Cluster Pumping Station with Autonomous Power Supply and a System of Thermal Water and Gas Reservoir Treatment as Energy-Saving Means

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Abstract. The article deals with the problem of associated gas utilization in the development of fields containing hydrogen sulfide, a fundamentally new method of oil production by influencing the oil reservoir is proposed. A scheme for using this gas in the process of the working agent pumping to maintain reservoir pressure is proposed. A method of oil production by treating the formation is considered, including oil withdrawal from the producing well, separation of water and associated gas from it in the separator, gas combustion in the heat engine, the use of the energy obtained in the engine to drive pumps and an electric generator, heating water and pumping it into the formation, pumping combustion products into the formation, characterized in that the gas supplied to the heat engine is taken from the producing well annulus and due to this, the pressure in the annulus is regulated, regardless of the pressure in the linear oil pipeline, ensuring maximum gas withdrawal while maintaining the optimal dynamic level in the well for a given operation mode, the gas from the separator is pumped into the reservoir, and the water is heated to a temperature higher than the melting point of paraffin for this field. The article offers a solution to this problem by generating electricity directly in the oil field using a heat engine. At the same time, hot water is pumped into the reservoir. The water is heated by the combustion products of the heat engine, which employs annular gas as fuel. The proposed method allows water to be heated to a temperature exceeding the melting point of paraffin and characterized in that the water is heated in a mixing heat exchanger. The proposed solution is characterized in that the combustion products together with the gas coming from the separator are pumped into the reservoir using water-gas technologies. It is important that nitrogen is separated from the combustion products, and the remaining gases are pumped into the formation, and gas is additionally supplied to the input of the heat engine from an external source.

1. Introduction
Washington organized an international online summit on combating climate change, which was held on April 22-23, 2021 [1]. It was attended by the leaders of 40 countries. The UN Secretary-General noted that the moment has come for the leaders of countries around the world to take decisive measures to combat climate change. In his speech, the Russian President outlined Russia's approaches in the context of establishing broad international cooperation aimed at overcoming the negative consequences of global climate change. In his speech, President Putin outlined Russia's approaches in the context of establishing broad international cooperation aimed at overcoming the negative
consequences of global climate change. For Japan, 2014 was marked by tectonic shifts on the way to a "hydrogen society" building. In June, the Hydrogen and Fuel Cell Strategy Board of the Ministry of Economy, Trade, and Industry of Japan completed a "Strategic Roadmap for Hydrogen and Fuel Cells". In November, the Tokyo authorities developed a policy that aims to make the holding of the Summer Olympic Games in the Japanese capital in 2020 an important step towards building a "hydrogen society", announcing specific actions and budget financing measures. Almost simultaneously, Honda Motor Co., Ltd. and Toyota Motor Corporation decided to launch the production of fuel cell vehicles, while Iwatani Corporation and JX Nippon Oil & Energy Corporation has published retail prices for hydrogen at hydrogen gas stations. Thus, there was a sharp intensification of efforts aimed at developing the use of hydrogen as an energy source.

In the practical application of hydrogen fuel cells, Japan from the very beginning has played an important leading role. A clear indication of this is the fact that in 2009, Tokyo Gas Co., Ltd. and Panasonic Corporation were the first companies worldwide to launch fuel cells for households (Ene-Farm systems). And then, in December 2014, Toyota finally implemented plans to bring mass-produced fuel cell vehicles to the market. This event was also widely publicized, as it is the first such event in the world.

Capstone network (USA). One of the most modern methods of electricity production, which can take a worthy place in the range of energy solutions used by Russian oil and gas companies, is the generation by microturbine generators running on natural gas, associated gas, and a number of other fuels. The American company Capstone Turbine Corporation is a world leader in microturbine power plants development.

As is known, oil and gas fields began to be developed in Western Siberia almost 50 years ago. At the same time, the general scheme for the associated gas collection and processing facilities placement and construction was adopted. By 1990, it was planned that the associated gas utilization in the USSR would be 90%. However, the communist regime collapsed, and so did the plans. And we all know what happened to associated gas production. And measures for the APG commercialization began to be developed only now. So the oil companies should not be blamed for the vandalism. Oilmen burn associated gas not out of harmfulness at all – the torches burn where APG utilization is economically unprofitable. Who is to blame that it has been much more profitable to burn in recent decades than to worry about the problem of recycling? Moreover, in the absence of the necessary access to the gas transmission system, low prices and state regulation of prices for associated gas.

