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Utilization of Associated Petroleum Gas: Economic Issues

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Abstract—The directions of associated petroleum gas use were reviewed, along with the methods of governmental support and economic incentives for associated petroleum gas utilization and the corresponding pricing policy.

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Associated petroleum gas (APG) is isolated from borehole fluid during oil extraction; its volume is rigidly bound to oil extraction and characterized by the gas-to-oil ratio, i.e., the ratio of the gas volume to the amount of oil extracted. Published data on possible gas-to-oil ratios are diversified. Estimation of this characteristic for Russia is troublesome, because many of the oil extraction fields are not equipped with gas metering facilities. For example, A.V. Savinov [1] estimated the average gas-to-oil ratio for Russia at 118 m^3 APG per oil ton (for 2006) and noted that "the volumes of the extracted, used, and burned associated petroleum gas for the most part are not measured by instrumental methods."

As regards the use of APG, it should be noted that, for a fairly long time, APG has been considered worldwide as a waste from oil extraction, which was mainly treated by venting or flaring. Those were peculiar methods of burial of the oil extraction "waste" in the atmosphere. A decisive step that altered this attitude to APG was made in 1946 by the State of Texas regulatory agency which required that oil companies utilize gas under the threat of oil extraction closure. Owing to significant efforts that followed, nearly 98% APG extracted in the US is utilized today [2]. In Russia, APG "is still regarded as a byproduct of oil extraction, rather than a valid mineral product such as, e.g., oil or natural gas" [3]. Direct (without flaring) release of APG into the atmosphere, which is sometimes practiced in oil extraction, undoubtedly poses certain damage.[1] Though very harmful to the environment and human health, APG "burial" in the atmosphere via flaring still takes place. According to NOAA (US) estimates, the world's largest amount of APG in 2008 was flared in Russia.

It should be noted that experts' opinions on the APG volume flared strongly differ. For example, in 2008 it was estimated by the Russian Federation Ministry of Natural Resources and Environment, the Russian Gas Society, PFG Energy (US), and NASA (US) (based on space survey data) at 15, 20, 38, and 50–60 billion m^3, respectively. The table lists the official data on APG production, flaring, and utilize-tion in Russia, available from the Central Dispatching Office of the Russian Federation Energy Ministry (CDU TEK).

In view of the fact that many of the oil fields are not equipped with metering facilities, those numbers are only estimates. However, even they suggest that large-scale APG flaring is widely practiced in Russia. Evidently, insufficient metering is supportive to this practice: It decreases the degree of the threat of the extraction license withdrawal and the fine to be charged for flaring in excess of existing limits.

Widely spread flaring practice suggests that, in many cases, oil companies do not associate any economic gain with changing to an alternative route, utilization. If an oil company prefers to pay for flaring in excess of appropriate limits rather than to undertake efforts aimed at APG utilization, this typically means that the loss it would suffer in the latter case exceeds the fine to be charged in the former. Possible ways to alter this situation include:

[1] For example, methane, the main APG component, is a ~25 times more potent greenhouse gas than CO_2.

Main characteristics of the APG use in Russia in 2001–2008

Characteristic	Year							
	2001	2002	2003	2004	2005	2006	2007	2008
Produced, billion m^3	35.9	42.6	48.5	54.9	57.6	57.9	61.2	60.5
Flared, billion m^3	7.1	11.1	11.1	14.7	15.0	14.1	16.7	14.6
Supplied to gas processing plants, billion m^3	23.7	26.0	31.6	34.0	34.9	35.5	34.8	36.7
Spent to meet internal oil field needs, billion m^3	5.1	5.5	5.8	6.2	7.7	8.3	9.7	9.2
Utilization rate, %	80.1	73.8	77.2	73.3	74.0	75.6	72.6	75.8

– prohibition against above-limit flaring (in many countries, this means above 5% of the APG volume produced) under the threat of oil extraction license withdrawal;

– multiple increases of the fines to be charged for above-limit (>5%) APG flaring;

– selective temporal governmental support to oil companies' efforts to increase the APG utilization rate; and

– governmental backing of the development of small- and low-capacity APG processing technologies.

