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The Power Supply System With Geothermal Heat Pumps Based Diesel Generator

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Abstract

The work of monobloctrigeneration experimental setup for autonomous energy supply objects is considered. The compound of installation consists of energy-power unit in the form of diesel generators, geothermal heat pumps as a source of heat and cold supply, waste heat boiler for exhaust gases heat. Heat pump compressors are driven by the shaft of the diesel engine through V-belt transmission. The proposed installation of autonomous energy consumers can be organized in the monogeneration mode, simple and complex cogeneration and trigeneration as well. The energetical and environmental indicators of the installation, confirming its efficiency in a mode of simple and complex cogeneration are researched.

Keywords:monobloctrigeneration plant; heat pumps; recovery boiler; heat exchanger; internal combustion engine..

1. Introduction

The issue of the energy saving is very important nowadays. The confirmation of these, is the act of «Energy saving and energy efficiency» of the Republic of Kazakhstan, that was accepted on 13 January 2012, and announced in January 2008 by the European Commission (EC) strategy of a comprehensive set of measures on the natural resources saving. One of the goals of the new legislation is to encourage the use of renewable energy [1]. In the EC Directive was considered the possibility of the heat usage, supplied by the heat pump (TN), since the conversion coefficient of the heat pump air-to-water ratio of 3.0, we can talk about the reality of the prospects for reducing CO2 emissions by 50% and save up to 30% of the energy of existing boilers running on fossil fuels. This significant issue is the main task of the CIS countries. Saving and rational use of energy resources (FER), the use of alternative and renewable energy sources, development and implementation of heat pump installations and combined heating and cooling systems for industrial and civil construction will be able to reduce the consumption of fossil fuels significantly.

Especially promising is the use of heat pumps in conjunction with systems based on renewable energy sources RES [2]. Such a combined heat supply system according to the degree of mutual integration of the heat pump system elements and system components based on renewable energy sources can be divided into two categories:

1. Installations based on a combination of renewable energy sources with traditional elements of heat pumps, primarily to supply compressor in parallel with the network, as well as independently (basing on standards of the industrial components).
2. Installations with the usage of unconventional components that are integrated into complex devices with the elements of renewable energy sources and heat pumps.

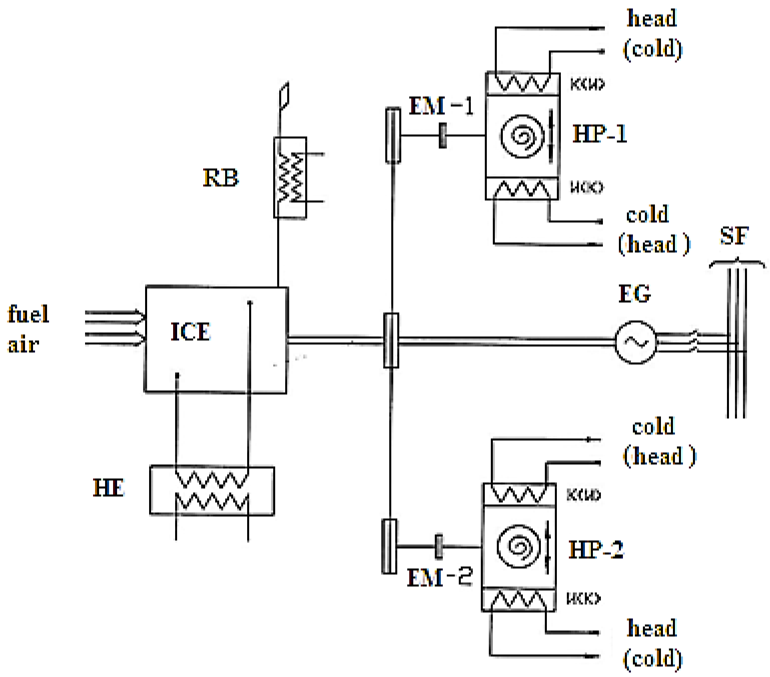
The second category may include also heat pumps, having as low-grade heat geothermal reservoir with the compressor drive motor on diesel-generator through V-belt transmission.

