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Proposal development for the boiler modernization at the Far North enterprise

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Abstract. The article presents the transfer relevance of the boiler from diesel to natural gas. There is an economic calculation of the efficiency in using a gas-equipped PKN-2 boiler with a GG-1 type burner, as well as the environmental efficiency of modernizing the boiler installation. Place: Novo Energy Services LLC enterprise, the Yamalo-Nenets Autonomous District, the Yurkharovskoye oil and gas condensate field, bush No. 2.

1. Introduction

The development of modern society is associated with the use of energy. In connection with the acceleration of scientific and technological progress fuel and energy resources are considered one of the most important issues. With the evolving structure of modern production, liquid and gaseous fuels – gas, diesel fuel, gasoline, fuel oil and various oils – play an important role. The evolution of boilers and heating systems went along with the development of human civilization. Along with the development of heating equipment, the range of materials used in the form of fuel expanded: first firewood, then coal, oil, fuel oil, diesel fuel, natural gas, liquefied gas, solar radiation, nuclear energy, etc. Along with the development of heating equipment, the struggle for fuel economy began – I wanted to burn fuel as little as possible, and get as much heat as possible. This task is becoming more and more urgent in our time, as the usual energy resources on the planet are depleted, and fuel, accordingly, is becoming more expensive [1].

The past 10–20 years the environmental component of fuel combustion became an important issue. The combustion process releases a large number of harmful elements (oxides). The most harmful of these are nitrogen oxides NOx and carbon monoxide CO. Moreover, the higher combustion temperature is the more harmful substances are released. Now there is a struggle to reduce the temperature of combustion in burner devices, and with it the reduction of emissions of harmful substances into the atmosphere [2–5].

The most acute problem of the high cost of fuel and the protection of the environment from flue gases with harmful substances is faced by the boiler plant Novo Energy Services, located in the Yamal-Nenets Autonomous District of Russia *(Nadym district, Yurkharovskoye oil and gas condensate field, bush No. 2).*

The climate features of the territory are affected by its northern position (680 N), influx of solar radiation, as well as increased cyclonic activity and the flat nature of the underlying surface. Permafrost, the proximity of the cold Kara Sea, and the abundance of swamps, lakes and rivers influence climate formation. The continent has a significant impact, which is manifested in the pronounced winter-summer features of the transformation of air masses and the continental climate.

The climate features of the region were adopted at the nearest weather station – Tazovsky. The climate of the region is characterized by long and cold winters, strong winds and blizzards, short and cool summers with long daylight hours. There is cloudy sky and relative humidity observed throughout the year. The annual and daily amplitudes of air temperatures are large, despite the proximity of the Kara Sea and the water content of the territory.

The average annual temperature is negative (–9.3 °C). The average temperature of the coldest month (January) –26.7 °C, and the hottest (July) –13.4 °C. The absolute minimum temperature falls in January –57 °C, the absolute maximum – July +31 °C. The period with a temperature below 0 °C is on average 243 days. The intensive study of the north requires good eather conditions with a large amount of heat due to harsh climate. For these purposes small-sized boiler houses running on diesel fuel were used.

Research objective is project development for the modernization of the boiler room at the Novo Energy Services enterprise (Yamal-Nenets Autonomous Okrug of the Russian Federation, Nadymsky District, Yurkharovskoye oil and gas condensate field, bush No. 2).

2. Methods and materials

The boiler room at the Novo Energy Services LLC is equipped with a steel boiler named ‘KSV-I, 9 LV "VK-3" with a burner that runs on liquid fuel. It is intended for heating and hot water supply in closed heat supply systems with a maximum cool temperature of up to 115 °C and a pressure of up to 0.6 MPa [4]. Diesel fuels represent a fraction from the boiling point of 140–200 °C to the boiling point of 330–360 °C. Chemical stability of diesel fuel considers the ability to withstand oxidative processes during storage. The presence of heteroatomic compounds, especially in combination with unsaturated hydrocarbons, contributes to their oxidative polymerization and polycondensation, thereby affecting the formation of resins and precipitates. Chemical stability is estimated by the amount of sediment formed in the fuel (mg/100 ml) according to ASTMD 2274.

