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Creation of the installation for studying the impact of current pulse excitation on the bottomhole formation zone

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Abstract: The article describes the laboratory research installation for studying the effect of plasma impulse excitation on the bottomhole formation zone with the aim of increasing oil recovery. The results of studies carried out using this installation form the basis of the author's dissertation paper. This installation allows conducting studies on the impact on the core of short-time pulses, including plasma-type ones, to assess the feasibility of its field use for bottomhole treatment.

1. Introduction

At present, there is a need to apply non-standard methods of stimulating the reservoir in order to increase oil and gas recovery which are based on increased controllability, energy efficiency, energy conservation and environmental friendliness, both in the late stages of field development and in the early stages with physically challenged hard-to-recover reserves. A controlled physical impact on filtration processes, for reserves categorised as hard-to-recover, can address the affected areas with residual reserves.

2. Research

Plasma impulse excitation (PIE) is one of the methods of intensifying oil production based on the use of resonant properties of the formation. The essence of this method is that when a specially created electric discharge is formed inside the volume of the fluid around its formation zone, ultrahigh hydraulic pressures occur that can perform useful mechanical work and are accompanied by a complex of physical and chemical phenomena [8,9] (7, 14).

The technology is based on an increase in the hydraulic and hydrodynamic effects and the amplitude of the shock action during a pulsed electric discharge in a conducting liquid [1].

At the same time, the following processes occur in the formation:

- heating of the near-well zone;
- acceleration (up to 1000 times) of gravity aggregation of oil and gas;
- increase in the relative phase permeabilities for oil to a greater extent than for water;
- increase in speed and completeness of capillary displacement of oil and water:
- emergence of seismoacoustic emission in reservoir rocks accompanied by the formation of microcracks;
- change in the stressed state of reservoir rocks and a related change in the structure of the pore space (dilatancy).

High-voltage current passes through the spark gap electrodes into the working interval inside the well. An electric arc characterized by a high degree of decomposition of the molecules leads to the formation of an instantaneous increase in temperature. Due to this, within a few microseconds, high pressure develops. An instantaneous shock wave with a speed above the speed of sound is transmitted to the surrounding fluid in the well, which leads to the formation of a compression shock wave.

On average, the energy is small, but due to an extremely short discharge time, the maximum energy reaches 20 MW. Instantaneous expansion creates a shock wave, and subsequent cooling and compression cause backflow into the well through the perforations in the casing, which at the initial stage of the well treatment facilitates the removal of colmatizing substances into the wellbore.

When the plasma impulse excitation is applied, the permeability of the bottomhole zone increases, the connectivity of the oil formation with the bottomhole is increased by clearing old filtration channels and creating new ones, the pore space is cleared and new microcracks in the bottomhole zone of the well and the filtration channels of the formation are formed.

During the impact, a shock wave occurs which, passing through the perforations into the zone of penetration into the elastic medium, causes its movement, rapidly damps, becoming a series of successive oscillations propagating at the speed of elastic waves.

3. Results and discussion

In order to study the impact of a pulsed electric discharge on the bottomhole formation zone, on the basis of the Industrial University of Tyumen (IUT), a laboratory research installation for pulsed discharge of electric current is being assembled and improved. Figure 1 shows the installation diagram.

