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BIOGAS Installation for Processing of ORGANIC BIOMASS

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ABSTRACT: In article are brought results heat physical features of the products of combustion biogas, got from biogas of the installation, built in subsidiary facilities under LLC Muborakneftgaz. To the analyzing energy efficiency of biogas formation, anaerobic processing requires certain temperature conditions and technological processes, preferably close to achieve the optimum process. The article shown factors determining the widespread adoption in the republic of technology of anaerobic decomposition of organic substances to produce biogas.

KEYWORDS: products of combustion, technological processes, degree of the soiling the air, heat of combustion, three atomic gases, factor of the excess of the air, dynamic viscosity, factor heat-conducting.

I.INTRODUCTION

The strategic directions of energy development in the Republic of Uzbekistan provide for the widespread use of non-traditional energy sources, including the energy of organic animal biomass. Calculations show that when processing organic biomass into biological gas, 4.2 times more energy can be produced annually than is produced at power plants in the Republic of Uzbekistan. Closely related to the problem of waste management is another - increasingly exacerbating - environmental protection, which also requires intensive and rational processing of organic biomass.

The use of renewable energy in the world is becoming increasingly important due to the fact that traditional sources of energy (coal, oil, natural gas) are limited, and their use for the production of heat and electricity causes great harm to the environment. In this regard, solar energy is becoming increasingly important, which can be used to produce environmentally friendly heat and electric energy [1,2,3,4].

The sun is a giant source of "clean" energy, not polluting the environment. Efficient use of solar energy can significantly reduce the consumption of natural resources. Climatic and weather conditions in the south of Uzbekistan create wide opportunities for the efficient use of solar energy in the Kashkakdarya region [2,3.4,5].

To achieve maximum efficiency of biogas formation, anaerobic processing requires certain temperature conditions and technological processes, preferably close to achieve the optimum process [6,7].

In the Republic, the main energy fuel is natural gas, in particular biogas, obtained from anaerobic decomposition of organic substances.

In the Republic, the most promising is the use of anaerobic decomposition of organic substances with biogas production.

II. INSTALLATION DESCRIPTION

Biomass processing under anaerobic conditions is carried out in special, pressurized digesters (Fig. 1). Under the influence of methane-forming bacteria in an oxygen-free environment at a temperature of 30 ... 55 ° C, the biomass is fermented in the reactor with the formation of combustible gas - biogas, which is used for technological and domestic needs. About 1 mt of manure with 90% humidity can produce about 220 m^3 of biogas with a calorific value of 28 ... 35 MJ/m^3. The remains of the fermentation mass in the digesters are a highly digestible liquid highly concentrated organic fertilizer (humus) easily digestible by plants and devoid of pathogens and weed seeds [8,9].

The main elements of biogas plants are a digester (fermentation reactor) (2) and a gas holder (biogas storage tank) (3). The productivity and economic efficiency of the entire installation depends on the design of the digester.

Biogas plants do not require special expensive equipment. The payback period of these plants is 2 ... 4 years.

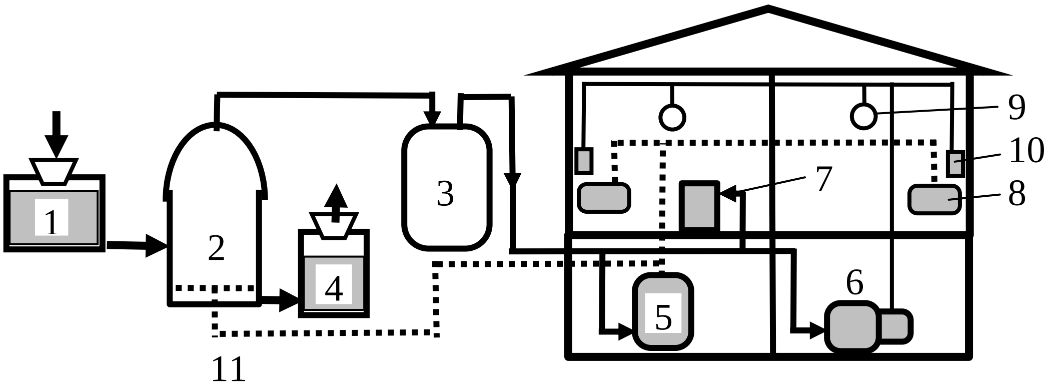

Fig. 1. Schematic diagram of a biogas plant for individual solar heating at muborakneftgaz llc:

1-organic waste; 2-digester; 3-gas holder; 4-solid waste; 5-boiler; 6-engine electric generator; 7-gas stove; 8-heating batteries; 9 and 10-lighting and electrical appliances; 11-heated digester.

