

## Estimation of Associated Petroleum Gas Resource in Oil Production

S. V. Shurupov and T. A. Kretova

*Center of Thermal Technologies for Extraction of Poorly Recoverable Fuels, Gazprom Promgaz OJSC,  
ul. Nametkina 6, Moscow, 117420 Russia  
phone: +7(495)5044278  
fax: +7(495)5044370,  
e-mail: S.Shurupov@promgaz.gazprom.ru*

Received June 10, 2010

**Abstract**—The resource of associated petroleum gas (APG) in crude oil production in the Russian Federation is estimated on the basis of statistical data from oil-extracting companies on oil production and associated petroleum gas, as well as the structure of gas utilization. The absolute value of the APG resource across the Russian Federation is estimated on the basis of the annual weighted average value of the gas-oil ratio at the deposits.

**DOI:** 10.1134/S1070363211120206

### INTRODUCTION

Associated petroleum gas (APG) is formed as a byproduct of crude oil production in field conditions. APG is extracted from the water-oil emulsion flow in separators at reduced pressure. These streams of associated gas are still considered by some oil-extracting companies as waste and flared, causing adverse environmental impacts in oil production areas. The volume of APG that is annually flared around the world ranges from 150 to 170 bln. m<sup>3</sup> year<sup>-1</sup>, which causes damage both to the environment and to the economy of oil-producing countries [1].

According to the data of the Central Dispatching Department of the Fuel and Energy Complex, Federal State Unitary Enterprise, for 2008, approximately 16 bln. m<sup>3</sup> year<sup>-1</sup> out of 60.5 bln. m<sup>3</sup> of APG extracted in the process of crude oil production was flared.

In his message to the Federal Council of the Russian Federation of 12.11.2009 the Russian President Dmitrii A. Medvedev pointed out the inadmissibility of this wasteful practice of APG flaring. At a meeting dedicated to the development of the oil and gas sector the Russian President stated, “Associated gas flaring remains an example of inefficient utilization of energy resources. The environment gets polluted and tens of bln.s of rubles turn to smoke. Recently the Govern-

ment once again turned to this problem and promised to put an end to this mess. It is necessary to act quickly and decisively and accept no excuses from the extracting companies.”

The Russian Federation is the world leader in APG flaring, as was informed by the World Bank with references to the space satellite data. According to this information, 50.7 bln. m<sup>3</sup> of APG was flared on the territory of the Russian Federation in 2004 [2]. It should be acknowledged that there is a significant variation in the assessment of flared APG volumes.

The Russian resource potential of APG is enormous and amounts to 2.3 trillion m<sup>3</sup> (2.2 trillion m<sup>3</sup> on dry land and the remaining part, in shelf areas).

Recording of losses and setting of norms for losses of extracted APG is a crucial scientific and technical task, as, according to the official statistical data, at present the production volume of APG in the Russian Federation amounts to 58–61 bln. m<sup>3</sup> year<sup>-1</sup>, while some experts give a higher value of approximately 70–75 bln. m<sup>3</sup> year<sup>-1</sup>.

### Collection of Statistical Information on APG Production and Utilization in the Russian Federation

The data on APG annual production volumes, APG utilization rates, and flared volumes for individual

**Table 1.** Crude oil production in the Russian Federation in 2000–2008

Parameter	Year								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Oil production in Russia, mln. t	323.4	348	379	421	443	470	480	491.5	488.5
APG production, bln. m <sup>3</sup>	27.80	28.8	31.5	37.4	40.2	41.3	43.7	44.4	45.9
APG resource, bln. m <sup>3</sup>	34.40	35.9	42.6	48.5	54.9	56.2	57.9 (59.1) <sup>a</sup>	61.2 (62.4) <sup>a</sup>	60.5 (61.2) <sup>a</sup>
Average gas-oil ratio, m <sup>3</sup> t <sup>-1</sup>	106	103	112	115	124	120	121 (123) <sup>a</sup>	125 (127) <sup>a</sup>	124 (125) <sup>a</sup>

<sup>a</sup> APG resource was calculated taking into account the lack of information on APG production rates from certain oil-producing companies. The correction was made on the basis of the annual weighted average value of the gas-oil ratio at the deposits of the parent company.

extracting companies, federal subjects, and for the Russian Federation as a whole published by various information sources publish are rough data provided by various structures (the Ministry of Natural Resources of the Russian Federation, the Ministry of Industry and Energy of the Russian Federation, the State Committee for Statistics (Rosstat), oil companies, and the World Bank) on the basis of their own sources.