One cost-effective option may be to pump the associated gas back into the reservoir, as is done in Norway. In this case, the gas maintains the necessary pressure in the reservoir and simply "pushes" the oil from the well to the surface. However, to do this, the oilman will have to fork out for gas compression units and equipment that can withstand high pressure.

Another well-known option for the associated gas utilization is to use it as a fuel for electricity generating directly in the field. Electricity tariffs are constantly increasing, so this procedure is economically justified. In many countries, such work with the APG utilization is dominant.

And how are things abroad? Norway is the world leader. Since 1971, when the country's oil boom began, the government immediately began to strictly regulate the associated gas burning. That is why this country has the lowest level of APG combustion – only 0,16% of the total volume. The main method of associated gas processing in Norway is pumping unutilized APG back into the reservoir (the so-called gas lift scheme of oil production).

In the US, 98% of APG is disposed of. In the United States, it is prohibited to burn more than 3% of the produced gas. The most common way of disposal is the re-injection of gas into the reservoir and its use in microturbines to generate electricity.

Kazakhstan has also banned gas combustion since 2004. However, all this did not happen immediately. The oil industry has been given time to establish a transition period for gas processing plants creation.

However, there is an increasing need to reduce greenhouse gas emissions (water and carbon dioxide). If the existing thermal power plants emit these gases into the atmosphere, then the oil field
has the opportunity to pump them into the reservoir. Thus, it is possible not only to dispose of, but also to get a useful effect by warming up the reservoir and saturating it with carbon dioxide, which will increase oil recovery.

Data from meteorological observations over the past 100-150 years indicate changes occurring on the Earth, which are expressed not only in an increase in the average temperature of the Earth's surface layer, which during this time increased by 0.74°C, but also in changes in other parameters of the climate system. In particular, an increase in the temperature of the lower layers of the troposphere and a decrease in the temperature of the lower layers of the stratosphere, an increase in the heat content of the upper layer (0-700 m) of the ocean, a decrease in the area of glaciers, an increase in sea level, etc. Moreover, the growth rate of changes is increasing.

The production, processing, transportation, and storage of oil and natural gas are associated with the inevitable emissions of methane and carbon dioxide into the atmosphere, which contributes significantly to anthropogenic emissions around the world. Up to 88 billion m³ or about 1200 million tons of methane and carbon dioxide are released into the atmosphere every year. [1-3]

Based on the modern requirements, the purpose of the study is to develop a scheme for installing heat engines (gas reciprocating engine or gas-turbine engine) at a cluster pumping station in the immediate vicinity of injection wells. The use of exhaust heat to heat the water entering the reservoir and the movement of greenhouse gases to heat the water entering the reservoir. It is assumed that this scheme will be used primarily in old deposits, where there is a significant cooling of the formation as a result of long-term injection of cold water.

To date, when operating wells, walking-beam pumping units are faced with the fact of increasing pressure in the annular space. This question is relevant, since the gas accumulation and an increase in its pressure, affects the depression reduction and the fall in the dynamic liquid level. The critical annular pressure is considered to be above 10 atm. Traditionally, to bring the pressure of the annulus gas in line with the linear pressure, non-return wellhead valves were used, installed in the wellhead. The use of these valves reduces the annular gas pressure but does not solve the problem of its subsequent disposal. The hydrogen sulfide-containing associated petroleum gas and the liquid are transported to the group metering pump station (booster pipeline pumping station). Where, after separation, most of it is burned in torches. The preparation and subsequent transportation of associated petroleum gas require significant capital investments.

Let us analyze the equipment used in oil wells with high annular pressure.

Modern methods of oil production enhancing and oil fields developing require the development of the latest technical devices for the reservoir products lifting and technologies for their application [4-7].

One of the most relevant areas for oil production technologies improving is to reduce the gas pressure in the annular space. Forced gas extraction from the annulus allows to exclude emissions of harmful substances into the atmosphere, reduce direct losses of oil gas, stabilize the liquid's dynamic level, and thereby increase the MRT of the well [8].

Reducing the gas pressure in the annulus is a significant reserve for oil production increasing, so at present, this technical problem is solved by various techniques at oil companies [9, 10]:
- restart of the gas from the annulus by the valve device [11-13];
- gas pumping using a compressor [14];
- gas removal using dispersants;
- removal of gas from the annulus space by jet devices.

