

Possibility of using associated petroleum gas as a fuel for a production boiler house

D S Balzamov¹, E Yu Balzamova¹, V V Bronskaya² and N V Valitov¹

¹Department of Power Supply of Enterprises and Energy Resource Saving Technologies, Kazan State Power Engineering University named after D.S. Balzamov, E. Yu. Balzamova, N.V. Valotov, Krasnoselskaya St., 51, Kazan 420066, Russia.

²Department of Chemical Technology of Petroleum and Gas Processing, Kazan National Research Technological University named after V.V. Bronskaya, Karl Marx St., 68, Kazan 420015, Russia

E-mail: dbalzamov@mail.ru

Abstract. Current legislation of the Russian Federation sets requirements for oil companies for utilization of produced associated petroleum gas (APG) at the level of 95%. Thus limiting its burning in torches in the fields. The most convenient way of APG utilization for oil companies is to pump it back into the reservoir, which sometimes allows to increase oil recovery. APG is also used for commercial generation of electricity and heat in fields by burning in gas turbine and gas-piston installations. Given the cheapness of associated gas in comparison with natural gas (NG), it is promising to replace NG with APG for large production boilers located in the immediate vicinity of the associated petroleum gas pipeline. The article provides a comparative analysis of the parameters of APG and NG, a scheme for preliminary preparation of APG for its subsequent combustion in the boiler room, an analysis of the performance of the boiler house to generate thermal energy, the feasibility of using APG as the main fuel for the production boiler room.

1. Introduction

The possibility of substitution of natural gas (NG), which is used as the main fuel in a production boiler with associated petroleum gas (APG), is considered. In this connection with it, a comparison of the characteristics of fuels was performed. Comparison of associated petroleum gas and natural gas is made in accordance with the fuel quality certificates. The comparison results are presented in table 1.

As can be seen from the table, NG and APG have significant differences. NG mainly consists of methane; APG also contains a significant amount of C₂-C₆, which may require the replacement of burner devices. If C₁-C₂ is burned relatively fully, C₄-C₆ when are burned together with C₁-C₂ are not completely burned according to the materials of literary sources [1,2].

The hydrogen sulfide content is significantly higher in APG than in NG, which ultimately will lead to increasing the content of sulfur dioxide in flue gases. This component is strictly regulated and controlled by environmental services. The risk of corrosion processes in economizers of boiler units increases [3].

The calorific value of APG is higher by 20-25%, which may lead to the need for modernization of burners.



Table 1. Quality indicator NG and APG.

Composition (volume concentration, %)	NG	APG
Methane	92.00 – 98.00	42.08
Ethane	-	20.00
Propane	-	13.45
Isobutane	-	1.30
Normalbutane	-	2.79
Isopentane	-	0.48
Normalpentane	-	0.42
Hexanes	-	0.17
Nitrogen	0.699	18.11
Carbondioxide	0.069	0.98
Helium	-	0.03
Hydrogensulphide	-	0.19
Volume fraction of oxygen	-	-
Mass concentration of mercaptan sulfur, g/m ³	0.021	<0.002
Mass concentration of hydrogen sulfide, g/m ³	<0.0001	2.64
Net calorific value (kcal/m ³)	8070	10492.00
Wobbenumber, kcal/m ³	11856	10728.00
Density, kg/m ³	0.6864	1.15
Dewpoint, °C	-	-6.00
Absolute humidity of gas, g/m ³	-	3.00

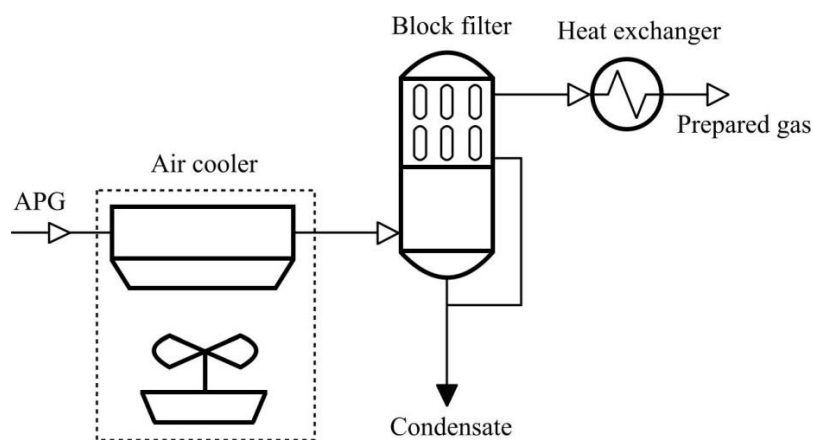
In the cold season, the use of wet APG can lead to the formation of crystalline hydrates on the inner surface of the pipelines and emergency shutdowns. There is a high probability of ice formation in burner devices and on butterfly valves when gas pressure is released [4, 5].