Summer diesel fuel

Density: about 860 kg/m³

Flash point: 62 °C

Pour point: –5 °C

Obtained by mixing straight-run, hydrotreated and secondary-origin hydrocarbon fractions with a boiling point of 180–360°C. An increase in the temperature of the end of boiling leads to increased coking of the nozzles and smokiness.

Winter diesel fuel

Density: about 840 kg/m³

Flash point: 40 °C

Pour point: –35 °C

Obtained by mixing straight-run, hydrotreated and secondary-origin hydrocarbon fractions with a boiling point of 180–340 °C. Winter diesel fuel is also obtained from summer diesel fuel by the addition of a depressant additive, reducing the pour point of the fuel, and slightly changing the temperature of the maximum filterability. By the artisanal method, up to 20 % of TS-1 or KO kerosene is added to summer diesel fuel, while the operational properties are practically unchanged.

Arctic diesel fuel

Density: about 830 kg/m³

Flash point: 35 °C

Pour point: –50 °C

Obtained by mixing straight-run, hydrotreated and secondary-origin hydrocarbon fractions with a boiling point of 180–330 °C. The boiling limits of Arctic diesel fuel approximately correspond to the boiling limits of kerosene fractions, therefore this fuel is, in fact, heavier kerosene. However, pure kerosene has a low cetane number of 35–40 and insufficient lubricating properties. To eliminate these problems, cetane-enhancing additives and mineral motor oil are added to Arctic fuels to improve lubricating properties. A more expensive way to produce Arctic diesel fuel is dewaxing summer diesel fuel [5].

Natural gases are colorless, odorless, and tasteless. The main indicators of combustible gases that are used in boiler houses are: composition, calorific value, specific gravity, combustion and ignition temperature, explosive limits and flame propagation speed. Natural gases from purely gas fields consist mainly of methane (82...98 %) and other hydrocarbons. The density of natural gas (methane) under normal conditions (0 °C and 0.1 MPa, i.e. 760 mmHg), rg = 0.73 kg/m^3 (i.e., lighter than air by about 1.8 times)

Compared to other types, gaseous fuel has the following advantages: it burns in the theoretical amount of air, which ensures high thermal efficiency and combustion temperature; during combustion does not form undesirable products of dry distillation and sulfur compounds, soot and smoke; It is relatively easily supplied via gas pipelines to remote consumption facilities and can be stored centrally; the possibility of increasing the efficiency (efficiency) of the boiler unit; facilitation of work of staff; easily ignited at any ambient temperature; it requires relatively small costs in production, which means it is a cheaper type of fuel compared to other; can be used in compressed or liquefied form for internal combustion engines; relatively high environmental friendliness, characterized by the absence of solid inclusions in the combustion products and less harmful gaseous emissions; has high anti-knock properties; during combustion it does not form condensate, which provides a significant reduction in wear of engine parts, etc.

At the same time, gaseous fuel also has certain negative properties as toxic effect, explosive mixtures formation when mixed with air, easy flow through leaks of compounds, etc. Therefore, gaseous fuel reactions require careful observance of the relevant safety rules.

Thus, there arise such issues as organization of a warehouse for storing liquid fuel stock with the accompanying toughened fire protection measures when operating a boiler plant on diesel fuel. It is necessary to provide measures against freezing, in the winter, of the liquid fuel supply pipeline to the boiler installation. Gas requires relatively low production costs, which means it is a cheaper type of fuel compared to other. Relatively eco-friendly , characterized by the absence of solid inclusions in the combustion products and fewer harmful gaseous emissions.

The study shows the most optimal method for upgrading the boiler room is to replace KSV-I, 9 LV VK-3 with a PKN-2M boiler equipped with a GG-1 burner. The need to modernize boiler houses is made by the equipment deterioration (up to 70–80 %), the presence of a large number of small boiler houses with inefficient liquid fuel boilers (actual boiler efficiency is 50–60 %, normal is 75–80 %). Almost all old boiler houses lack water treatment.

