The high-efficiently thermal generator development for transport park buildings

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Abstract. The article discusses the issue of a heat providing to consumers in terms of capital and operating costs. Our energy complex is the first installation that does the simultaneous use of vapor compression and absorption heat pumps to transform low-grade heat of the same source, due to the operation of the heat engine. The schemes and results of calculating the modes of the heat generator at ideal and real conditions are presented. The economic calculation of the heat generator capital and operating costs and the most common sources of heat supply: gas, electric, solid fuel and liquid fuel boilers, gas condensate boiler and heat pump, has been performed. A feasibility and comparative analysis of the results is carried out. The conclusion is drawn on the using efficiency the heat generator of increased power and on the prospects of further scientific research in this direction.

1. Introduction

The problem of ensuring reliable heat and hot water supply is extremely important in the context of constantly developing cities, as well as the growth and concentration of heat loads [1, 2]. Energy efficiency and sustainability are therefore a top priority [3, 4]. After all, the use of organic fuel-based power plants for heat generation [5, 6] leads to pollution of the environment, not to mention the increasing prices of energy and resources every year [7].

Of the most relevant studies in the field of energy consumption forecasts, at the current level of consumption coal reserves will suffice for 250 years, gas - for 60 years, oil - for 40 years [8]. British Oil and Gas Corporation BP predicts 30 percent growth in global energy demand by 2035 [9]. Thus, it is very important to manage non-renewable resources rationally. The high-power thermal generator developed in the project allows more efficient use of organic fuel than traditional thermal generators can do.

Despite the fact that the level of gasification is growing every year, there are still many settlements without gas in our country (Russian Federation). As of January 1, 2019, Russia has an average gasification rate of 68.6% in the country, with 71.3% in the city and 59.4% in country settlements [10].

In addition, about 70% of Russia is not covered by centralized electricity supply [11]. Such a problem exists not only in our country, but also in the rest of the world. Even the most developed countries have settlements that are not supplied with gas and electricity. Nevertheless, the problem of economical and reliable energy supply is particularly acute in Russia due to large territories at the Far North [12-14]. Our heat generator can run on gas/gasoline/diesel fuel, so it is autonomous, which...
significantly expands the limits of its application. In addition, when using a heat generator, the emission of harmful substances will decrease due to the use of thermal energy from the environment. This is explained both by the requirements of the existing legal acts and regulatory and technical documentation, as well as by the requests of consumers.

2. Technological features of the thermal generator

Thermal generator is designed for heat supply due to simultaneous use of an organic fuel and low-potential energy sources. The scheme of the thermal generator operation at ideal conditions is shown in Figure 1.

![Diagram of thermal generator operation](image)

**Figure 1.** The scheme of operation of the thermal generator at ideal conditions.

With this configuration and interconnection of power plants, the energy efficiency factor can reach a value of 3.75. At that, coefficient of performance (COP) for absorption heat pump (ABHP) is 2.5, and for steam compression pump (SCHP) - 7. The diagram of the device operation in real operating conditions is shown at the figure 2.
Figure 2. The scheme of operation of the thermal generator in real conditions.

Here, the energy efficiency factor is 2.08. At that, COP for ABHP can be equal to 1.7, and 3.2 for SCHP.

A significant difference and advantage of the thermal generator is reduced (from 1.5 to 4 times) fuel consumption at similar heat output. Thus, the purpose of the developed product coincides with the purpose of traditional thermal generators - a heating and hot water supply. This is the modernization of existing and new heating and hot water supply systems - for individual houses, for housing and utilities facilities, trading complexes, agricultural, agro-industrial and sanatoriums. The thermal generator feature like to consume a reduced amount of fuel makes it possible to consider it for autonomous and mobile heat thermal systems, where fuel transportation is difficult or limited.

Figure 3. The dependence of the COP on the temperature difference of the source and the receiver for SCHP

Figure 4. The dependence of the COP on the temperature difference of the source and receiver for ABHP
3. The thermal generator preliminary calculation

1. Total power of internal combustion engine:

\[ N_{ICE}^{TOTAL} = N_{ICE}^{MECH} + Q_{ICE}^{HEAT} = 10 + 23.33 = 33.33 \, kW \]  

(1)

2. The COP calculation for SCHP and ABHP. Temperature difference between receiver and source is:

\[ \Delta t_{HEAT} = \frac{55 + 45 - 0 + (-10)}{2} = 55 \, ^\circ C \]  

(2)

As shown in Figure 3 SCHP COP is 3.2, ABHP COP is 1.7.

3. SCHP Power:

\[ Q_{SCHP} = N_{ICE}^{MECH} \cdot COP_{SCHP} = 10 \cdot 3.2 = 32 \, kW \]  

(3)

4. Heat received at ABHP from internal combustion engine, taking into account waste gas losses:

\[ Q_{ICE}^{HEAT} = Q_{DRAWN} - Q_{LOSES} = 23.33 - 1.33 = 22 \, kW \]  

(4)

5. ABHP Power:

\[ Q_{ABHP} = Q_{ICE}^{HEAT} \cdot COP_{ABHP} = 22 \cdot 1.7 = 37.4 \, kW \]  

(5)

6. Heat power of the Thermal generator:

\[ Q_{TG} = Q_{SCHP} + Q_{ABHP} = 32 + 37.4 = 69.4 \, kW \]  

(6)

7. If the developed plant will be used for buildings with medium heat insulation (about 100 W per 1 m²), the area which can be heated by this unit:

\[ \frac{Q_{TG}}{Q} = \frac{69400}{100} = 694 \, m^2 \]  

(7)

8. Fuel consumption of the Thermal generator:

\[ G = \frac{Q_{TG}}{Q_{LV}} = \frac{33.33}{35.88 \cdot 10^3} = 0.929 \cdot 10^{-3} \, m^3/sec \]  

(8)

4. Comparative analysis of some thermal generators

4.1. Heat Loss Calculation for Heating Period

1. Coefficient of a heating load non-uniformity during heating period is:

\[ K = \frac{t_{IN} - t_{HP}}{t_{IN} - t_{OUT}} = \frac{24 - 0}{24 - (-22)} = 0.522 \]  

(9)

The heat amount of required for a heating of the building during a heating period is:

\[ E_{HEAT} = 24 \cdot 3600 \cdot Q_{HP} \cdot z_{HP} \cdot K = 
\]

\[ = 24 (h/d) \cdot 3600 \, (sec/h) \cdot 65 \, kW \cdot 171 \, d \cdot 0.522 = 501295392 \, kJ \]  

(10)

2. The heat amount for a hot water supply:
\[ E_{HWS} = V \cdot \rho \cdot c_w \cdot n \cdot z_{yr} \cdot (t_{HWS} - t_{CW}) = 0.105 \frac{m^3}{\text{pers} \cdot \text{d}} \cdot 983.3 \frac{kg}{m^3} \]
\[ = 4.19 \frac{kJ}{kg \cdot ^\circ C \cdot \text{pers} \cdot \text{d} \cdot (55 ^\circ C - 10 ^\circ C) = 56844013 kJ} \]

3. The heat amount for a heating and hot water supply of the building during a heating period is:
\[ E_{HEAT,HWS} = E_{HEAT} + E_{HWS} = 501295392 + 56844013 = 558139405 kJ \]

5. Conclusion
The above calculations show the efficiency of the thermal generator construction and its advantages over "traditional" heat sources.

It’s important to take into account the cost was calculated exactly with imported equipment, and the installation will pay off during the entire operational life. During the development of the thermal generator the domestic equipment will be used, some parts of the equipment will be developed on the domestic basis. In this case thermal generator will pay off within a few years.

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