

Brief information about the project

Name of the project	AP26105185 Effective use of computer technologies to optimize the combustion of hydrocarbon fuels in thermophysical devices with an injection system
Relevance	The project's relevance stems from the need to improve the combustion efficiency of liquid hydrocarbon fuels while reducing pollutant emissions in the face of increasingly stringent environmental requirements and global climate challenges. Despite the development of alternative energy sources, liquid fuels continue to play a key role in the energy and industrial sectors, requiring improved technologies for their use. The use of modern 3D computer modeling of thermophysical processes enables a deeper understanding of atomization and combustion mechanisms, optimizes the operating modes of thermal power plants, and ensures both economic and environmental efficiency.
Purpose	Conducting applied research into the thermophysical processes occurring in combustion chambers during the atomization, decomposition, dispersion, and evaporation of jet non-isothermal injections of various types of liquid fuels under high turbulence, based on fundamental approaches in technical physics, using the latest computer technologies and physical modeling methods, and optimizing combustion modes to achieve maximum heat generation while minimizing pollutant emissions.
Objectives	1. Conduct an analysis of existing global research on the combustion of liquid hydrocarbon fuels, considering key aspects of combustion efficiency, the impact of various technologies on emissions, and the economic and environmental consequences of using liquid fuels. This work will identify the most efficient combustion methods and identify ways to reduce pollutant emissions. 2. Develop a comprehensive 3D computer model consisting of physical, mathematical, geometric, and global chemical submodels describing the thermophysical processes during the combustion of non-isothermal liquid injections of various fuels under high turbulence, considering the processes of droplet decay, collision, ignition, dispersion, and evaporation. 3. Develop a new statistical model to describe, analyze, and predict the behavior, dynamics, and interaction of liquid fuel injections with a reacting medium under high turbulence: mechanisms of droplet breakup, atomization, and distribution by various characteristics (size, shape, and temperature), and types of interactions between droplets (coalescence, condensation, and evaporation). 4. Optimize and adapt a 3D modeling software package with improved algorithms for testing functionality and performance for conducting computational experiments simulating the combustion of liquid hydrocarbon fuels. 5. Conduct computational experiments on the combustion of various types of liquid hydrocarbon fuels in devices with an injection system with varying droplet sizes and obtain 3D visualization of droplet dispersion by radius and temperature along the combustion chamber height; temperature fields of a two-phase flow; concentration fields of combustion products (carbon oxides, nitrogen and oxygen flow rates); Vector velocity fields in directions and heat flux density throughout the combustion chamber and determine optimal combustion modes. 6. Conduct computational experiments on the combustion of various types of liquid hydrocarbon fuels in devices with an injection system with varying droplet temperature and obtain a 3D

	visualization of droplet dispersion by radius and temperature along the height of the combustion chamber; temperature fields of a two-phase flow; concentration fields of combustion products (carbon oxides, nitrogen and oxygen flow rates); Vector velocity fields in directions and heat flux density throughout the combustion chamber and determine optimal combustion modes. 7. Conduct computational experiments on the combustion of various types of liquid hydrocarbon fuels in devices with an injection system with varying droplet mass and obtain a 3D visualization of droplet dispersion by radius and temperature along the height of the combustion chamber; temperature fields of a two-phase flow; concentration fields of combustion products (carbon oxides, nitrogen and oxygen flow rates); Vector velocity fields in directions and heat flux density throughout the combustion chamber and determine optimal combustion modes. 8. Conduct computational experiments on the effect of injection types on the combustion processes of various types of liquid hydrocarbon fuels in devices with an injection system and obtain 3D visualization of droplet dispersion by radius and temperature along the combustion chamber height; temperature fields of two-phase flow; concentration fields of combustion products (carbon oxides, nitrogen and oxygen flow rates); vector velocity fields in directions and heat flux density throughout the combustion chamber and determine optimal combustion modes. 9. Conduct a comparative analysis of the obtained results of liquid hydrocarbon fuel combustion simulations using a new statistical model of droplet atomization, disintegration, dispersion, and evaporation under high turbulence with experimental data available in the literature. Summarize the parameters of the optimal combustion mode for various types of liquid fuels, reducing fuel costs, minimizing the negative impact on the environment, and ensuring the reliable and safe operation of injection systems. Propose general recommendations for the efficient organization of the liquid fuel combustion process in thermophysical devices. 10. During the entire period of the project, publish articles in peer-reviewed scientific journals indexed in the Web of Science and Scopus databases, as well as an article in a peer-reviewed foreign or domestic publication recommended by the SHEQAC.
Expected and achieved results	Results achieved: 1. An analysis of current research on the combustion of liquid hydrocarbon fuels was conducted, considering efficiency, emissions, and environmental and economic aspects. Key factors and effective methods for increasing combustion efficiency and reducing emissions were identified. 2. A comprehensive 3D model was developed, including physical, mathematical, geometric, and chemical submodels, accounting for key processes (decomposition, evaporation, ignition, etc.). The model was tested and is ready for further research. 3. A statistical model was created describing the dynamics and interaction of droplets in a turbulent environment, considering spraying, distribution, and phase processes. Its performance was confirmed. 4. The 3D modeling software package was optimized and adapted, improved algorithms were implemented, and testing was conducted. Its correctness and readiness for computational experiments were confirmed. Expected results:

	The project will include a series of computational experiments to simulate the combustion of various types of liquid hydrocarbon fuels, producing detailed 3D visualizations of thermophysical processes; a comparative analysis of the simulation results with experimental and published data to confirm the validity of the developed models; determination of optimal combustion modes that improve energy efficiency and reduce pollutant emissions; development of practical recommendations for improving combustion processes in thermophysical devices with an injection system; publication of the obtained results in international scientific journals and their validation by the scientific community.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	1. Bolegenova Symbat Alikhanovna, PhD, associate professor (h-index Scopus - 13, h-index Web of Science – 12, Researcher ID - A-9696-2015, ORCID - 0000-0003-1061-6733, Scopus Author ID - 57195694754). https://www.scopus.com/authid/detail.uri?authorId=57195694754 2. Askarova Aliya Sandybaevna, Doctor of Physical and Mathematical Sciences, Professor (h-index Scopus - 21, h-index Web of Science – 21, Researcher ID - N-6081-2014, ORCID - 0000-0003-1797-1463, Scopus Author ID – 6603209318). https://www.scopus.com/authid/detail.uri?authorId=6603209318 3. Bolegenova Saltanat Alikhanovna, Doctor of Physical and Mathematical Sciences, Professor (h-index (Scopus) - 20, h-index (WoS) - 18, ResearcherID - A-9696-2015, ORCID - 0000-0001-5001-7773, Scopus Author ID – 57192917040). https://www.scopus.com/authid/detail.uri?authorId=57192917040 4. Ospanova Shynar Sabitovna, PhD (h-index (Scopus) - 8, h-index (WoS) - 5, ResearcherID -A-8880-2015, ORCID - 0000-0001-6902-7154, Scopus Author ID – 55988678700). https://www.scopus.com/authid/detail.uri?authorId=55988678700 5. Maksimov Valery Yuryevich, PhD (h-index Scopus - 16, h-index Web of Science - 15, Researcher ID - F-6214-2013, ORCID- 0000-0003-4120-1071, Scopus Author ID – 57130389500). https://www.scopus.com/authid/detail.uri?authorId=57130389500 6. Nugymanova Aizhan Olzhabekkyzy, PhD (h-index Scopus - 10, h-index Web of Science - 15, Researcher ID N-4527-2014, ORCID- 0000-0003-0393-5672, Scopus Author ID – 57193723169). https://www.scopus.com/authid/detail.uri?authorId=57193723169
Usage	The project's results will be used to optimize combustion processes in thermal-physical devices, improve energy efficiency, and reduce emissions, as well as in scientific research, engineering practice, and education.
Priority compared to real-world alternatives	The project has a distinct advantage over existing approaches due to its use of an integrated approach combining 3D physical modeling, statistical methods, and verification with experimental data. Unlike most known studies, which consider processes separately, the project provides an integrated description of the atomization, evaporation, and combustion of liquid fuels under highly turbulent conditions. An additional advantage is the development of a proprietary statistical model and the adaptation of the software suite, which ensures higher forecast accuracy, expands the applicability of the results, and enhances their

	practical significance.
List of publications with links to them	1. A.S. Askarova, S.A. Bolegenova, Sh.S. Ospanova, S.A. Bolegenova, A.Z. Nurmukhanova, G.Y. Baidullayeva Investigation of Dispersion, Breakup, and Combustion Processes of Liquid Fuel Droplets under High Turbulence // Bulletin of the Karaganda University. Physics Series. – 2025. - Vol. 30, No. 4 (120). – P. 83-94. https://doi.org/10.31489/2025ph4/83-94 (WofSC, Q4; SHEQAC) 2. S.A. Bolegenova, A.S. Askarova A., Sh.S. Ospanova, S.A. Bolegenova, A.Z. Nurmukhanova, Sh.K. Assilbekova Coupled sputtering and combustion dynamics of diverse fuel types // Eurasian Physical Technical Journal. – 2026. (Scopus, процентиль 26, Q3; SHEQAC – in print)
Patents	Patent of the Republic of Kazakhstan. Authors Bolegenova S.A., Ospanova Sh.S., Tuyakbaev A.A., Bolegenova K.A., Nusipzhan A. Patent for utility model №11898 «Device for determining the specific heat capacity of metals». 13.03.2026 г.