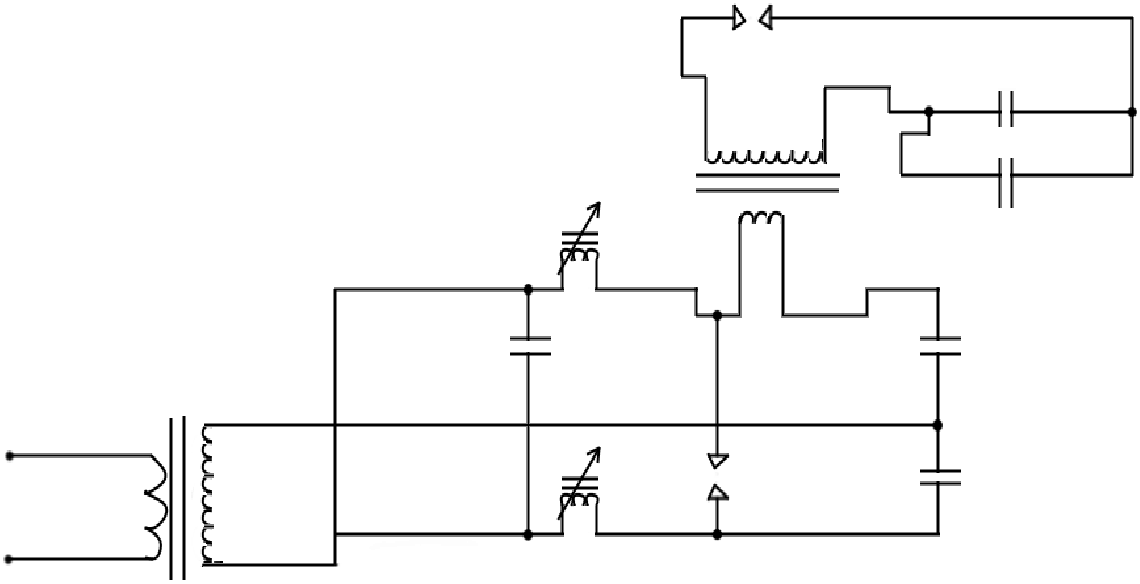

Figure 1. Installation diagram.

The principle of the installation operation: the voltage supplied to the step-up transformer is regulated by a laboratory autotransformer (LATR). After increasing the voltage, the current moves to the converter of electrical energy (conversion of the input electric current of an alternating direction into a unidirectional current) and then to n, near which the spark gap (SG) is located. The main purpose of the SG is overvoltage control. In the case when a certain voltage is reached at the electrodes, the conductivity of the SG increases sharply, and the electric breakdown occurring in it leads to a decrease in the voltage, preventing damage to the electrical equipment. When the energy in

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the capacitors accumulates to the desired value, it moves to the second step-up transformer, then to the high-capacity storage capacitors. When the voltage in the capacitors rises to a predetermined value, at which the breakdown and all the energy stored in the capacitor immediately flows to the working interval in the liquid (discharge, in the hydrodynamic part), where it is released as a short electric pulse of high power. The impact is carried out on rock samples located in the hydrodynamic part of the installation. This procedure is repeated a predetermined number of times. The effect is shown in Figures 2-3. [5-7, 10-14]

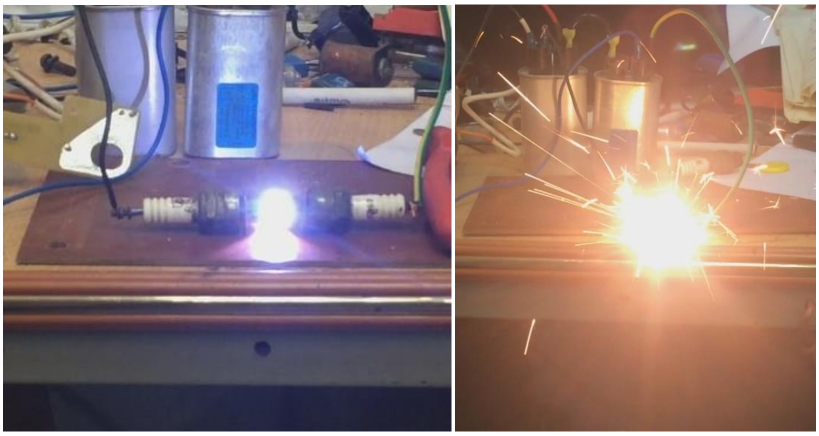

Figure 2. Effect of the installation.

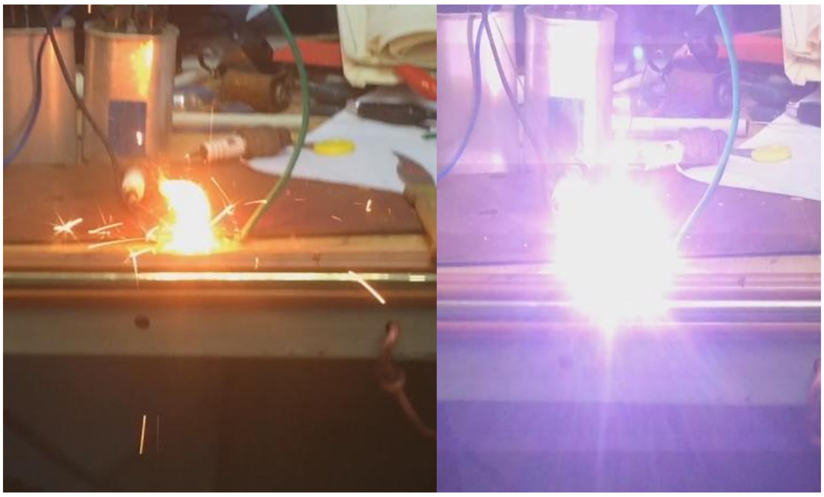

Figure 3. Effect of the installation.

The hydrodynamic part of the installation consists of metal pipes with a wall thickness of 8-10 mm, capable of withstanding the high pressure produced during a pulsed current discharge. The diagram of the hydrodynamic part is shown in Figure 4.

