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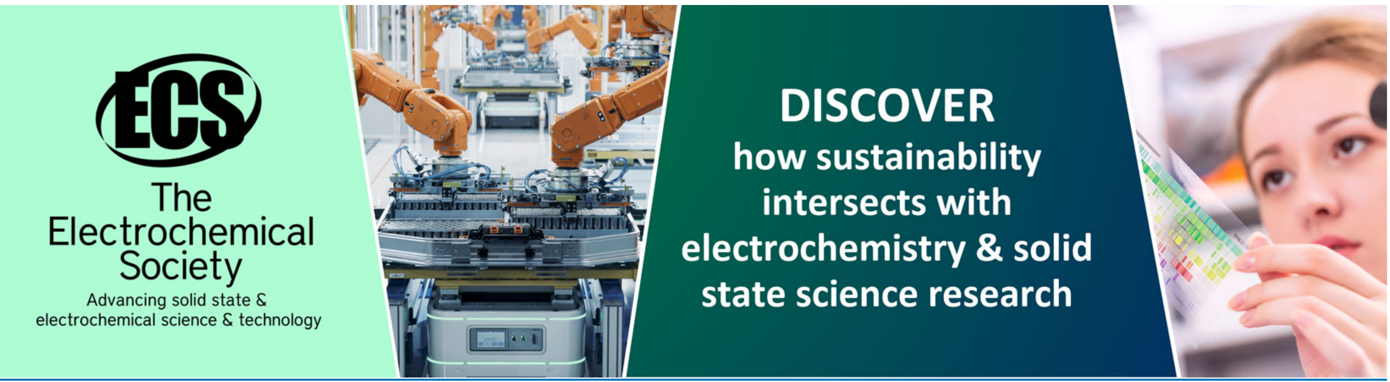

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Application of Linear Valve Submersible Electric Motors in Oil Production Units for Marginal Wells

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Abstract. In recent years, the share of marginal wells has been steadily increasing in the structure of the mechanized stock. But traditional types of artificial lift, such as sucker rod pumping units, have many disadvantages. Therefore, manufacturers of oil equipment are faced with the urgent tasks of creating innovative products that allow efficient production of fluid in wells with low flow rates. The article presents a diagram and components of the installation of an EP01 submersible electric plunger pump with a linear valve motor. A description of her work is given. The advantages of using the unit during the operation of marginal oil wells are shown.

1. Introduction

The total stock of operating oil wells in Russia has grown by about 18% over the past decade. The number of wells, resulting in products and installations are equipped with electrical submersible pumps (ESP), in 11 years increased by 55% and plants equipped with sucker-rod pumping (SRP) – decreased by 20% [1]. Currently, ESP installations extract about 81% of the total oil production to the surface [2].

In recent years, the share of low-yield wells in the structure of the mechanized Fund has been steadily increasing [3]. Constructive improvement of equipment, organizational solutions and search for alternative ESP equipment are suggested as solutions to increase the efficiency of operation of low-capacity wells with ESP.

According to various estimates, the stock of operating oil wells with a flow rate of less than 30 m^3/day is about 50% of the total well stock. To date, the main methods of mechanized oil production from low-capacity wells are: application of the SRP; use of small-flow ESP (up to 30 m^3/day); use of ESP in periodic mode; use of electric screw (ESP) and rod screw pumps (ESP).

For low-yield wells, the traditional and widespread type of mechanized oil production is USGS, which in the Russian Federation is equipped with a significant part of the existing Fund of oil wells.

This is due to the fact that the plunger pump used in SRP has a higher efficiency on a low-capacity Fund compared to other pumps. However, this type of equipment is sensitive to a number of complicating factors and has a number of disadvantages: high metal consumption; insufficient efficiency in inclined wells, as well as in the production of high-viscosity oil and high gas content; low inter-repair period, etc., which reduces the profitability of oil production from wells equipped with SRP.

The share of electricity costs in the cost of mechanized oil production is more than 50% [4], and according to statistics, this share is steadily growing. In addition, currently a significant number of wells

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are operated at the limit of production profitability, and many wells are idle for various reasons – unprofitability, inability to operate traditional production technologies, etc.

2. Technology relevance

The relevance of using innovative technological solutions that increase the energy efficiency of the process of mechanized production from low-yield wells is extremely high. Such technologies, in addition to increasing profitability, allow you to involve inactive and mothballed wells in economic turnover, which can give a significant economic effect for the industry.

Theoretically, for oil production from low-capacity wells, it is advisable to use plunger pumps, which in this case have a high efficiency. However, the use of plunger pumps as part of the SRP, in turn, is complicated by the fact that the drive to the plunger pump is located on the surface.

