Research an Adaptation Processes of the System «Rock and Coal Massif – Underground Gasgenerator» on Stand Setting

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ABSTRACT: The results of borehole underground coal gasification researches on the stand seating with account technological and geological conditions and technological parameters at coal seam gasification process are examined.

During an experiment the products of coal seam gasification, high-quality composition of generator gas and chemical products at different thermo chemical conditions was determined.

The serve of blowing and gas inlet with account permeability of gasgenerator are approved.

KEYWORDS: *gasification, coal seam, rock and coal massif, gasgenerator, stand setting.*

AN AIMS AND PURPOSE OF THE EXPERIMENT

A research object is a process borehole underground coal gasification (BUCG). A purpose of the work is an exposure of factors, which characterize the process of underground coal gasification of the coal seam c_5, Western Donbas, taking into account the change of the rock and coal state which contain a coal seam.

For achievement of the put purpose on the stand and laboratory setting and also analytically the followings tasks was decided:

- to set functional dependence of change the composition BUCG gas as far as goaf growth at the permanent expense of blowing reagents and combined scheme of reagents serve taking into account enhanceable humidity (44-67 %) of soil and ash-content of coal (36-42 %);
- to set boundary path warming up the rocks of roof above coal seam taking into account the change of the rocks state as far as goaf growth;
- to define high-quality composition of runback after underground gasification of the designed coal seam taking into account his element composition;
- to set the parameters of reactionary channel forming taking into account the modes: ignition, forming an oxidization zone (the process of coal burning PCB) with a transition to forming the stable zone of exothermic and endothermic reactions on the length of underground gasgenerator reactionary channel (the process of underground coal gasification UCG).

DETERMINATION THE CRITERIA OF SIMILARITY TO THE NATURAL CONDITIONS

The experiments on natural stand setting making for the imitation the processes of BUCG taking into account the design of geological conditions and technological parameters [1].

With the purpose of imitation the process of borehole underground coal gasification on the stand setting geometrical, mechanical and kinematics scale factors which allow executing the conditions of similarity were set.

Pressure in the models of underground gasgenerator and high-quality composition of generator gas in the scale of similarity answers model conditions. The expense of air at the air blowing, in obedience to project information, will make 7930 m^3/h (2,32 m^3/kg coal), for blowing enriched by oxygen – 4911-5127 m^3/h (1,89 m^3/kg coal).

CALCULATION THE PARAMETERS OF MASS AND THERMAL BALANCE ON THE BUCG STAND SETTING

At table. 1 the results for mass and thermal balance calculation on the BUCG process stand setting are given

Table 1. Element and technical composition of coal seam c_5

W^r %	W^a %	A^c %	S^d %	V^{daf} %	C^{daf} %	H^{daf} %	O^{daf} %	N^r %	Q^r Mj/kg	γ, g/sm^3	The length of reaction channel, m	Seam thickness, m	Water inflow, m^3/t
45,8	46,9	36	1,6	42,2	80,3	5,5	7,2	5,0	23,4	1,2	1,8	0,2	0,1

The mathematical model of mass and thermal balance of BUCG process on the stand setting was provided by the program «MTBalanse SPGU», which was developed in National mining university on the department of underground mining. The algorithm of parameters calculation the borehole underground coal gasification process, which is related to the thermo-chemical converting of hard fuel into a gases and runback at the set element composition of coal, external water inflow and thermal balance are foreseen [2]. The parameters of coal seam gasification process on the BUCG stand setting are presented in tables 2, 3, 4, 5.

Table 2. The parameters of mass and thermal balance at the coal seam c_5 gasification process on the stand setting

Type of blowing	Parameter of blowing m^3/h	BUCG gas escape from gasgenerator, %							The speed of coal seam gasification, м/доб	Chemical efficiency, %	Heat of gas combustion, MJ/m^3	Energy of the underground gasgenerator zone, MJ		Gas humidity, g/m^3	Intensification, t/h
		H_2	CH_4	CO	N_2	H_2S	CO_2	O_2				Oxidation	Restoration		
Air	162	11,9	4,67	5,03	61,26	0,22	15,98	0,85	1,7	54,27	3,61	1547,7	-565,48	459	0,09
Steam-air O_2 N_2 steam	258 28,4 144,5 85,1	18,5	5,79	4,02	45,34	0,32	24,52	1,48	1,62	57,38	3,76	516,64	-884,14	518	0,18
Oxygen O_2 N_2	132 54,2 77,8	8,54	5,21	24,16	41,84	0,37	18,54	1,33	1,21	64,74	6,37	1616	-794,89	507	0,108

