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Automation the Pathway to "Green" Oil-Production Technology

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Abstract

At present, oil production is characterized by the increased development of new deposits with poor reservoir properties. All of this is leading to the application of ESP units with low capacity and high head in oil production. At some oil-production enterprises, the number of wells equipped with low-capacity ESP units can account for more than half of the existing stock. Moreover, low-capacity ESP units provide for the bulk of oil production. The operation of such ESP units in oil production results in complications associated with the unit's parameters or the properties of high-pressure product water. To date, over twenty techniques have been developed for estimating the condition of product water, and measures have been taken to control the related complications. One of these measures involves reinforcement of the ESP unit's cable line and downhole motor. Increasing the thermal strength of the cable line being used as part of the ESP unit reduces the number of electrical failures (R-0) of the equipment. However, the operation of a centrifugal pump at high temperatures leads to salt deposition inside the pump's internal components. The theory and practice of salt deposition control, as developed by the author of this paper, is described in many works and monographs. It was a theoretically demonstrated that the operation of a low-capacity ESP unit is always accompanied by a temperature rise of the downhole motor and centrifugal pump. A downhole motor with a greater diameter than the centrifugal pump always participates in contact heat exchange with the production string; hence, its temperature is only slightly dependent on the properties of the pumped gas-liquid mixture. The centrifugal pump is the focus of the study of the ESP unit's thermal behavior. During the pumping of complex mixtures, the centrifugal pump is always impacted by high temperatures. The main point discussed in the aforementioned works deals with identifying the thermal behavior of a centrifugal pump as a function of formation-fluid properties and the parameters of the pump itself. The study of the pump's temperature as a function of the properties of the pumped gas-liquid mixture allows us to solve two major problems: 1) complications during the low-capacity ESP unit's operation; 2) automation of the centrifugal pump's control. ESP unit automation will open up the possibility of developing clean oil-production technology and a transition to "digital oil fields."

Keywords: ***Oil well operation with ESP units, Decline in well output, Growth of low-capacity wells, Centrifugal pump, Prediction of salt deposition, Control automation.***

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1. Oil production using electric centrifugal pumps (ESPs) is the most popular technique in the global oil industry. ESPs cover a wide capacity range, starting from 10 m^3/day. What's more, this technique is flexible and can be easily automated.
2. In recent years, developed reserves have started to become depleted, which is driving an increase in the number of wells equipped with low-capacity ESPs with a pumping pressure of over 2,000 m. The operation of a low-capacity ESP in the "left branch of the head and rate" leads to the loss of centrifugal pump efficiency. The share of energy applied to the pump is converted into thermal energy. Thermal release in a centrifugal pump causes its temperature to rise.
3. The thermodynamic condition of a pump, depending on the parameters of the pumped gas-liquid mixture and the ESP unit's specifications, are studied in the works [1-5] and described in the textbook [20]. It was shown that the temperature rise causes the "boiling of associated water" in the pump. The boiling of associated water is inherently accompanied by scale formation on the surface of the heat-flow source, i.e. on the surface of the ESP's working components.
4. The study of the ESP's thermal behavior as a function of the process parameters and the properties of the pumped fluid encapsulates the main problem associated with the operation of complicated well stocks equipped with low-capacity pumps. Very often, low-capacity ESPs run under conditions where the head generated by the ESP barely exceeds the hydrostatic pressure at the ESP level. In this case, the suction pressure is less than the saturation pressure, while the gas content in the liquid-gas mixture is such that the efficiency factor is minimal [3-7].
5. The approximate solution to the problem of the centrifugal pump's thermal behavior as a function of the process parameters (under conditions nearing pump starvation) is described in [7], and is written as:

$$\Delta T_w = T_w - T_f = \frac{\phi}{1-\phi}\frac{q_0 R_2 P_{нас} P_{пр}}{2(1-B)h\Gamma P_{ат}}\left\{\frac{1}{\alpha}+\frac{\delta_{из}}{\lambda_{из}}\right\} \qquad (1)$$

where T_w – temperature inside the pump housing, T_f – temperature of the liquid-gas mixture on the intake side, – radius of the pump's cylindrical housing (0.05 m), R_2 – bubble-point pressure (atm), $P_{нас}$ – reservoir gas-oil ratio (m^3/m^3), Γ – pump head (atm) with free gas h in the mixture (fraction), φ – thickness of gas bubbles on the pump surface (approx. 0.98 m), B – water content in the production stream, in fractions (less than 2), $\delta_{из}$ – gas blanket heat conductivity on the pump's housing surface (W/(m*K)), $\lambda_{из}$ – convection heat-transfer coefficient (W/(m^3*K)) in the labyrinths of the pump elements with respect to the liquid-gas mixture, α – heat-source power density per one running pump (W/m^3), q_0 – atmospheric pressure (atm). Investigations of the annular space between the ESP and the production string from the pump intake to the dynamic fluid level are described in the monograph [20]. It was shown that in the course of ESP startup and ramp-up, this space is gradually filled with oil [8-19].