Thus, the use of APG can be considered a promising type of fuel under the following conditions [6-8]:

1. Purification of APG from hydrogen sulfide to the level of mercaptan sulfur in NG.
2. Drying APG, or treatment with anti-icing agents (alcohols, glycols).
3. Application of universal burner devices.

2. Materials and Methods

A scheme for preparing APG for combustion in the boiler plant (Figure 1) is proposed. It allows to solve the above conditions.

**Figure 1.** APG purification Scheme for Combustion.

The APG with a pressure of 6 kgf/cm² enters the air cooler for maximum allowable cooling, then the gas enters the block filter, which includes a separator and a coalescer filter to completely remove droplet moisture, and also mechanical impurities. At the exit from the block filter unit, dried gas and water condensate flows are formed. Gas is supplied to the heater, where it is heated to a temperature of 40°C due to the coolant.

Dried fuel gas enters the burner type MDGG-250B, the results of which are presented in table 2.

Table 2. Gas burner setup results MDGG-250B

№	Parameter	Dimension	The method of obtaining indicators (values)	Burner load, step number							
				1	2	3	4	5	6	7	8
1.	Burner loading	%	Calculation	14.4	25.6	37.6	44.4	56.4	66.0	76.8	85.6
2.	Heating capacity. Q_{hc}	MW	Calculation	0.36	0.64	0.94	1.16	1.41	1.65	1.92	2.14
Fuel is associated petroleum gas, $Q_{nev} = 10343$ kcal/nm ³											
3.	Inlet gas pressure P_i	kPa	measurement	15.0	15.0	14.5	14.0	13.8	13.0	12.5	12.0
4.	The gas pressure before the burner P_b	kPa	measurement	13.5	13.0	12.2	11.5	10.5	9.2	8.0	6.2
5.	Gas consumption	nm ³ /h	measurement	30	54	79	98	119	139	161	180
6.	Gas pressure in burner manifold	kPa	measurement	+7	+14	+32	+47	+64	+90	+117	+145
Air											
7.	Combustion air temperature, t_{air}	°C	thermometer					+18			
8.	Air combustion	m ³ /h	measurement, Calculation	450	800	1200	1500	1800	2100	2400	2700
9.	Vacuum in the burner air manifold	kPa	measurement	+0.07	+0.1	+0.15	+0.2	+0.25	+0.3	+0.35	+0.4

The APG contains hydrogen sulfide in the amount of 0.19%, which at high humidity can cause corrosion of the supply pipes. Replacing burners and inlet pipelines will prevent such problems. Environmental standards for the content of hydrogen sulfide, sulfur oxide, mercaptans will not be violated when working under the proposed scheme. The proposed burners are designed for tasks with a high content of hydrogen sulfide and are successfully used in the combustion of associated gas with a hydrogen sulfide content of up to 4%. A specially developed configuration of the combustion chamber, as well as a significant excess of oxygen, allows sulfur-containing compounds to be burned to residual H₂S concentrations of less than 1 ppm [9]. The main combustion product of sulfur-containing compounds in excess oxygen is sulfur dioxide [10-12]. The estimated flue gas composition for APG combustion is shown in Table 3.

It is seen from table 3 that the content of sulfur dioxide does not exceed 100 ppm. The indicated sulfur dioxide content corresponds to GOST R 50831-95 "Boiler installations. Thermomechanical equipment. General technical requirements." According to the specified GOST, specific emissions of sulfur dioxide are normalized depending on the thermal capacity of the boiler [13, 14]. The most stringent requirements apply to boilers of maximum thermal power (more than 300 MW), the specific

emission should not exceed 300 mg/MJ. The specific dioxide emission for boilers based on twenty megawatt burners when using associated petroleum gas will not exceed 150 mg/MJ, the restriction according to the given GOST for these types of boilers is 500 mg/MJ.