There are two independent channels performing the collection and analysis of information on APG production and utilization on the state level.

**Table 2.** Production of crude oil and condensate by oil companies, thousand t

Name	Year		
	2006	2007	2008
Lukoil OJSC	91144	91432	90245
Rosneft' OJSC	106616	110383	113847
Gazprom Neft' OJSC	32671	32570	30735
Surgutneftegaz OJSC	65552	64495	61684
TNK-BP holding OJSC	70798	69438	68794
V. D. Shashin Tatneft' OJSC	25453	25933	26060
Bashneft' Joint-Stock Oil Company OJSC	11937	11799	11738
Slavneft' Oil and Gas Company OJSC	23301	20910	19571
Russneft' Oil Company OJSC	14505	14169	14247
Gazprom OJSC	13417	13170	12723
Novatek OJSC	2609	2610	2736
Other producers	17475	20584	24126
Operators of production sharing agreement	5071	13824	11983
Total for Russia	480548	491317	488488

At present, in compliance with Resolution of the Government of the Russian Federation of 06.09.2002 no. 663 On Formation and Use of State Information Resources of the Fuel and Energy Complex of the Russian Federation, the Central Dispatching Department of the Fuel and Energy Complex, Federal State Unitary Enterprise, performs the collection, processing, accumulation, and storage of the state information resources for the fuel and energy complex.

On the state level the collection and processing of primary information on production and utilization of raw hydrocarbons in the Russian Federation, including APG, is performed by the Federal State Statistics Service of the Russian Federation (Rosstat) under the authority of the Ministry of Natural Resources of the Russian Federation.

Unfortunately, there is still no unified system for recording of APG production volumes. Instrumental quantitative measurements of the extracted, utilized, and flared volumes of APG are not carried out at all sites. According to the data of the Federal Service for Ecological, Technological and Nuclear Supervision (Rostekhnadzor) for 2007, only 265 installations out of 522 flare units belonging to different extracting companies working on the territory of the Khanty-Mansi Autonomous Region are equipped with meters [2].

Records on extracted volumes of APG are based on calculations, i.e. crude oil production volume (t) is multiplied by the gas-oil ratio (m<sup>3</sup> t<sup>-1</sup>).

The gas-oil ratio is the amount of separated gas relieved during the production of 1 ton of degassed oil. The gas-oil ratio is determined on the basis of thermodynamic calculations or by experiment in compliance with the instruction [3] and guidance [4] as a result of gas liberation and analysis of samples of the unstable condensate or oil, taken at field parameters.

