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Efficiency of Gas Turbine Vessel Power Plant of a Vessel for Recycling Plastic Waste Into Diesel Fuel and Electricity

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Environmental pollution due to plastic waste is a very serious global problem. The total amount of the world polymer waste generated exceeded 400 million tons up to 2024. At the same time, more than 0.5 percent of their total amount ends up in the aquatic environment of the seas and oceans.

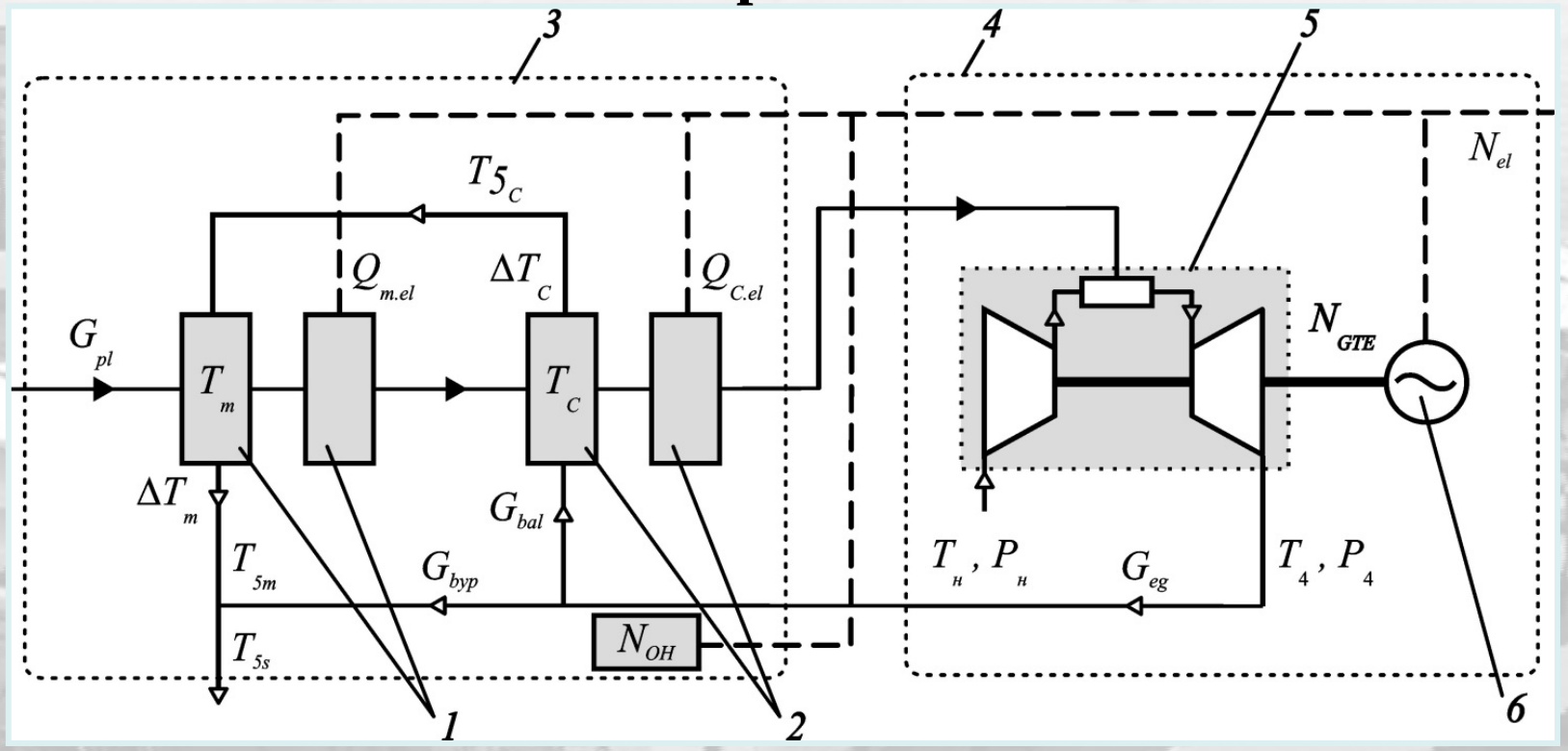
Great Pacific Garbage Patch: Trash and Plastic Waste

"Garbage islands" have formed in the oceans, the most famous of which is called the Great Pacific Garbage Patch. In order to extract plastic waste from the water column, marine plastic waste col-lection systems have been created. At the same time, specialized vessels are known for recycling plastic waste in to fuel and electricity production.

