Project name: IRN AP19675062 " Development of clean coal technology for the production of volatile combustible substances "

Relevance:

Frequent burning of fuel oil can affect the reliability of the energy supply in the most undesirable way. This is explained not only by the danger of corrosion, which shortens the overhaul period of the heating surfaces of boilers, but also by the formation of sooty deposits that impede the operation of boilers and clog tubular air heaters and lead to an explosion of electrostatic precipitators.

The high price of fuel oil, a number of negative technical, economic and environmental consequences during the combustion of liquid and solid fuels, operational difficulties associated with preparing for combustion and cleaning flue gases, makes reducing the share of fuel oil and coal in the fuel balance of boiler units a very urgent task of modern thermal power engineering.

This technology can be used in all pulverized coal-fired power plants and boiler houses. It allows you to completely eliminate the use of fuel oil for firing up the boiler and maintaining a stable ignition of a dust-like torch, when the boiler is operating at reduced loads, as well as limiting the combustion of coal as the main fuel of TPPs and boiler houses.

This gives a significant reduction in financial costs associated with the high cost of fuel oil, reducing emissions of nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO) and vanadium pentoxide (V2O5).

Target:

The purpose of this project is to rationalize the processes of burning liquid and solid fuels by developing a technology for the thermal processing of coal to replace starting fuel oil and coal with the resulting gaseous fuel, which will increase the efficiency and effectiveness of boiler units.

Expected and achieved results:

To achieve the goals of the project, it is planned to obtain the following results:

1. A theoretical review of sources on the study and analysis of existing methods for kindling pulverized coal-fired boilers and thermal treatment of coal, namely, operating characteristics of devices, temperature heating conditions.

2. Phenomenological model of the technology of oil-free kindling and maintenance of flame combustion by volatile combustible substances obtained from coal.

3. Three-zone physical and mathematical model of the furnace space of the heating chamber, with the definition of fuel heating zones, the release of combustible gases and other products of the process; stoichiometric model of the obtained combustible organic matter during the development of the processes of generation of combustible gases and combustion; physical and mathematical model of heat transfer in a heat generator, taking into account hydro-gas dynamics, convection and thermal radiation in technology.

4. Results of a numerical study of the optimal parameters of the technology for obtaining volatile combustible substances obtained from coal; temperature conditions, pressure conditions, coolant flow rate, level of toxic emissions, technical and economic requirements.

5. Optimal parameters of the furnace space of the heating chamber, its convective part, parameters of the conditions for internal geometric correction.

6. Basic requirements for the installation: in terms of heated area, heat consumption, fuel categories, duration of the chamber's working cycle, pressure, temperatures.

7. Technological scheme of integrated energy supply of remote settlements with three types of energy: heat, electricity and gas for domestic needs.

8. Draft design documentation for a sample of the heating chamber for the technology of oil-free kindling and maintaining the combustion of the torch with volatile combustible substances obtained from coal

9. Suggestions and recommendations for the implementation of the results of the studies performed; if possible, integrated energy supply for small remote settlements.

10. Three publications in peer-reviewed scientific publications in the scientific direction of the project, indexed in the Science Citation Index Expanded Web of Science database and (or) having a CiteScore percentile in the Scopus database of at least 35 (thirty-five): 2024 - 1 article, 2025 - 2 articles.

11. Publications in domestic journals with a non-zero impact factor (recommended by the KOKSNVO); 2023 - 1 article, 2024 - 2 articles, 2025 - 2 articles. Implementation of the obtained results in the educational process of the Kazakh Agrotechnical University named after. S. Seifullin, including the courses of disciplines "Special Issues of Fuel Combustion", "Boiler Plants and Steam Generators", "Theoretical Foundations of Thermal Power Plants" in the educational programs of the bachelor's degree "Heat and Power Engineering" and "Heat and Gas Supply and Ecoengineering in Agriculture", Educational Master's Programs "Thermal power engineering".

12. The technology obtained can be used at all pulverized coal-fired thermal power plants and boiler houses. It allows to exclude the use of fuel oil or natural gas to fire up the boiler and maintain stable ignition of the pulverized flame, when the boiler is operating at reduced loads, and to limit the use of pulverized coal fuel in low-power boilers. This gives a significant reduction in financial costs associated with the high cost of fuel oil, reducing emissions of nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO) and vanadium pentoxide (V2O5). Also, energy consumption for the plant's own needs, associated with the multi-stage preparation of fuel oil for combustion, is reduced. Efficiency and efficiency of boiler units operation increases.