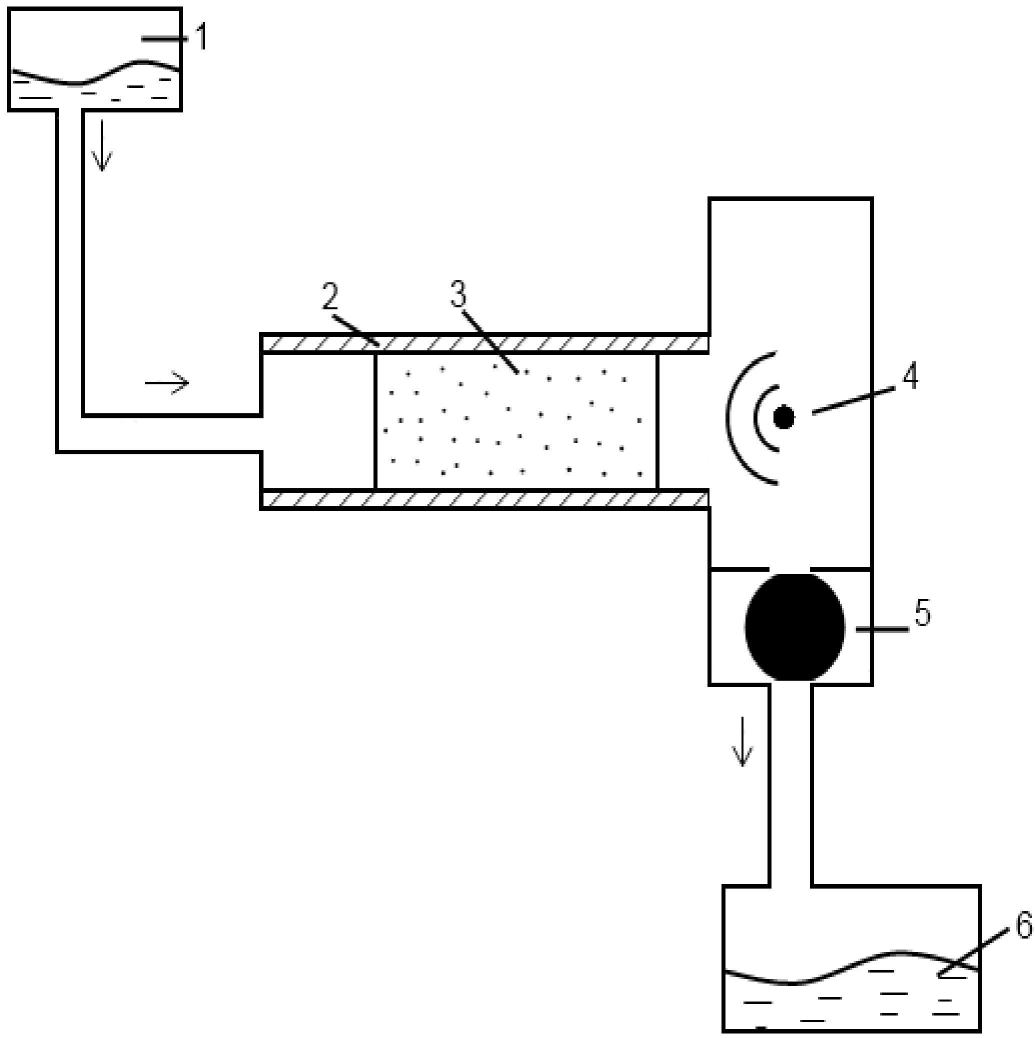

Figure 4. Diagram of the hydrodynamic part of the installation.

The operating principle of the hydrodynamic part of the installation: water enters from the vessel (1) into the compartment with the rock sample (3), then into the chamber, where the pulsed discharge (4) occurs and further into the vessel (6). Samples of rock are preliminarily fixed in the compartment (2) near the chamber of pulsed current discharges. This pulse-discharge chamber can be divided into two compartments. The first compartment is designed to discharge the voltage, instantly arriving at the working interval in the liquid, where it is released as a short electric pulse of high power, affecting the sample. The second compartment serves as a valve (5). At the time of the electric pulse, pressure is generated which acts on the valve closing it, thereby preventing the energy from moving further into the vessel. At the end of the action, pressure in the discharge chamber drops, allowing the valve to open, after which the liquid continues its movement to the vessel (6).