2. Research methods

A method of oil production is known [3] according to which a piston pump with a cavitation-type mixing device is mounted on the injection well, while a water pipe is supplied to the pump, and a gas line with associated gas and the resulting water-gas dispersion are fed to the reservoir formation through the injection well. The disadvantage of this method is that it does not use the possibility of obtaining energy from associated gas using a power plant.
A method for developing an oil deposit is known [4] (prototype), according to which a working agent is injected through injection wells, oil is taken through production wells, followed by the associated gas separation from oil and its combustion, characterized in that the combustion of associated gas is produced in an oxidizer consisting of a mixture of oxygen and recirculating combustion products. In this case, the combustion products of the associated gas in the form of carbon dioxide and carbonized water are pumped into the injection wells as a working agent.

The disadvantage of this method is the need to produce oxygen, which is quite an expensive process.

The object of the invention is to increase the efficiency of oil production, both by increasing the oil recovery factor and by reducing the cost of production because electricity is produced directly in the field. In addition, the problem of greenhouse gas utilization is being solved.

We propose to solve the specified task by:

1. A method of oil production by influencing on an oil reservoir, in which oil is extracted through producing wells, followed by separation of associated gas from the oil and its combustion, and then the combustion products of the associated gas are injected into the injection wells in the form of carbonized water, characterized in that the associated gas is burned in a heat engine (for example, gas turbine or gas piston engine), get useful work, which is employed to drive the devices of the injection system (directly due to mechanical coupling or by converting the associated gas into the combustion products are first sent to the mixing heat exchanger, where they have direct contact with the injected water, and then the combustion products are sent for injection into the formation.

2. The method according to paragraph 1, characterized in that the combustion products after the mixing heat exchanger are sent to a gas separation unit (for example, an adsorber or a device with a membrane) in which nitrogen is separated and sent either to the atmosphere or used for technical purposes, and the remaining gases are pumped into injection wells.

3. The method according to paragraph 1, characterized in that it is periodically replaced by the method according to paragraph 2, or the methods according to paragraph 1 and paragraph 2 are carried out simultaneously.

Figure 1 shows a diagram of this method. The technique is carried out as follows.

The associated gas separated from the extracted oil is burned in a heat engine (for example, a gas turbine engine) 1, which gives its power to a high-pressure pump 2 and an electric generator 3. The combustion products of this engine are directed by means of a smoke pump 4 to the lower part of the mixing heat exchanger 6. The upper part of this heat exchanger is fed through sprinklers 7 with water intended for injection into the injection wells. This water, which flows down through the nozzle 8 (for example, Raschig rings), is heated by the heat of the combustion products and absorbs part of the carbon dioxide, as well as the water vapor contained in these products since the temperature of the incoming water, is lower than the dew point temperature. Then this water, which has become carbonized, is fed by a low-pressure pump 11 to a high-pressure pump 2, from which the water is directed to the injection wells. The combustion products from the heat exchanger 6 are sent by means of a smoke pump 5 and a compressor 13 for injection into the formation, for example, into the gas cap (i.e., the free part of the formation), or directly into the injection wells.

The method according to paragraph 2 differs in that the combustion products after the mixing heat exchanger through the smoke pump 5 are sent to the gas separation unit 9 (for example, an adsorber or a membrane device), in which nitrogen is separated and pumped either into the atmosphere, or compressed by a compressor 10 is used for technical purposes. The remaining gases are pumped into the injection wells using the compressor 12.

The method according to paragraph 3 differs in that the methods according to paragraph 1 and paragraph 2 periodically replace each other or are carried out simultaneously in accordance with the particular oil reservoir characteristics.
Figure 1. Scheme of oil production by reservoir treatment.

1-Heat engine; 2 – high-pressure pump; 3-generator; 4-smoke pump; 5-smoke pump; 6-mixing heat exchanger; 7-sprinkler; 8-nozzle; 9-gas separation unit; 10-compressor; 11-pump; 12-compressor; 13-compressor.

3. Conclusions

The proposed solution allows the associated gas utilization for electricity generation. Among the above-mentioned techniques, one of the most common is the use of associated gas as fuel for power plants (APG is used to generate energy at a gas turbine and gas piston stations). The effectiveness of this technique is quite high. APG processing at the production site employing cryogenic separation into fractions (construction of modular complexes for the generation of electric and thermal energy and the production of liquefied petroleum gases);

- the use of APG in the diesel generator sets systems of dual-fuel operation (modernization of diesel power plants);
- production of electric and thermal energy in gas turbine and gas-piston power plants with heat recovery systems;
- construction of modular APG utilization complexes at the production sites with electric and thermal energy generation, production of butane, propane, NGL, and liquefied methane, ethane with the transportation of products by universal tank containers. Advantages of the proposed solution: modularity (allows you to vary the capacity from 30 million m3 per year to 1000 million m3 per year by selecting the optimal number of functional modules).