Table 3. Thermal balance of coal seam c_5 gasification on the BUCG stand setting

Indexes	**Type of blowing**					
	Air		**Oxygen**		**Steam+air**	
	MJ/kg	%	MJ/kg	%	MJ/kg	%
Heat of combustion	23,454	95,836	23,454	88,854	23,454	93,020
Heat capacity of rock mass in the oxidation zone	0,701	2,864	1,154	4,372	0,653	2,590
Heat capacity of blowing	0,318	1,299	1,788	6,774	1,107	4,390
In all:	**24,473**	**100,000**	**26,396**	**100,000**	**25,214**	**100,000**
Heat of BUCG gas combustion	3,610	15,391	6,370	24,308	3,760	14,732
Heat loses:						
1.Ash and slag heating, Mj	0,312	1,330	0,214	0,817	0,316	1,238
2.Heating and evaporation of moisture (water inflowi, coal and rock humidity), J	3,708	15,809	2,634	10,052	4,047	15,856
3.Heating of containing rocks (roof, soil), MJ	9,206	39,250	7,983	30,464	9,410	36,869
Heat capacity of dry generator gas.	6,619	28,220	9,004	34,360	7,990	31,305
In all:	**23,455**	**100,000**	**26,205**	**100,000**	**25,523**	**100,000**
A gas temperature in the gas outlet borehole, ^{0}C	143		187		115	

Table 4. Blowing and gas expanse at BUCG

Type of blowing	Blowing expense		Output BUCG gases	
	m^3/h	m^3/d	m^3/h	m^3/d
Air	162	3888	221	5304
Steam+air	258	6192	370	8880
Oxygen	132	3168	207,4	4978

Table 5. A calculation output of basic chemical products at designed BUCG (kg)

Type of blowing	Output of chemical products at gasification, kg			
	Coal resin	Benzol	Ammonia	Sulphur
Air	73,7	20,48	32,8	1,02
Steam+air	84,9	43	57,3	1,02
Oxygen	96,2	44	66,5	1,2

STRUCTURAL FEATURES OF THE STAND SETTING

The necessity of experiment conduction on stand models is explained by necessity of more careful study of coal from Western Donbas and rock mass behavior at coal seam gasification process, and also receipt of initial data for development the method for coal seam gasification in natural conditions [3, 4].

The experimental stand setting is projected and patented in national mining university and built by «Neftemash» at sponsorship by department of education and science of Ukraine. Installed and geared-up after the assistance of technical services of mine «Juvileina» SC «Pavlogradvugillia» and situated on the mine territory (fig. 1).

The unfolded variant of the stand setting is a model of underground gasgenerator. In a general view, setting consists of three elements: blowing system, tent-bed test with a control and measuring block and gas outlet system.

Fig. 1. General view of the operating systems: 1 – compressor RM-3138; 2 – steam generator AVPE-11/9; 3 –high-pressure pipeline; 4 – receiver (air, steam and oxygen); 5 – a water reservoir; 6 – a tank-cooler; 7 – flowmeter IRVIS-300C; 8 – lime filter (catching of H_2S); 9 – exhauster DR-1,0-00.00PS; 10 – offtake; 11 – tank of dew and slags collection; 12 – flexible pipeline; 13 – the stand setting; 14 – ignition borehole; 15 – platform for coal seam angle simulation

The central link of model is a stand box (fig. 1), cooked from sheet steel. A stand is executed from one section (2,2 2,5 2,0 m) with an active platform. Pressurizing of stand box is foreseen a removable two section cover, equipped by active vents for the sensors of moving (ranging marks) and thermocouples.

For diminishing of heat loses a stand from a middle is isolated by heat-insulation material (heat-resistant brick and chamotte) on the perimeter of the designed rock mass and on the coal seam soil (fig 2 a, b,*)*. A heat-resistant brick provided heat-insulation impermeability of stand box to contoured coal seam.

Blowing system include: compressor RM-3138, steam generator of AVPE-11/9, 4 receivers., distributors, pipeline and flowmeter IRVIS 300К, and also from a rubber high-pressure pipeline, d = 3 sm, with the perforated heat-resistant attachment on the ends, fig. 1 (3). A high-pressure pipeline imitates work of flexible pipeline, provides transference of blowing serve as far as coal seam gasify. Controlled pipeline is given through the screw-thread opening in the wall of stand box on an imitation blowing borehole in the seam (fig. 2 b).

