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GAS-PRODUCER TECHNOLOGIES OF ORGANIC-WASTE PROCESSING

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The technologies of gasification of combustible organic waste are considered. The characteristics of the processes of gasification of vegetable biomass waste in the gas producers of direct and inverse combustion processes are given.

The necessity of increasing ecological safety and the efficiency of obtaining energy from biomass calls for the changeover from direct combustion to more advanced technologies. In this connection, in the last few years in the USA, Canada, Sweden, Finland, and Austria, technologies based on thermal gasification of the biomass have been actively developed. Gasification can convert low-grade fuel (waste) containing a large amount of ballast (moisture, ash) and having a low combustion heat into a high-quality gaseous fuel (gas with a combustion heat from 4 to 20 MJ/nm^3).

At the present time, in the world there exist many manufacturers of large gas producers (e.g., "Rheinbraun" and "Gotaverken" (Sweden), "Foster Wheeler" (Finland), "Lurgi" (Germany), "Tampella" (Finland), TPS (Sweden)) and small systems for biomass gasification (e.g., "ARCUS Umwelttechnik GmbH" (Germany), Stock company "Energotekhnologiya" (Russia), "Melima" (Sweden)). Wide practical experience of biomass gasification has been gained in Finland, where at low-power (from 6 to 35 MW) thermal power stations commercial gas producers of the type of "Bioneer" and "Pyroflow" are operating. However, these gas producers have not found wide practical application because of the high cost of the generated energy compared to the cost of energy obtained from petroleum products and gas.

As the most interesting projects of practical application of the biomass gasification technology, the following ones should be noted. In Germany, the "Wamsler Umwelttechnik" company is developing plants for gasification of biomass together with plastic and textile waste (power from 1.5 to 11 MW). The Institute of Gas Technology (USA) and the company "Enviropower Inc." (Finland–Sweden) under a joint project are engaged in developing a technology of biomass gasification for steam-gas-turbine plants. In Finland, a circulating fluidized-bed plant producing gas under pressure has been created. At the plant, a combined cycle of steam and gas turbines is carried out (electric power of 7.9 MW, thermal power of 14 MW).

There exist a large number of low-power plants for biomass gasification with the aim of obtaining thermal and electric energy. Plants of such type can be used for independent heat and power supply in rural areas and regions, where considerable amounts of biomass are formed, whose transportation to large gas-producing stations is inexpedient for economic reasons. The plants of power from 50 to 500 kW manufactured by the company "Energie Versorgung Nord GmbH" (Germany) permit obtaining from 1 kg of wood biomass 1 kW·h of electric energy and 2 kW·h of thermal energy. Gas-producing stations supplying heat and electric power of power 600 kW, incorporating a bed gas producer of the inverse process, a system of gas cleaning, a hot-water boiler, and a diesel-generator of power 299 kW are made in Russia.

In Belarus, to bring the technologies of obtaining energy from biomass and other kinds of waste by their thermal gasification to a commercial level, it is necessary to first improve the gas-producing equipment. In so doing, it is necessary to use the experience gained in the field of gasification of coals and peat [1, 2].

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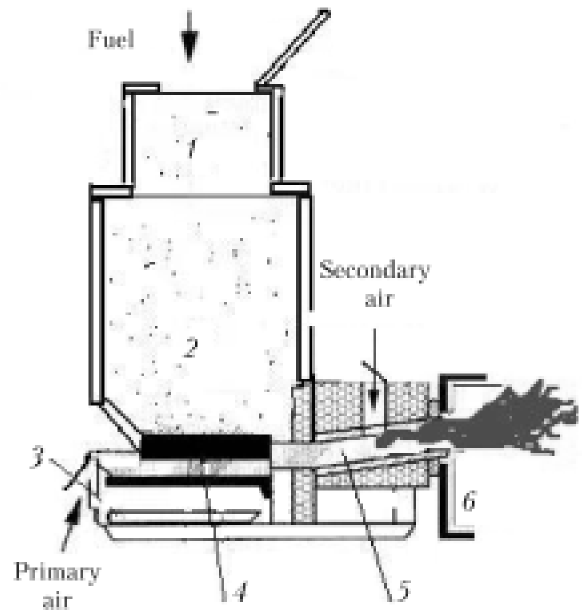

Fig. 1. Scheme of the gas producer.

