On the issue of assessing the importance of associated petroleum gas as a valuable raw material in the fields of the Khanty-Mansiysk Autonomous Okrug

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Abstract: The purpose of this article is to consider the problem of flaring associated petroleum gas (APG), as one of the most relevant and acute for our country, because Russia occupies a leading position in the world in terms of APG flaring volumes. Burning APG leads to environmental damage, contributes to the greenhouse effect, harms public health, as well as the country's economy - valuable chemical raw materials and energy resources are simply thrown away. According to the Ministry of Natural Resources of the Russian Federation, out of 55 billion m$^3$ of APG produced annually in Russia, only 26% (14 billion m$^3$) is sent for processing, 47% (26 billion m$^3$) goes to the needs of the fields, or is written off as technological losses and 27% (15 billion m$^3$) is flared.

Key words: associated petroleum gas, utilization, processing, oil production, field development, subsoil use, ecology, environmental protection.

1 Introduction

In connection with the emergence of new technologies, the development of innovative activities in Russia and, in particular, the development of such industries as oil production and processing of obtained resources, new, more economical and capacious opportunities for processing oil and gas mixture by-products are emerging. Russia is steadily increasing its oil production volumes, and given that most of it is oil and gas fields, the production of associated petroleum gas (APG) is correspondingly growing. APG production increased by 1.6 times, while oil production increased by 1.38 times over the same period. And all this time, field development projects were drawn up without special attention to associated gas, which led to the current state of its use [1]. Today, the negative situation that is currently observed with the use of APG is primarily due to the lack of effective legal, economic and organizational regulatory mechanisms in the field of subsoil use.

Associated petroleum gas is a valuable raw material, an indisputable fact known to everyone. Those companies that cannot use it effectively burn gas. The examples of Surgutneftegaz and Tatneft, which, having their own gas processing plants, utilize more than

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95% of associated gas, are currently an exception to the rule. The wave of attention of the leadership of the Russian Federation to the problem of associated gas, raised by the President of Russia, is expressed in a set of measures aimed at achieving maximum utilization of associated gas.

According to the federal authorities, a “subsoil user” or a new participant in this industry, when developing fields, already at the stage of study and preparation of the project, must calculate its economics taking into account the use of associated gas: be it, for example, the generation of heat and electricity, the supply of gas for processing or return injection of gas into the reservoir, provide your economic and other calculations (with justification for the most acceptable method of disposal) to the state as the owner of the subsoil in order to make a decision on the field development system (table 1).

Table 1. Composition of APG from various fields in Western Siberia

<table>
<thead>
<tr>
<th>Field</th>
<th>CH4</th>
<th>C2H6</th>
<th>C3H8</th>
<th>C4H10</th>
<th>C5H10</th>
<th>C6H12</th>
<th>C7H12</th>
<th>CO2</th>
<th>N2</th>
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<td>4.13</td>
<td>13.05</td>
<td>4.04</td>
<td>8.61</td>
<td>2.52</td>
<td>2.65</td>
<td>0.59</td>
<td>1.48</td>
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<td>8.31</td>
<td>13.51</td>
<td>4.05</td>
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<td>2.21</td>
<td>1.80</td>
<td>0.69</td>
<td>1.51</td>
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<td>Aganskoe</td>
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<td>6.89</td>
<td>17.37</td>
<td>4.47</td>
<td>10.84</td>
<td>3.36</td>
<td>3.88</td>
<td>0.51</td>
<td>1.53</td>
</tr>
<tr>
<td>Soviet</td>
<td>51.89</td>
<td>5.29</td>
<td>15.57</td>
<td>5.02</td>
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<td>1.02</td>
<td>1.53</td>
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<td>Fedorovskoe</td>
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<td>5.33</td>
<td>14.82</td>
<td>4.32</td>
<td>9.87</td>
<td>2.65</td>
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<td>15.77</td>
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<td>3.41</td>
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<tr>
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<td>4.87</td>
<td>13.21</td>
<td>_</td>
<td>4.56</td>
<td>10.11</td>
<td>2.35</td>
<td>2.69</td>
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<tr>
<td>Vat-Eganskoe</td>
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<td>5.43</td>
<td>16.34</td>
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</table>
The problem of utilization of associated petroleum gas faces all oil companies [2]. At the moment, gas, in most cases, is flared, complicating the already difficult environmental situation in the production areas. The use of gas in the energy sector allows not only to improve the environmental situation, but also to solve the problem of heat and power supply for oil companies [3]. With constantly rising electricity tariffs and their share in the cost of production, the use of APG for electricity generation can be considered economically justified. Considering the high energy consumption of oil production, there is a worldwide practice of using APG to generate electricity for field needs. The use of associated petroleum gas in gas piston power plants (GPPPs) is widely used by all the world's leading companies. Gradually, this experience is being introduced in our country.