The gas-outlet system (fig. 1) consists of collapsible tank with a tray for slag collection (11), gas-outlet highway with a distributive armature and control and measuring block (manometers, pyrometers, газоаналізатори GASBOARD-3200L, BX170 and flowmeter IRVIS 300C), tank-cooler (6) with a tank for runback collection, lime filter (8) and exhauster (9).

Fig. 2. Model of underground gasgenerator: a) heat-insulation of stand box; b) coal seam formation: 1 – a coal seam; II – a blowing borehole; III – a gas outlet borehole, IV– reactionary channel (imitation of hydrofracturing)

Compressors, exhauster and steam generator feed on from the mine electric system tension 380 V, control and measuring apparatus – 220 V, total power of stand setting make 40 kWt.

Coal seam forming was carried out by blocks with a size 0,2 × 0,5 × 0,1 m (fig. 2). The blocks (bricks) of coal seam are formed in accordance of mode (scale 1:10).

A bottom and walls of stand box was assessed heat-insulation (heat-resistant brick and chamotte), the seam soil is laid out a rock (slate), a coal seam was laid out from a "brick" which was clamped between itself by cement solution.

In a coal seam was free space for the imitation of blowing and gas-outlet boreholes and gasification channel. A reactionary channel is formed from the pieces of coal faction 2,5-6,8 sm (1 part of cement to a 10 part of coal fine coal), imitating hydrofracturing in seam between operating boreholes.

After coal drying out over a coal seam was installed direct roof consisted taking into account the coefficients of heat-conducting, heat capacity and diffusivity of rocks. A direct roof (slate) and basic roof (shist) was formed from a mine breed and fire-clay solution, that provided an observance the thermal coefficients in the model conditions.

Direct roof thickness, in obedience to a scale – 0,8 m. Due to pressurizing and heat utilization of direct roof was provided parameters of permeability, heat-conducting, diffusivity and heat capacity of rock mass. Rock mass with thermocouples and ranging marks establishment in the model of underground gasgenerator are shown on fig. 3 a, b.

Process control of gasification was carried out the serve of blowing from the compressor RM-3138 on a high-pressure flexible pipeline, which is connected with a high-pressure pipeline and heat-resistant attachment.

Varying pressure in the oxidization zone (exothermic processes) of reactionary channel and taking of generator gases from the restoration zone (endothermic processes) in a gasgenerator with providing equilibrium of physical speeds and kinetic reactions, provided the combined serve of blowing mixture in the pulsating mode.

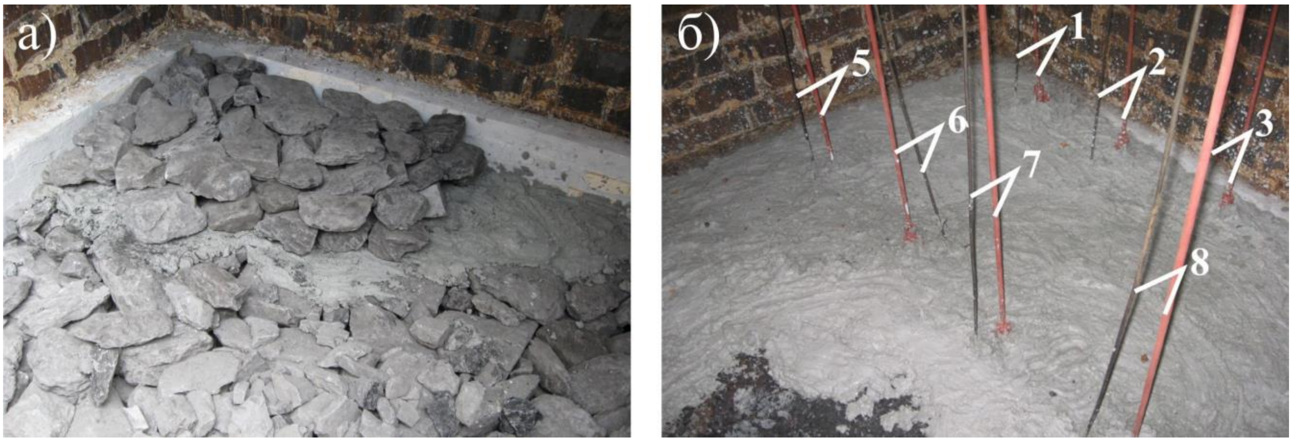

Fig. 3. Model of underground gasgenerator: a) rock mass forming of underground gasgenerator; b) thermocouples and ranging marks establishment: 1-8 system of thermocouples (on the left) and sensors of rocks moving (on the right)

The parameters of thermocouples and ranging marks situation in rock mass are shown in the table.6.