The insertion point of the gas pipeline should be made into the existing high-pressure steel gas pipeline Du 100, Ru 1.2 MPa. The PKN-2M boiler is a stationary vertical-water tube, double-drum boiler with screens included in the circulation circuit through four collectors. Screens and convective beam are made of steel pipes with 57x3 diameters. The boiler is designed to operate in steam mode.

The PKN-2M boiler is equipped with a GG-1 type burner manufactured by Perlovsky Power Equipment Plant OJSC and designed to burn gaseous fuels. GG-1 burners passed state tests. The parameters of the PKN-2M boiler and burner are presented in table 1.

For the operation of the boiler room, gas will be supplied from the Yurkharovskoye field through the main gas pipeline.

The project provides for: connection to the existing steel gas pipeline Du 100, Ru 1.2 MPa; installation of cabinet hydraulic fracturing; entering a low pressure gas pipeline into the boiler room; internal gas equipment of a boiler room, installation of automatic control and safety controls for boiler units, installation of a gas alarm according to CO and CH4 [6].

The main fuel provided is endowed natural gas according to GOST 5542-87.

The project was developed in accordance with the requirements of SNiP 42-01-2002, "Gas distribution systems" [7], "Safety rules in the gas sector" and provides for the conversion of the boiler house to natural gas.

Prior to the start of installation of gasification, a customer’s technical supervision representative should be appointed from among the engineers who passed the exam for knowledge of the “Safety Rules in the Gas Sector” and the relevant chapters of SNiP.

Table 1. Boiler parameters pkn-2m and gg-1 burners

№	*Name of parameter*	*Range Unit*	*Capacity*
	BOILERS PKN-2M Art. No. 1–3.		
1	Thermal value	T/per hour	1,0
2	Vapour pressure	Kg/sm	8,0
3	Boiler inlet water temperature	ºC	50
4	Saturated-steam temperature	ºC	150–170
5	The efficiency of the boiler at rated load (calculated)	%	78
6	Gas-flow rate	Nm/per hour	190
7	Flue-gas temperature	ºC	260
8	End-to-end dimensions		
	– length	mm	3330
	– width	mm	2160
	– height	mm	2465
9	Heating surface	m^2	57
10	Water zone	$м^3$	2,3
	GG-1 BURNER		
1	Amount	Pcs	1
2	Normal heat release	Cal/ per hour	1.1
3	Gas calorific rate $Q^р_н$=7960ккал/$м^3$	Nm /per hour	119
4	Burner inlet gas temperature	ºC	0–40
5	Burner inlet water temperature	ºC	10–40
6	Burner inlet gas pressure rating	kPa	0,72
7	Minimum coefficient of excess air at rated thermal power	–	1,1
8	Dimensions:		
	– length	mm	265
	– width	mm	720
	– height	mm	870

The finished project must be agreed with the gas supply organization and registered with the gas technical inspection [5].

The boiler house gas supply system includes: GRPSh with an RDNK-50 regulator; high pressure steel overhead gas pipeline (Du 50, Ru 1.2 MPa); steel internal gas pipeline of low pressure (DN 150, Ru 0.002 MPa); entering the gas pipeline into the boiler room; gas equipment of the boiler room; automatic safety of combustion, regulation and alarm operation of boilers.

The project provides for a special gas service, which is entrusted with the following tasks: continuous technical supervision of the gas industry; conducting preventive audits; repair of gas equipment and facilities on them; performing gas hazardous work in the gas industry and ensuring readiness at any time to take measures to prevent or eliminate the accident associated with the operation of gas pipelines and gas equipment; maintaining the stability of gas parameters and ensuring uninterrupted supply of gas in the quantities necessary for consumers; accounting of gas consumption and control of its rational use.

The gas service is managed by the chief power engineer of the enterprise or his deputy, and in the absence of such a position, it is run by the chief mechanic. The chief power engineer of the enterprise or his deputy is the person responsible for the gas economy of the enterprise.

Directly the gas service is headed by the head of the gas service. The gas service should be equipped with a telephone service with a gasified boiler room and the Raigaz emergency service.

Persons no younger than 18 years old who have been trained under a special program for gas boiler operators can be allowed to care for boiler units. A staffing schedule is provided for servicing the boiler house, consisting of: a senior operator; boiler room operator (2 in 1 shift); electrician.

