

On reducing the carbon footprint through the rational use of petroleum gas

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Abstract. This study is devoted to the problems of irrational combustion of petroleum gas. The problems of introducing APG application methods are indicated, the methods of using gas in the fields are analyzed. The analysis of the data made it possible to establish that the harmful effect can be reduced by injecting oil gas into the reservoir with water in the form of a water-gas mixture (SWAG-technology). Exhaust or flue gases can also be used. Flue gases emitted during the flaring of associated petroleum gas can also be captured and injected as a water-gas mixture. Pump-ejector systems are proposed as a technical solution.

1 Introduction

An urgent global topic today is the ways of decarbonization of industry and the search for technical and technological solutions to reduce the impact of harmful CO₂ emissions into the atmosphere through their use. According to [1], the contribution of the oil and gas sector of industry to the total amount of CO₂ emissions from the energy sector is two-thirds of 40 gigatonnes. This value includes emissions associated both directly with the extraction, preparation, transportation and processing - in the amount of 20%, and indirectly with the consumption (for example, combustion) of hydrocarbons for other purposes - 80%.

Figure 1 shows data on gas flaring around the world, obtained directly from a satellite launched in 2012 and controlled by the US National Oceanic and Atmospheric Administration (NOAA). Figure 2 shows data on the intensity of gas flaring, correlated with the amount of oil produced for each country.

Being the world leader in APG flaring, Russia, like many other countries, continues to strive to increase oil recovery from reservoirs. The waterflooding technology in various fields has shown its shortcomings [2, 3], taking into account the deterioration in the structure of developed reserves, when searching for solutions, the possibility of jointly solving these two global problems should be taken into account.

When burning petroleum gas, combustion products enter the atmosphere, incl. carbon dioxide. This directly affects the ecological situation in the region. However, the efficiency of flare installations in the most optimistic view tends to a value of 98%. This means that 2% is emitted into the atmosphere in its pure form. Among these components, there is methane, a gas whose greenhouse effect is many times greater than the effect of an increase in carbon

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dioxide concentration [4]. In different fields, the composition of petroleum gas (and the volumetric ratio of components) may fluctuate. It is logical to conclude that when gas is directed to flare installations, the composition of both the combustible mixture and combustion products will be different. The proposal [5] for the modernization of devices for burning petroleum gas only makes it possible to reduce the volumes of gas that bypass the combustion process, which solves the problem to a very limited extent.



Fig. 1. Visualization of data on gas flaring in the world for 2019 [1].

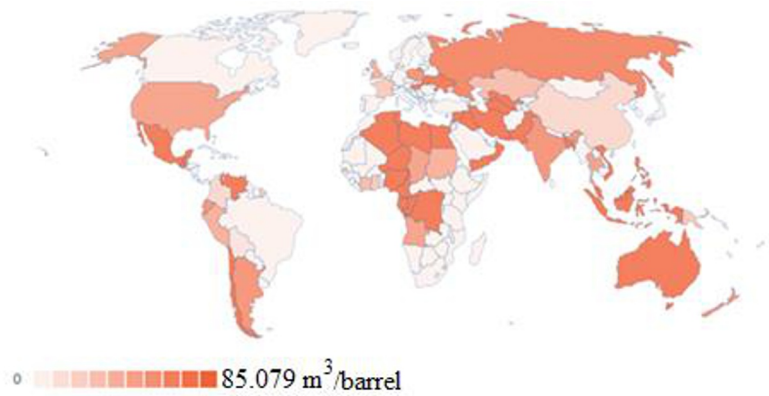


Fig. 2. Visualization of data on the intensity of flare burning in the world for 2019 [1].

2 Application of "green" technologies

If we analyze the term "associated petroleum gas" itself, then it seems that this product is an associated emission. So it was when oil production was just beginning to develop. Over many decades, experts have found the use of this product and methods for its delivery from the field, which fundamentally changes the idea of petroleum gas as a resource.

Some oil companies are pursuing a policy of environmentally friendly development using so-called "green" technologies. The beneficial use of petroleum gas allows companies to increase profits both by reducing fines and by maintaining production volumes. The introduction of methods that increase oil recovery with the injection of gas components increases interest from an economic point of view [6].

The most obvious solution is to build gas processing plants at the fields. Hydrocarbon components can be taken and supplied to consumers, nitrogen as an environmentally neutral component can be emitted into the atmosphere, carbon dioxide and other impurities cause a number of difficulties. The construction of a plant and gas treatment facilities requires capital investments. This decision in the conditions of Russian fields is complicated by the fact that Western Siberia is the main oil-producing region, many fields are significantly remote from consumers of raw materials. This makes it difficult to access both the transport of treated and processed gas, and the process of oil production itself.

An alternative option is to organize an underground storage of associated petroleum gas [7]. This proposal involves the injection of petroleum gas into a sealed reservoir.

Part of the oil gas is burned in furnaces to provide electricity to the field itself. The results obtained in [8-10] made it possible to establish that hydrogen obtained after CO₂ capture and processing can be used as an energy source for the fishery.