The main factors determining the widespread adoption in the republic of technology of anaerobic decomposition of organic substances to produce biogas are:

1) high technological readiness and economic profitability; technological and operational simplicity of biogas technology;

2) for biogas technology, raw materials are available almost everywhere (organic industrial, agricultural and household waste, manure, etc.);

3) climatic conditions provide the maximum yield of commercial biogas; winter temperature conditions allow mesophilic fermentation to be ensured (at 30 ... 40 °C) at minimum biogas costs for heating in digesters, and in the summer time - heating costs disappear;

4) wide opportunities for the integrated use of biogas plants in conjunction with solar plants.

III.METHODS

Biogas usually contains 75 ... 81% methane. Other components include ethane, propane, butane (1.8 ... 6.2%) [8,9]. Heavier hydrocarbons are of great value as chemical raw materials. The composition of gaseous fuel is set in volume fractions and is written in the following form [6,10,11].

$$\sum_{i=1}^{i=m} C_nH_{2n+2}+\sum_{i=1}^{i=m} C_nH_{2n}+H_2+CO+H_2S+O_2+N_2+CO_2=100\% . \tag{1}$$

Thermotechnical calculations are usually carried out for the dry composition of gaseous fuels. The calorific value of dry gas is determined by the volumetric composition in percent (%) and the known calorific value of the components.

Calorific value of gaseous fuel, kJ/m^3.

inferior

$$\begin{aligned} Q_{in} = {} & 358CH_4 + 638C_2H_6 + 913C_3H_8 + 1187C_4H_{10} + \\ & + 1461C_5H_{12} + 126{,}5CO + 107{,}5H_2 + 234H_2S ; \end{aligned} \tag{2}$$

the highest

$$\begin{aligned} Q_{th} = {} & 398CH_4 + 698C_2H_6 + 993C_3H_8 + 1282C_4H_{10} + \\ & + 1572C_5H_{12} + 126{,}5CO + 127{,}5H_2 + 254H_2S . \end{aligned} \tag{2a}$$

With the known physicochemical composition of natural gas, the highest Q_{th} and lower Q_{in} of the calorific value, the thermal equivalent of natural gas $E = Q_{in}/ 29300$, are determined. For the resulting biogas is: Q_{in} = 37600 ... 39100 kJ/m^3; Q_{th} = 41800 ... 44700 kJ/m^3; E = 1.28 ... 1.34. As can be seen from the above values, biogas has a high calorific value. This is due to the fact that biogas has an increased content of heavy hydrocarbons. When these hydrocarbons are extracted (as chemical raw materials), the calorific value of biogas drops by 4 ... 8%.

For thermotechnical calculations, the value of the lower heat of combustion of the fuel is taken. The theoretical amount of air (m^3/m^3) required for the complete combustion of gas is determined by the formula [10.11,17,18,19,20].

$$\begin{aligned} V_{air} = {} & 0{,}0476\ [0{,}5CO+0{,}5H_2+2CH_4+ \\ & +1{,}5H_2S+\sum_{i=1}^{i=m} (m+n/4)C_mH_n\text{-}O_2] . \end{aligned} \tag{3}$$

For biogas is V_{air} = 10,4...11,15 m^3/m^3.

In real conditions, air for burning fuel is supplied in a larger quantity compared to its theoretical amount V_{air}. The ratio of the actual amount of air V_{aair} supplied to the combustion device to the theoretically necessary V_{tair} is called the coefficient of excess air:

$$\alpha = V_{aair} / V_{air} . \tag{4}$$

The coefficient of excess air α depends on the design features of the combustion device, the type and method of burning fuel. Values of α vary in the range of α = 1.02 ... 1.5. The results of theoretical and experimental studies are shown in Fig. 2.

The products of complete combustion of fuel at α = 1 contain: dry (non-condensing in the combustion device) triatomic gases R_2O (CO_2 and SO_2); H_2O - water vapor obtained by burning hydrogen; N_2 - fuel nitrogen and nitrogen in the theoretically necessary amount of air.

In addition, the composition of the products of fuel combustion includes water vapor resulting from the evaporation of moisture in the fuel, steam introduced into the furnace with moist air. For α> 1, excess air (additional oxygen and nitrogen) will be present in the combustion products.

The biogas combustion products from LLC Muborakneftegaz do not contain sulfur dioxide SO_2 and therefore, $R_2O = CO_2$ is assumed.