3. Results

The result analysis of calculations of emissions dispersion of harmful substances into the atmosphere from the sources in question shows that the use of natural gas as a fuel, in comparison with solid fuel – coal, can significantly improve the sanitary and hygienic conditions in the adjacent territory, by eliminating the content of ash in the air basin, soot, dust, sulfur dioxide and reduce nitric oxide. (The reduced concentration of carbon monoxide COa = 1.0 in the exhaust gases at a load of 32 % is 0 mg/m^3, at a load of 62 % – 0 mg/m^3, the concentration of nitrogen oxides NOx a = 1.0 in the exhaust gases at a load of 32 % – 319 mg/m^3, 62 % – 365 mg/m^3. The specific content of carbon monoxide CO per 1 ton of emitted steam at a load of 32 % is 0 g/t, at a load of 62 % – 0 g/t, the specific content of nitrogen oxides NOx per 1 ton of emitted steam at a load of 32 % is 43.80 g/t, with a load of 62 % – 49.30 g/t. The hourly emission of carbon monoxide at 32 % load is 0 kg/h, at 62 % – 0 kg/h, the emission of nitrogen oxides at 32 % load ke 0.11 kg/h, 62 % load – 0.23 kg/h. Emission of carbon monoxide per 1 thousand m^3 of burnt gas with a load of 32 % – 0 kg/thousand m^3, at 62 % – 0 kg/thousand m^3, emission nitrogen oxides per 1 thousand m^3 of burnt gas with a load of 32 % – 0.431 kg/thousand m^3, with 62 % – 0.490 kg/thousand m^3).

The technological process of gas combustion is provided by an automation system, which guarantees environmental safety of operation. The automation and control system of the boiler room is equipped with the necessary number of sensors that provide complete protection of the environment from harmful emissions.

According to the “Interim Methods for the Regulation of Gas Consumption in Medium and Low Power Boilers”, the control individual gas consumption rate for boilers of a given heating capacity is: for boilers PKN-2M-190 kg. t/t/h, which corresponds to an efficiency of 74.8 %. The reference individual gas flow rate for boilers of a given heating capacity is 168 kg. t/t/h, which corresponds a boiler equal to 85.0 % [8–14].

The results of the tests and the calculation of the economic side of the conversion of the boiler house to gas showed that the annual economic effect amounted to 47 million rubles in 2018 (by increasing the efficiency of installed gas boilers to 90–92 %, introducing general boiler automation, modern water treatment, and reducing costs) for transportation and storage of fuel). During the economic calculation of the return on investment through the use of highly efficient energy-saving technologies based on modern highly cost-effective equipment, it is 6.5 months. Savings for the heating season during the operation of the gas boiler will amount to 11 783 431.19 rubles. This is achieved largely by replacing diesel fuel with gas fuel. There is a decrease in emissions of pollutants into the environment, which means that the payment for emissions has decreased.

The basic principles of organizing the operation of boiler ensure reliable, economical and trouble-free operation of the equipment, therefore, it is necessary to develop a safety regulation for the maintenance of a modernized boiler plant.

The results of tests, economic calculations and an environmental assessment of the modernization of the boiler plant at the Novo Energy Services LLC enterprise revealed its high economic and environmental efficiency.

4. Conclusion

1. An effective method of upgrading the boiler installation in the conditions of the Novo Energy Installations LLC enterprise is to replace the boiler *KSV-I, 9 LV VK-3* with a burner operating on liquid fuel for a PKN-2M boiler equipped with a *GG-1 burner*.

2. Gas is an “internal" fuel cheaper than other sources and the most environmentally friendly in comparison with diesel fuel, because it is imported and the cost of its transportation is needed.

3. In the practical implementation of the proposed modernized boiler plant, there will be a reduction in emissions of toxic gases into the atmosphere.

4. The reduction in pollution charges for the environment will amount to 1,317.19 rubles (in 2018 prices).

5. To ensure reliable, economical, trouble-free operation of the boiler installation, qualified specialists and compliance with labor safety measures (including electrical and fire safety rules) are required.

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