Specialists from the Institute for Problems of Nature Management and Ecology (IPNME) of the NAS of Belarus have developed bed gas producers based on a Pinch-type gas producer for obtaining thermal energy [3].

The chief economic problem inhibiting wide use of gas-producer technologies of obtaining energy resources from solid fuel is the higher cost of thermal and electric energy compared to the cost of energy obtained by direct combustion of vegetable biomass. However, the advantage of using gas producers is that burning of low-quality fuel and waste increases ecological safety.

The technical problems arising in developing high-efficiency systems of gasification of various kinds of biomass and waste can be conventionally subdivided into three groups:

1) problems connected with the development of small- and medium-power (from 50 kW to 4.0 MW) gasification plants for obtaining thermal and electric energy — fine cleaning of producer gas from resins and dust, corrosion of equipment, erosion of gasification plant components, blocking of flue gas paths when used in internal combustion engines and gas-turbine plants;

2) problems inherent in high-power (4.0 MW and higher) gasification plants — cleaning of large quantities of producer gas, development of systems of cleaning at higher pressures and temperatures, wear of equipment, preparation and feeding of the raw material into the gas producer;

3) problems connected with the conversion of the operating thermal power plants designed to burn natural gas and liquid and solid fuels to producer gas — redesign of combustion chambers, development of adequate designs of burners.

Despite the existence of a wide spectrum of problems (scientific, technical, economic), thermal gasification seems to be a promising direction for developing high-efficiency (power production efficiency up to 45%, high ecological indices) technologies and equipment with the aim of vegetable biomass conversion into the most convenient energy carriers [4–12].

Below, a gas-producing plant for obtaining gas from combustible waste for its direct burning and a gas-producing power plant are considered.

Thermal Energy Gas Producer. Within the framework of the scientific and technical cooperation between the A. V. Luikov Heat and Mass Transfer Institute of the NAS of Belarus and the IPNME of the NAS of Belarus, a gas producer for obtaining thermal energy on the basis of local kinds of fuel (wood waste, peat, used tires, etc.) of power 1300 kW has been developed (Fig. 1). The technical and economic characteristics of the gas producer are as follows:

Fuel bunker feed volume, m^3	3.8

Rated fuel consumption, kg/h	390–430
Rated calorific power in burning lump wood fuel, kW	1400
Temperature of combustion jet in secondary furnace, ^{o}C	900–1300
Efficiency, %	87
Lightning time, h	<0.5
Working cycle between feeds, h	2.5–3.5
Gas-producer dimensions, mm	
length	2800
depth	2500
height	4500
Weight, kg	≤3700
Attending personnel, persons	1

The gas producer is a unit of modular design easily adaptable to work with serially produced hot-water or steam boilers and air heat exchangers with the aim of obtaining hot water, steam or hot air for technological processes, etc. The principle of operation of the gas producer is based on the direct process of fuel combustion in a thin bed with transfer of producer and flue gases into the secondary furnace (flue tube).

Fuel is fed into the low-temperature carbonization shaft 1 of the gas producer through the charging opening located in its upper part and goes into the main shaft 2 of the gas producer. The presence of the low-temperature carbonization shaft improves the conditions for fuel preparation and increases the feed mass. The gasification chamber 3 is made integral with the gas-producer shaft.

The flue gases heat the fuel to the gasification temperature (depending on the kind of waste). The process of thermal decomposition in the gasification zone proceeds due to the heat of the rising stream of combustible gases from the combustion zone.

In the process of gasification, the material being processed moves due to gravity and passes sequentially through the zones of drying, thermolysis, and combustion. The gasification temperature is controlled by the quantity of air supplied into the gas producer. Fuel combustion and gasification occur on the fire grate 4 holding the fuel beds and distributing draught over the gas-producer cross-section. Its height is determined by the draught intensity, the fuel particle size, and the height at which the fuel dissector is located over the grate.

At the exit from the bed the gas with a combustion heat from 3 to 5 MJ/nm^3 enters the flue chamber 5, where, through a channel with a regulated gate, the secondary air is supplied additionally for gas after-burning. The main components of the gas stream are carbon monoxide and dioxide, hydrocarbons, hydrogen, nitrogen, water vapors, and solid particles. The producer gas in a mixture with the secondary gas ignites in the flue chamber and, in the form of a jet, is supplied to the furnace of the boiler or the heat-exchanger, jointly with which the gas producer operates. The temperature of waste flue gases reaches 900–1300^{o}C. The thermal energy recuperated in the boiler 6 can be used for household or production purposes.