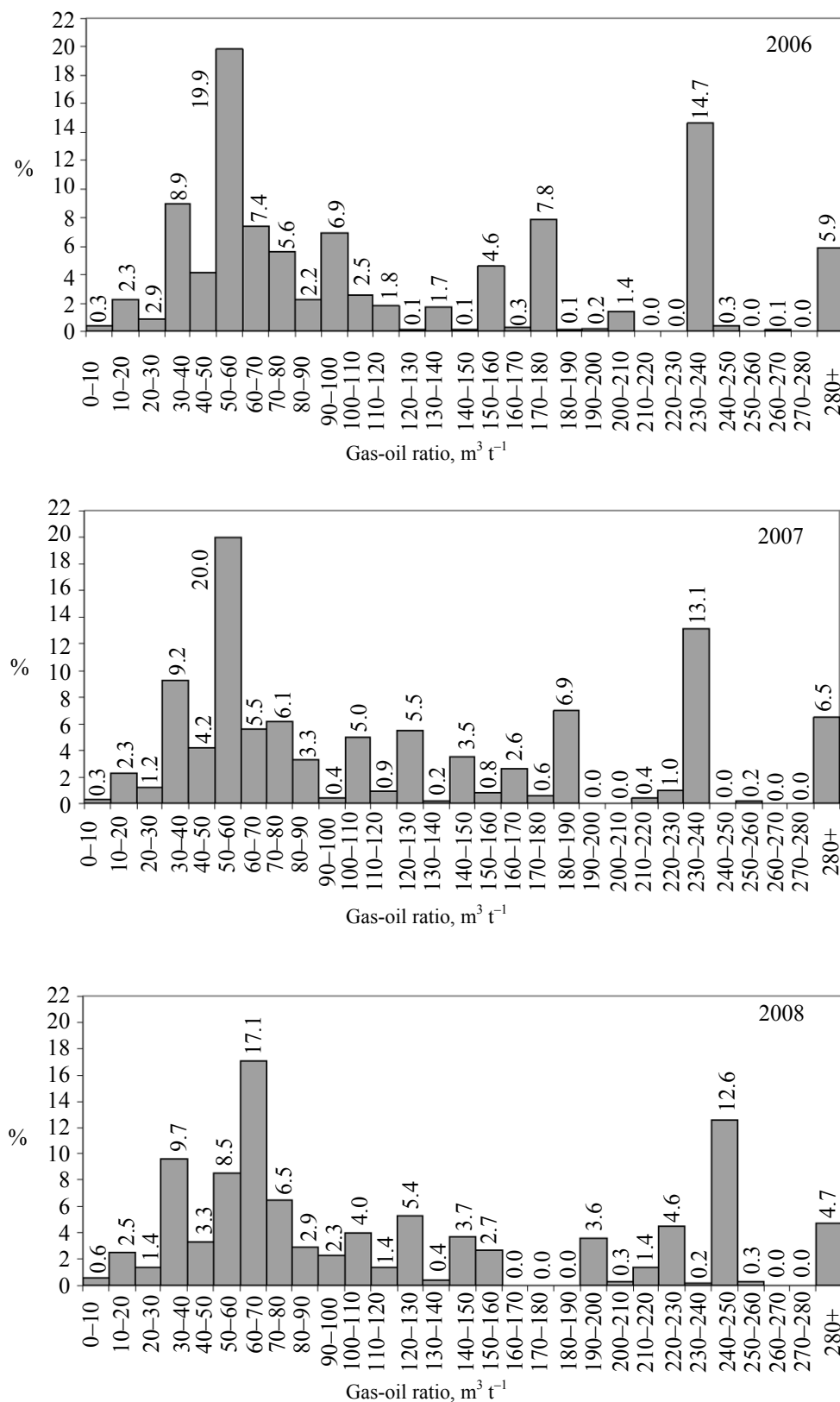
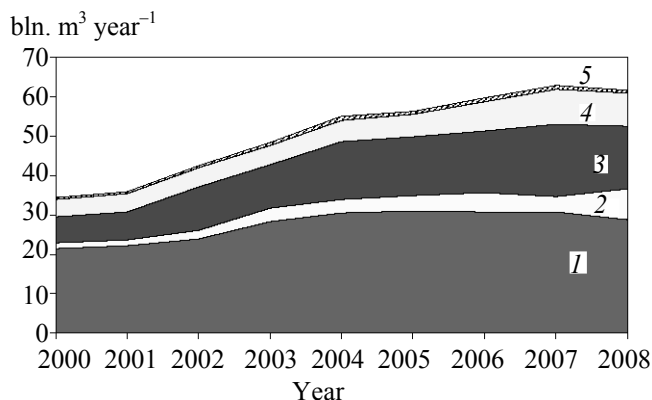


Fig. 1. Distribution of annual weighted average values of the gas-oil ratio in the Russian oil industry in 2006–2008.