Therefore, manufacturers of oil equipment are faced with the urgent task of creating innovative products that allow efficient production of liquid in wells with a small flow rate.

3. Application of LVPSEM in the installation

In the 70-80-ies of the last century in the Soviet Union, research and development aimed at improving the effectiveness of SRP. One of the directions was the idea of replacing the ground engine of the installation together with the rod system with a Rodless submersible linear asynchronous motor (LAM) in combination with a plunger pump. The gain in efficiency was supposed to be obtained by eliminating intermediate drives of various types (for example, rod drives) and the associated friction losses, etc. The main development took place at the Institute PermNIPIneft (Perm), Special design Bureau of the linear motor (Kyiv), Institute of electrodynamics Ukrainian Academy of Sciences (Kiev) and Special design Bureau of magnetic hydrodynamics (Riga).

Despite the large number of developed technical solutions, these installations have not received practical application due to the low specific and energy indicators of LAM. Research in this direction in the Soviet Union was curtailed. However, development of submersible electric plunger pumps continued in other countries.

In the mid-2000s, Chinese developers introduced the installation [5], which managed to combine the advantages of an energy-efficient plunger pump and a submersible linear valve motor with permanent magnets.

Installations under the patent [5] are currently produced and used in oil fields in the people's Republic of China and are also offered at a high price to Russian oil companies. The high price is one of the main, but not the only, drawbacks of these installations. In [6], data on the use of Chinese electric plunger installations at the Talinskoye field of JSC «rn-Nyaganneftegaz» are published. It is reported that the official representative of the Chinese company «Hailu» LLC «it Center» provided Rosneft with two sets of plunger pump with a submersible linear motor for testing. These tests showed that, despite the reduction in energy consumption, the use of Chinese electric plunger installations has, in addition to the high price, the following disadvantages and limitations:

– there is no Assembly, as well as service bases that carry out repair / maintenance of equipment on the territory of the Russian Federation (production is in China; deliveries are made only by a sales representative);

– the design of the linear motor does not provide for its current repair;

– there is no unified highly reliable connection with the construction length of the cable (a 70 cm long cable segment is removed from the engine, then it is spliced with the construction length of the cable line at the wellhead);

– the linear drive control station is not a digital device, but an analog one: the operating parameters of the pump – motor system is monitored by analyzing current changes;

– there is no submersible telemetry, pressure and temperature measurements at the entrance to the submersible pump unit, exits to the telemechanics system are not provided.

Russian researchers and manufacturers have recently developed various options for installing submersible electric plunger pumps [7 – 11].

Russian enterprises that currently produce their own submersible linear valve motors for driving plunger pumps are Russian standards of mechanical engineering LLC (Rustmash LLC), part Of TRIOL Corporation, and Center it LLC (Perm).

In recent years, Rustmash LLC has created its own production of submersible electric plunger pumps EP01 based on the implementation of the patent [12] and a few subsequent patents obtained subsequently (Figure 1).

The scheme and components of the EP01 shown in Figure 3.

The installation kit includes:

– linear valve submersible electric motor (LVPSEM);
– submersible deep-water pump (WP);
– control station (CS);
– telemetry system;
– a set of tools and spare accessories.

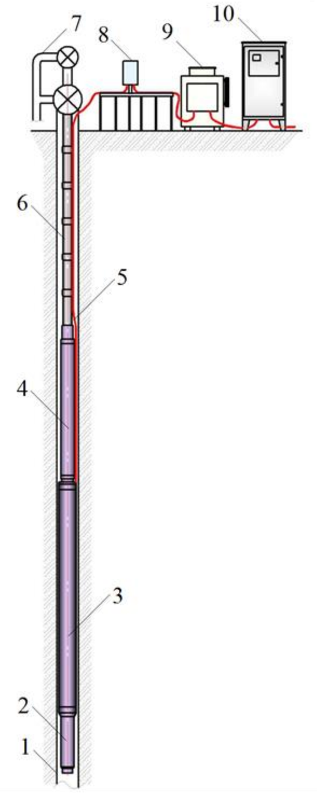

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Figure 1. EP01 diagram in the well: 1 – well, 2 – submersible telemetry (CT), 3 – linear valve submersible electric motor (LVPSEM), 4 – submersible deep water pump (WP), 5 – cable, 6 pump and compressor pipes (tubing), 7 – wellhead fittings, 8 – terminal box, 9 – transformer, 10 – control station (CS).

At the customer's request, the additional delivery package may include:

– transformer oil Submersible pumps sealed;
– cable, as well as other additional components (valves, sludge collectors, etc.).

The Submersible pump is equipped with a built-in gravity gas separator.

The cable is attached to the WP and tubing with metal belts or cable protectors, selected depending on the tubing diameter, overall dimensions of the cable and the internal diameter of the production string of the well in which the equipment is installed.