2.Design and characteristic modes of monoblock trigeneration plantMTGP

This article describes a work-piece trigeneration experimental setup consisting of two geothermal heat pump [3]. As an energy-power unit, diesel or gas piston (with the spark-ignition) internal combustion engine is used (ICE models - Kubota D905).

The chemical heat of the fuel in the engine is partly converted into mechanical N_M, which is in the form of torque is transmitted directly to the shaft of an asynchronous electrical generator (MG) and, simultaneously, using V-belt transmission on the pulleys of 2 freon compressors of the heat pumps HP-1 and HP-2 (of the manufacturer - THERMO KING).

The work of heat pump units, as shown in Illustration 1, may be arranged on the basis of the internal combustion engine. The engine is running partly or fully on driving the compressor heat pump. For this purpose, in the experimental apparatus two additional compressor driven by the engine shaft via a belt transmission are mounted. A drive pulley mounted on the transmission shaft on a fixed electric landing. The connection of electrical generator and the motor shafts is saved staff. The drive pulley has two streams under the belt. A driven pulley mounted on the compressor's shaft contains electromagnetic clutch pulleys with the shafts of the compressors.

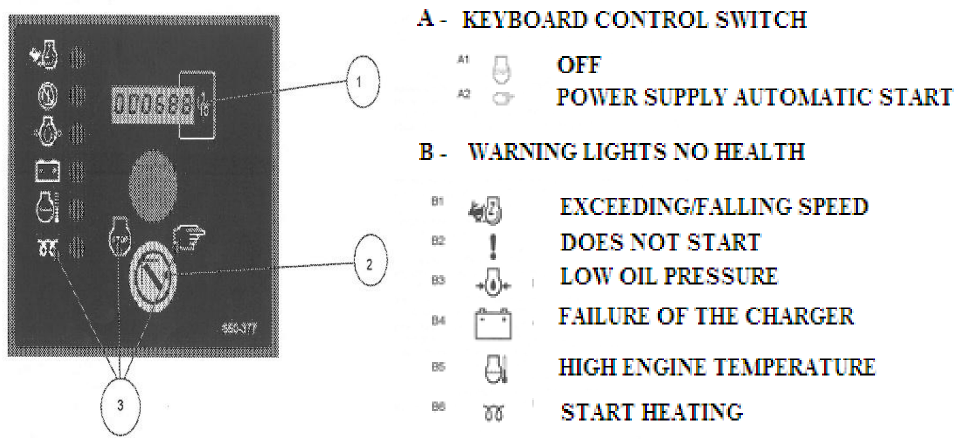


ICE - internal combustion engine, diesel or gas powered;
HE - heat exchanger water / water cooling system engine jacket;
RB - recovery boiler (gas / water) heat from the exhaust gases;
HP-1, HP-2 – reversible vapor compression heat pumps with mechanical direct driven by the internal combustion engine;
C - the condenser; E - the evaporator; EG - electric generator; SF – supply feeder.

Figure 1 - Generalized technical structure monoblocktrigeneration plant (MTGU)

The inclusion of clutches made from an electronic control unit by a computer. Thus, the trigeneration plant engine can only work on a power generator. At the same time an electric energy in an amount of $N_e = 6.5$ kW and the thermal energy as a result of exhaust gases heat recovery and the heat of the engine cooling system will be generated. The engine can operate on power generator and on the one of the compressors. In this case, the electric power will be produced in amount of $N_e = 3.5$ kW, thermal energy by utilizing heat of exhaust gases and the engine cooling system, as well as in the heat pump system in an amount $Q_{HPS} = 17.5$ kW. Engine can run on both compressors. In this case, the generator must operate in an idle mode, because all the mechanical energy generated by the motor will be spent on the compressor drive, and only thermal energy will be produced, obtained in the heat pump system, and as a result of the exhaust gases heat utilization and the engine cooling system.

Work program of trigeneration installation is set with an electronic control unit (Figure 2). Start of the engine, its work program and stop are carried out in automatic mode. At the same time every two minutes during the work of the installation, pressure and coolant temperature are registered in all circuits and tanks - heat storage tanks. The values of these parameters are fixed on the concept of the installation in the points of the sensors, shown in Figure 3.