Table 6. Parameters of thermocouples and ranging marks situation

№ thermocouple and ranging marks	Depth of situation, m	Distance from thermocouple, m		
		to a blowing borehole	between rows	to a gas outlet borehole
First row				
1	0,1-0,4	0,1	0,7	0,1
2	0,1-0,4	0,4	0,7	0,4
3	0,1-0,4	0,4	0,7	0,4
4	01-0,4	0,4	0,7	0,4
Second row				
5	0,2-0,5	0,4	0,7	0,4
6	0,2-0,5	0,4	0,5	0,4
7	0,2-0,5	0,4	0,5	0,4
8	0,2-0,5	0,4	0,5	0,4

RESEARCH THE BOREHOLE UNDERGROUND COAL GASIFICATION TECHNOLOGY ON THE STAND SETTING

On the experimental stand setting the next conformities of parameters change at gasification process as far as coal seam was gasify were probed in 2011 year:

- coal seam reactivity at it ignition in the combined mode and blowing and generator gases outlet;
- parameters of direct reactionary channel burning in the combined mode taking into account hydrofracturing imitation between operating boreholes;
- conditions of process stability as far as goaf growth and rocks of roof deformation;
- change of generator gas composition taking into account imitation geological terms and parameters of coal seam gasification;
- concentration of chemical components (ammonia, sulphur, pyridines, carbohydrates, resin and other chemical components) in gas condensate taking into account the change of the rock mass stat.

Coal seam ignition was carried out through the openings in stand box d = 100 mm. For realization the process in ignition borehole the incandescent coal was filled.

Through a pipeline with heat-resistant attachment, in a blowing borehole, the air blowing was given force-feed P = 0,3 MPa on incandescent coal which brought to education hearths over of coal self-ignition in the temperature condition 510-523 ^{0}C, at the fixed middle temperature – 510,7 ^{0}C.

Thus front of seam warming up coincided with motion of blowing in direction of reaction channel burning. Pressure was increased P = 0,42–0,5 MPa, burning of channel carried out by the speed 0,8-0,95 m/h. In obedience to an experiment the serve of blowing was carried out in the forcing mode.

Passing to the combined mode compressor – exhauster allowed to decrease pressure to 0,3-0,41 MPa and increase burning to a 1,3-1,5 m/h. After coal ignition and reactionary channel burning (6 o'clock of experiment) a process passed to forming the zone in reactionary channel. During stabilizing the gasification regime (8 hours) on thermocouple (4) (fig. 3) the temperature 667-735 ^{0}C was fixed, on thermocouple (3) 822-901 ^{0}C. Oxygen was diminished in the products of BUCG to 2,0 %, the contents of carbon dioxide diminished to 15,9 %.

After 13 hours of experiment there was destabilization of gasification process (decline of gas temperature in the channel, growth in gases composition passive elements). It was related to goaf growth S = 1,88 m^2 and by the presence of cavity in the supporting area, in connection with clay natural fracturing pattern which was used as an hermetic and heat isolator. The parameters of temperatures were fixed by thermocouples (stationary mode) and pyrometer (dynamic mode), fig. 4.

Taking into account an existent situation, pressure of blowing was diminishes to P = 0,1-0,14 MPa and the combined mode of blowing mixture serve was entered, that allowed during two hours to support the process of gasification in the stable state.

It should be noted that instability of gasification process on the first stage was promoted by heat loses 45-66 %. The middle index of generator gas humidity during an experiment was determined after expression:

$$W_P = \frac{\gamma_B}{V^k} \cdot (0{,}111 \cdot H^r + 0{,}0124 \cdot W^r + 0{,}016 \cdot V^o + \frac{\gamma_B}{g}) =$$

$$\frac{0{,}804}{2{,}3} \cdot (0{,}111 \cdot 5{,}4 + 0{,}0124 \cdot 36 + 0{,}016 \cdot 7{,}46 + \frac{0{,}804}{3{,}1} = 0{,}429$$

There was evaporation of moisture in the coal seam and rock mass (in the soil). Humidity of rock mass consist 30,6-45,7 %, and ash-content in coal seam A_c = 36-45 %, what was increased as a result of fastening the blocks of coal between itself by clay solution for creation coal and rock mass.