Prohibition against above-limit APG flaring. This measure requires rigid administration. An attempt to introduce this institution was made in the framework of Resolution of the Russian Federation Government, taken in January 2009. It sets a 5% limit for APG flaring starting from 2012. Certainly, this makes sense only in the case when each oil field is equipped with facilities for measuring the volume of the APG extracted from the borehole fluid, as well as of the gas being flared. Control bodies, independent of oil extractive companies, should enjoy free access to both the measuring system and the measurement results. Also, there is a need in developing and putting into operation a standardization system for APG measurements. This administrative (in terms of its application) measure does not take into account the specific economic situation with oil and APG extraction and the gas utilization potentialities. It is essentially based on the presumption that oil companies have a possibility but no "desire" to undertake APG utilizetion, but this presumption is not universally true. The efficiency of this measure is partly negated by the fact that it is initially declared as a threat to oil companies that will be effective after a period of several years, which actually is taken into account in the above-mentioned Resolution of the Russian Federation Government.

Multiple increases of the fines to be charged for above-limit APG flaring. By contrast to prohibition of flaring above the permissible level, this is an economic measure. It is aimed to alter the economic behavior of oil companies as motivated by the desire to avoid increased losses they will suffer because of flaring above the permissible level. This measure takes into account the fact that, considering the specific situation at APG production sites, the APG utilization still may not represent a beneficial alternative, even despite multiple increases of fines. This makes this option more economically acceptable than prohibition; it could be made more attractive by time phasing of the fine increases in order that oil companies could adapt to the new conditions.

Selective temporal governmental support to oil companies' efforts to increase the APG utilization rate. This is another economic measure, selective to the extent that, in certain cases, in view of the lack of a gas utilization infrastructure and the economic inefficiency of other conventional gas utilization methods, coupled with financial stress, the introduction of a 5% limit for APG flaring or a sharp increase of fines for above-limit APG flaring, if rigidly administrated, would cause oil companies to abandon the development of oil fields. If appropriate analysis suggests that this course of events is undesirable, the extractive company in question needs a temporal economic governmental support via altering the taxation scheme or providing preferential loans for implementation of the program aimed to bring the APG utilization rates to compliance with the established standards. However, this measure should not apply to major oil companies.

Governmental backing of the development of APG processing technologies. The need in this measure is dictated by the fact that, as suggested by practice, the market mechanism sometimes does not possess the “economic power” sufficient for the development of APG utilization technologies to rely on the inner resources of oil companies. This is the case of not very large oil companies undertaking the development of oil fields that are distant from the existing APG utilization infrastructure. In this situation, APG utilization requires small-scale high technologies whose development and introduction would entail costs that could not be covered by small oil companies.

The above-discussed measures can affect the attitude of oil companies toward APG utilization via making it more beneficial than flaring in virtually all the cases. Oil companies may select one of the APG utilization options, among which of primary importance are the following: reinjection into the reservoirs, burning in power installations, and fractionation into components to be further sold and/or subjected to processing.

Reinjection into the reservoirs. This option showed good results in many countries and regions, e.g., in Norway and Nigeria, as well as on Alaska, as a means to achieve enhanced oil recovery and significantly decreased gas volume flared. In Russia, extensive use of gas-based methods of oil reservoir stimulation is hindered by both relatively high capital intensity and complex application procedure. It was demonstrated [4] that reinjection of APG into reservoir would require major efforts aimed at preparation of the initial data and a set of facilities, including a pump station for liquid phase injection, multistage compressor station for high-pressure APG injection, facilities for pre-compression gas treatment, special tooling systems for gas-injection well mouths, and an automated control system. Experts believe that introduction of a gas-based method for oil reservoir stimulation is a fairly complicated engineering task which, nevertheless, can be accomplished, so that utilization of associated petroleum gas at distant fields could be achieved.