Ground equipment –converts the AC voltage industrial network to the value that encasers an optimal input voltage of LVPSEM taking into account the voltage drops in the cable that provides control of a Submersible installation and protection in emergency modes.

The installation works as follows.

The LVPSEM is powered via a cable. The linear valve Submersible electric motor is structurally a valve motor deployed in length. The movable part of the linear motor LVPSEM (hereinafter – slider) performs reciprocating movements with the frequency and speed set on the controller CS operator. The motor slider consists of magnets and magnetic field concentrators fixed on a non-magnetic axis, which encaser the concentration and direction of the magnetic flux. The slider moves inside the housing due to the magnetic force generated by the stator coils.

The ground control unit supplies three-phase alternating power to the submersible linear motor, creating a traveling magnetic field in the stator, ensuring smooth reciprocating motion of the slider.

The WP plunger pump is a downhole rod pump (according to GOST 51896 or API Spec 11 AX) installed in a special housing for connection to the LVPSEMD. The slider is connected through the rod to the plunger pump and provides reciprocating movements of the plunger.

The plunger pump, by means of reciprocating movement of the plunger, extracts borehole fluid from the wellbore through suction valves, a gravity gas separator, and pushes the reservoir fluid through the discharge valves into the tubing string.

The LVPSEM has a built-in telemetry system. The ground unit in the control station receives data from the telemetry unit (values of pressure parameters, downhole fluid temperature, engine oil temperature, vibration), providing control of the inflow in the well and the temperature regime of the submerged part, changes the operating mode of the submerged engine, maintaining the required flow rate.

The components of LVPSEM are shown in Figure 2, and WP – in Figure 3.

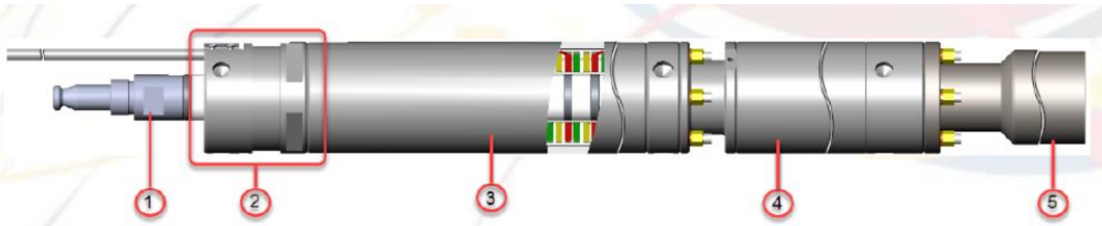

Figure 2. Components of a linear valve submersible electric motor: 1 – slider, 2 – cable gland, 3 – stator, 4 – hydraulic compensator, 5 – submersible telemetry unit.

The plunger depth pump is a volumetric hydraulic machine for pumping water-oil-gas mixture from the bottom of the well to the surface. The liquid supply is carried out by reciprocating the plunger in the cylinder without idling the moving part and can be operated in horizontal wells. Pumps can be either single-pass (for very small flow rates) or two-pass (for slightly higher flow rates).

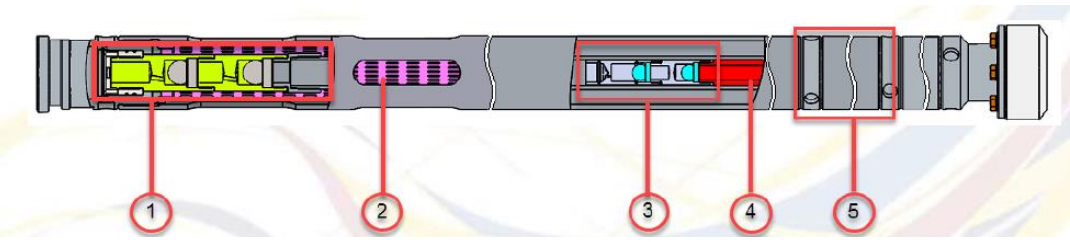

Figure 3. Components of a submersible submersible pump: 1 – pump flow line, 2 – inlet filter, 3 – valve assembly, 4 – pumping plunger, 5 – damper.

4. The results of research

In the period from 2017 to 2019, pilot tests of experimental EP01 samples were conducted in eight wells of several Russian oil fields. The operating conditions in these wells were different. The depth of descent of the units ranged from 1220 to 2484 m, the pressure at the pump intake during the operation of the EP01 – from 1,2 to 3 MPa. The highest achieved current time to failure as of 15.07.20 g. – 1092 days, while the installation of EP01 is in operation. Comparison of operation parameters by specific power consumption and well debits before and after the use of EP01 is shown in Figure 4 and 5 it is Clearly seen that the introduction of EP01 allowed to reduce energy consumption and increase oil production.

