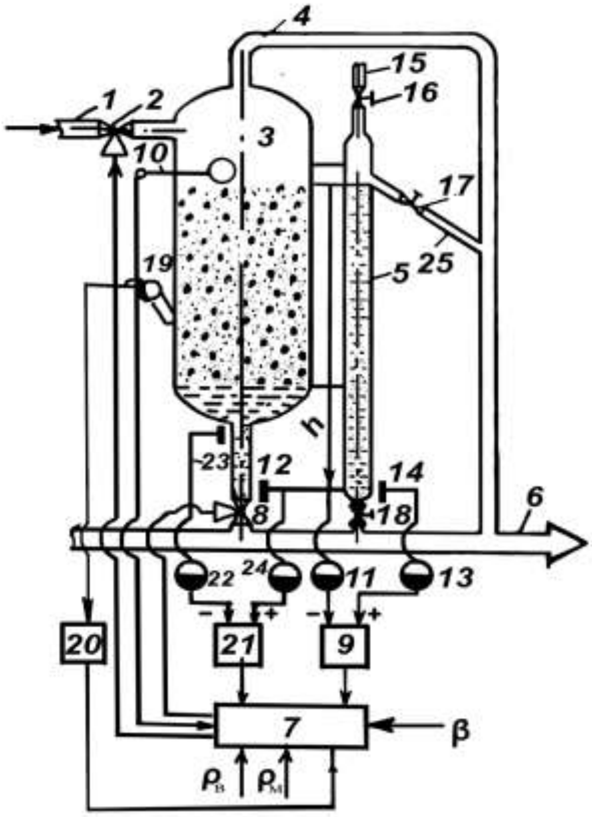

FIGURE 1: The schematic of the device

At the end of the calculation, on a signal from unit 7, the oil fluid is drained from separator 3 into common collector 6. The moment of the end of the discharge is determined from the information coming from differential pressure gauge 21 from sensor 23 located in the lower part of separator 3, at a certain distance above sensor 12. The temperature of the extracted oil fluid is measured by sensor 19 and converter 20. All obtained parameter values are loaded into the memory of unit 7, where the values of G_w G_o and G_of are calculated, which are also recorded in unit 7. Then, on a signal from unit 7, the emptying of the separator starts. The moment of the complete discharge of the oil fluid into collector 6 is determined by the signal received from the output of differential pressure gauge 21, and immediately, in accordance with the program in unit 7, the next well is connected to the measurement system.

Example

Input data:

$\rho\_o=0.86$ g/cm^3 ; $\rho\_w=1.060$ g/cm^3

$\Delta \rho\_{(13-11)}=0.177$ atm = 178000 dyne

h=2m; r=0.5 m ; $\beta=0.1$; $\rho\_2=1\cdot10^{-3}$ g/cm^3;

$V=\pi r^2= 3.14\cdot(0.5)^2\cdot2=1.57$ m^3; $\tau=1.62$ h.

$W= (\Delta\rho\_{(13-11)}/gh - \rho\_{o} - \beta\rho\_g)/(\rho\_w-\rho\_o-(\rho\_w-\rho\_o)\beta) = (177000/(980\cdot200) - 0.86-1\cdot10^{-3}\cdot0.1)/(1.06-0.86-0.2\cdot0.1) = 0.25$

$G\_o= (V\_o\cdot24)/\tau\,(1-W)\,\rho\_o\, g=(1.57\cdot24)/1.62\cdot0.75\cdot0.86=15$ t/day

$G\_w= (1.57\cdot24)/1.62\cdot0.25\cdot0.86=5$ t/day

$G\_{of} = G\_o+G\_w=15+5=20$ t/day

The technical effect of the proposed method consists in the accuracy and reliability of measuring the oil flow rate of a group of wells.

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