**Fig. 2.** APG utilization structure and balance in the Russian Federation in 2000–2008: (1) gas delivery to gas-processing plants and compressing stations; (2) gas delivery to other consumers; (3) gas flared and emitted into the atmosphere; (4) gas consumption for PEN and PTN; and (5) process losses.

The volume of APG production depends on the quantity of extracted oil, as the gas dissolved in oil or a mixture of the dissolved and gas-cap gases from all types of raw hydrocarbon deposits extracted through oil wells are classified as APG [5].

Table 1 provides the data on crude oil production (including gas condensate) and APG resource

extracted on the territory of the Russian Federation within the period of 2000–2008.

The value of the gas-oil ratio at different deposits varies in a wide range from 5 to 1000 m<sup>3</sup> t<sup>-1</sup>. As a rule, at the initial stage of the oil field operation the value of the gas-oil ratio is low but increases with time. This fact can be explained by oil accumulation conditions, non-uniformity of rocks, presence of marginal waters and gas caps etc. Therefore, the averaged value of the gas-oil ratio is used in the calculation of annual APG production volume [2]. The only physical meaning of this value is that this value makes it possible to assess (calculate with certain accuracy) the potential quantity of APG relieved in the process of crude oil production.

The shortage of information on direct measurement values of the gas-oil ratio at specific oil deposits results in the necessity to carry out estimates of the gas-oil ratio on the basis of quantitative data on crude oil production volumes, APG production and utilization, and the volume of flared gas.

The data from Table 1 demonstrate that the annual weighted average value of the gas-oil ratio in crude oil production in the Russian Federation amounted to 116±13 m<sup>3</sup> t<sup>-1</sup> within the period of 2000–2008.

**Table 3.** APG resource for oil-producing companies for the period of 2000–2008, mln. m<sup>3</sup>

Oil-producing company	Year								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Lukoil OJSC	4720	4786	4931	5186	5585	6151	7081	7724	7498
Rosneft' OJSC	2999	3377	4127	5093	5701	8489	11154	11715	12019
Yukos Oil Company OJSC	2703	3268	4689	5645	5777	2605			
Gazprom Neft' OJSC	1734	2140	2547	3478	5365	5661	4389	4878	4503
Surgutneftegaz OJSC	11765	11627	13936	14642	15292	15417	15634	14993	14780
TNK-BP Holding OJSC	4948	5070	7100	8252	10026	10699	11663	12414	12359
V. D. Shashin Tatneft' OJSC	780	784	749	759	769	771	779	783	814
Bashneft' Joint-Stock Oil Company OJSC	417	404	409	414	413	429	405	386	392
Slavneft' Oil and Gas Company OJSC	1418	1515	1576	1081	1369	1533	1428	1368	1296
Russneft' Oil Company OJSC			71	832	1190	1555	1713	1627	1482
Gazprom OJSC							2159	2089	1952
Novatek OJSC							120	136	130
Other producers	2655	2521	2158	2754	2948	2051	1712	1904	2121
Operators of Production Sharing Agreement	278	420	343	367	463	465	856	2246	1913
Total for Russia	34416	35913	42634	48504	54897	56269	59092	62447	61246

Figure 1 provides the distribution of annual weighted average values of the gas-oil ratio for the Russian oil industry in 2006–2008 and clearly demonstrates the presence of two peak points in the distribution of the gas-oil ratio ( $60 \pm 5 \text{ m}^3 \text{ t}^{-1}$  and  $240 \pm 5 \text{ m}^3 \text{ t}^{-1}$ ). The picture remains the same for a long period of time, at least in 2004–2008.

Statistical data on crude oil production volumes (including gas condensate) of some oil-extracting companies taken from open sources [6–8] are given in Table 2.

In compliance with the scheme of accounting indicators within the Russian APG balance sheet, the resource of APG is formed by the quantity of gas extracted by the producing companies plus irrecoverable losses resulting from flaring and corresponding emissions into the atmosphere [2, 9].