6. If an ESP is running at a temperature far exceeding the formation fluid's temperature, the outer surface of the pump will always be covered with gas bubbles [5,6], whose heat conductivity is much less than that of oil or

water (let alone that of the metal pump housing). Therefore, the pump's temperature largely depends on the thermal properties of the gas bubbles covering its surface.

7. The study of the pump's thermodynamic condition leads us to the conclusion that the pump's temperature depends on the respective enterprise's operating practices and that it therefore must be controlled to ensure trouble-free operation. Fig. 1. shows the dependency of the pump's temperature on the pressure at its level under borehole conditions; let's call it the "suction pressure" (Psuc). The lower the suction pressure Psuc, the higher the pump temperature. Point C is the boiling point of associated water under pressure (Pboil). While moving left along the Psuc curve, a gradual temperature rise of the pump takes place. This process is reversible: while moving right along the Psuc curve, a gradual temperature drop of the pump takes place (e.g. along the Psuc2 curve). Thus, by regulating the pump's suction pressure, it is possible to avoid complications (salt deposition).

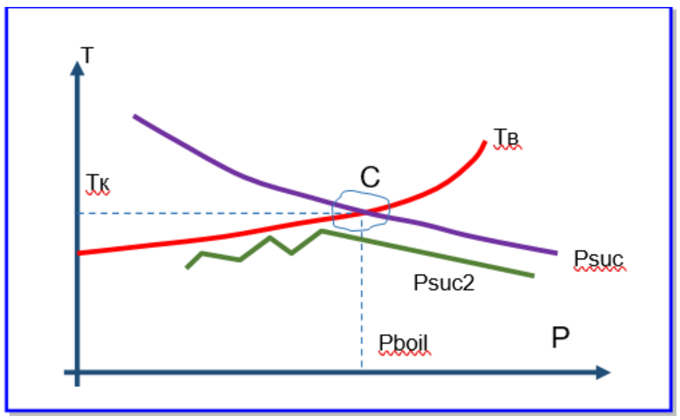

Fig. 1. Pump temperature vs. suction pressure (all other operating parameters remain unchanged). The curve area below Tв is the area of trouble-free operation.

8. By regulating the suction pressure Psuc of a centrifugal pump, the pump's temperature can be maintained within the areas below Tboil. The centrifugal pump's temperature, as shown in [20], can be controlled by adjusting the pump's shaft rotation speed or by running the ESP unit under special process conditions.
9. The ESP unit's operation must be fully automatic and controlled by the program downloaded to the control station. Similarly, other operating practices sought after during economic instability can be automated.

- Ultimate level of production

  This production condition of a well (deposit) can be easily achieved without additional financial investments.
- Limited level of production

  This production condition is achieved by launching the corresponding software on the centrifugal pump's control station and is maintained in a certain sequence (e.g. oil production step-down or step-up).
- Oil production with specified power consumption.

  This production condition is achieved with limited specific power consumption. This production condition can be implemented for the purposes of finding the optimal specific power consumption at the maximum level of production.

Thus, the study of the centrifugal pump's thermodynamics in oil production will allow for the full automation of the field development process.

10. The author invites ESP developers to participate in mutually-beneficial cooperation aimed at the design engineering and industrial use of automatic ESPs [20]. This operating technology will make it possible to reduce oil production costs and abandon the application of chemical methods for the control of salt deposition. At present, a Russian patent has been obtained; further patenting is in process in a number of developed world economies.

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Author Biography

Gareyev Adib was born on 1950**.** He received graduation degree from the Department of Physics and Mathematics with Bashkir state University in 1975. Currently, he is engaged in creating an automatic installation of a centrifugal pump in oil production and the problems of full automation of oil field development. His research interest include heat engineering. For the first time, he developed the thermodynamics of a centrifugal pump when pumping a liquid with free gas bubbles. He has also published monograph on modern problems of operation of electric centrifugal pumps in mining, a textbook for students.

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