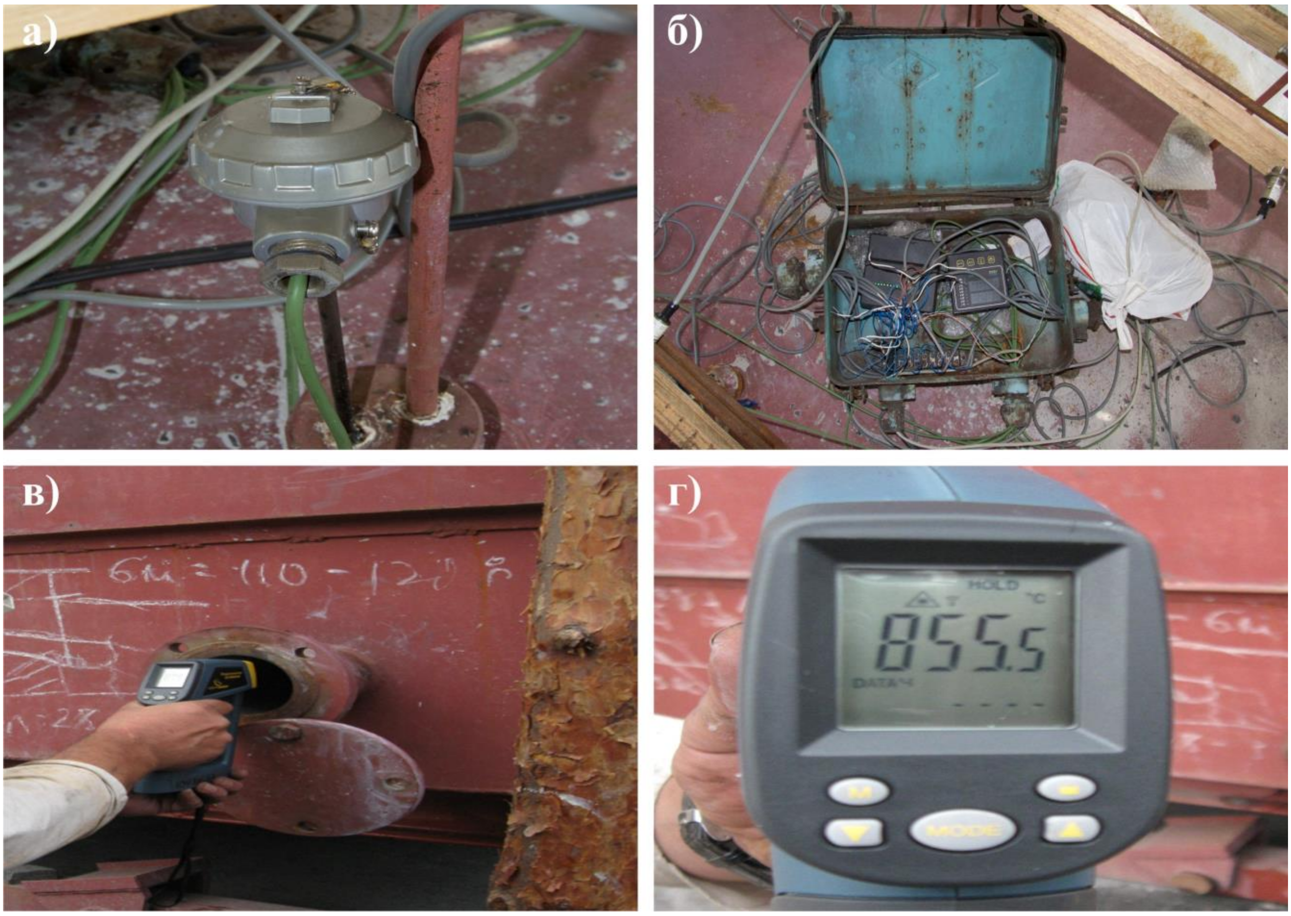

Fig. 4. Devices for measuring the temperatures: a ,b – in the stationary mode (thermocouples); в, г – in the dynamic mode (pyrometer)

Change the gas temperatures on the length of reactionary channel, depending on the coal seam gasification mode and forming the zones of exothermic and endothermic reactions as far as stabilizing of process, presented on fig.5.