Processing of associated gas is primarily a significant source of income for oil producing companies. An important aspect in APG processing is the protection and preservation of the environment. In addition, this is the production of additional production products, such as flammable gas, electricity and other products used in production and support processes.

Combustion products of associated petroleum gas (APG) entering the environment pose a potential threat to the normal functioning of the human body at the physiological level. Statistical data for the Tyumen region, an oil and gas producing region of Russia, indicate that the morbidity rate of the population for many classes of diseases is higher than all-Russian indicators and data for the West Siberian region as a whole (indicators for respiratory diseases are very high!). For a number of diseases (neoplasms, diseases of the nervous system and sensory organs, etc.) there is an upward trend. Exposures are very dangerous, the consequences of which are not immediately apparent. These include the influence of pollutants on people’s ability to conceive and bear children, the development of hereditary pathologies, weakening of the immune system, and an increase in the number of cancer diseases [4,5].

Currently, subsoil users have again become interested in the problem of commercial processing of associated gas. The reason for this is primarily the state’s requirement for oil companies to utilize petroleum gas in accordance with the terms of licenses for the exploitation of oil fields. Failure to comply with these conditions may serve as grounds for depriving the subsoil user of an oil production license. The main concept of work is to create a comprehensive proposal for the production of standard tested equipment for the preparation and utilization of APG for sale to oil companies or their installation in fields for the purpose of subsequent repurchase (utilization) of APG and obtaining marketable products from it.

APG is the most valuable hydrocarbon raw material along with oil and natural gas. In an era of growing energy shortages, the rational use of associated petroleum gas is an integral part of efficient energy use and one of the utilization of 90-95% of produced associated petroleum gas, while in Russia, even according to official data, at least 30% of this hydrocarbon raw material is burned.

Burning APG results in more than half a million tons of harmful emissions into the atmosphere in Russia and the CIS countries annually and trillions of dollars in lost profits. The main losses of oil gas are formed due to small and medium-sized remote fields, the share of which in the world continues to rapidly increase [6]. However, organizing gas collection from such fields according to the schemes proposed for the construction of large gas processing plants is a very capital-intensive undertaking, requires considerable time for implementation, does not allow the utilization of oil gases from the final separation stages, and is actually inapplicable to geographically isolated small and medium-sized fields [7].

An alternative way out to resolve the situation with flare gas utilization is to attract specialized companies that can quickly and efficiently implement such projects without attracting the main financial resources of subsoil users. The most optimal solution to the problem is to integrate an APG processing project at the production field itself, which allows reducing a number of costs for both the oil producing organization and the processing
company, therefore increasing the revenue base and reducing the cost of obtaining by
products after the APG processing process. Solving the issue of refining by
the producing company itself requires significant capital investments, since this is a separate technological
process, control and compliance with legal requirements, protection and safety standards, as
well as the involvement of specialized personnel and a number of additional costs related to
the launch of new parallel production of the main activities of oil producers. This is especially
true for small and medium-sized fields, because sometimes for such companies these are
unacceptable additional costs, which can drag down the entire activity to the unprofitability
of the entire range of activities of the organization. The most pressing issues of disposal or
processing are faced by small and newly discovered deposits. APG processing for such fields
is simply an expensive and inaccessible process, and the option based on APG combustion
is the only acceptable solution, which in turn entails legal risks and penalties, which is also a
negative and “sore” point in the activities of a mining company.

The dew point lowering unit simultaneously combines two gas preparation processes—
gas drying from moisture and C3+ hydrocarbons by freezing. The standard solution consists
of separate technologies and involves first drying the gas from moisture using an adsorption
or absorption method, and then condensing hydrocarbons at subzero temperatures. Also, the
use of freezing technology makes it possible to abandon the use of compression (increasing
pressure) and carry out the process at the gas pressure of the technological
process for the formation of associated gas, which, undoubtedly, is one of the main trump cards of this
technology from the point of view of the technical process itself and its economics.

Depending on the area of field development, 1 ton of oil produces from 25 to 800 m³ of
APG. At the moment, the market for proposals for APG utilization is at the stage of formation
and oil producing organizations do not have a clear policy on the chosen technology [8]. As
a rule, simplified schemes for the preparation
of associated gas are used, including:

- Removal of mechanical impurities (filtration), this process is based on the use of a filter medium such as membranes, meshes
  or porous materials that are capable of retaining particles by size. These filters have a
  specific penetration threshold that determines the smallest particle size that can be retained.