Table3. Exhaustgascomposition

Components	Volumeconcentration, %
Methane	< 1 ppm
Ethane	< 1 ppm
Propane	< 1 ppm
Butane	< 1 ppm
Pentane	< 1 ppm
Hexanes	< 1 ppm
Nitrogen	72.6
Helium	0.013
Hydrogensulphide	< 1 ppm
Carbondioxide	9.21
Sulphurdioxide	0.0094
Oxygen	2.55
Watervapor	15.6

To prevent condensation, it is proposed to use a complex preparation method, including a coalescer filter, to separate droplet moisture and mechanical impurities with a filter fineness of 3 microns and further heating the gas stream to a temperature of 40°C. Such a scheme eliminates the possibility of condensation along the entire pipeline line [14]. With the indicated composition, pressure and temperature of associated petroleum gas, the temperature of the hydrocarbon dew point will be minus 28°C, the hydrate formation temperature is lower than the freezing temperature of water, the assessment was carried out using the modern «Aspen Technologies» software package.

Since cooling during the planned operation of the installation is not expected to be below +10°C, the formation of hydrocarbon condensate is excluded. Table 4 shows the approximate composition of the water condensate obtained from the coalescer filter during gas cooling in an air-cooling apparatus to a minimum temperature (+10°C).

Table4.Component composition of condensate.

Components	Massconcentration, %
Methane	less 0.0001
Nitrogen	0.0022
Helium	<0.0001
Hydrogensulphide	<0.0028
Carbondioxide	0.0050
Water	99.99

The estimated cost of this solution taking into account the project for the replacement of burners, equipment delivery will be 150 million rubles.

The maximum possible supply of APG from the supplier to the production boiler house is at the level of 50 million m³/year, which is confirmed by an official letter from the supplier.

3. Results

In order to assess the feasibility of switching from NG to APG, an analysis of the operation of the boiler room was carried out.

The dynamics of the fuel consumption of the production boiler room during the year is presented in Figure 2.

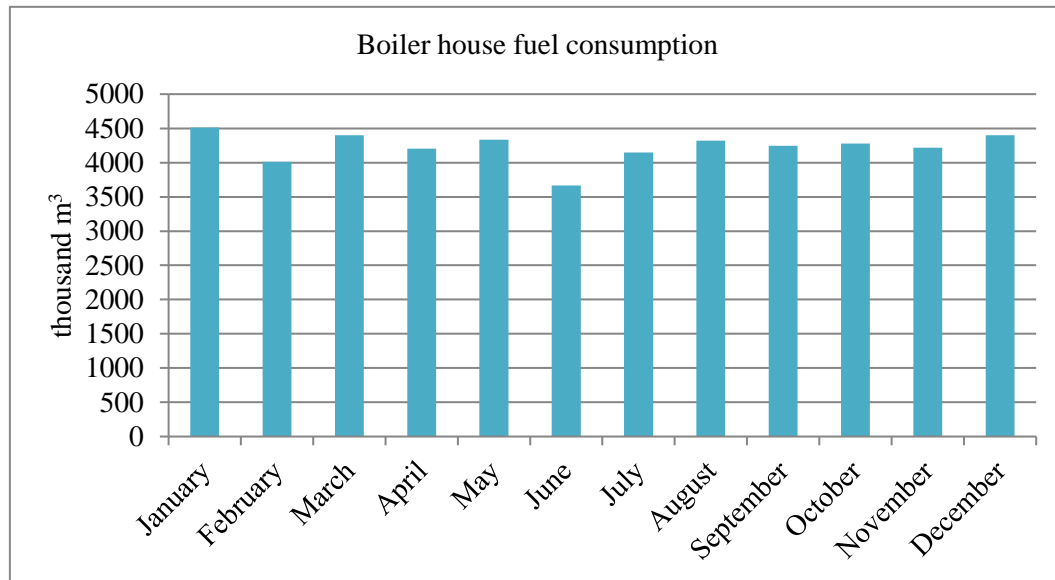


Figure 2. Dynamics of fuel consumption boiler house

From the analysis of the fuel consumption schedule it follows that the total fuel consumption of the boiler house is 50736.062 thousand m³.

In the summer period, the productivity of the steam boiler house slightly decreases, while the specific fuel consumption for steam generation increases (Figure 3).

