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TECHNICAL AND ECONOMIC FEASIBILITY OF USING A GAS GENERATOR UNIT USING THE EXAMPLE OF ANGREN TPP JSC

Kavkatbekov M.M., Babakhodjaev R.P.
Tashkent State Technical University named after Islam Karimov

Abstract– The article provides a feasibility study for the implementation of a layered gasification installation for Angren brown coal, as well as the possibility of using the resulting generator gas as fuel for lighting in boilers of the TP-230-2 type at Angren TPP JSC. The qualitative characteristics of the resulting generator gas are given, and annual atmospheric emissions from the combustion of generator gas are calculated. A technological scheme for connecting a gas generator installation to an existing boiler unit of the TP-230-2 type is proposed.

Key words– brown coal, layered gasification, economic efficiency, production costs, atmospheric emissions.

I INTRODUCTION

Rational use of technical potential and reduction of the anthropogenic impact of industrial enterprises on the environment are key economic indicators [1-3]. At the Angren TPP, double-drum steam boilers of the TP-230-2 type are operated on boiler house blocks No 1-3. The boilers are designed to burn brown coal from the Angren deposit, as well as fuel oil and underground gasification gas. Underground coal gasification (UCG) gas is used to illuminate the burned coal. The design calorific value of the CCGT gas is 1180 kcal/nm3, and the actual calorific value is 840 kcal/nm3.

Increasing the share of use of generator gas with a high heat output on existing boiler equipment will improve standard indicators for reliability, efficiency, and ecology.

The use of a layered gasification unit to produce generator gas as an alternative to CCGT gas will increase the service life, the period of overhaul of boiler equipment, and also reduce harmful emissions into the environment. In the article under consideration, Angren brown coal of the BOMSH B2 grade was used as a raw material (Table 1) [4].

The values of the generator gas were obtained experimentally [5], the results of which are presented and compared with the values of the underground gas of Yerostigaz JSC in Table. 2.

Humidity W^w, %	34,9
Ash content A^w, %	13,4
Carbon C^w, %	36,2
Sulfur $Sp^w + So^w$, %	1,3
Hydrogen H^w, %	1,9
Oxygen O^w, %	7,8
Nitrogen N^w, %	0,4
Lower calorific value $Q_L^w, kcal/kg$	2 940

TABLE 1: CHARACTERISTICS OF THE WORKING MASS OF ANGREN BROWN COAL GRADE B2.

Generator gas	**"Yerostigaz" JSC**	**Experimental installation**
CO, %	2-12	25-28
CO_2, %	18-28	6-8
CH_4, %	1,5-10	1,5-2
H_2, %	12-35	11,5-13
O_2, %	up to 1	up to 0,5
N_2, %	40-60	48,5-55,5
Specific gas yield, nm^3/kg	2,3	3,0-3,5
Lower calorific value of generator gas, $Q_L^w, kcal/nm^3$	800	950-1000

TABLE 2: COMPARISON OF QUALITY INDICATORS OF PRODUCER GAS

Based on the results given in table. 2, a calculation was made of a gas generating unit designed to produce gas from coal from the Angren deposit (Table 3).

N	Index	Meaning
1	Coal consumption, $kg/hour$	up to 100
2	Gas output, $nm^3/hour$	300 - 350
3	Caloric content of gas, $kcal/kg$	950 - 1000
4	Chemical efficiency, %	60
5	Size of fuel pieces, mm	10-30
6	Combustion air consumption, $nm^3/hour$	400 - 500
7	Electrical power consumption, kW	5
8	Overall dimensions of the gas generator, mm	3880x950x950
9	Weight of metal structures, kg	1500

TABLE 3: TECHNICAL CHARACTERISTICS OF THE GAS GENERATING UNIT

Based on the calculated data of the gas generating unit, a schematic diagram of connecting the main and auxiliary equipment of the gas generating unit to the TP-230-2 boiler was drawn up (Fig. 1).

