ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 11, Issue 3, March 2024

Heat Balance of the Solar with Heat Accumulator - Biogas Plant

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ABSTRACT: The article analyzes the efficiency of heating from the solar collector for obtaining biogas from biomass, as well as the heat technical indicators of the device. The article also proposes a solar-biogas system with a heat accumulator for providing heat to the biogas reactor. As a result of the application of a heat accumulator and a solar collector to this type of biogas plant, a temperature of 52-55 ℃ can be obtained for the thermophilic temperature regime. As a result, it is possible to reduce private energy consumption for biogas production by 30-35%. The goals of the calculation-theoretical studies of the biogas plant in the article are mainly directed to the approximate assessment of their thermal efficiency, taking into account the degree of optimization of the thermal technical parameters.

KEYWORDS: heat accumulator , solar collector, biogas reactor, biomass, amount of heat, film coating, temperature, time.

I. INTRODUCTION

The limited reserves of hydrocarbon natural fuels in the world, the increase in the price of organic fuels and the environmental problems arising from their use are the reason for the development of the use of alternative energy sources. One of the types of alternative energy is biomass energy, which is a classic renewable energy [1].

Biomass energy use technologies, especially biogas technologies, are among the world's developing trends in obtaining biogas and highly effective biofertilizers. For example, 20% of the energy produced in Sweden, Austria and Finland corresponds to the share of biogas. More than 10,000 biogas plants operate in Germany, and it is planned to double their number by the end of 2025. In England, the demand for energy in agriculture is fully covered by biogas [2, 3].

Effective use of renewable alternative energy sources is an urgent task in solving ecological problems arising from the reduction of reserves of organic fuels and the increase in their cost. The use of solar and biomass energy from renewable energy sources in our republic is highly effective [1].

II.MATERIALS AND METHODS

2 methods are mainly used in world practice to obtain alternative fuel from biomass. First, only gaseous fuel - biogas and biofertilizer - is obtained in the biological method, that is, in the anaerobic digestion method, in different temperature regimes (psychrophilic, mesophilic, thermophilic temperature regimes). Secondly, it is possible to obtain solid, gaseous and liquid fuels in the pyrolysis method [4, 5].

Experiments carried out in biogas plants and information from field scientists show that up to 60% of the biogas obtained in biogas plants based on the anaerobic digestion method is used for the private needs of the plant [6].

In order to increase the energy efficiency of the biogas plant, to utilize the secondary energy resources that are inevitably lost to the environment, an energy-efficient bioenergy plant consisting of a combination of pyrolysis and biogas plants was developed and preliminary tested. The combined option of the pyrolysis-biogas plant, that is, the combined bioenergy plant, is based on the utilization of the condenser hot water energy, which is inevitably lost to the environment from the pyrolysis plant, in the biogas reactor and energy saving.

By processing biomass and various local organic wastes, it is possible to obtain biogas and produce heat and electricity from it. Similarly, in our country, priority tasks for wide implementation of “green technologies” in agriculture, energy, transport and other sectors of the economy have been defined [6-15].

Based on the conducted experiments and obtained scientific results, a solar -biogas device with a semi-cylindrical film covering, which works at the expense of an alternative energy source, has been developed. The design and scheme of the proposed solar biogas plant is shown below (Figure 1).