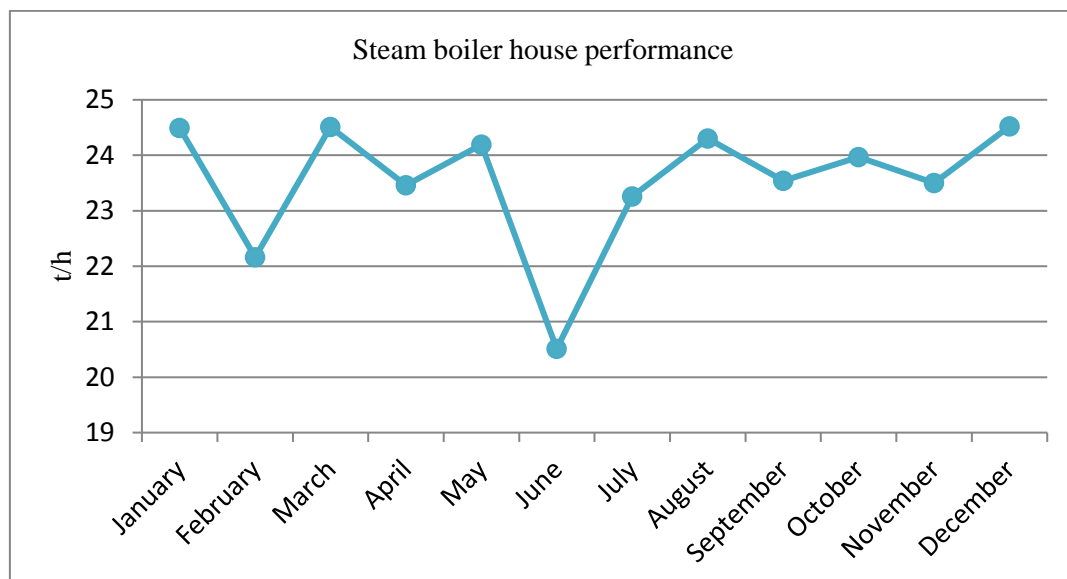


Figure 3. Specific fuel consumption depending on the performance of the boiler house

From the presented figure it follows that the fuel efficiency at a steam capacity of 25 t / h is 15% higher than at 20.51 t/h. At the same time, indicators for months with incomplete hourly loading of boilers (March, June, November) fit into the general statistical regularity. At the same time, as follows from the regime maps, the efficiency gross boilers in this load range varies slightly.

The boiler house has three BEM-25/16-310G steam boilers with a rated steam capacity of 25 t/h. Combustion products are removed through a metal chimney 60 m high and 1,44 m in diameter. The heat load of the boiler room has no seasonal dependence. There are always three boilers in operation.

Each boiler is equipped with an economizer in the form of an integrated tube bundle. The tube bundle is made of steel finned tubes with a diameter of 25 mm.

Boilers are supplied with chemically cleaned and deaerated water using feed pumps. When operating a single boiler, usually only one feed pump is used. The boiler room has centrifugal multistage sectional feed pumps.

Ignition is carried out remotely from the workplace of the boiler operator, after stabilization of the gas-air duct operation mode.

The combustion modes are automated: automatic control of the gas-to-air ratio, vacuum in the boiler furnace, average water level in the boiler drum, steam pressure in the drum (fuel regulator), continuous purge flow rate, and steam temperature are provided. Automatic adjustment of these processes is carried out using microcontrollers.

The boiler house is supplied with gas from a medium-pressure gas pipeline of category II $P_g \leq 6,0 \text{ kgf/cm}^2$. Natural gas enters a gas distribution plant located in the boiler house, where it is reduced to a working pressure of $P_g = 0.45\text{--}0.5 \text{ kgf/cm}^2$.

The main feature of the technological scheme of the boiler room is the absence of connected heating networks. From the production boiler house, only the heating networks connected to the adjacent boiler house are fed.

Release of thermal energy – 356722 Gcal per year.

The cost of natural gas is 5600 rubles/thousand m^3 .

Annual fuel costs are:

$$E_{ng} = 50736.063 \cdot 5600 = 284\,122 \text{ thousand rubles.}$$

The specific fuel consumption in the boiler room amounted to 164,21 kg of equivalent fuel/Gcal or 142.3 m^3/Gcal .

The cost of APG – 3650 rubles/thousand m^3 .

The specific APG consumption for heat generation at enterprises using this type of fuel is 170 kg of equivalent fuel/Gcal or 113.33 m^3/Gcal .

The volume of APG for the production of 356722 Gcal will be 40427.3 thousand m^3 .

APG costs will be:

$$E_{apg} = 40\,427\,300 \cdot 3650 = 147\,560 \text{ thousand rubles.}$$

Savings when switching from NG to APG will be:

$$S = 284\,122 - 147\,560 = 136\,562 \text{ thousand rubles.}$$

It is worth noting that when calculating the payback period of the transition from NG to APG, it is necessary to take into account the capital costs of laying the APG gas pipeline, obtaining technical conditions for connecting to the pipeline, the interest rate on the loan for the project, the costs of developing the project and other factors [15].