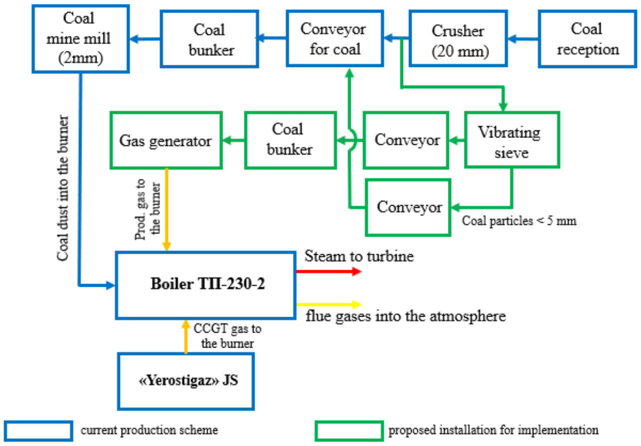

Fig. 1: Schematic diagram of the operation of boiler equipment at the Angren TPP

Calculation of economic effect

The main indicators used to calculate economic efficiency are taken [6]:

- net income;
- payback period.

The total investment consists of:

- transportation costs, 5% of the cost of equipment;
- equipment installation costs, 30% of the equipment cost;
- commissioning costs, 10% of the cost of equipment.

We take the data on the composition and cost of the main and auxiliary equipment of the gas generator installation equal to 310 000 000 sums.

Transportation costs, sum

$$K_T = 0,05 \cdot K_1 \tag{1}$$

where, K_1 – total cost of equipment;

Costs for equipment installation work, sum

$$K_M = 0,3 \cdot K_1 \tag{2}$$

Commissioning costs, sum

$$K_C = 0,1 \cdot K_1 \tag{3}$$

Total investment:

$$K = K_1 + K_T + K_M + K_C \tag{4}$$

The annual supply of thermal energy when using generator gas will be:

$$Q_{gen} = B_{gas} \cdot Q_L^w \cdot \eta_{brutto} \tag{5}$$

where, $B_{gas} = 2,56 \cdot 10^6\ nm^3/year$ – annual consumption of generator gas; $Q_L^w = 1000\ kcal/kg$, lower calorific value of generator gas;

In accordance with the category of technological equipment, the estimated service life of the gas generator is taken to be $T_{SL} = 12\ years$.

Let's determine the annual depreciation rate:

$$H_D \approx \frac{100}{T_{SL}} = \frac{100}{12} = 8,3[\%].$$

Thus, the depreciation rate will be 8,3%.

Let's calculate the costs of the gas generator.

Fuel costs:

$$C_F = B_F \cdot C_F \tag{7}$$

where, C_F- cost of 1 ton of coal [7].

Depreciation costs:

$$C_D = K \cdot H_D \tag{8}$$

Repair costs:

$$C_R = 0,4 \cdot H_D \tag{9}$$

Salary costs:

$$C_{SC} = 1,543 \cdot 10^8 \quad [sum/year] \tag{10}$$

Payroll deduction costs:

$$C_{PD} = 0,12 \cdot C_{SC} \tag{11}$$

Electricity costs:

$$C_{EE} = C_E \cdot N_E$$

where, C_E=900 $sum/kW \cdot hour$ is the cost of electricity; N_E=40 000 $kW \cdot hour/year$ – annual total electricity consumption of the main and auxiliary equipment of the gas generator plant.

Other costs:

$$C_0 \approx 0,15 \cdot (C_D + C_R) \tag{12}$$

Total costs:

$$\sum C = C_D + C_{SC} + C_R + C_F + C_{EE} + C_{PD} + C_0 \tag{13}$$

Cost of thermal energy when using generator gas:

$$C_{TE}^{gas} = \frac{\sum C}{E_{prod}} \tag{14}$$

Annual income from the generated thermal energy using generator gas.

$$C_{GT} = (C_{TE}^{coal} - C_{TE}^{gas}) \cdot h \tag{15}$$

Payback of a gas generator installation:

$$T_0 = \frac{\sum C}{C_{gas}} = \frac{4,519 \cdot 10^8}{1,513 \cdot 10^8} = 3[year]. \tag{16}$$

Calculation of the repair fund for the TP-230-2 boiler after the introduction of a gas generator plant.