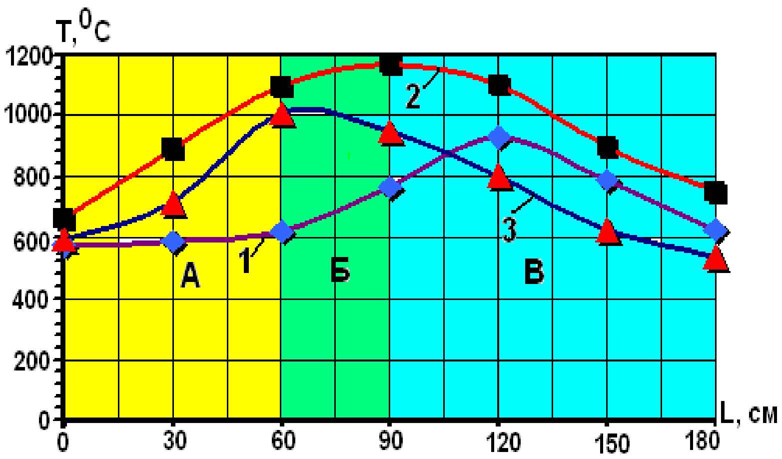

Fig. 5. Change the gas temperatures on the length of reactionary channel, depending on the coal seam gasification mode and forming the zones of exothermic and endothermic reactions as far as stabilizing of process: A – oxidizing zone; B – transitional zone; B restoration zone; 1 – coal seam ignition and burning, 2 – regime of coal seam gasification, 3 – regime of gasification process fading

The main indexes of generator gas composition gotten during the experiment are presented in the table 7.

Table 7. Composition of initial gases

Time from the beginning , h.	Components of generator gas						
	CH_4 %	CO %	H_2 %	CO_2 %	N_2 %	H_2S %	O_2 %
3:30	1,8	4,7	3,2	20,3	65,2	1,5	3,3
4:30	2,1	6,2	4,9	19,7	63,4	1,4	2,3
5:30	2,4	7,8	6,6	19,1	60,5	1,4	2,2
7:00	2,9	9,4	7,5	18,2	58,4	1,3	2,3
9:00	4,4	9,8	10,1	15,9	55,8	1,4	2,6
11:00	3,8	9,2	8,3	17,2	54,4	1,3	5,8
13:00	3,6	8,5	7,4	17,4	56,35	1,35	5,4
15:00	3,2	5,1	6,5	17,55	60,81	1,36	5,48
16:00	2,2	3,7	4,6	17,6	65,1	1,4	5,4
18:00	1,2	2,8	2,6	17,5	68,9	1,3	5,7

A temperature condition and output of combustible components depending on the temperature condition are shown in the graph (fig. 6). On the zone of burning (an oxidizing zone 0,34-0,45 m) a temperature in the gasification channel changed between 510 to 1139 ^{0}C.

As a result of experiment on the stand setting of underground coal gasification information was gotten about rocks, which contain gasgenerator, composition of generator gas, parameters of coal seam ignition, burning of reactionary channel with application the combined mode of coal incineration. A temperature on this area changed on length within the limits of 1005-618 ^{0C}. Parameters of burning and coal gasification on the experimental stand setting at the different modes of the thermal processing are presented in table. 8.

Table 8. Parameters of burning and coal gasification on the experimental stand setting BUCG

Time from the process beginning, hours	Pressure, MPa		Volume indexes, m^3/h		Pushing blowing, sm	max t C in the channel, m
	reciever	blowing	blowing	gas		
Coal seam ignition and reactionary channel burning						
3:30	0,3	0,1	188,6	288,9	0	572/0,14
4:00	0,3	0,1	187,9	269,7	0	590/0,22
4:30	0,3	0,14	250,6	365,8	0	621/0,22
5:00	0,55	0,32	266.7	384,2	0	765/0,45
5:30	0,56	0,34	270,5	391,4	0,02	814/0,57
6:00	0,54	0,32	271,2	388,5	0,02	825/0,84
6:30	0,55	0,32	270,8	390,6	0,02	929/0,92
Coal seam gasification						
7:00	0,25	0,11	222,0	342,1	0,02	1044/0,94
7:30	0,27	0,15	222,3	345,3	0,04	1139/0,95
8:00	0,25	0,12	232,7	354,6	0,04	1159/0,92
8:30	0,22	0,1	233,5	353,5	0,04	1173/0,9
9:00	0,22	0,1	243,7	363,6	0,04	1154/0,9
9:30	0,2	0,1	245,7	365,9	0,06	1114/0,88
10:00	0,28	0,17	249,6	370,7	0,06	1093/0,85
Fading of gasification process						
11:00	0,15	0,1	215,7	322,8	0,06	1090/0,82
11:30	0,16	0,1	217,2	324,5	0,07	1005/0,76
12:00	0,12	0,095	213,8	319,3	0,07	1005/0,75
12:30	0,17	0,095	218,4	320,4	0,07	1004/0,8
13:00	0,18	0,089	220.2	313,3	0,07	996/0,77
13:30	0,15	0,085	217,0	305,6	0,08	989/0,75
14:00	0,19	0,085	225,1	302,2	0,08	918/0,74
14:30	0,21	0,091	226,8	302,1	0,09	852/0,76
15:00	0,2	0,086	221,9	273,5	0,09	811/0,8
15:30	0,18	0,075	220,1	245,8	0,11	762/0,73
16:00	0,16	0,07	219,6	240,2	0,12	744/0,75
17:30	0,15	0,067	218,7	237,7	0,12	675/0,69
18:00	0,1	0,051	203,6	225,8	0,14	558/0,61