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International Journal of AdvancedResearch in Science, Engineering and Technology
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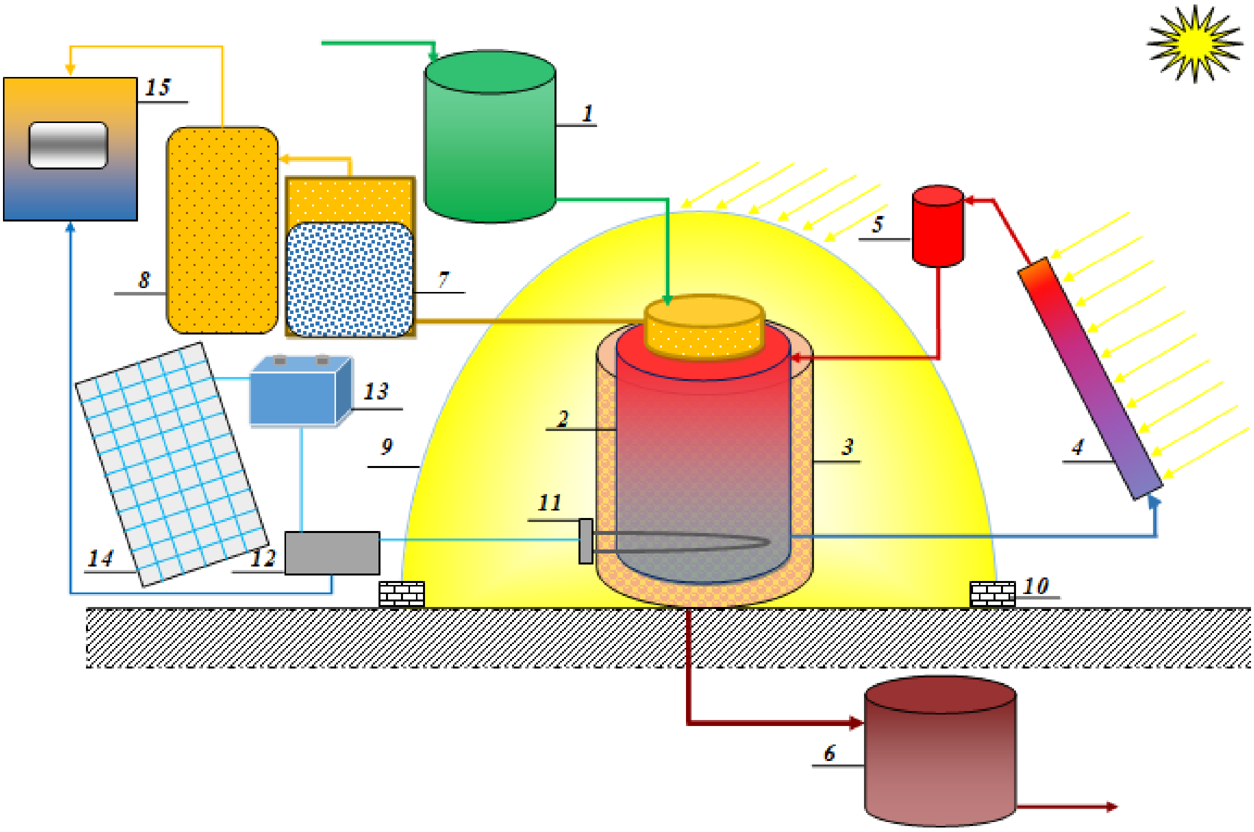

Fig. 1. Scheme of a solar-biogas device with a heat accumulator.

Here, 1 – organic waste capacity, 2 – bioreactor, 3 – heat-insulating stone heat accumulator, 4 – solar collector, 5 – heat accumulator, 6 – liquid biofertilizer capacity, 7 – biogas purification filter, 8 – gasholder, 9 – film, 10 – film coating base, 11 – electric heater, 12 – voltage inverter, 13 – battery, 14 – photoelectric converter,
15 – consumer.

It is important to determine the energy consumption in ensuring the required temperature regime of the solar-biogas device with a heat accumulator. Therefore, the heat balance equation of the proposed device was formulated.

III. RESULTS AND DISCUSSIONS

The heat balance equation of a solar-biogas device with a heat accumulator is as follows [3]:

$$Q_{tot} = Q_{usef} + Q_r^{py} + Q_r^{SC} + Q_{acc.} - (Q_b + Q_{lost}) + Q_{e.h.}, \quad J; \qquad (1)$$

where, Q_{usef}– heat of biogas fuel obtained from the device, J; Q_r^{py}– solar energy entering through the film coating, J; Q_r^{SC}– heat from the solar collector, J; $Q_{ac.}$– accumulated heat, J; Q_b- amount of heat used to heat biomass, J; Q_{lost}- amount of heat lost from the reactor to the environment, J; $Q_{e.h.}$- the amount of heat provided by the electric heater, J.