The annual repair fund for 2023 for the equipment of the TP-230-2 boiler No 1 of stage amounted to C_R^p=489 423 120 sum.

The abrasive wear caused by fly ash damages the metal inside the firebox. Therefore, the main material costs for repairs fall on the internal metal of the furnace (screen system, water supply pipes, lower collectors of the screen system, steam transfer pipes, superheater manifold and others).

At the moment, coal is burned in the amount of 30 tons/hour in boilers TP-230-2 No 1-3 [8]. Therefore, the annual coal consumption will be:

$$B_{coal}^{year} = B_{coal}^{hour} \cdot 8000 = 30 \cdot 8000 = 240000 \quad [t/year] \tag{17}$$

Taking into account the production capacity of the gas generator, direct combustion of coal in the furnace of the TP-230-2 boiler is reduced by 800 tons/year. The ratio of coal used for gasification to the total volume of burned coal in boilers TP-230-2 No. 1-3 stages will determine the degree of reduction in abrasive wear of metal structures, i.e.:

Degree of reduction of abrasive wear:

$$K_{abr.w.} = \frac{B_{gas}^{year}}{B_{coal}^{year}} = \frac{800}{240000} = 0,0033 \tag{18}$$

Parameter	Meaning
Total annual costs, $sum/year$	451 900 000
Financial profit, $sum/year$	151 272 000
Annual heat generation, $Gcal/year$	2,07
Heat cost, $sum/Gcal$:	218 309
Payback period, *years*	3

TABLE 4: GENERAL ECONOMIC INDICATORS GAS GENERATING UNIT

Environmental indicators

At the Angren thermal power plant, the flue gases include: fly ash, carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxides (NO_2).

Calculation of fly ash emissions. Mass emission of fly ash when burning coal and generator gas using a dust collector [9], t/year.

$$M_{fa} = B_T \cdot \frac{A^w}{(100 - G_{fs})} \cdot \alpha_{sh} \cdot (1 - \eta_e) \tag{18}$$

where, B_F = 800 t/year – annual fuel consumption;

A^w = 26 % – working ash content of coal;

A^w = 1,6 % – working ash content of gas;

G_{fs} = 2% – content of flammable substances in the entrainment;

$\alpha_s h$ = 0,85 – share of ash in carryover;

η_e = 0,869 – efficiency of dust collector cleaning [10,11].

Annual fee for fly ash emission when burning coal and generator gas for boilers No 1-3 stages [12]:

$$y^{atm} = \frac{M_{fa} \cdot P_{MBV} \cdot \eta_{fa}^{br}}{K_{fa}} \tag{19}$$

where, P_{MBV} = 330 000 sum – the minimum basic calculated value established in the Republic of Uzbekistan;

η_{fa}^{br} = 0,0228 – base rate for fly ash;

K_{fa} = 6 - multiplicity factor when exceeded (decreased), when their validity period has expired or in the event of an accident.

Calculation of carbon oxide emissions. The mass emission of carbon oxides is determined by the formula, t/year.

$$M_{CO} = 0,001 \cdot B_F \cdot K_{CO} \cdot (1 - \frac{q_{mech}}{100}) \tag{20}$$

$$K_{CO} = (q_{chem} \cdot R \cdot Q_L^w)/1,013 \tag{21}$$

where,K_{CO} – carbon monoxide output when burning solid fuel or liquid, g/kg or gaseous, g/m^3; q_{mech}= 1,2% – heat loss from mechanical incomplete combustion of fuel in the boiler;

q_{chem}= 2,4% – heat loss from chemical incomplete combustion of fuel;

R is a coefficient that takes into account the share of heat loss due to chemical incomplete combustion of fuel, caused by the content of carbon monoxide in the products of incomplete combustion. For solid fuel $R = 1$, for gas $R = 0,5$, for fuel oil $R = 0,65$;

Q_L^w= 12,343 MJ/kg – lower heating value of coal;

When burning generator gas, the formation of carbon oxides is neglected. Calculation of sulfur dioxide emissions. The mass emission of sulfur dioxide is determined by the formula, $t/year$.

$$M_{SO_2} = 0,02 \cdot B \cdot S^p \cdot (1 - \eta'_{SO_2}) \cdot (1 - \eta''_{SO_2}) \tag{22}$$

where, S^p = 1,3 – sulfur content in fuel per working weight, %;

η'_{SO_2} = 0,5 – the proportion of sulfur dioxide that is bound by the fly ash of the fuel;

η''_{SO_2} = 0,03 – fraction of sulfur dioxide captured in the ash collector for wet ash collectors.