1 - operating hours counter, 2-button control switch and emergency stop button of the engine; 3 - warning light.

Figure 2 - The regular remote control

3.Experimental determination of the energy and environmental performance of MTGU

Experimental studies of energy and ecological indicators of MTGU on trigeneration installation were done. The aim of research was the experimental determination of the components of the energy balance in the prototype installation and composition of the exhaust gases at different load levels, as well as performance testing of heat pumps in the mode of production of thermal energy.

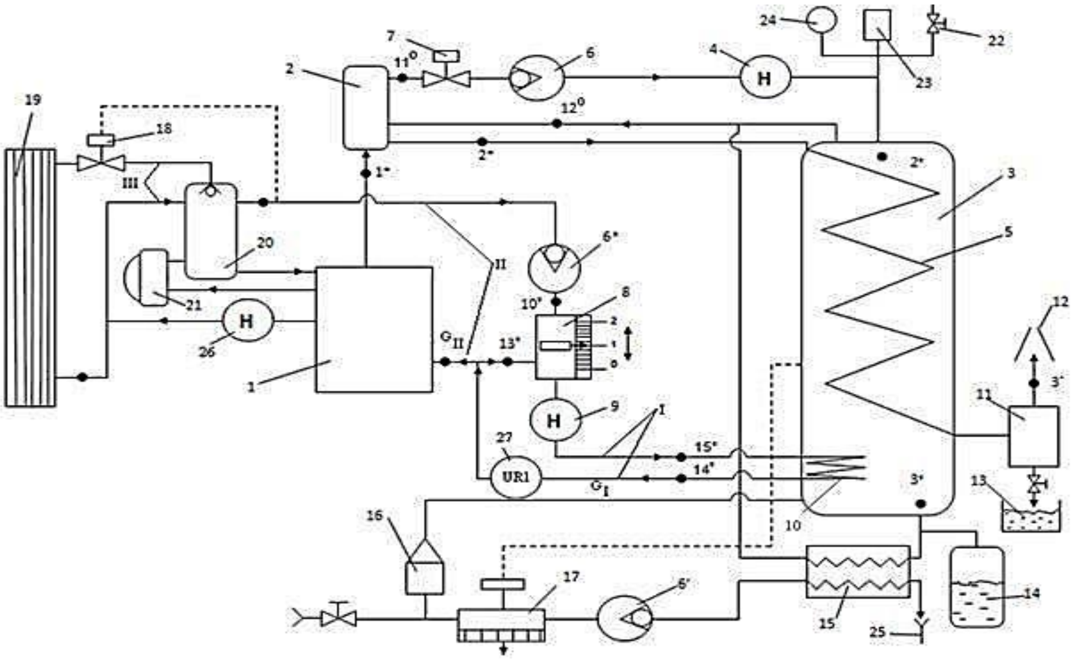
The test parameters required for calibration of mathematical models and the subsequent analysis of energy efficiency MTGU acting in a real structure of energy consumption. This analysis, in turnis necessary for the development of sound selection methods and criteria of optimization of power modes.

On the trigeneration installation were measured following parameters: fuel consumption, coolant flow rate, inlet temperature output engine, heat exchangers and tanks storage, output voltage and current. For this concept has been involved heat recovery system of exhaust gases and the engine cooling water, as shown in Figure 3.

MTGP load carried by an electric boiler (boiler) with the possibility of adjustment of power (0 to 100%).

Fuel and heat transfers consumption are recorded visually and written down in the table every two minutes of plant's working . The measured fuel consumption data plotted (as shown in Figure 4), also a calculation of relative energy equivalence fuel is maid (at 100% of the incoming power to the DG).

Theoretical and experimental determination of the gas temperature at the outlet of the engine of the gas-water heat exchanger and a gas exhaust into the atmosphere is maid, also certain amount of heat energy recoverable from the exhaust gases by reducing their temperature in the gas-water heat exchanger and the gas-tube heat exchanger installed in the tank - storage heat [4-6].