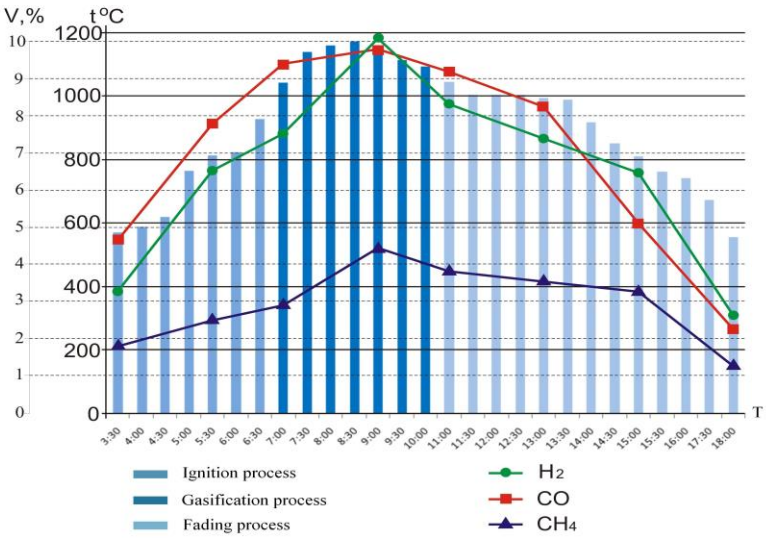

Fig.6. Temperature condition (t°) and output of combustible components (V) dependently to time from the beginning of experiment (t)

The results of analysis of liquid products after coal gasification got during an experiment on the stand setting are presented in table 9.

A runback is a liquid with the presence of hard matters and not characteristic for a coke-chemical enterprise smell which reminds the smell of tar. At the protracted contact with air a test acquires a black.

Power indexes of gasification process, during an experiment on the stand setting presented in table 10.

Analysing the results of experiments, it is possible to establish, that in the distance 0,5 m (2 m in nature) from a seam, the rocks of roof are added the intensive warming up by the gaseous products of borehole underground coal gasification due to their migration on cracks and stratifications in rock mass.

Table 9. Results of runback analysis

№	Name of indexes	Amount, mg/m^3	Amount, g/m^3	kg/612kg of coal	g/kg of coal
1	Phenols	7 500	7,5	4,60	7,53
2	Sulphuretted hydrogen	11 900	11,9	7,31	11,95
3	An ammonia is volatile	3 100	3,1	1,90	3,11
4	An ammonia is CPLD	2 580	2,58	1,58	2,59
5	Resinous matters	5 450	5,45	3,34	5,47
6	Aromatic connections	100	0,10	0,06	0,10
7	Ammonium of thiosulphate	112 000	112	68,80	112,43
8	Ammonium of sulfate	27 000	27	16,58	27,10
	At all	142 630	142,63	87,62	143,18

Table 10. Power indexes of gasification process

Amount of coal, kg	Output of generator gas, m^3		Thermal power of the stand setting, GKal		Power of the stand setting, MVt	Q, MJ/m^3	Output of chemical products g/kg of coal
	generator gas	(CH_4, CO, H_2)	for 1 h	for 15 h			
612	1432,1	529,4	2,89	43,35	3,35	2,13	0,143

Intensity of warming up begins to fall for powers of rocks (slate) above goaf by a coal seam due to diminishing of sizes of the broken rockmass.

The degree of warming up the rocks of roof above a designing gasgenerator at the different values of pressure in the stable mode of gasification is presented on figure 7.

At the change of pressure to 0,5 MPa in the separate places, were breaches on the surface the gaseous products of BUXG. It took a place on a 10 o'clock of experiment, at varying the pressure with the goaf increase the losses of gas and blowing were increased, the high-quality indexes of coal seam gasification process were worsened.