Analysis of field data shows that in many cases it is possible to utilize petroleum gas by transporting it together with liquid (oil or water-oil emulsion) through pipelines to oil and gas complex treatment plants with subsequent gas supply to consumers. It is important that this requires minimal additional capital investments, and in some cases operating costs can be reduced if the existing field infrastructure is used to the maximum by supplementing the equipment of booster pumping stations with jet apparatus [11].

3 Advantages of water-gas methods

Technologies for the beneficial use of petroleum gas imply its injection into oil-saturated reservoirs through gas or SWAG-technology. At the same time, components with better solubility in oil are re-extracted in the process of oil production. The separated gas can be re-injected into the reservoir, which affects the rationality of the application of methods.

Exhaust and flue gases can be injected as a gas phase, which also helps to reduce emissions into the atmosphere. A laboratory pilot study [12] confirms that flue gas injection into light oil reservoirs can be a cost-effective gas displacement method to enhance oil recovery, especially in reservoirs with low porosity and permeability. An experimental study on the mechanism of light oil displacement by flue gases at a reservoir temperature of 116 °C and typical reservoir pressures from 27.63 MPa to 46.06 MPa confirmed that flue gases displace oil in the process of direct contact, resembling the combined mechanism of oil displacement by gas behind due to multi-contact evaporation and condensation.

Based on the fact that the component composition of flue and exhaust gases is similar, this allows us to confirm the possibility of using the latter in enhanced oil recovery processes less efficiently than pure CO₂. Based on the composition of exhaust gases, several possible mechanisms have been identified that affect oil recovery [13, 14]. One mechanism is direct displacement by free gas provided by the presence of N₂, the other is solubilization provided by the solubility of CO₂, and also affects the change in wettability and relative permeabilities.

The study [15] compared the effectiveness of WAG (water-alternating-gas injection) with CO₂ and artificially created flue gases (70 mol.% N₂ + 30 mol.% CO₂ and 85 mol.% N₂ + 15 mol.% CO₂) for heavy oil fields with low reservoir pressures, i.e. under conditions of immiscible displacement. The presence of N₂ in the flue gas composition (at 30% CO₂) reduced the solubility of carbon dioxide, resulting in less oil 'swell' than when pure CO₂ was displaced, and a slight decrease in viscosity at lower system pressures. However, drive results with a mixture of 30% CO₂ + 70% N₂ and 15% CO₂ + 85% N₂ showed a recovery factor that was higher than with pure gas (N₂ or CO₂). Thus, nitrogen in the injected mixture did not have a detrimental effect on oil recovery compared to oil production with pure CO₂. This suggests that some other mechanisms besides oil swelling and viscosity reduction are responsible for the enhanced oil recovery from the immiscible displacement process.

4 Technical solution

From a technical point of view, it is preferable to use a liquid-gas ejector to create a water-gas mixture [16-18]. The jet apparatus is able to operate efficiently both in the pump mode, and in the compressor mode, and in the multiphase pump mode when pumping gas-liquid mixtures in the presence of a solid phase in the flow, as applied to low-viscosity and high-viscosity media. The simplicity of jet apparatus designs, as a rule, contributes to a significant improvement in reliability indicators and a reduction in production costs [19].

A schematic diagram of the pump-ejector system for SWAG is shown in Figure 3. In addition to the main elements, the pump-ejector system [20, 21] can include a dosing pump to add surfactants and create a more stable fine system [22].

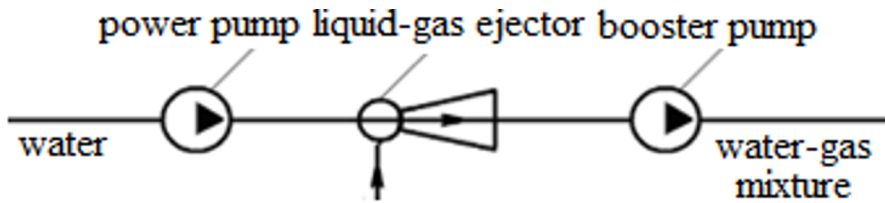


Fig. 3. Schematic diagram of the pump-ejector system for SWAG-technology [11].

Existing other methods of creation have significant drawbacks: high cost and complexity of maintenance. The use of PES allows not only to simply and efficiently create a water-gas mixture, but also to regulate the operation of the system with varying gas flow rates [23]. The source of exhaust gases can be industrial power generating plants operating on associated petroleum gas (APG). In this case, CO₂ volumes are reduced both from APG flaring and after its alternative use for generating electricity and heat.

In fields with high values of linear pressures, when it is impossible to bypass gas from the annulus of production wells, modifications of the pump-ejector system [24] can also be used to pump out annular gas and obtain a water-gas mixture. Reducing annular pressures (and increasing drawdowns) in combination with SWAG-technology allows you to increase production.

5 Conclusions

The technology of SWAG-technology is effective in cases of miscible and immiscible displacement, while the principle of displacement of residual reserves is different.

The gas released from oil during the introduction of SWAG-technology can be reused as a displacing agent.

The results of the analysis show that the synergistic effect of the method of beneficial use of oil, exhaust and flue gases and the technology of enhanced oil recovery can significantly increase the efficiency of development by increasing oil recovery and reducing fines while reducing the volume of burned petroleum gas.

The use of alternative energy sources will reduce the amount of gas burned, which also helps to reduce the carbon footprint.

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