The process of controlling the voltage of the installation is based on pulse width modulation (PWM), by changing the pulse relative duration at a constant frequency. In PWM, transistors are used as key elements (other semiconductor devices can also be used) not in a linear but in a key mode, that is, the transistor is either all the time open (disengaged) or closed (in a saturation state). In the first case, the transistor has almost infinite resistance, so the current in the circuit is very small, and although all the supply voltage drops in the transistor, the power released in the transistor is practically zero. In the second case, the resistance of the transistor is extremely small, and, therefore, the voltage drop in it is close to zero - the power released is also small. In transition states (the transition of a key from a conducting state to a nonconducting state and vice versa), the power released in the key is significant, but since the duration of transition states is extremely small, with respect to the modulation period, the average loss power for switching is negligible.

Figure 5 exemplifies one of the two-level PWM methods using an analogue comparator. To one of the inputs of the comparator a sawtooth voltage is delivered from the auxiliary generator, and to the other input - a modulating voltage. The output state of the comparator is PW-modulation. [2,3,4].

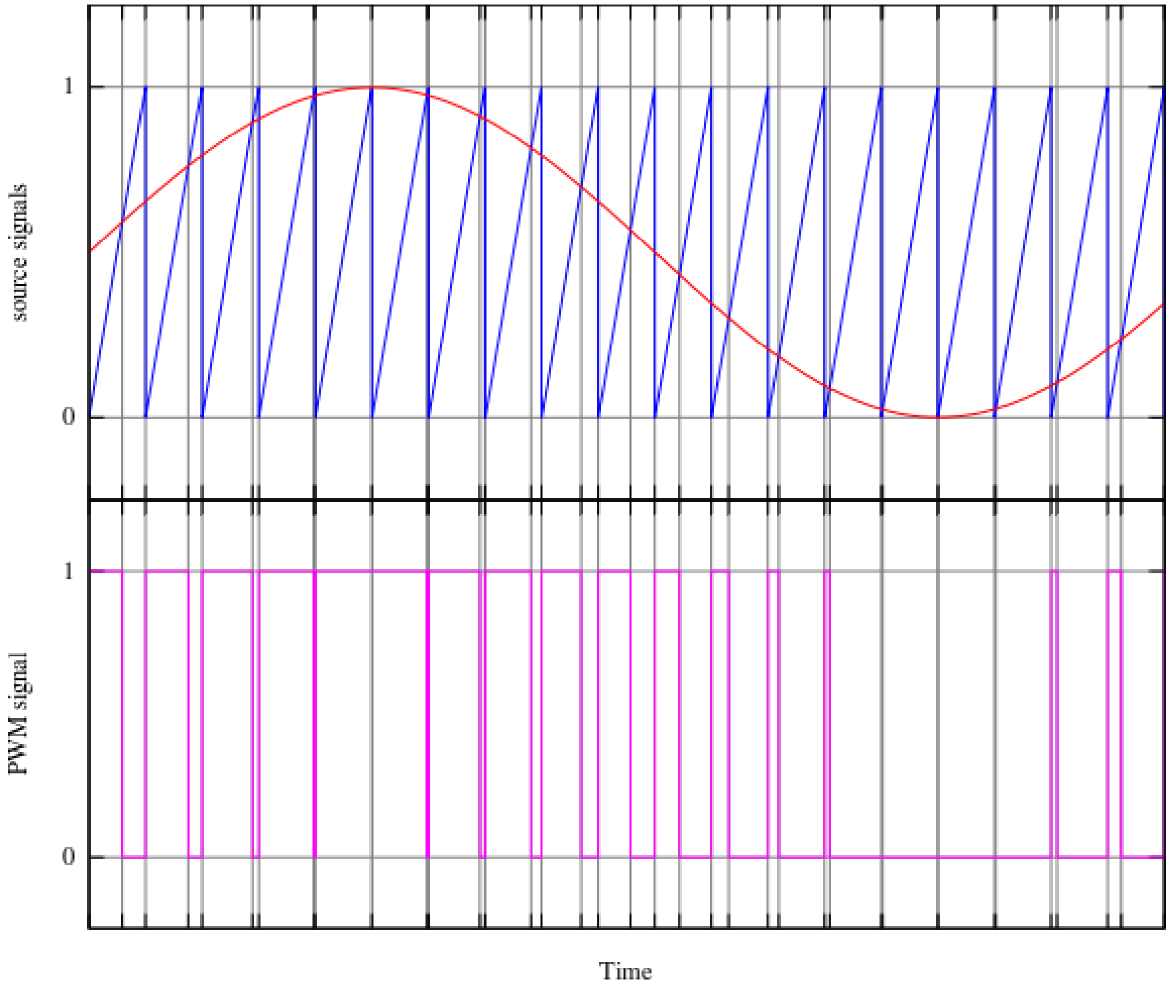

Figure 5. Above - a sawtooth signal and a modulating voltage, below - a PWM result.

4. Conclusion

Currently, the above-described method of stimulating the oil and gas bearing strata is poorly understood, represents a great prospect and requires further study in this area.

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