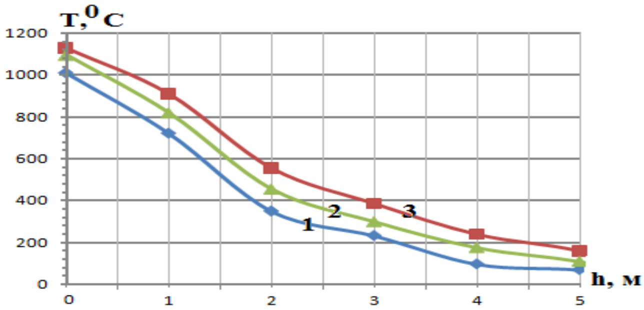

Fig. 7. A degree of warming up the rocks of roof at the different values of pressure in the stable regime: 1-p=0,15 MPa; 2-p=0,22 MPa; 3-p=0,35 MPa; h – power of warming up the rocks of roof; T – a temperature in reactionary channel

The degree of warming up the rocks of roof depends on pressure in a gasgenerator and from the state of blowing mixture (fig. 7). Moving the rocks of roof in an underground gasgenerator are related to the mining and geological conditions, technological parameters of underground gasgenerator and process of coal seam gasification. Lines which characterize the changes the rocks of roof as far as coal seam gasify in the conditions of stand setting are presented on fig. 8.

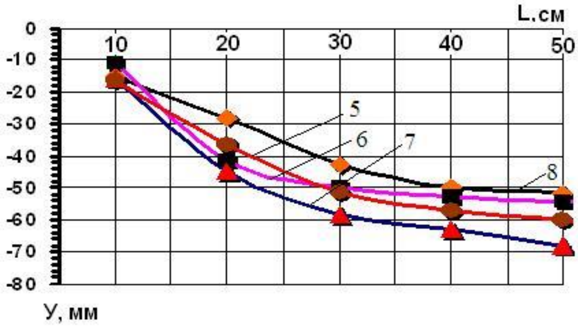

Fig. 8. Lowering the rocks of roof at gasification: 5, 6, 7, 8 – ranging marks in the direct roof (fig. 3); L – the length of half gasgenerator; Y – lowering the rocks of roof

Lowering of rocks of roof in a maximum made 67,2 mm, that it is related to the well-organized lowering and ash presents, which make 15-18 % from coal seam. Rocks swelling above a combustion face was calculated, coming from the coefficient of swelling K_{sw} = 1,27-1,42.

CONCLUSIONS

1. Authenticity of model on the stand setting is provided by criteria of similarity to the mine and geological conditions of nature.
2. Application the combined system of blowing serve and gas outlet allows on 40 % to short time on coal injection and on 32 % to rise up forming of reactionary channel at diminishing the blowing quantity on 14-18 %.
3. Stability of coal gasification at rocks instability at the increase of goaf in gasgenerator are provided: by sufficient impermeability of underground gasgenerator, varying of temperature and pressure in blowing, by point of transfer, and also support and control the thermal and adiabatic mode of zone in reactionary channel.
4. At the stable regime of gasification and enhanceable rocks humidity to 30-36 % the output of generator gas make 2,34 m^3/kg coal with the calorific value 2,13 MJ/m^3, output of chemical matters 0,14 kg/kg coal and maintenance of combustible components in generator gas (air blowing) - 21-30 %.

REFERENCES

[1] Фальштинський, В. С., Дичковський, Р. О., Станьчик, К., Свядровскі, Є., & Лозинський, В. Г. (2010). Обґрунтування технологічних схем експериментального шахтного газогенератора. Науковий вісник Національного гірничого університету, (3), 34-38.
[2] Chen F. (2008). The UCG progress in China / F. Chen. In: Proceedings of the 3rd International UCG conference. London, UK. Underground coal gasification partnership.
[3] Лозинський, В. Г., Саїк, П. Б., Паваленко, О. В., & Кошка, Д. О. (2010). Аналіз сучасного стану і перспективи промислового застосування свердловинної підземної газифікації вугілля в Україні. In Матер. IV междунар. научно–практич. конф. "Школа подземной разработки".–Д.: НГУ (pp. 351-363).
[4] Falsztinskij, W., Diczkowskij, E., & Łozinskij, G. (2010). Ekonomiczne uzasadnienie celowości doszczelniania skał stropowych nad obszarem podziemnego zgazowania węgla metodą otworów wiertniczych. Prace Naukowe GIG. Górnictwo i Środowisko/Główny Instytut Górnictwa, (3), 51-59.