- Removal of dripping liquid (separation), this process is based on the use of low temperatures to liquefy liquid. The
gas mixture is cooled to such low temperatures that the liquid condenses into droplets. The
liquid droplets are then removed using various filters and separators;
  (low temperature separation, two-stage filtration) in this case, the gas mixture passes
  through two filters with increasing degrees of filtration. The first filter catches large drops of
  liquid, and the second removes smaller drops;

- Removal of sulfur-containing compounds (Hydrotreating) In this process, sulfur-containing compounds present in oil or gas are
  reacted with hydrogen in the presence of a catalyst. This reaction converts sulfur-containing
  compounds into insoluble compounds, which are then separated from the main stream of
  crude oil or gas;

- Adsorption) in this process, sulfur-containing compounds found in crude oil or gas are
  adsorbed on the surface of special substances called adsorbents. These adsorbents can be
  natural or artificial, and they have the ability to attract sulfur-containing
  compounds, thereby removing them from the stream;

- Deep desulfurization) is based on the use of special chemical reagents. These reagents
  react with sulfur-containing compounds, converting them into more easily removable
  compounds. Additional processing then occurs to separate these compounds from the main
  crude oil or gas stream.
2 Materials and methods for processing associated petroleum gas

Processing of associated petroleum gas (APG) is an area that is receiving increased attention today [9]. This is facilitated by a number of circumstances, primarily the increase in oil production and tightening environmental standards. According to 2019 data, a total of 34.2 billion m$^3$ of APG were extracted from the subsoil in the Russian Federation, of which 28.2 billion m$^3$ were consumed. Thus, the level of APG use was 82.5%, while about 6 billion m$^3$ (17.5%) were burned in flares. In the same 2019, Russian gas processing plants processed 12.3 billion m$^3$ of APG (43.6% of the “consumed” gas), of which 10.3 billion m$^3$ were processed in the Tyumen region, the main APG production region.

For field needs (oil heating, heating of rotational camps, etc.), taking into account technological losses, 4.8 billion m$^3$ (17.1%) were spent; another 11.1 billion m$^3$ (39.3%) were used for electricity generation at state district power plants.

Further growth in APG utilization to the 95% stipulated in license agreements encounters a number of difficulties. First of all, with the existing price “forks” 1, the sale of gas to a gas processing plant from a small field (1-1.5 million tons of oil per year) is profitable if the processing plant is located at a distance of no more than 60-80 km. However, the newly introduced oil fields are 150-200 km away from the gas processing plant. In this case, taking into account all cost elements brings the cost of associated gas to a level at which the option of utilizing associated gas at the gas processing plant is ineffective for many subsoil users and they are looking for options for processing associated gas directly at the oil fields.

The main solutions for APG utilization that oil producing companies can use today are as follows:

1. Processing of APG using petrochemicals.
2. “Small energy” based on APG.
3. Injection of APG and mixtures based on it into the reservoir to enhance oil recovery.
4. Gas processing into synthetic fuel (GTL/GTL technologies).
5. Liquefaction of prepared APG.

As can be seen from the figures given earlier, in the Russian Federation only two of these areas are being developed on a “global scale”: the consumption of APG as fuel for the purpose of generating electricity and as a raw material for petrochemicals (production of dry-stripped gas, gas gasoline, natural gas liquids and liquefied gas for households). Meanwhile, new technologies and equipment make it possible to implement many processes directly at the fields, which will completely eliminate or significantly reduce the need for expensive network infrastructure, involve unused volumes of APG into processing, and improve the economic efficiency of oil production.

According to the analysis, promising areas for commercial APG utilization today include:

- Microturbine or gas piston units that cover the needs of oil fields for electrical and thermal energy;
- Small-sized separation plants for obtaining marketable products (fuel methane for own needs, natural gas liquids, gas gasoline and PBT);
- Complexes (installations) for converting APG into methanol and synthetic liquid hydrocarbons (motor gasoline, diesel fuel, etc.).
3 Fractional (“non-chemical”) processing of APG

As a result of APG processing at gas processing plants (plants), “dry” gas, similar to natural gas, and a product called “wide fraction of light hydrocarbons” (NGL) are obtained.

With deeper processing, the range of products expands: gases (“dry” gas, ethane), liquefied gases (LPG, PBT, propane, butane, etc.) and stable gas gasoline (SGB). All of them, including natural gas liquids, are in demand both in the domestic and foreign markets.