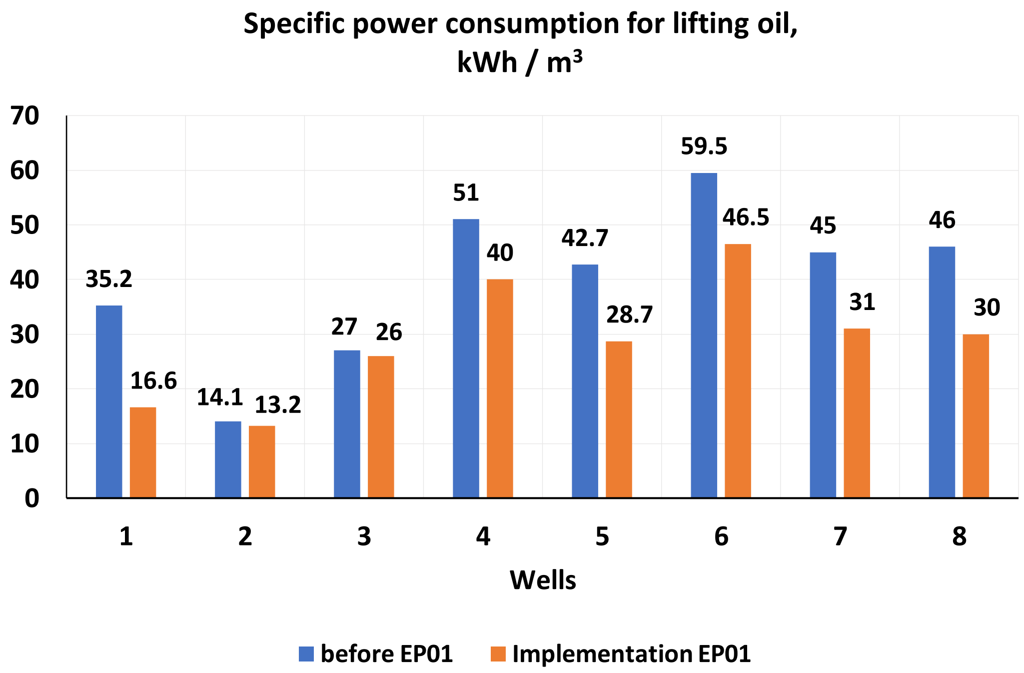

Figure 4. A comparison of the values of the specific energy consumption for lifting oil wells.

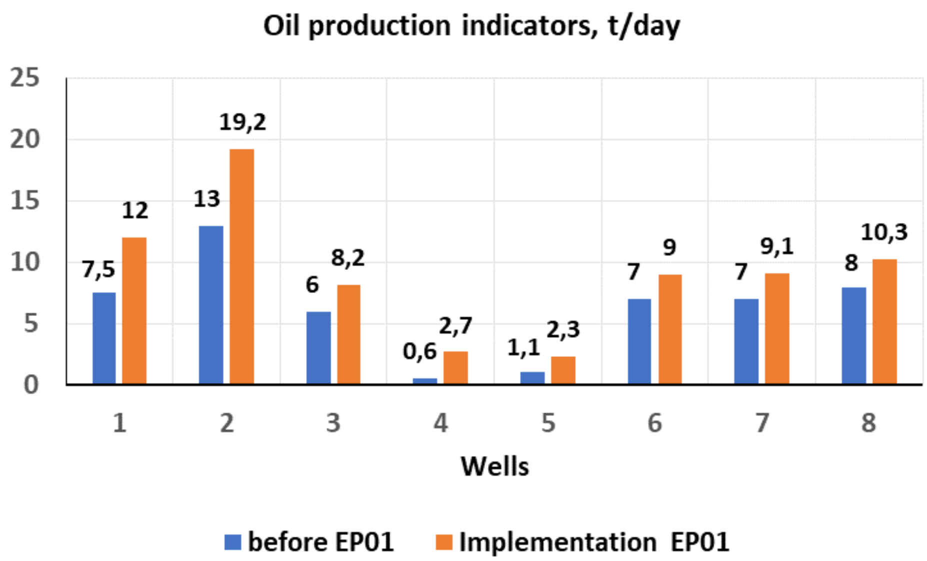

Figure 5. Comparison of flow rates on the oil before and after the implementation of ESP in wells.

5. Conclusions
In conclusion, it should be noted that there are significant reserves in the field of improving the installations of Submersible electric plunger pumps for the operation of low-flow oil wells in complicated conditions, the main ones according to [13] are: increased content of free gas and mechanical impurities in the pumped products, as well as high viscosity of the extracted liquid.

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