One of the promising areas for recycling plastic waste is processing into artificial liquid fuels, the quality indicators of which allow to use these fuels.
A specialized mathematical model was developed to study and optimize the operating parameters of gas turbine engines with alternative fuels.

The model developed by the authors allows to study the parameters and indicators of the gas turbine engine with a new type of fuel – artificial fuel produced from thermoplastic waste by controlling cracking process.

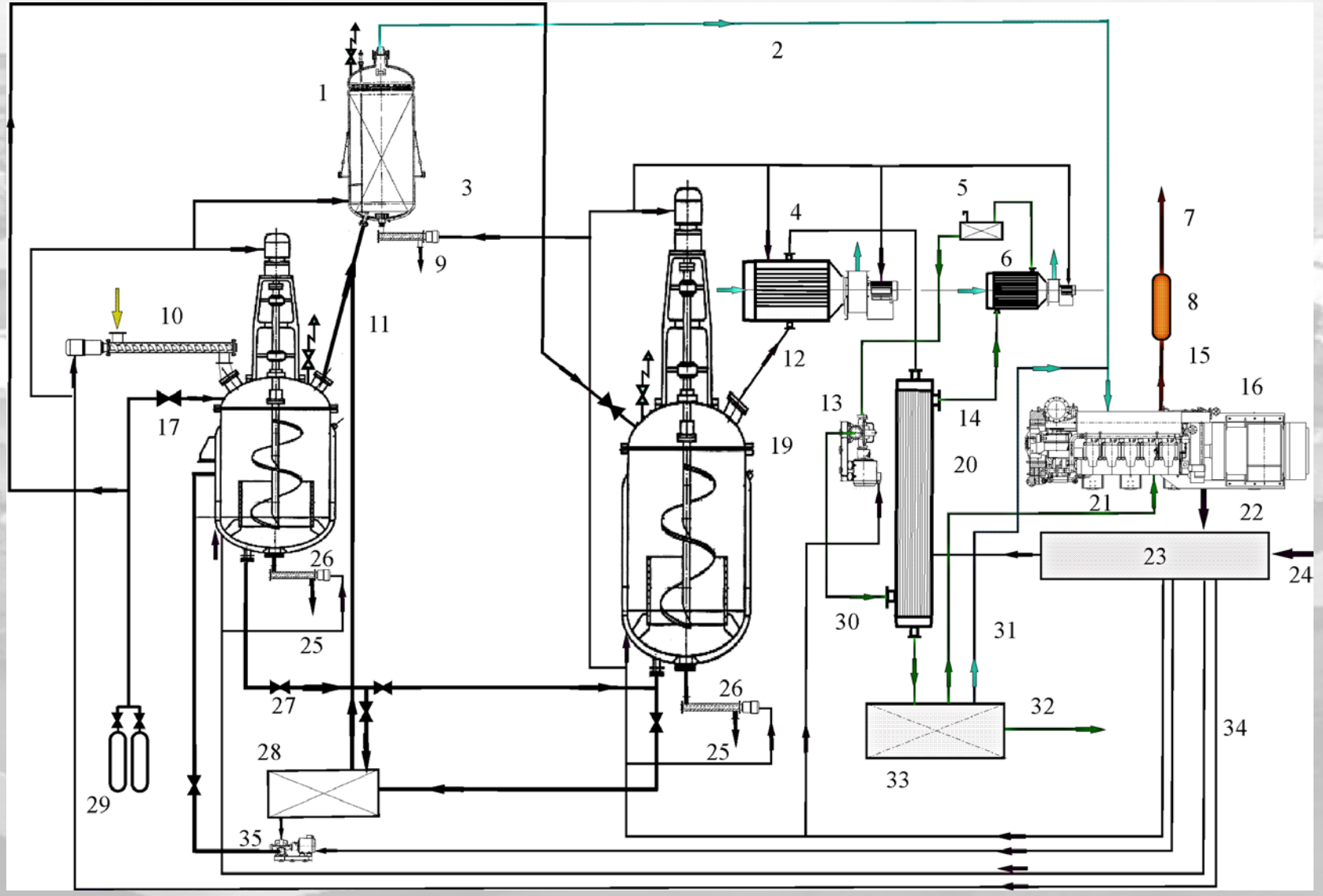
Simplified diagram of a gas turbine marine power plant of a modern specialized vessel



1 – First stage of the technologic process, 2 – Second stage of the technological process, 3 – Technological subsystem, 4 – Energy subsystem, 5 – Gas turbine engine, 6 – Electricity generator.