2023 results:

1. A clean coal technology has been developed for the production of volatile combustible substances released during the heat treatment of coal and a preliminary design. This technology is based on the use of gaseous fuel obtained from the thermal processing of coal.

The release of flammable volatiles is carried out in a combustion device, in which the coal layer is heated without access to oxygen. This process is not coal gasification, since heating is carried out only to temperatures necessary for the release of flammable volatile substances. This temperature depends on the type of coal and its technical characteristics. Combustible volatile substances released after heating, consisting of CO, H2, CH4. , and others, in the case of kindling, are directly fed into the boiler furnace after kindling, they can be accumulated in a special gas storage, at a certain pressure, and subsequently used to maintain the combustion of the torch.

In accordance with the developed technology, it is possible to completely eliminate the use of fuel oil at stations, and at the same time, all the difficulties associated with its operation are eliminated. In essence, the station becomes single-fuel, and the main and starting fuel will be coal used at the station. If the thermal characteristics of a given coal do not correspond, in order to obtain volatile combustible substances, other coal with a higher yield of volatiles can be delivered to the station.

This process of obtaining volatile fuels from coal is not a process of coal gasification. Gasification technologies are more complex and expensive. The process under consideration differs from the processes of high-temperature pyrolysis and gasification in that heating is carried out only to the temperatures necessary for the release of flammable volatile substances, in the required volume and with sufficient heat of combustion. which depends on the characteristics of the coal.

2. In order to obtain gaseous fuel that can replace heating oil at pulverized coal stations, three types of solid fuel, the deposits of which are located in Kazakhstan, were experimentally studied: Maykubenskoye brown coal, Shubarkulskoye hard coal and Saryadyrskoye brown coal.

Stage 1 of experimental research:

For each type of coal, four experiments were carried out, differing in heating temperature.

A pre-treated coal sample (a particle about 5 mm in size) was placed on a substrate in the experimental chamber. Next, a gradual increase in voltage was carried out. As a result of an

increase in voltage and an increase in temperature, the process of thermal destruction of the sample begins, thereby initiating the sublimation of volatile compounds, after which heating continued while maintaining a constant voltage level by adjusting the current.

The duration of the experiment was limited by reaching the specified maximum temperature of 600 °C. All resulting products of the thermal process were investigated: gas, liquid and solid.

The second stage of experimental research:

The second stage of experimental research consisted of determining the quantitative composition of combustible gas obtained from the above-presented coal samples from three deposits by thermal treatment of coal samples at different heating rates.

The studies were carried out on the same experimental setup. For each type of coal, four experiments were carried out, differing in heating rates.

The duration of the experiment was limited by reaching the specified maximum temperature of 800 °C.

The results of experiments to determine the composition of the combustible gas showed that with an increase in the heating intensity of all types of coal presented, the concentration of carbon dioxide CO2, hydrogen H2 and methane CH4 decreases. Against the background of the changes described above, an increase in the content of carbon monoxide CO is observed, the value of which compensates for the concentration of flammable components and increases the calorific value of the resulting gas.

Based on the results of the work carried out, an article was published:

A.K.Mergalimova, S.B. Ybray, A.V. Atyaksheva, B.T. Bakhtiyar. Қазандық өртіне арналған таза көмір технологиясы // Bulletin of ToU, Energy Series. - 2023. - No. 3. - pp. 244-256. 171.pdf (tou.edu.kz)

Study group members:

project Manager -

1) Mergalimova Almagul Kairbergenovna - scientific supervisor of the project, PhD "Heat power engineering".

He manages the project "Development of an effective technology for oil-free firing of the boiler with volatile combustible substances obtained during the heat treatment of coal." He is engaged in the organization of work, experimental research, the conclusion of contracts and agreements, the preparation and publication of articles, and the coordination of the work of all program executors.

Research interests: thermal power engineering, thermal power plants, thermal processing of fuels, gasification. He is the author of the method on which this technology is based. The presence of a scientific backlog: a patent and publications on the subject of the project. He is one of the authors of the method on which this technology is based.

He is a certified energy auditor, head of the Center for Energy Saving and Knowledge Promotion "Astana" at NJSC "KATU named after S. Seifullin", a reviewer of the scientific journal "Bulletin of ToU" at Toraigyrov University, Pavlodar, an expert in educational programs of higher and postgraduate education of the "Bologna Process Center and Academic Mobility" of the Ministry of Education and Science of the Republic of Kazakhstan, an expert of the Republican Scientific and Practical Center "Uchebnik", an expert of scientific projects of the Center for Scientific and Technical Information under the Ministry of Innovative Development of Uzbekistan.