Delivery of APG processing products to consumers is most often carried out via pipeline. It must be remembered that transportation by pipeline is quite dangerous. Like APG, NGL, LPG and PBT are heavier than air, therefore, if the pipe is leaking, vapor will accumulate in the ground layer with the formation of an explosive cloud. An explosion in a cloud of sprayed flammable material is characterized by increased destructive power.

Alternative options for transporting NGLs, LPG and PBT do not present technical problems. Liquefied gases are transported in railway tanks, etc. “universal containers” under pressure up to 16 atm. railway, river (water) and road transport.

When determining the economic effect of APG processing, it should be borne in mind that Russian LPG producers are subject to the so-called “balance target” for the supply of LPG to household consumers at “balance prices” (according to AK SIBUR, this is 1.7 thousand rubles/t). “Tasks” in practice reach 30% of production volume, which leads to an increase in the cost of LPG for commercial users (4.5-27 thousand rubles/t depending on the region).

Due to consistently high prices for LPG in Europe, it is more profitable to process APG and NGL into LPG. In Russia, it may be more profitable to produce methanol or BTX (a mixture of benzene, toluene and xylene). The BTX mixture can be further processed by dealkylation into benzene, which is a marketable product in high demand.

4 Injecting APG into the reservoir to enhance oil recovery

The number of technologies, operating schemes and equipment (of varying degrees of efficiency and sophistication) for increasing oil recovery is very large.

APG, due to its homological proximity to oil, seems to be the optimal agent for gas and water-gas stimulation (WGI) on the formation by injection of associated petroleum gas and other working fluids using it (APG + water, water-polymer compositions, acid solutions, etc.). At the same time, the increase in oil recovery compared to flooding the formation with untreated water depends on specific conditions. The developers of the WGV (APG + water) technology indicate that, along with the utilization of APG, additional oil production amounted to 4-9 thousand tons/year of oil per site. Technologies that combine APG injection and processing seem more promising.

5 Installation of power units

One of the most common ways to utilize APG is to use it as fuel for power plants. Given an acceptable APG composition, the efficiency of this method is high. According to the developers, a power plant with heat recovery (efficiency of about 80%) runs on APG, with its accounting cost of 300 rubles per 1000 m³, pays off in 3-4 years.

The supply of power units on the market is very wide. Domestic and foreign companies have launched the production of installations, both in gas turbine (GTU), and in piston versions. As a rule, for most designs it is possible to operate on natural gas liquids or...
6 APG processing into synthetic fuel (GTL)

GTL is an industrial process for synthetically converting gas (methane) into liquid hydrocarbons [10]. The source of methane can be coal, natural and associated petroleum gas. The following products can be considered as products of the GTL process:

1. Synthetic oil – not used locally, but is mixed and transported for processing with conventional oil (condensate).
2. Diesel fuel – used locally.
3. Other products (naphtha, lubricating oils, paraffins).

The commercial use of this technology has always been limited by two main factors:

1. periods of low oil price, which immediately made research in the field of alternative fuel a task of secondary importance;
2. high capital costs required for the construction of factories.

7 Cryogenic processing of APG into liquefied gas

Developers and manufacturers offer both large-capacity liquefied natural gas production plants with a capacity of 10-40 t/hour with a high (more than 90%) liquefaction coefficient of the processed gas, and low-capacity plants with a capacity of up to 1 t/hour. The liquefaction method is the use of a closed single-flow refrigeration cycle using a mixture of hydrocarbons and nitrogen.

For low-capacity liquefied natural gas plants, the following liquefaction methods are possible:

- the use of a single-flow refrigeration cycle when processing low flow rates of source gas (liquefaction coefficient 0.95);
- application of the expander cycle:
  a) closed with a liquefaction coefficient of 0.7-0.8;
  b) open with a liquefaction coefficient of 0.08-0.12.

The latter is recommended for use at gas distribution stations, where the reduction unit is replaced by an installation for producing liquefied natural gas with gas expansion in an expander and its partial liquefaction. This method requires virtually no energy consumption.

The performance of the installation depends on the flow rate of gas supplied to the gas distribution stations and the range of pressure differences at the inlet and outlet of the station.

8 Conclusion

Today, many small, medium and large fields remain undeveloped or poorly developed precisely because of the high capital and operating costs associated with preparing gas for transportation. The problem of gas drying (primarily from moisture, which makes it difficult to utilize associated petroleum gas on site) also exists when extracting gas from underground storage facilities. The installation for processing associated petroleum gas allows you to operate at the pressure of the original flow, which avoids additional capital investments for gas compression and subsequent operating costs.
References

1. In Russia, more and more gas is flared [Electronic resource]. Access mode: https://riarating.ru/macroeconomics/20220823/630227956.html.