The content of combustion products is presented:

in percentage and share

$$RO_2 + N_2 + H_2O = 100\% ; \quad X_1+ X_2 + X_3= 1 ; \tag{5}$$

$$X_1= N_2/100 ; \quad X_2= RO_2/100 ; \quad X_3= H_2O/100 .$$

in volumetric content

$$V_{cp}=V_{RO}+V_N+V_{HO} . \tag{6}$$

Theoretical amount of nitrogen, consisting of air nitrogen and fuel nitrogen

$$V_N = 0{,}79\ V_{air}+0{,}8N_2/100; \quad V_N = 8{,}5\ldots 8{,}86 \text{ m}^3/\text{m}^3. \tag{7}$$

The volume of dry triatomic gases

$$V_{RO} = 0{,}01[CO_2+CO+H_2S+\sum_{i=1}^{i=m} mC_mH_n]; \quad V_{RO} = 1{,}09\ldots1{,}137 \text{ m}^3/\text{m}^3. \qquad (8)$$

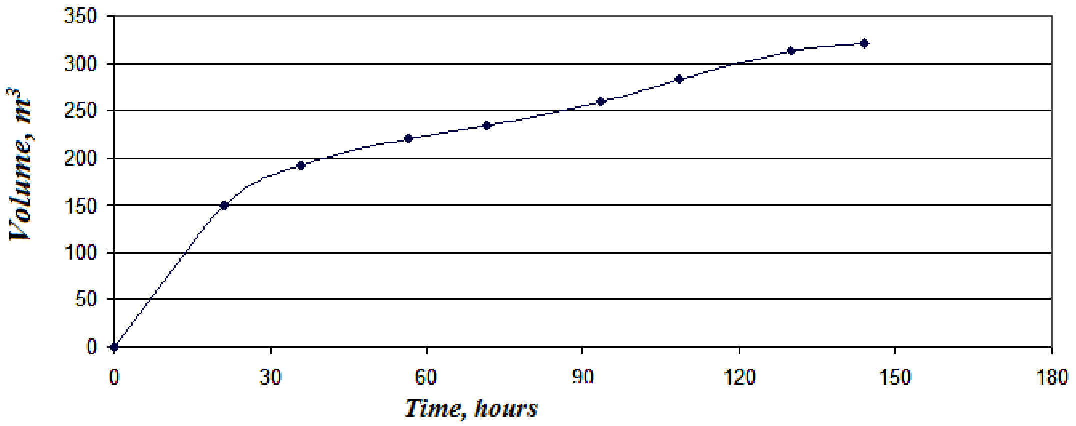

Fig. 2. The dependence of the volume of biogas obtained on the duration of fermentation of manure of small cattle.

Theoretical volume of water vapor generated by the combustion of hydrogen and contained in the air

$$V_{HO} = 0{,}01[H_2S+H_2+2CH_4+\sum_{i=1}^{i=m} \frac{n}{2} C_mH_n+0{,}124x_{г}]+0{,}0161V_{air}; \qquad (9)$$

$$V_{HO} = 2{,}255\ldots2{,}349 \text{ m}^3/\text{m}^3. \qquad (9a)$$

Volumetric content of fuel combustion products according to the formula (6)

$$V_{cp} = 11{,}862\ldots12{,}357 \text{ m}^3/\text{m}^3. \qquad (10)$$

The percentage of components of the products of combustion of fuel

$$N_2 = 100\times X_1 = 68{,}92\ldots71{,}79\%\,; \quad RO_2 = 100\times X_2 = 8{,}83\ldots9{,}2\%\,;$$

$$H_2O = 100\times X_3 = 19{,}01\%\,. \qquad (11)$$

The theoretical fuel temperature is determined based on equations of the energy balance of the combustion process of 1 m^3 of fuel [10,11]

$$Q_{in}\frac{100-q_3-q_4-q_6}{100-q_4} + Q_{в} = \sum_{i=1}^{i=3} (V_i\,C_i)(T_m - T_o); \qquad (12)$$

$$\sum_{i=1}^{i=3} (V_i\,C_i) = V_{RO}\,C_{RO} + V_N\,C_N + V_{HO}\,C_{HO}\,; \qquad (12a)$$

where q_3 *is the heat loss from chemical underburning,%;* q_4 *— heat loss from mechanical incompleteness of combustion,%;* q_6 *- heat loss with physical heat of slag, %;* Q_h *- heat introduced with hot air heated within the combustion device, kJ/m*^{3}*;*

C_{RO}, C_N, C_{HO} - specific volumetric heat capacity of the components of the products of fuel combustion, J/(m^{3}K).

