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Environmental trends in fracturing technologies

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Abstract. The development of heavy oil fields has been actively on the agenda. The problem arises due to the depletion of deposits with easily recoverable reserves, as well as due to the large reserves of shale oil and gas. Modern technology is gradually reaching an acceptable level of profitability. Many tasks remain to reduce environmental pressure on the environment. An important step in this direction was made with the introduction of electric fracturing technology. Technologies for isolating the mining zone are being developed. A variety of approaches are used to recover heavy oil. Use formation heating in various ways. Separate formation fluids into fractions in order to diversify recovery methods. Great prospects are opened using combined methods of exposure to kerogen. At the same time, many questions remain on methods for the further development of shale hydrocarbons. This is the development of norms and rules for the development of heavy oil. Coordination of actions of law-enforcement bodies and activity of technology developers is required. It is necessary to develop technological approaches that have shown their environmental effectiveness.

1. Introduction

There is a lot of controversy in the world community regarding the pros and cons of developing shale deposits. Proponents of shale gas production speak of positive factors. Indicate the possibility of shale gas production in populated areas in close proximity to the final consumer. On the other hand, opponents of the development of shale deposits cite a number of negative and significant factors. Shale gas production is unprofitable, deposits are characterized by rapid exhaustion and a decrease in initial production rates. And the most significant disadvantage is environmental risks in the process of development and production of shale gas.

The main method of shale gas production is hydraulic fracturing or the so-called fracking. This technology involves the drilling of vertical and a series of horizontal wells with a length of 2 to 4.5 kilometers. After that, a special mixture of water, sand (or a special proppant) and chemicals is fed into the finished network of wells under high pressure. Under high pressure of the injected solution, cracks form in the shale rock and existing ones expand, releasing shale gas. Sand (proppant) and chemicals do not allow the pores to close, and thus, the permeability coefficient of shale rocks increases.

The resource of oil sands, super heavy oil and oil shale is many times greater than the reserves of traditional oil [1-6]. In the last decade, the volume of production of this type of oil has been increasing in the world. This was the result of rising oil prices at the beginning of the century. The development of technology has reduced costs. Oil importing countries seek to reduce their energy dependence on exporting countries.

Shale oil and low permeability oil (Tight (Light Tight) Oil) have attracted industry attention due to the decline in traditional oil inflows. The depletion of fields in Western Siberia generates interest in heavy oil development technologies.

Over time, the extremely high resource intensity of shale deposits and the low level of their environmental efficiency have formed a number of environmental restrictions. They held back (and some still hold back) the growth of oil shale production.

Today, the development of shale oil is associated with a huge amount of water consumption. Water is evaporated from the rock, evaporated in cooling systems, and is used for fracturing. From a technological point of view, water is the main obstacle to increasing the production of shale oil. About one hundred tons of chemicals are used for each hydraulic fracturing operation. Chemicals used in hydraulic fracturing get into drinking water. The use of contaminated water leads to the development of a number of diseases in people living nearby. An important aspect of the environmental impact of shale oil is the high energy intensity of the extraction process. The systems of constant circulation of the coolant and the use of own reserves of the fields made it possible to increase energy efficiency indicators.

A reduction in well production involves repeating up to five times a year in each section of the developed gas-shale field of fracking operations. In a number of fields, a drop in well productivity by 70-80% was recorded in 2-3 years. The territory in the areas of shale gas deposits is turning into a desert filled with highly toxic waste. It will take several decades for such territories to become habitable.

To date, the United States is the world leader in shale gas production. However, already today in some US states there are environmental problems, gradually acquiring disaster status. In soils and drinking water in the areas of shale development, a methane concentration of ten times higher than the norm was found. According to some reports, medical institutions show an increase in chemical poisoning. The number of oncological diseases has increased significantly in areas directly adjacent to the shale gas production zone.

During fracking operations, the mixture pumped under high pressure causes destructive processes in the soil itself. This leads to seismic instability and earthquakes. The number of people dissatisfied among the population in countries that are actively developing new deposits is growing.