1 - internal combustion engine D905-EGB-2; 2 - gas-water heat exchanger; 3 - the storage tank heat capacity of 300 liters; 4 - circulation pump; 5 - tube heat exchanger; 6,6 ', 6 * - Check valve; 7 - shut-off valve; 8 - valve that regulates the 3 way mixing; 9 - circulation pump; 10 - the heat exchanger water-water pipe; 11 - condensate collection tank; 12 - gas output device; 13 - tank for condensate; 14 - hydrogas battery; 15 - refrigerator; 16 - filter; 17 - regulating valve; 18 - tap automatic temperature limit; 19 - radiator water; 20 - water-oil heat exchanger; 21 - regular oil pump engine oil system; 22 - valve to release the air from the storage tank; 23 - safety valve; 24 - gauge; 25 - drainage; 26 - regular water pump engine cooling system; 27 - UR1 heat meter with flow of water; 1 *, 2 *, 3 * - thermocouple; 2 °, 3 °, 10 °, 11 °, 12 °, 13 °, 14 °, 15 ° - temperature sensors (thermistors); I - water circuit of the tubular heat exchanger water-water storage tank heat; II - water circuit of the cooling system of the engine; III - water circuit radiator regular cooling system of the engine.

Figure 3 - Schematic diagram of the heat recovery system of exhaust gases and the engine cooling water

Energy equivalent fuel (100% of the incoming power to the DG):

$$N_t = G_t \cdot Q_p^{н} / 3600, \ kW \qquad (1)$$

where G_t -fuel consumption for the period $\Delta\tau$; $G_{tк}$;$G_{tн}$ - fuel meter readings at the beginning and end of the experiment.

$$G_t = (G_{tк} - G_{tн}) / \Delta\tau, \ \frac{kg}{s} \qquad (2)$$

Sets of the duration in 1 experience $\Delta\tau = 120s$, fuel consumption per hour

$$G_t^{hour} = G_t^s \cdot 3600, \ \frac{kg}{h}$$

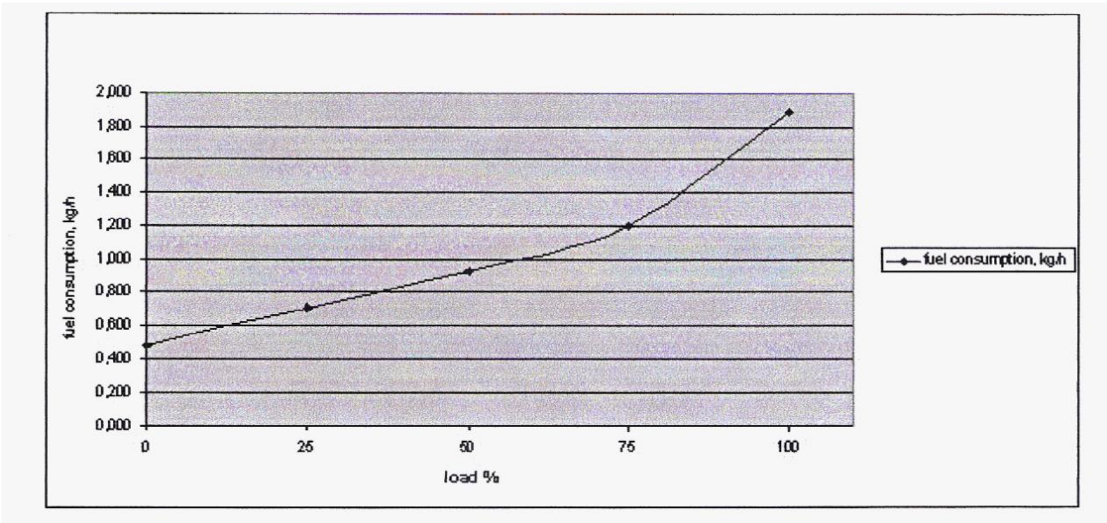


Figure 4 - The fuel consumption in dependence of the load

According to the testimony of fuel flow and a flow meter were calculated heat energy generated by utilizing the heat of exhaust gases MTGP. The heat transferred from the accumulator tank, exhaust gas in gas-water heat exchanger by lowering their temperature for each time period Δτ.