Burning in power installations with the aim of heat energy and/or electric power generation. This option is used fairly extensively; power installations may be located both near and far from the gas production sites. In the former case, APG may go for meeting the oil field needs in energy resources, and in the latter, when the higher hydrocarbon concentration in APG is fairly low, it can be sold to remote consumers of natural gas. The calorific value of APG exceeds that of methane, but its burning, like injection into reservoir, entails a loss of valuable petrochemical feedstock. At the same time, gas burning with the aim to meet the needs of oil fields or of nearby consumers has a limited application.

Fractionation into components to be further processed. This is the option that allows the economic potential of APG to be exploited to the greatest extent. However, it requires large investments into APG collection and transportation to oil-processing plants, whose construction, in turn, entails large costs which are justified only in the case of fairly large volumes of gas being processed.

There can be no universal APG processing option because of noticeable variations in the gas composition and volume, as well as in the distances separating oil fields and compressor stations, gas processing plants, conservation facilities, and consumers.

One of the schemes suggested for selection of an appropriate technology for APG utilization [4] consists in the following. When APG is produced in small volumes, the recommended choice is to spend it for meeting the oil field needs. In the case of larger gas volumes this option is to be complemented by power production and primary distillation of APG into dry lean gas (DLG) to be used as fuel for boilers and liquid hydrocarbons to be discharged into an oil reservoir. In the case of APG amounts of 50–150 million m^3 $year^{-1}$ a reasonable option consists in distillation into DLP, stable natural gasoline (SNG), and liquefied hydrocarbon gases (LHG), as well as power generation. For APG volumes in excess of 150 million m^3 $year^{-1}$, the recommended option is distillation into DLG, SNG, and LHG.

A widespread world practice consists in development of gas-chemical plants on the basis of APG and natural (ethane-rich) gas. This route was chosen by oil and gas chemical industry in the United States and Canada in which the gas processing and gas chemical industries were integrated, and now is followed by some less developed countries in Near and Middle East, Southeast Asia, and Central and South America. Especially impressive is the success achieved by Saudi Arabia which created major oil and gas chemical industry on the basis of APG and natural (ethane-rich) gas.

Russia neglected this experience, and APG and natural gas find little use for meeting Russia’s oil and gas chemistry needs. The Surgut Gas Chemical Complex construction and "Ob'polimer" (in the town of Nyagan) projects were suggested for meeting the needs of oil and gas chemical industry in the potential hydrocarbon recourses of APG in major oil areas, but they were not implemented.

This kind of projects implies vertical and horizontal integration of oil and gas production, oil and gas processing, and oil and gas chemical industry. The "scale effect," rational use of valuable gas components, optimization of feedstock, semiproduct, and product flows, and shared engineering and social infrastructure have made it possible to obtain synergistic effect, produce competitive oil and gas chemical products, flexibly respond to changes in the demand conditions, and smoothen the negative aspects associated with cyclic development patterns intrinsic for oil and gas chemistry.

There exist possibilities for fairly efficient symbiosis of large- and small-sized oil and gas chemical enterprises. In particular, the products, above all, polyolefins available from large oil and gas chemical enterprises (like in the case of Surgut Gas Chemical Complex and "Ob'polimer" projects), could be processed into articles in small business sector. On the other hand, it is reasonable that, at the sites of collection of transportable products available from small-scale APG processing plants (e.g., methanol), a medium-sized or a large plant for production of valuable and useful poly(ethylene terephthalate) (PETP) from methanol be arranged.

Utilization of APG to the benefit of all stakeholders (government, oil companies, gas concern, investors, small business sector) is a difficult but still accomplishable task.

In the former USSR, a two-stage scheme for APG processing was implemented in the major oil and gas areas (Volga Region and Western Siberia). In this scheme, the first stage involves distillation, at gas-processing plants (GPPs), of APG into SNG, DLG, and broad fraction of light hydrocarbons (BFLH), which consists of a mixture of propane, butane, *i*-butane, pentane, *i*-pentane, and hexane. The resulting DLG which is primarily comprised of methane is supplied to the gas mains system. As to BFLH, it is subjected to the second stage of processing at an oil chemical combine, in which light hydrocarbons are separated into components intended as feedstock for preparation of monomers, polymers, tires, and other items.