4. Conclusion

Replacing natural gas with associated petroleum gas in order to generate thermal energy in the form of water vapor is a fairly cost-effective solution, given the difference in tariffs at the level of 35-40%.

References

- [1] Vazim A, Romanyuk V, Ahmadeev K and Matveenkov I 2015 Associated petroleum gas utilization in Tomsk Oblast: energy efficiency and tax advantages *IOP Conf. Series: Earth and Env. Sci.* **27** 012078
- [2] Knizhnikov A Yu and Il'in A M 2017 *Problemy` i perspektivy` ispol'zovaniya poputnogo nefryanogo gaza v Rossii* [Problems and prospects of associated petroleum gas use in Russia] (Moscow: WWF Rossii) [In Russian]
- [3] Balzamov D S, Sabitov L S, Timershin B F and Balzamova E Yu 2018 Increase of efficiency of heat sources work due to application of condensation economizers on an example of a boiler PTVM-180 *IOP Conf. Series.: Mater. Sci. Eng.* **412** 012007
- [4] Balzamov D S, Balzamova E Yu, Ibatullin S R and Sabitov L S 2019 Efficiency increase of gas turbine work in the summer period *IOP Conf. Series.: Mater. Sci. Eng.* **570** 012008
- [5] Filimonova I V, Eder L V, Mishenin M V and Mamakhatov T M 2017 Current state and problems of integrated development of mineral resources base in Russia *IOP Conf. Series: Earth and Env. Sci.* **84** 012011
- [6] Balzamov DS, Timershin B F 2017 Obzor peredovykh tekhnologiy dlya generiruyushchikh kompaniy [Overview of advanced technologies for generating companies] *Modern Science* **2** 26-9 [In Russian]
- [7] Galikeev R M, Leontiev S A and Umrenkov M V 2011 Primenenie poputnogo nefryanogo gaza dlya sobstvenny`x nuzhd na Xoxryakovskom mestorozhdenii [Application of passing gas for domestic use on Khokhryakovskoye field] *Nauka i TE`K* **3** p. 37-43
- [8] Barkan M S and Kornev A V 2017 Prospects for the Use of Associated Gas of Oil Development as Energy Product *Int. J. of Energy Economics and Policy* **7(2)** 374-83
- [9] Taymarov M A, Akhmetova R V and Akhmetov E A 2019 Efficiency of application of various layout arrangements of oil-gas burners in thermal power plant boilers *IOP Conf. Ser.: Mater. Sci. Eng.* **552** 012008
- [10] Vigon G, Rubcov A and Egov C 2012 *Utilizatsiy poputnogo nefjnogo gaza: problema* [Associated petroleum gas utilization: a problem] (Moscow: Energeticheskii centr SKOLKOVO) [In Russian]
- [11] Tokarev A N 2009 Resheniye problemy utilizatsii poputnogo nefjnogo gaza: interesi I rol neftedobivaushih kompani [Solving the problem of associated petroleum gas utilization: interests and role of oil-producing regions] *Region: Ekonomika i Sociologiy* **3** 212-31 [In Russian]
- [12] Zubareva V D and Ozdoeva A Kh 2019 Osobennosti e`konomicheskoy ocenki primeneniya poputnogo nefryanogo gazadlya texnologii GTL [features of economic assessment of application of associated oil gas for GTL] *Ximiya i texnologiya topliv i masel* **4(614)** 3-7 [In Russian]
- [13] Kozodoev L V, Kuzin N A, Amosov Y I, Kirillov V, Sobyenin V A and Kireenkov V 2011 Novaya texnologiya pererabotki poputny`x neftyany`x gazov v mestax ix doby`chi [New technology of associated petroleum gas processing in oil production fields] *Promy`shlennost` i E`kologiya Severa* **11(19)** 40-3 [In Russian]
- [14] Tarasova M Yu, Klevtsov E A and Fakhretdinov I Z 2018 O povy`shenii e`ffektivnosti ispol'zovaniya nefryanogo gaza koncevy`x stupeney separatsii [On the raising efficiency of associated petroleum gas utilization at the final separation stages] *Transport i podgotovka nefti* **3** 74-6 [In Russian]
- [15] Feigin V I 2011 *Issledovanie sostoyaniya i perspektiv napravlenij pererabotki nefi i gaza, nefte- i gazoximii v RF* [Investigation of trends and prospects of oil and gas, petrochemicals and gas in Russia] (Moscow: Econ-inform) [In Russian]