For gaseous fuels, the components of the heat balance q_3, q_4 and q_6 are taken $q_3 = q_4 = q_6 = 0$. Thus, the combustion temperature of gaseous fuel in accordance with formula (12) will be determined by the expression:

$$T_m = (Q_{in} + Q_h)/ \left[\sum_{i=1}^{i=3} (V_i\, C_i)\right] + T_o \,. \qquad (13)$$

Molecular mass

$$M_{cp}=M_{RO}\, X_2+ M_N\, X_1+ M_{HO}\, X_3 \,. \qquad (14)$$

The values of M_{RO}, M_N, M_{HO} *are shown in table 1.*

M_{cp}= 27,571 kg/kmol. (14a)

Mass heat capacity of combustion products

$$C_{cp}= M_{RO}\, X_2 C_{RO} / M_{cp}+ M_N\, X_1 C_N / M_{cp}+ M_{HO}\, X_3 C_{HO} / M_{cp} \,. \qquad (15)$$

Values of C_{RO}, C_N, C_{HO} are given in table 1.

The density of dry combustion products, kg/m^3

$$\rho^d_{cp}= 0{,}01[1{,}96\, CO_2+1{,}52\, H_2S+1{,}25\, N_2+1{,}43O_2+1{,}25CO+0{,}0899H_2+$$

$$+\Sigma(0{,}536m+0{,}045n)C_mH_n] \,; \quad \rho^d_{cp}= 0{,}84...0{,}875 \text{ kg/m}^3 \,. \qquad (16)$$

Density of wet fuel combustion products

$$\rho^w_{cp} = \frac{\rho^d_{cp}+\frac{x_c}{1000}}{1+\frac{x_c}{804}}; \quad \rho^w_{cp}=0{,}835...87 \text{ kg/m}^3. \qquad (17)$$

Density of combustion products with temperature

$$\rho_{dcp}=\frac{P_0 M_{cp}}{R_0 T_i} \qquad (18)$$

The thermal conductivity of the combustion products - gas mixture is determined by the formula [11]

$$\lambda_{cp}= \lambda_1 X_1 + \lambda_2 X_2 + \lambda_3 X_3 \,; \qquad \lambda_{cp} = 0{,}0218 \text{ W/(m K)}. \qquad (19)$$

The dynamic viscosity of the combustion products is determined by Wilk [11]

$$\mu_{cp} = \frac{\mu_1}{1+\frac{x_2}{x_1}\Phi_{1,2}+\frac{x_3}{x_1}\Phi_{1,3}} + \frac{\mu_2}{1+\frac{x_1}{x_2}\Phi_{2,1}+\frac{x_3}{x_2}\Phi_{2,3}} + \frac{\mu_3}{1+\frac{x_1}{x_3}\Phi_{3,1}+\frac{x_2}{x_3}\Phi_{3,2}}; \qquad (20)$$

where $\Phi_{1,2}$ ... $\Phi_{3,2}$ are viscosity functions:

$$\Phi_{1,2}=\frac{[1+(\mu_1/\mu_2)^{1/2}(M_2/M_1)^{1/4}]^2}{2\sqrt{2}(1+M_1/M_2)^{1/2}}; \quad \Phi_{1,3}=\frac{[1+(\mu_1/\mu_3)^{1/2}(M_3/M_1)^{1/4}]^2}{2\sqrt{2}(1+M_1/M_3)^{1/2}};$$

$$\Phi_{2,1}=\frac{[1+(\mu_2/\mu_1)^{1/2}(M_1/M_2)^{1/4}]^2}{2\sqrt{2}(1+M_2/M_1)^{1/2}}; \quad \Phi_{2,3}=\frac{[1+(\mu_2/\mu_3)^{1/2}(M_3/M_2)^{1/4}]^2}{2\sqrt{2}(1+M_2/M_3)^{1/2}};$$

$$\Phi_{3,1}=\frac{[1+(\mu_3/\mu_1)^{1/2}(M_1/M_3)^{1/4}]^2}{2\sqrt{2}(1+M_3/M_1)^{1/2}}\,;\quad \Phi_{3,2}=\frac{[1+(\mu_3/\mu_1)^{1/2}(M_2/M_3)^{1/4}]^2}{2\sqrt{2}(1+M_3/M_2)^{1/2}}\,. \qquad (20a)$$