$$Q_{\Gamma i}(t) = G_{Gi} \cdot C_{r,G} \cdot \left(t_{Gi}^{income} - t_{Gi}^{outcome}\right), \text{kW} \qquad (4)$$

Thermal energy is reserved in the tank battery from engine cooling jacket ICE MTGP

$$Q_{\text{TO}} = G^{cool} \cdot \text{C}_{\text{p}}^{cool} \cdot \Delta t^{cool}, \ kW \qquad (5)$$

Electrical power three cylinder diesel generator DG calculated according to the formula

$$N_э = I_1 \cdot U_1 + I_2 \cdot U_2 + I_3 \cdot U_3 ,\ kW \quad (6)$$

The calculation of energy performance MGTP conducted according to the method described in work [3-6] and listed in Table 1. According to Table 1, the graphs in Figure 5 as the dependence of the energy performance of the load on the engine.

Table 1 - Data of generated energy

Load%	Fuel capa-city, kW	Electracapa-city, kW	Heat energy from the jacket of cooling liquid ICE, kW	Heat energy from the utilizing boiler, kW	Costs of thermal energy for its own needs, kW	Loss of thermal energy by radiation and vibration, kW	Useful usage of thermal energy, kW
0	5,67	0,00	3,02	1,17	0,88	0,56	4,22
25	8,39	1,46	3,91	1,52	0,88	0,57	6,94
50	10,91	2,92	4,31	2,05	0,88	0,70	9,33
75	14,17	4,48	5,05	2,85	0,88	0,82	12,47
100	22,31	5,87	9,73	4,72	0,88	0,97	20,46

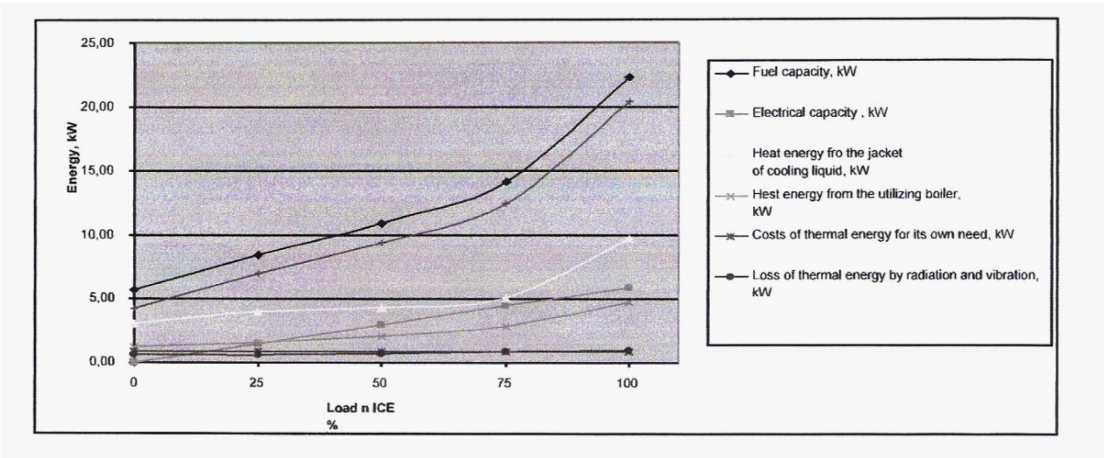


Figure 5 - Thermal energy and power depending on the load

Also conducted experimental studies of the environmental performance of the MGTP. Chemical analysis of the exhaust gases produced by internal combustion engines has been using the device 350 TESTO xl - analyzer to determine the content of O2, CO, CO2, SO2, H2, as well as two, three, polyatomic gases included in the exhaust gas. Readings taken with the analyzer are shown in Table 2, according to the tables were compiled graphs (Figure 6).