To light the gas producer, there is a door with a valve for controlling the supply of primary air. The gas-producer parts operating at higher temperatures are made from heat-proof materials. The outer surfaces of the chamber bodies are heat-insulated. The gas producer is set so that its flue tube joins the furnace of the boiler or the heat-exchanger.

An important advantage of this gas producer is the fact that in one unit the gas-generation chamber and the improved design of the flue chamber (a kind of burner) are integrated to decrease heat losses. The application of the gas producer permits upgrading the efficiency of using the fuel due to the creation in the flue tube of a higher temperature compared to the temperature in the bed on the fire grate, which is important for reducing the amount of harmful substances released in the process of burning combustion waste. It also makes it possible to convert the existing equipment from liquid to local solid fuel.

Gas Producer of the Inverse Combustion Process. A power gas producer (Fig. 2) has been developed for obtaining gaseous fuel with a combustion heat from 1000 to 1250 kcal/m^3 on the basis of local kinds of fuel (wood, polymer waste, peat, etc.). The gas producer works on the principle that permits obtaining resin-free gas. Part of the dry distillation products formed (resins and acids) burns up, and part of them is subjected to the cracking process (decomposition with a release of combustible gases). Upon cleaning and cooling down below 40^{o}, the gas produced can

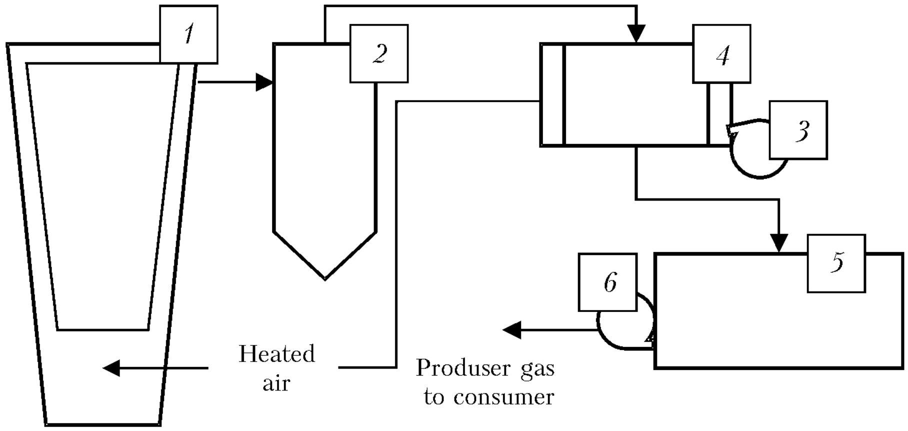

Fig. 2. Technological scheme of obtaining thermal and electric energy from local kinds of fuels.

be conducted to the internal combustion engine integrated with the electric energy generator. It can also be used as a gaseous fuel (8.5 m^3 of producer gas is equivalent to 1 kg of fuel oil). The technical characteristics of the SGGU-60 gas producer are as follows:

Fuel bunker feed volume, m^3	1.5
Rated fuel consumption, kg/h	≤120
Feed mass (wood of size up to 150 mm or mixture with polymer waste), kg	410
Producer-gas yield, nm^3/h	240
Gas combustion heat, MJ/nm^3	≥4.3
Available power of the gas internal combustion engine, kW	45
Installed power of the blower, kW	1.5
Efficiency, %	73–76
Gas-producer dimensions, mm	
length	3700
depth	2520
height	3400
Weight, kg	≤2600
Attending personnel, persons	1

The gas-producer plant consists of a power gas producer 1, a cyclone of preliminary cleaning of gas 2, a gas-cooling coarse filter 4 with a guiding, cooling filter-blower housing, a deep-bed filter-washer of fine cleaning of gas 5, a lighting fan 6, and a blower 3.

In the gasification chamber, fuel combustion with an excess-air coefficient less than unity occurs. As a result of the combustion, carbon dioxide ($C + O_2 \rightarrow CO_2$) and carbon oxide ($2C + O_2 \rightarrow 2CO$) are formed.