The model includes modified system of balance equations for energy and mass flows in processing and generation equipment establishes the relationship between the thermodynamic and consumption parameters of the elements, which provides reliability of the modelling results.

The simplified principal plastic waste processing diagram



On the basis of the developed model the research of the influence of the initial air temperature on the performance of the modern specialized gas turbine marine power plant as applied to GT6000 GTE produced by "Zoria–Mashproekt" enterprise has been carried out.

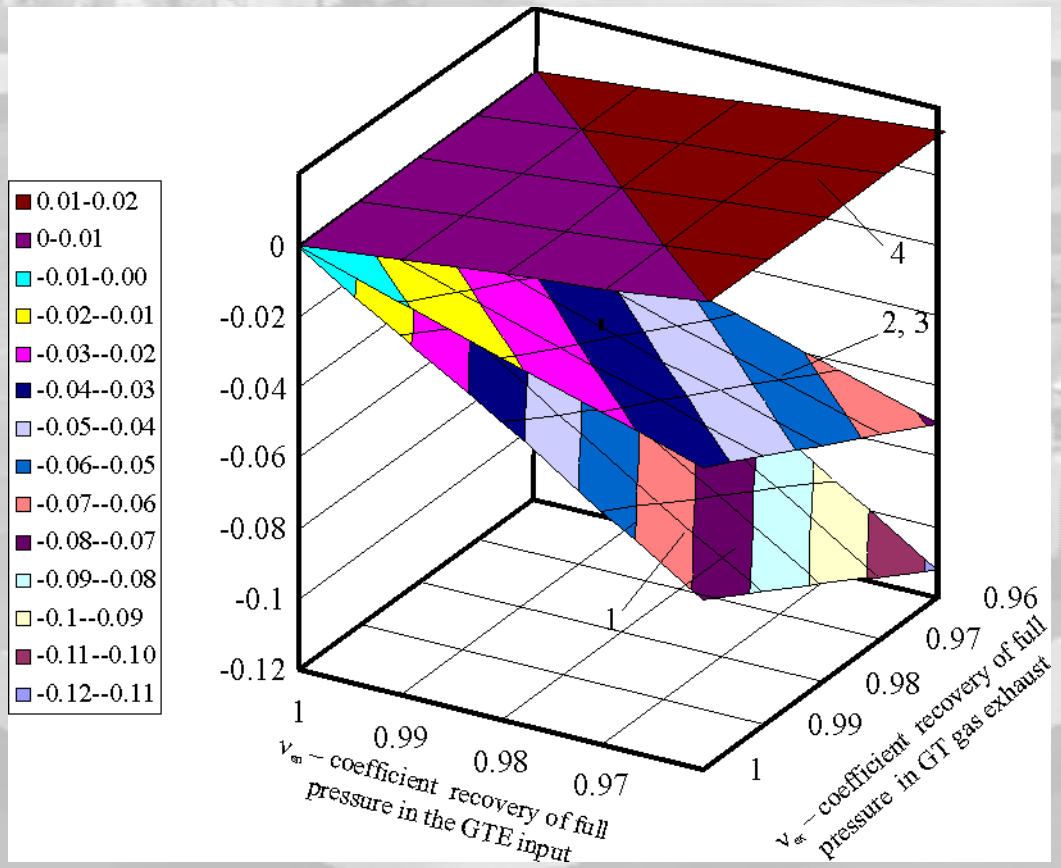
The main characteristics of GT6000 under ISO 2314 conditions are the following:

Indexes	Value
Engine	
Mechanical engine power, kW	6700
Engine's efficiency, %	31.5
Outlet exhaust gas temperature, K	693
Exhaust gas flow rate, kg/s	31.0
Technological equipment	
Specific power consumption for auxiliary processing equipment, Wh/kg	200
Specific heat consumption for the first processing stage, Wh/kg	300
Specific heat consumption for the second processing stage, Wh/kg	900