The employing this technique makes it possible to:
- stop APG flaring – improving the environment and avoiding fines;
- compliance with the terms of the license agreement;
- additional income from the APG selling.

Let us consider gas turbine stations with a gas utilization system

The main unit of a simple cycle GTPP is a power unit, which includes a gas turbine unit (with a gearbox if necessary) and a synchronous generator with an excitation system. The engine is equipped with start-up systems, protection and alarm systems, and anti-icing systems. The kit includes an air intake and purification system, an oil supply unit, an automation unit, a fire extinguishing and ventilation, engine shelters. The GTPP can be built on top of a hot water or steam boiler with a heat recovery unit with the transition of the installation to the status of a gas turbine mini combined heat and power plant (mini-CHPP).
Gas turbine mini-CHP plants with a capacity of up to 1000 kW can be equipped with microturbines.

Conclusions: A scheme has been developed for installing heat engines (as reciprocating engine or gas-turbine engine) at a cluster pumping station in the immediate vicinity of injection wells. The use of exhaust heat to heat the water entering the reservoir and the movement of greenhouse gases to heat the water entering the reservoir. The use of this scheme is justified primarily on old deposits, where there is a significant cooling of the formation as a result of long-term cold water injection.

The proposed technique will solve the problems arising in the process of production wells operation:
• Reducing the dynamic fluid level in the wellbore;
• Reducing fluid flow;
• Associated gas utilization;
• Increase in reservoir temperature due to the associated gas injection into the formation;
• Reducing the paraffinity of oil due to an increase in the reservoir temperature.

4. References
[1] Varsamov S E Durneva Yu M and Bolotin N B 2008 Patent RU 2376457 Offshore drilling platform
[2] Akhmetov R B Pozharnov V A Grishutin K S ZheltoV Yu V and Kudinov V N 1993 Patent RU 2038467 Method for developing an oil deposit
[3] Zapadinsky A L 2000 Patent RU 2181158 Method for oil fields development
[4] Taurov D N and Taurova S A K 2014 Estimation of annular gas emitted into the atmosphere from the Azneft oil fields European science review 3-4
[5] Vakhitova R I 2005 Improving the efficiency of wells equipped with ESP operation In IV Congress of Russian Oil and Gas Producers Problems of Developing Hard-to-Recover Hydrocarbon Reserves p 325
[6] Saracheva D A Vakhitova R I & Abramova E V 2012 Gas removal from the annulus of wells equipped with ESP, jet pumps Materials of the scientific session of scientists of the Almetyevsk State Oil Institute 1 p 139-141
[7] Mishchenko I T 2003 Downhole Oil Production: A Textbook for Universities (Moscow: Publishing House "Oil and Gas" Russian State University of Oil and Gas named after I.M. Gubkin) p 158-166.
[8] Tronov V P 2002 Gas separation and reduction of oil losses (Kazan)
[9] Gumerov A G 2010 Utilization of associated petroleum gas in the fields (Ufa) p 11
[10] Gabdrakhmanova K F, IzmaIylova G R, Larin P A, Vasilieva E R, Madjidov M A & Marupov S R 2018 Nomogram method as means for resource potential efficiency predicative aid of petrothermal energy Journal of Physics: Conference Series 1015 (3) p 032036
[11] Gabdrakhmanova K F, Izmaylova G R & Larin P A 2018 The way of using geothermal resources for generating electric energy in wells at a late stage of operation IOP Conference Series: Earth and Environmental Science 194 (8) p 082012
[12] Gabdrakhmanova K F, Soloviev N N, Izmaylova G R, Kuleshova L S & Marupov S R 2019 Equipment for paraffin removal from oil pipelines in order to ensure energy saving in Arctic conditions IOP Conference Series: Earth and Environmental Science 378 (1) p 012038
[13] Gabdrakhmanova K F, Izmaylova G R, Kuleshova L S, Gabdrakhimov V E & Gimaev, E V 2019 Use of geothermal energy from abandoned oil wells IOP Conference Series: Earth and Environmental Science 378 (1) p 012053
[14] Gabdrakhmanova K F, Izmaylova G R & Samigullina L Z 2020 Probabilistic statistical model for predicting the effectiveness of hydraulic fracturing In IOP Conference Series: Materials Science and Engineering 952 (1) p 012045