The useful heat energy obtained in the device is equal to the following [4] .

$$Q_{usef} = G_g Q_d^w, \quad J; \qquad (2)$$

where, G_g– the amount of biogas produced in the reactor during the cooking process, m ^{3}; Q_d^w- combustion heat of biogas, J/m ^{3}.

Solar heat entering through a transparent film is defined as:

$$Q_r^{py} = q_r K_{py} F \tau, \quad J; \qquad (3)$$

where, q_r- solar radiation energy density, W/m ^{2}; K_{py} – coefficient of transmission of solar radiation of transparent coating (film); F- transparent coating surface, m ^{2}; τ- time, sec.

The heat production efficiency of the solar water heating collector is determined as follows:

$$Q_r^{SC} = G C_p (t_2 - t_1) \tau, \quad J; \qquad (4)$$

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in this G- consumption of water heated in the collector, kg/sec; C_p– specific heat capacity of water, J/kg*sec; t_1- temperature of cold water, ^{0}C; t_2- the temperature of water heated in the collector, ^{0}C.

The heat accumulated in the external battery is as follows:

$$Q_{ac} = m_{ac.}C_{p.ac.}\Delta t, \quad J; \tag{5}$$

where, $m_{ак}$ – the mass of the battery body, kg; $C_{p.a}$– specific heat capacity of the battery, J/kg*sec; Δt- heating level of the battery body, ^{0}C;

The heat used to heat the biomass loaded into the reactor to the boiling temperature is determined from the following formula [3, 4]:

$$Q_b = m_b C_b \left(t_b - t_{an.f.}\right), \quad J; \tag{6}$$

where, m_b– mass of biomass loaded into the reactor, kg; C_b– specific heat capacity of loaded biomass, J/kg*sec; t_b– loaded biomass temperature, ^{0}C; $t_{an.f.}$- baking temperature, ^{0}C.

The heat lost from the surface of the reactor by giving heat to the environment is determined from the following equation [3, 4, 5]:

$$Q_{lost} = \alpha F_r (t_{s.r.} - t_{en.})\tau, \quad J; \tag{7}$$

where, α is the coefficient of heat transfer from the surface of the reactor to the environment,

W/m ^{2} * ^{0}C; F_r- the heat exchange surface of the outer surface of the reactor, m ^{2}; $t_{s.r.}$– the temperature of the outer surface of the reactor, ^{0}C; $t_{en.}$- the temperature of the outside air, ^{0}C.

The heat supplied by the electric heater is determined from the following equation [4]:

$$Q_{e.h.} = N_{el.} n\tau, \quad \text{kW} * \text{hours}; \tag{8}$$

where, $N_{el.}$ - electric power of the heater, kW; n- the number of electric heaters;

τ- time, sec.

The conducted calculations and studies show that the heat required for private needs of the device is fully covered by solar energy during 6-8 hours in winter and autumn season in daytime mode on sunny days. It was found that it is possible to save up to 30-40% of thermal energy in the night mode due to the heat accumulated in the accumulator. In the spring and summer seasons, the temperature regime is 45-50 ^{0}C only during the day from 8 ^{00} to 20 ^{00} through the solar device, the required temperature regime can be set at the expense of natural solar energy during the rest of the day. In this case, the film is removed from the device. The double electric heater installed in the device is designed for the night mode in the winter season.

IV.CONCLUSION

- The proposed combined bioenergetic device has the following advantages:
- hot water from the pyrolysis condenser (secondary heat energy) fully ensures the temperature regime of the biogas device, that is, it provides the necessary heat energy for private needs.
- by burning the biogas obtained in the biogas plant in the pyrolysis reactor, energy is saved for private needs in the pyrolysis plant as well.
- in a pyrolysis device, gaseous, solid and liquid fuels are collected for full beneficial use.
- energy savings and a stable temperature regime occur in the heat balance of the biogas reactor due to the solar energy obtained from the flat solar collector in sunny days.
- the raw material (biomass) cooked in the biogas reactor is thermally processed again in the pyrolysis reactor for the second time. As a result, it is possible to obtain maximum alternative fuel from raw materials.

As a result of the use of passive (film coating) and active solar devices (solar water heater) in the proposed combined device, efficiency an opportunity to increase is created.

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ISSN: 2350-0328

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