2. Fracturing using electrical impulses.

To increase the productivity of low permeability formations, hydraulic fracturing is used [7]. Cracks resulting from fracturing are held open using calibrated sand. Formation fracture forms a significant surface for hydrocarbon migration through the formation of initially low permeability. Improvement of fracturing technology is ongoing. Hydraulic fractures (cracks) increase the stress state of the reservoir due to compression of the reservoir. Compression occurs by the amount necessary to form the volume of the crack. This increased stress in the formation leads to a decrease in its permeability. Hydraulic fracturing can be a significant part of the cost of drilling and completion operations. Large volumes of water are pumped into the formation and subsequently removed from the formation.

Electrical destruction of the rock is described in [8]. Electric plasma arcs are considered as a means to remove rocks in order to develop thin veins of gold ore.

The placement of electrodes in hydraulic fractures is considered in development [9]. In this patent, electrical voltage is applied across the fracture in order to heat the formation for pyrolysis of kerogen inside the formation.

In [7], a method for producing hydrocarbons from a formation using an electric discharge is proposed. Therefore, a lower environmental burden is achieved. The installation of a pair of electrodes in the reservoir is the technical basis of the method. Between pairs of electrodes serves pulses of various voltages. The potential difference between the electrodes is ten or more kilovolts. The initial permeability of the formation is less than 10 mD. The voltage is applied in several pulses. The pulse duration is less than 500 nsec. Electrodes are located at a distance of 10m to 300m from each other. Permeability is provided by removing the mass, which also provides a decrease in stress in the reservoir. This method may be useful for productive formations with low initial permeability, (0,00001mD - 10,0mD).

High voltage pulses can cause plasma discharges, which can travel along random paths between the electrodes. Electrodes can be formed by placing electrically conductive proppants in hydraulic fractures. This approach provides electrodes of a large area. Alternating cracks (gaps) extending from the horizontal shaft can be filled with oppositely charged electrodes. Then, mass can be removed from the formation between the two electrodes.

The problem of seismic instability remains. The fracturing procedure destroys the structure of shale rock near a productive well over an area of several square kilometers. Vertical damage extends to several tens of meters. Differential pressures lead to the appearance of numerous seismic low-magnetic phenomena. The number of these microseismic phenomena can be several hundred per year. Their value varies from 1.5 to 3.6 points on the Richter scale.

It is necessary to remember the risks of the spread of destructive processes to other layers other than shale. In places of hydroblows dips can form. There is currently no documented evidence of the effect of fracking operations on seismic activity. However, data on an increase in the number of low-magnitude fluctuations in shale gas production regions indicate the opposite.

3. Environmental trends of modern technology

With thermal mining methods, the rock is heated to a high temperature. Obtained by distillation, the liquid is separated for further processing.

Or, using injection wells, they increase the permeability of the reservoir and push the mixture to the surface, similar to traditional oil, which does not require any additional processing [10, 11].

In general, the process of oil production from shale can be carried out by two methods. Processing of oil shale is carried out on the surface (surface retorting - external retorting). The second method is called in-situ retorting (in-situ within the reservoir).

Surface retorting is divided into three main types:

- Indirect retorting involves pyrolysis of oil shale by heating. Natural gas is used as a heat carrier. The coolant circulates through the marginal space of the retort and heats the shale in the retort.
- Direct retorting, when natural gas is pumped directly into the retort and heats the shale shredded there.
- Mixed (combined) retorting combines both of these methods.

The technology of thermal distillation of solid hydrocarbons is described in [12]. Evaporation, thermal decomposition of oil shale, combustion, processing and cooling are carried out in one multi-chamber rotating horizontal retort.

The process inside Shell ICP reservoir retorting is based on the gradual heating of isolated shale formations over a long period of time (2-4 years). Submersible electric heaters are used. Due to the relatively low thermal conductivity of the shale and the alignment of the “freezing walls” around the heated circuit, it is possible to uniformly heat all the shale formations to a temperature of 200 ° C.