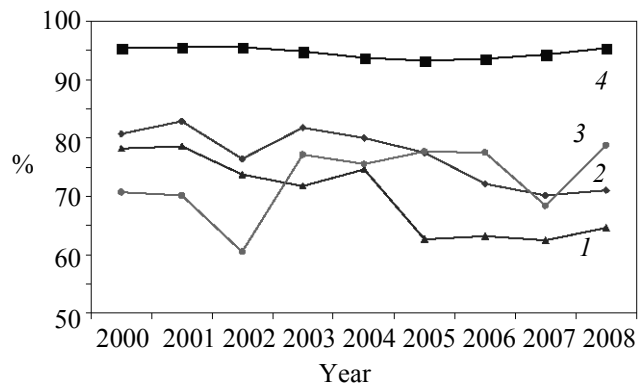
The extracted volume of APG is partly used to satisfy the oil-extracting companies' own needs, which include production and energy needs (PEN) and production and technical needs (PTN), as well as gas process losses [2, 9]. The major part of the extracted APG (from 24 to 36 bln.  $\text{m}^3 \text{ year}^{-1}$ ) goes for processing to gas-processing plants, compressing stations, and other consumers.

Figure 2 shows the utilization structure and balance of APG extracted on the territory of the Russian Federation within the period of 2000–2008.

The information on APG resource appraisal for the Russian oil-producing companies for the period of 2000–2008 is given in Table 3.

The resource of APG (59.1 bln.  $\text{m}^3$  for 2006, 62.4 bln.  $\text{m}^3$  for 2007, and 61.2 bln.  $\text{m}^3$  for 2008), which was calculated taking into account the lack of information on APG extraction volumes from some oil-producing companies and based on the information on the annual weighted average value of the gas-oil ratio at the deposits of the parent oil company, exceeds the resource of APG calculated for the same period without such a correction by 1.2, 1.2, and 0.7 bln.  $\text{m}^3$ , respectively (Table 1).

Taking into account the fact that the average value of the gas-oil ratio for the whole oil industry for the period of 2000–2008 amounted to  $115 \pm 12 \text{ m}^3 \text{ t}^{-1}$ , it is possible to assess the error in APG resource determination as  $\pm 10\%$ . The value of the gas-oil ratio has remained almost unchanged since 2004 and has amounted to  $123 \pm 4 \text{ m}^3 \text{ t}^{-1}$ .



**Fig. 3.** APG utilization rate for major oil companies: (1) Rosneft OJSC, (2) Lukoil OJSC, (3) TNK-BP Holding OJSC, and (4) Surgutneftegaz OJSC.

This fact suggests that despite the introduction of new oil deposits and the lack of information concerning the value of the gas-oil ratio at these objects, the absolute value of the Russian APG resource can be calculated via multiplication of the annual crude oil production volume by the annual weighted average value of the gas-oil ratio. In such calculation the margin of error does not exceed  $\pm 3.3\%$ . At the annual crude oil production rate of 500 mln. ton

**Table 4.** APG utilization (%) in 2006–2008

Oil-producing company	Year		
	2006	2007	2008
Lukoil OJSC	72.2	70.2	71.0
Rosneft OJSC	63.2	62.5	64.6
Gazprom Neft OJSC	46.5	35.3	47.6
Surgutneftegaz OJSC	93.5	94.3	95.4
TNK-BP Holding OJSC	77.5	68.4	78.7
V. D. Shashin Tatneft OJSC	95.0	95.0	94.6
Bashneft Joint-Stock Oil Company OJSC	76.0	80.0	82.3
Slavneft Oil and Gas Company OJSC	62.5	68.0	69.5
Russneft Oil Company OJSC	73.7	71.4	60.5
Gazprom OJSC	75.7	82.5	85.0
Novatek OJSC	36.0	25.1	20.7
Other producers	45.4	40.1	36.1
Operators of production sharing agreement	64.9	89.1	90.5
Total for Russia	75.6	72.6	75.9

the absolute error of  $1 \text{ m}^3 \text{ t}^{-1}$  in the calculation of the gas-oil ratio results in the absence of 0.5 bln.  $\text{m}^3$  of APG on the balance sheet.