In the combustion zone situated over the fuel bed, the process of dry distillation proceeds, as a result of which gaseous and steamy products are released. The combustion products and the steam-gas mixture obtained pass through the red-hot coal bed situated below the combustion zone. Here, under the action of the red-hot surface the incombustible carbon dioxide transforms into a combustible one — carbon oxide ($CO_2 + C \rightarrow 2CO$). In the same zone, decomposition of water vapors also occurs to form a combustible gas — hydrogen (H_2) and carbon oxide ($H_2O + C \rightarrow CO + H_2$) or, at an insufficiently high temperature, — hydrogen and carbon dioxide ($2H_2O + C \rightarrow 2H_2 + CO_2$). Part of the hydrogen, reacting with carbon, yields a combustible gas, methane ($C + 2H_2 \rightarrow CH_4$).

From the active zone the gas flows to the circular space between the bunker and the gas-producer housing, dries the fuel in the bunker and, through the upper gas-abstracting pipe, gets into the cyclone of preliminary cleaning of gas 2, where it is cleaned from dust and course-disperse polluting particles. Then the gas arrives at the gas-cooling coarse filter 4. This filter is made in the form of a tubular radiator with role cassettes of a stainless net inside and an air blower outside.

Final cleaning of the producer gas is carried out in the deep-bed, fine filter-washer 5. A vacuum in the gas producer can be created by the internal combustion engine, and in its absence — by the lighting fan 6.

The gas producer is equipped with a system for conducting air to the reaction zone and a system for abstracting gaseous products. The gasification process is controlled by changing the quantity of the air being conducted. The gas-producer parts working at higher temperatures are made from heat-resistant materials. The outer surfaces of the chamber housing are heat-insulated.

Thus, the realized scheme of the gas-producer plant makes it possible to considerably reduce the content of resins and solid particles in the producer gas, which is important in using this gas in internal combustion engines. And the efficiency of the plant thereby increases from 73 to 76% due the air heating in the system of rough cleaning, the cooling of the producer gas, and its feeding into the gasification chamber.

REFERENCES

1. V. V. Al'ferovich and A. A. Margolin, Gas producers for conversion of steam and hot-water boilers to low-grade solid fuel, *Nauch.-Tekh. Novosti* (edition of the Russian Society of Chemists), No. 1, 25–26 (1996).
2. P. L. Falyushin, V. K. Zhukov, I. S. Kulikov, and N. I. Bokhan, Liquid and gaseous energy carriers based on vegetable biomass, in: *Proc. Int. Sci.-Tech. Conf.* [in Russian], Minsk (2004), pp. 197–199.
3. P. L. Falyushin, I. I. Lishtvan, I. S. Nashchkevich, et al., *Gas Producer for Solid Fuels*, Inventor's Certificate 1732, Application No. 950098 (1997).
4. L. V. Zysin and N. L. Koshkin, Some advances in using vegetable biomass in power engineering in developed countries, *Teploénergetika*, No. 4, 28–32 (1997).
5. N. B. Éskin and A. N. Tutov, Analysis of different technologies of thermal processing of solid domestic garbage, *Énergetika*, No. 9, 12–17 (1994).
6. A. A. Khalatov, Z. A. Martsenyuk, and M. D. Kas'yanov, General concept of the partial use of industrial waste as fuel for industrial boiler houses, *Prom. Teploénerg.*, **18**, No. 3, 80–85 (1996).
7. S. D. Fedoseev and A. B. Chernyshev, *Low-Temperature Carbonization and Gasification of Solid Fuel* [in Russian], Gostekhizdat, Moscow (1960).
8. G. G. Geletukha and T. A. Zheleznaya, Review of technologies of biomass gasification, *Ékotekhnologii i Resursosberezhenie*, No. 2, 21–29 (1998).
9. L. Dinkelbach and M. Kaltschmitt, Gasification of Biomass in Europe, in: *Proc. 9th Eur. Bioenergy Conf.*, Copenhagen, 24–27 June 1996, Pergamon (1996), Vol. 2, pp. 1382–1387.
10. G. G. Geletukha and T. A. Zheleznaya, Review of technologies for generation of electric energy obtained as a result of biomass gasification, *Ékotekhnologii i Resursosberezhenie*, No. 3, 3–11 (1998).
11. E. S. Pantskhava, V. A. Pozharnov, L. V. Zysin, et al., Conversion of biomass energy. Experience of Russia, *Teploénergetika*, No. 5, 33–38 (1996).
12. D. V. Aristarkhov, N. N. Egorov, G. I. Zhuravskii, É. P. Polesskii, and N. S. Sharanda, *Steam Thermolysis of Organic Waste* [in Russian], A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, Minsk (2001).