Calculation of nitrogen oxide emissions. The mass emission of nitrogen oxides is determined by the formula, t/year.

$$M_{NO_2} = 0,001 \cdot B \cdot Q_L^w \cdot K_{NO_2} \cdot (1 - \beta) \tag{23}$$

where, Q_L^w = 4,184 for generator gas – lower heating value of fuel, MJ/kg;

$K_{NO_2}^{coal}$ = 0,18, $K_{NO_2}^{gas}$ = 0,09 – parameter characterizing the amount of nitrogen oxides per 1 GJ of heat, kg/GJ;

β = 0,5 – coefficient that takes into account the degree of reduction in nitrogen oxide emissions as a result of the use of technical solutions.

Annual fee for the emission of carbon oxides when burning coal and generator gas on boilers No 1-3 stages:

$$y_{NO_2}^{atm} = M_{NO_2} \cdot P_{MBV} \cdot \eta_{NO_2}^{br} : K_{NO_2} \tag{24}$$

Sum of emissions of harmful substances:

$$M^{atm} = M_{fa} + M_{CO} + M_{SO_2} + M_{NO_2} \tag{25}$$

Total payment for the emission of all harmful substances into the atmosphere.

$$y_{NO_2}^{atm} = y_{fa}^{atm} + y_{CO}^{atm} + y_{SO_2}^{atm} + y_{NO_2}^{atm} \tag{26}$$

The table shows the summary of calculations for the quantity and payment for harmful emissions when burning coal of 800 tons/year.

Emissions	**Coal**		**Producer gas**	
	Emissions, t/year	Payment for emissions, sum/year	Emissions, t/year	Payment for emissions, sum/year
Fly ash	23,63	29 636	6,3	7 566
CO	23,1	7 612	-	-
SO_2	10,1	16 165	16,14	25 832
NO_2	0,89	3 251	0,63	2 298
Total	**57,7**	**56 664**	**22,8**	**33 696**

According to the table Figure 5 shows that when burning generator gas with a flow rate of B = 320 $nm^3/hour$ (416 $kg/hour$ or 3328 $t/year$), it is possible to reduce harmful atmospheric emissions to ΔM^{atm}= 34,9 $t/year$ (45 370 $nm^3/year$) or save thermal energy of exhaust gases $Q_{nat.gaz} = m \cdot I_r = 45370 \cdot 271 = 12\ 295\ 270$ $kcal/year$, which is equivalent to saving 1,756 kg of standard fuel or 1,535 m^3 (1 383 217 sum) of natural gas. If the scale of use of generator gas increases to B = 32 000 $nm^3/hour$ (41600$kg/hour$), the annual savings of natural gas when operating one gas generator will be $E_{nat.gas}$= 153 500 m^3 or 138 321 700 sum.

II CONCLUSION

Based on the calculation of the technical and economic indicators of a layered gas generator with a coal consumption of 100 kg/hour for a boiler of type TP-230-2 at Angren TPP, the following indicators were obtained:

- investment costs – 451 900 000 *sums*;
- annual benefit – 151 272 000 *sums*;
- savings in annual operating costs for repairs of boiler equipment – 0,0033%;
- total annual benefit of material resources – 152 887 709 *sums*;
- payback period – 3 *years*;
- useful service life of the equipment – 8 *years*;
- reduction of emissions into the atmosphere - 35 $tons/year$;

- annual natural gas savings of up to 1 535 m^3 due to reduced emissions into the atmosphere;

The quality indicators of the generator gas allow it to be used as an alternative fuel for gas from the CCGT plant of Yerostigaz JSC.

The payback period of the project is 3 years, which classifies it as an average payback period.

Based on the above performance indicators, we can say that the investment project is economically feasible and financially sound.

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