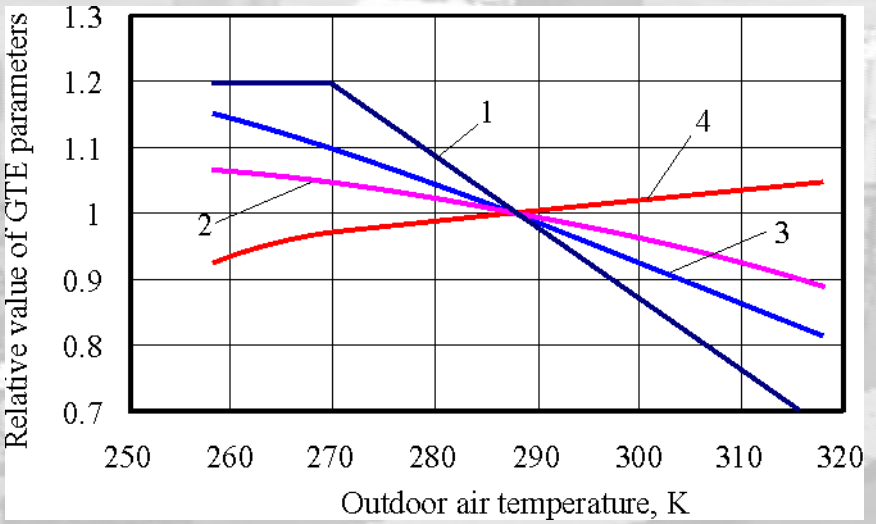
Some modelling results of gas turbine marine power plant research and development

The nominal parameters gas turbine engine GT6000 under ISO 2314 conditions: mechanical power – 6700 kW, efficiency – 0.315