According to formulas (20), (20a):

$$\mu_{cp} = 1{,}466 \times 10^{-5} \text{ Pa c.} \qquad (20b)$$

With the known values of C_{cp}, λcp, ρ_{cp} and μ_{cp}, the kinematic viscosity coefficients ν_{cp} (m^2/s) and thermal diffusivity a_{cp} (m^2/s) are determined, the number

Prandtl Pr_{cp}

$$\nu_{cp} = \mu_{cp} / \rho_{cp}\,; \quad a_{cp} = \lambda_{cp}/(\rho_{cp}\, C_{cp}); \quad Pr_{cp} = \mu_{cp}\, C_{cp} / \lambda_{cp}\,. \qquad (21)$$

The dependence of thermal conductivity λ_{cp} and dynamic viscosity μ_{cp} of combustion products on temperature is determined by the formula Sutherland [11.12]

$$\lambda_{cp} = \lambda_{cpo}\, A_i\ ;\ \mu_{cp} = \mu_{cpo}\, A_i\,; \qquad (22)$$

where $$A_i = \frac{273{,}15 + B_i}{T_{oi} + B_i}\left(\frac{T_{oi}}{273{,}15}\right)^{3/2}\ ; \quad T_{oi} = t_{oi} + 273{,}15\,. \qquad (22a)$$

Bi values are given in table 1.

Thus, with known values of the thermophysical parameters of the products of fuel combustion, the heat of combustion in accordance with formula (13) is:

$$T_t = 1915...1995 \text{ K or } t_t = 1642...1722\ ^{o}\text{C}. \qquad (23)$$

Table 1

Physical parameters of air and combustion products at t = 0 ^{0}C

Parameter	*Air*	N_2 Nitrogen	CO_2 Carbon dioxide	H_2O Water vapor
M_i, kg/kmol	28,95	28	44	18
$100 \times X_i$,%		71,79	9,2	19,01
C_{pi}, kDj/(kg K)	0,9956+ +0,00009299t	1,024+ +0,00008855t	0,8654+ +0,0002443t	1,833+ +0,0003111t
λ_{oi}, W/(m K)	0,02438	0,0243	0,0137	0,0162
$\mu_{oi} \times 10^5$, Pa c	1,7198	1,66	1,37	0,88
B_i	122	113	239,7	961

At combustion temperatures t_t> 1650 °C, nitrogen oxides are formed (NO, NO_2; N_2O_4; N_2O_5), which, when combined with moisture and air, form nitric acid [12,13]. The formation of NO and NO_2 accelerates with increasing temperature, pressure and excess air. Reducing the formation of NO, NO_2 and their emissions into the atmosphere can be ensured by observing the condition $\alpha = 1$ and lowering the fuel combustion temperature t_t <1650 °C. The best way to reduce the combustion temperature is to dilute the fuel with flue gas, i.e. recirculation use of fuel combustion products. Recirculation of flue gases during the combustion of natural gas can reduce the emission of NO and NO_2 by 60% [13.14,15].

CONCLUSION

The results of the thermophysical characteristics of biogas combustion products obtained from a biogas plant built in a subsidiary farm at Muborakneftegaz LLC are used to study the heat balances of furnace devices and boiler plants, to simulate heat and mass transfer of heat processes using the heat of fuel combustion products.
Legend:
ai is the coefficient of thermal diffusivity, m^2 / s; Ci — specific heat, J/(kg K); Mi - molecular weight, kg / kmol; Po - barometric pressure, Pa; Ro is the universal gas constant, J/(K kmol); t_i is the temperature, ° C; T_i is the absolute temperature, K; x_m - moisture content, kg/kg; Xi - volume fractions of the components of the coolant mixture; λ_i is the coefficient of thermal conductivity, W/(m K); μ_i is the dynamic viscosity coefficient, Pa s; ν_i is the kinematic viscosity coefficient, m^2/s; ρ_i is the density, kg/m^3; Pr_i - Prandtl similarity criteria.