It should be noted that, globally, not only APG but also natural gas undergoes processing to yield ethane, along with the above-mentioned hydrocarbons. The volume of associated petroleum and natural (ethane-rich) gas processed in 2008 was estimated at ca. 1.6 trillion m^3, the capacity of 1879 GPPs available on the planet, at 2.6 trillion m^3 $year^{-1}$, the extent of their use, at 61.2%, and the amount of liquid product, at nearly 250 million ton. The largest number of GPPs is located in the United States and Canada (577 and 967, respectively). Large APG processing plants exist in Saudi Arabia, Mexico, Kuwait, Iran, and other countries, where liquid hydrocarbons extracted from APG serve as the major petrochemical feedstock. There are 19 GPPs in Russia, all of which were constructed in the Soviet period, except for Purovsk GPP, NOVOTEK, which was put into operation in the post-Soviet period (since 1991). Six GPPs belong to Gazprom, one GPP, to NOVOTEK, and 13 GPPs, to oil companies. In 2008, ca. 37 billion m^3 APG was supplied to GPPs in Russia. Four central gas-fractionation units in Russia undertake BFLH processing (in 2008, 3.3 million tons of propane and butane, as well as 0.7 million tons of pentanes, was obtained from 4.7 million tons of BFLH).

Worldwide, APG processing belongs to the scope of oil companies, but in Russia, owing to corporization and privatization in oil and gas industry, some GPPs were not included into privatized assets of oil companies. This led to appearance of APG markets in Western Siberia, thereby generating very complex problems in coordination of the activities of APG sellers and buyers.

One problem consists in the lack of safeguarded nondiscriminatory assess for APG to the main gas pipelines. The gas main system owner, Gazprom, often alleges a heavy workload borne by the gas transmission network, as well as the fact that APG injection into the main system generates transportation problems. The discriminatory policy is also pursued by power supply networks: They refuse the power available from independent small companies, which was generated with the use of APG.

An even more pressing problem is that of APG prices. Since the time of appearance of APG markets till 2009, government-controlled APG prices existed in Russia. Associated petroleum gas was regarded as a product of little value, for which reason the APG prices were kept for a long time at a very low level set without due economic justification. Until 1999, irrespective of the production conditions and quality, a uniform price of 55 rubles per 1000 m^3 was set for APG, and subsequently it was increased to 150 rubles per 1000 m^3. However, this level was also considered by major oil producers to be too low to cover the production costs they bear. In the middle of 2001 an APG price corridor of 275–350 rubles per 1000 m^3 was established. It turned out, however, that this measure was not sufficient for APG producers and consumers to conclude contracts. This domain needs more institutions. The collision was essentially around the fact that the prime cost of APG in Western Siberia, as calculated by oil companies, strongly exceeded the APG prices that were declared as being the maximal loss-free prices by Sibur.

More recently, a technique was developed for determination of an APG price such that ensures, on the one hand, self-repayable APG processing by the two-stage procedure with a minimal profitability (which was essential for APG processing companies) and, on the other, takes into account the differences in the APG quality (which was essential for oil companies): the larger the content of higher hydrocarbons, the higher the APG price. The above-mentioned technique took into consideration both the costs of the two-stage APG processing and all the sources of profits earned from manufacture of products from APG, including those gained from SNG sales to residential sector. In 2002, the Russian Federation Government set a market-based controlled price range for APG depending on its “fatness.” This range was subjected to mild administration, i.e., parties, by mutual consent, could depart from this range. This situation existed until deregulation of the APG market in 2009, as specified by the appropriate resolution of the Russian Federation Government. This resolution was based on the results of analysis of deregulated market, carried out by S.Ya. Chernavskii and O.A. Eismont [5], who demonstrated that, provided cooperative behavior of stakeholders, a maximal social well-being could be achieved.

However, it was also shown in [5] that, to achieve a social efficiency of the APG market, it is necessary to monitor the market with the aim to identify deviations of the market APG prices from socially optimal ones which are be calculated by special procedures taking into account the current market conditions.

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