Change in relative parameter value

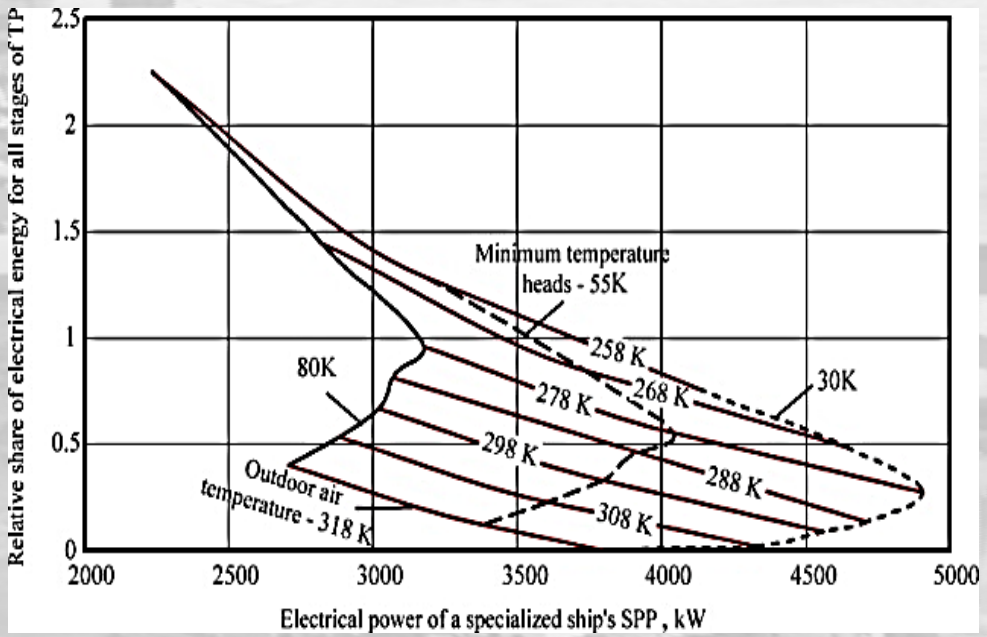


Relative parameter value

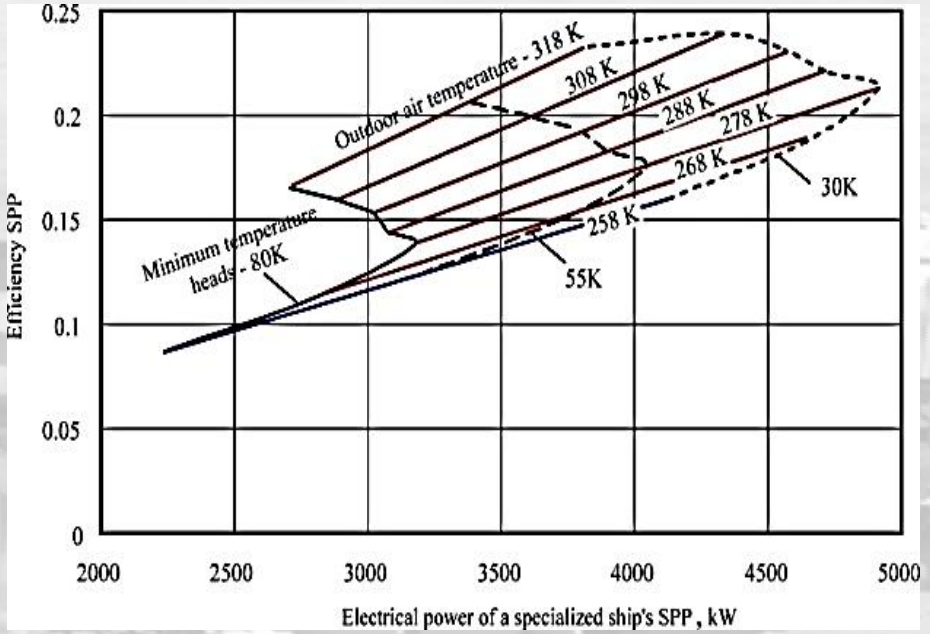


1– mechanical power,
2 – efficiency,
3 – exhaust gas flow rate,
4 – outlet gas temperature

The influence of outside air temperature on the performance of the marine power plant of a modern specialized vessel based on the GT6000 gas turbine engine

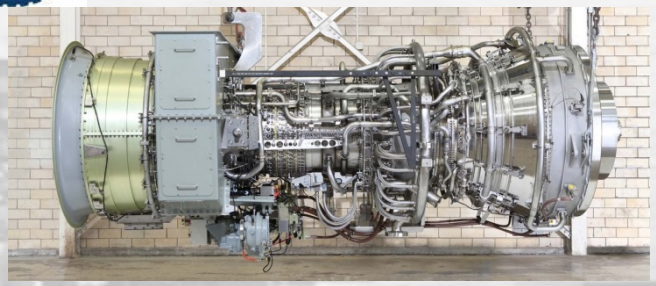


a



b

a – relative share of electrical energy for all stages of the technological process;
b – efficiency and power at nominal parameters GTE GT6000 under ISO 2314 conditions: mechanical power – 6700 kW, efficiency – 0.315.



Analysis of presented results in the considered range of parameters indicates the following: there are exist maximum values of efficiency and electric power of the marine power plant of an modern specialized vessel (**a**).

The maximum efficiency value of the marine power plant is achieved in the range of outdoor air temperature (300..305).

The maximum value of the electrical power of the marine power plant is achieved at significantly lower outdoor temperatures (270..280) K.

This effect occurs as a consequence of two opposing processes occurring in the subsystems of the power control system of a marine power plant. When the outside air temperature decreases, the efficiency of the gas turbine engine increases and the electrical power generated in the power subsystem of the power plant increases. At the same time, the temperature of the exhaust gases of the gas turbine engine decreases, which leads to an increase in the cost of electrical energy for process heating in the first and second stages of the technological process (**b**). This leads to a decrease in the efficiency and electrical power of the marine power plant.

CONCLUSIONS

The principal schematic diagram of a marine power plant, utilizing alternative fuel derived from the processing of thermoplastic polymer waste, has been developed and analyzed. This technical solution enables the full exploitation of the advantages offered by marine gas turbine plants when using alternative fuels. Furthermore, the use of alternative fuel produced from thermoplastic polymer waste helps to reduce harmful sulfur oxide emissions into the environment.

A simulation model of a gas-turbine power plant for a modern specialized vessel was created, which revealed the impact of climatic factors and the properties of the alternative fuel on the efficiency of the gas turbine marine power plant. Additionally, the influence of inlet and outlet resistance on the GT6000 parameters was determined.

The study demonstrates that, for the marine power plant of a specialized vessel using alternative fuel from processed thermoplastic polymer waste, the maximum efficiency is achieved within an outdoor air temperature range of 300 to 305 K.

It is also shown that the maximum power output of the marine power plant for a modern specialized vessel using thermoplastic polymer waste as an alternative fuel is reached within a temperature range of 270 to 290 K.

Based on these results, we believe that presented results of research and development allow optimizing gas turbine engine operation in different ambient conditions, especially at tropical. Also these results allow to choosing rational parameters at gas turbine engine when it operates with alternative fuel.