REFFERENCES

1. Uzakov G. N., Aliyarova L. A., Davlonov Kh. A., Toshmamatov B. M., Khusenov A. A. “The use of Solar Energy in Systems of Heat-Moisture Treatment of Air of Heliogreenhouse”. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*// ISSN (P): 2249-6890; ISSN(E): 2249-8001// Vol. 10, Issue 3, Jun 2020, pp.3813-3820.
2. G.N. Uzakov, Kh.A. Davlonov, K.N. Holikov, Study of the Influence of the Source Biomass Moisture Content on Pyrolysis Parameters// *Applied Solar Energy*, Vol. 54, No. 6, pp, 481-484. 2018, (05.00.00; №4. Scopus CiteScore 2018, IF:0.9).
3. Uzakov G.N., Toshmamatov B.M., Kodirov I.N., Shomuratova S.M. On the efficiency of using solar energy for the thermal processing of municipal solid waste.// *Journal of critical reviews*. ISSN- 2394-5125 VOL 7, ISSUE 05, 2020. Pp 1887-1892.
4. Khujakulov S.M., Uzakov G.N., Vardiyashvili A.B. Effectiveness of solar heating systems for the regeneration of adsorbents in recessed fruit and vegetable storages. //Applied Solar Energy. – USA. 2013. – vol.49, № 4. – pp. 257-260.
5. Uzakov G.N. Technical and economic calculation of combined heating and cooling systems vegetable store-solar greenhouse// Applied Solar Energy. – Allerton Press, USA, 2012. –vol.48, №1. –PP. 60-61.
6. Z.U. Saipov, I.X.Abduganiev, D.Z. Olimxanova «Matematicheskaya model sistemi podogreva i teplovogo balansa v bioreaktore biogazovoy ustanovki» Sbornik trudi Mejdunarodnom konferensiya «Fundamentalnie i prikladnie voprosi fiziki» Fiziko-texnicheskiy institut NPO «Fizika-Solnse» ANRUz. Tashkent. 2017 s. 250-253.
7. Obosnovanie trebuemogo urovnya podgotovki gaza na vixode Mubarekskogo GPZ. Osnovnie texnicheskie i texnologicheskie resheniya. (Obzor). -Tashkent.: Fan. 1996. -140 s.
8. Allokulov P.E., Xayriddinov B.E., Kim V.D. Netraditsionnaya teploenergetika.Tashkent: Fan, 2009. - 188 s.
9. Germanovich V., Turilin A. Alternativnie istochniki energii i energosnabjeniya. Prakticheskie konstruksii po ispolzovaniyu energii vetra, solnsa, vodi, zemli, biomassi. - SPb.: Nauka i texnika, 2014. - 320 s.
10. Teplotexnicheskiy spravochnik. Tom 1. -M.: Energiya. 1976. -744 c.
11. Larikov N.N. Teplotexnika. -M.: Stroyizdat. 1985. -432 s.
12. Viktorov M.M. Metodi vichisleniy fiziko-ximicheskix velichin i prikladnie raschyoti. -L.: Ximiya. 1977. -359 s.
13. Jixar G.I., Bogdanovich I.G. Kineticheskaya model goreniya uglevodorodnogo topliva i obrazovaniya oksidov azota i seri. //Promishlennaya teplotexnika. -Kiev.: Naukova dumka. 1987. №6. S. 83-87
14. Shinskiy F. Upravlenie protsessami po kriteriyu ekonomii energii. -M.: Mir. 1981. -389 s.
15. Toshmamatov B.M., Uzakov G. N, Kodirov I. N& Khatamov I. A. Calculation of the heat balance of the solar installation for the thermal processing of municipal solid waste.// *International Journal of Applied Engineering Research and Development* (IJAERD) ISSN (P): 2250–1584; ISSN (E): 2278–9383 Vol. 10, Issue 1, Jun 2020, India. PP. 21–30.
16. A.Sychov, V.Kharchenko, P.Vasant, G.Uzakov. “Application of various computer tools for the optimization of the heat pump heating systems with extraction of low-grade heat from surface watercourses”.//International Conference on Intelligent Computing & Optimization. 10.4. (2018) Springer, Cham: 310-319.
17. G.N. Uzakov. “Calculation of the heat engineering characteristics of a combined system of a vegetable storage facility and solar greenhouse”. // Applied Solar Energy 47.3 (2011): 248-251.
18. V.V. Kharchenko, A.O. Sychov, G.N. Uzakov. “Innovative Instruments for Extraction of Low-Grade Heat from Surface Watercourses for Heating Systems with Heat Pump”. // Innovative Computing Trends and Applications (2019): 59-68.
19. G.N. Uzakov. “Efficiency of the use to energy of the biomass for autonomous power supply fruit-vegetable-vault”. Europaische Fachhochschule ORT Publishing (2015): 92-94.
20. G.N. Uzakov, A.B. Vardiyashvili. “Intensity influence of solar radiation on shrinkage of goods in fruit and vegetable stores”. Applied Solar Energy 47.1 (2011): 27-30.