Table 2 - Composition of exhaust gases

Capa-city	Content O_2 %	Content CO_2 %	Content CO ppmw	Content SO_2 ppmw	Content NO ppmw	Content NO_2 ppmw	Content NOxppmw	Content H_2 ppmw
0	17,1	2,8	219	7	144	51,8	197	27
25	15,62	3,92	137	5	261	34,2	297	24
50	13,14	5,75	82	7	384	22,6	407	18
75	11,1	7,34	107	9	399	22,4	378	16
100	5,14	11,7	424	0	401	10,7	413	51

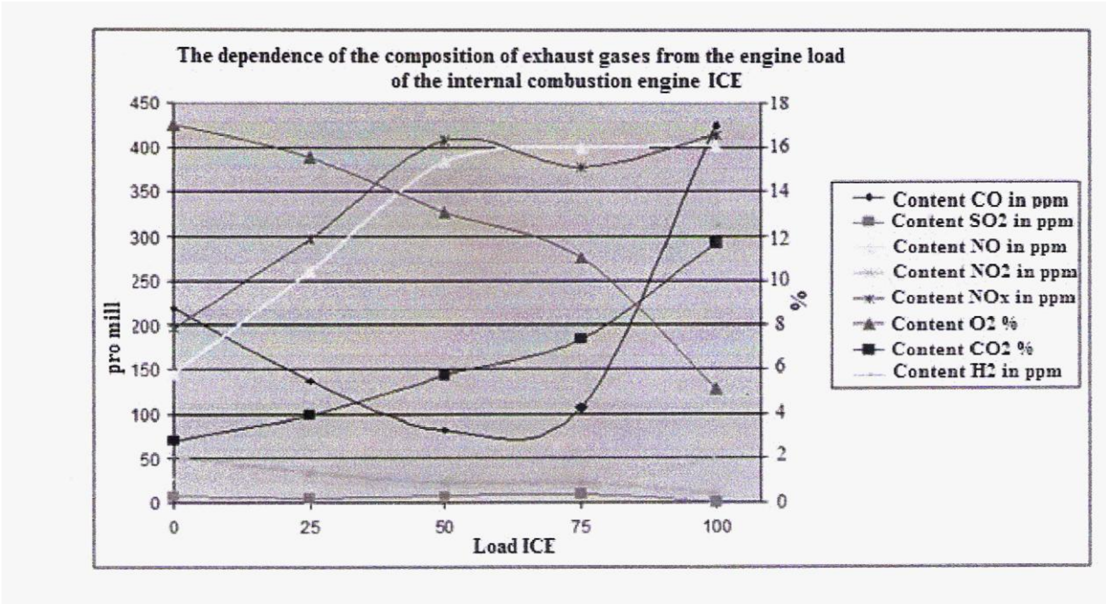


Figure 6 - Composition of exhaust gases in dependence from the engine load

Obtained during the test of MGTP experimental data and calculation of energy and environmental indicators confirm its efficiency in operation, "Simple cogeneration". In the next phase will be tested the installation verification regime "complex trigeneration" in order to determine the heat and cooling capacity of heat pumps.

4. Conclusions

Experiments were conducted to determine the energy characteristics of heat pumps as part of the monoblocktrigeneration plant. The quantity of heat generated in the heat pump, the power of a mechanical drive compressor, the total heat from the heat recovery system of diesel generator and heat pump, heat and electric power TNU[7-10].

The values of the coefficient of energy conversion for the individual heat pump TH-1 in the MTGP values are in the range 2,75 <μ <3,61, which corresponds to the ideas of efficiency of heat pumps sold on other sites. In this case, thermal power VT was = 7.07 kW, and the electric power consumption = 2.4 kW. The weighted average of the conversion factor of the heat pump.

Close to 3.5, which confirms the effectiveness of the energy heat pump technology to TN mechanically by the internal combustion engine MTGU.

Obtained during the test MTGP experimental data and the calculation of the energy and environmental performance of the installation confirm its efficiency in operation "complex cogeneration". Compression heat pumps TH-1 and TH-2 can work driven by the heat engine in the modes of production of heat and cold.

5.Summary

As a result of experimental studies of the energy characteristics of MTGU identifies the components of the energy balance of the prototype installation and composition of the exhaust gas at different load levels.

The results confirm the correctness of the accepted theoretical assumptions and testing of technical solutions in the Assembly of MTGU. To analyze the energy efficiency of MTGU should we continue to study the work of installation, operating conditions of the real structure of energy consumption.

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