“Freezing Walls” is Shell's unique technology. It allowed the company to solve the problem of groundwater pollution during in-situ production of shale oil. “Freezing walls” are created through injection wells. Aqueous ammonia is supplied through them as a refrigerant. Wells forming “freezing walls” are drilled around the production zone. Freeze the rock and groundwater at a temperature of -42 ° C throughout the entire production cycle.

The field development process under the ICP project was built in several stages. At the first stage, the field is prepared for production. Then “freezing walls” are installed along the contour. After installing the “freezing walls”, production wells are drilled. However, first water flows through them. The layer is dehydrated to the maximum [12,13]. Then separate “heating wells” are drilled. In their depth are placed heat pumps. From the moment the pumps are immersed until the start of production, as a rule, 2-4 years pass. By heating the shale formations to a temperature of 200 ° C, in situ distillation of oil begins. Light hydrocarbons (usually diesel or jet fuel) are injected into the injection wells. This allows you to separate light fractions from heavy ones. A mixture of low boiling hydrocarbons (unstable gas condensate and associated petroleum gases) is supplied to the mouth of production wells.

The Chevron in-situ process involves in-situ production [13]. Heated natural gas is pumped into the reservoir under high pressure. Due to this heat, partial fractionation of kerogen in the formation occurs. A significant number of wells are drilled around the production circuit for pumping water out of the formation. This solves the problem of soil water. Limit their entry into the production zone. Heated gas fracturing is used as the main production technology. Energy efficiency is achieved through recirculation of air through waste formations under high pressure. Air acts as a coolant. Heated air in the waste seams due to the combustion of heavy hydrocarbon residues. Heated air enters new production strata through injection wells. The decay of kerogen is stimulated by the high temperature of the coolant. The mining zone is significantly damaged. The process is characterized by significant CO2 emissions and significant volumes of evaporated water. The oil yield during production by this method is more than 90%. The technology is being tested at the Green River Formation (USA).

The ExxonMobil Electofrac process is based on electrolysis methods of stimulating the formation [14]. Wells are filled with an electrically conductive fluid. The formation itself acts as a resistive element of the circuit and heats up under the influence of electricity. The reservoir becomes a coolant during in-situ retorting of the kerogen contained in it. After heating, oil is extracted by traditional wells. The process is being tested in Colorado.

AMSO EGL technology provides an example of indirect retorting within a formation [15]. It is built on a closed heating pipe system. Pipes are located in the depth of the reservoir in the maximum proximity to the shale deposits. As heat carriers, various liquid fluids based on oil or water heated in a boiler can be used. The shale oil contained in the formation is heated by heat from the circuit, liquefied, and begins to flow into the network of production wells. High temperature is provided throughout the formation. As a result of thermal decomposition of oil shale, gases are formed. Exhaust gases enter the boiler and serve as raw materials for heating the coolant.

4. Conclusion

The significance of the development of the largest gas-helium deposits in Eastern Siberia stems from the understanding that helium is a passing product, and not the target product of their development. For the initial stages of development, before the creation of the appropriate infrastructure, it is necessary to provide for the reverse injection of helium-bearing gas into gas-producing strata. These measures will preserve helium reserves and support reservoir pressure in the oil part of the reservoir.

In almost all countries where there is the potential for the start of commercial shale gas production, environmental commissions have been created to consider possible environmental disasters from the development of shale deposits. Of great importance for the development of shale gas production are the conclusions of the Environmental Protection Agency (EPA) of the United States. The agency is studying the environmental impact of shale gas production technology.

To prevent the drill from being jammed by rock pressure, drilling fluids use flushing fluids containing a number of environmental pollutants. It is likely that as shale gas production expands, the components of the flushing fluids will fall into water horizons, and then into the food chain.

The only way out of these problems is to develop technologies that minimize harmful effects on nature. And such technologies are emerging, even among hydraulic fracturing techniques.

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