Let us use this approach to assess the absolute quantity of crude oil extracted on the territory of the Russian Federation by oil-producing companies, for which the information on APG production volumes and, correspondingly, the APG resource is not available. As a result we see that in 2006, 2007, and 2008 the quantity of oil in question amounted to 9.9, 9.4, and 5.6 mln. t, respectively, which is 2.1, 1.9, and 1.1 % (weight) from the total volume of crude oil produced for the period.

Below we provide some information on the existing level of APG utilization in the Russian Federation.

Table 4 provides data on APG utilization rate for oil-producing companies for the period of 2006–2008 [6–13].

APG utilization rate for the major oil-producing companies of the Russian Federation is given in Fig. 3.

Surgutneftegaz OJSC has the highest APG utilization rate in the Russian Federation (95.40% in 2008 and 95.65% in 2009).

Companies with a low APG utilization rate are developing and implementing programs aimed at increasing APG utilization efficiency.

In order to increase APG utilization rate, Lukoil OJSC is constructing gas-fired power plants at oil fields within the framework of development of the small-scale energy sector. This measure makes it possible to reduce gas flaring and cut power production costs. The company is implementing the Program of APG Utilization by the Companies of the Lukoil Group for 2008–2010, which was approved in 2007 and stipulates an increase in APG utilization rate at the Lukoil Group deposits up to 95% [11].

Gazprom Neft' OJSC adopted a medium-term investment program on APG recovery and increased

efficiency of APG utilization, which will make it possible to raise APG utilization rate at the deposits of the company up to 95% starting from 2012 [12].

The program of Rosneft' Oil Company OJSC for the period till 2012 is also aimed at increasing APG utilization rate to 95% for each of the license blocks [13].

## REFERENCES

1. Rachevskii, B.S., *Mir Nefteproduktov*, 2008, no. 7, pp. 24–31.
2. Solov'yanov, A.A., Andreeva, N.N., Kryukov, V.A., and Lyats, K.G., *Strategiya ispol'zovaniya poputnogo neftyanogo gaza v Rossiiskoi Federatsii* (Strategy for Utilization of Associated Petroleum Gas in the Russian Federation), Moscow: ZAO Federatsiya Gazety Kvorum, 2008, p. 320.
3. *Instruktsiya po kompleksnomu issledovaniyu gazovykh i gazokondensatnykh plastov i skvazhin* (Instruction for Integrated Survey of Gas and Gas-Condensate Strata and Wells), approved by the USSR Gas Industry Ministry on 14.06.1979.
4. Gritsenko, A.I., *Rukovodstvo po issledovaniyu skvazhin* (Well Surveying Guidance), Moscow: Nauka, 1995.
5. *Nalogovyi kodeks Rossiiskoi Federatsii* (Tax Code of the Russian Federation), Part II.
6. *MINTOP Zhurnal Toplivno-Energeticheskogo Kompleksa Rossii*, 2007, no. 1, pp. 22–27.
7. *MINTOP Zhurnal Toplivno-Energeticheskogo Kompleksa Rossii*, 2008, no. 1, pp. 22–28.
8. *MINTOP Zhurnal Toplivno-Energeticheskogo Kompleksa Rossii*, 2009, no. 1, pp. 22–27.
9. Shurupov, S.V., *Gazokhimiya*, 2008, no. 1, pp. 42–44.
10. *Godovoi otchet OAO Gazprom za 2008* (Gazprom OJSC Annual Report for 2008), p. 117.
11. *Godovoi otchet OAO Lukoil za 2008* (Lukoil OJSC Annual Report for 2008), p. 204.
12. *Godovoi otchet OAO Gazprom Neft' za 2008* (Gazprom Neft' OJSC Annual Report for 2008), p. 223.
13. *Otchet v oblasti ustoichivogo razvitiya OAO NK Rosneft'* (Sustainable Development Report of Rosneft' Oil Company OJSC), 2008, p. 142.