A total of 45 papers have been published, 9 of which are in Web of Science and Scopus. 1 article quartile Q1, percentile 98, 2 articles Q2, 2 patents of the Republic of Kazakhstan for a utility model.

Hirsch index in Scopus-3, Web of Science – 1., Web of Science Researcher ID: AAG-2522-2021, https://orcid.org/0000-0002-5990-8182 , Scopus Author ID: 57202363283 Mergalimova, A - information about the author – Scopus.

research group:

2) Atyaksheva Aleskandra Vladimirovna - performer, (specialty - "Heat and gas supply and ventilation") candidate of technical sciences, associate professor. The project participates in all stages of R&D of the project. Calculation and modeling of heat and mass transfer processes and generation of combustible gases. Preparation of a report, articles and patents. Has research experience in the implementation of projects: “Improving the regulatory and technical base in the fuel and energy complex” (Customer: Ministry of Energy of the Republic of Kazakhstan, 2018). 12 Guidelines have been developed, including those on the topic of the project “Methodology for calculating gas-oil fuel consumption rates when burning brown coal with a volatile matter yield of more than 30% at thermal power plants”, “Method for calculating gas-oil fuel consumption rates for burning coal with a volatile matter yield of less than 20% at thermal power plants”. She was the responsible executor of the project "Scientific and theoretical study of the transfer of the upper equipment of special equipment (PPU, APPM, etc.), welding and compressor units (UDD-400, etc.) of Aktobemunaigas JSC from liquid to gaseous fuels (Customer: Aktobemunaigas JSC" , 2019). Developed 6 Professional Standards, including Professional Standards "Installation and operation of gas supply systems" and "Installation and operation of sanitary devices and ventilation". (Customer: Ministry of Labor and Social Protection of the Republic of Kazakhstan).

Hirsch index in Scopus -2, Scopus author ID: 57204188485 Atyaksheva, Alexandra V. - information about the author - Scopus, https://orcid.org/0000-0003-2523-3890.

3) Bakhtiyar Balzhan Torepashkyzy - performer, (specialty - Thermal power engineering), candidate of technical sciences, associate professor.

Participates in all stages of the project, in carrying out computational and analytical studies, preparing reports, articles, patents, calculating regimes and modeling emissions of toxic substances.

Hirsch index in Scopus -2, Scopus author ID: 57219651463, Bakhtiyar, Balzhan T. - information about the author – Scopus.

4) ILIEV ILIYA KRASTEV – performer, foreign scientist, PhD, professor at the Department of Industrial Heat Engineering at the University of Rousse, Bulgaria.

He takes part in the development of clean coal technology for the production of volatile combustible substances, in participation in international conferences to test the results of research, in the preparation and publication of articles with an impact factor included in the WoS and Scopus databases.

In total, more than 200 publications, 17 patents have been published. Hirsch index - 5.

Scopus Author ID: 56410563800. ORCID https://orcid.org/0000-0003-4443-5113.

5) Ybray Sultan Barlymbayuly - performer, master of technical sciences, doctoral candidate in the specialty "Heat power engineering". In this project, he takes the position of the performer. In the project he is engaged in the collection and systematization of information, organization and conduct of experimental studies, processing of research results.

Participation of Ybrai S.B. in the project is justified by the fact that the scope of his scientific research, as a doctoral candidate, coincides with the subject of the project: thermal power engineering, thermal power plants, decarbonization, reduction of harmful emissions from the combustion of fossil fuels, and will be useful both for the project and in his research and writing a doctoral dissertation dissertations. Participation of young researchers is one of the requirements of the project CA.

Hirsch index in Scopus -1, Web of Science – 1 https://orcid.org/0000-0002-5262-2149 Scopus Author ID: 57202946965 Web of Science ResearcherID: ABB-1483-2021

Information for potential users:

In the foreseeable future, the Strategy "Kazakhstan - 2050" focuses us on the priority development of highly efficient advanced technologies, without which the dynamic development of the state economy is impossible.

One of the directions for the development of the fuel and energy complex is the implementation of the latest coal technologies

Modern clean coal technologies should provide a more complete use of the chemical energy of solid fuels, compactness of the main equipment and high efficiency with the lowest emissions of harmful substances.

When fuel is burned at thermal power plants, combustion products are formed, which contain: fly ash, particles of unburned pulverized fuel, sulfuric and sulfurous anhydride, nitrogen oxide, gaseous products of incomplete combustion. When fuel oil is burned, vanadium compounds, coke, sodium salts, and soot particles are formed. The ash of some fuels contains arsenic, free calcium dioxide, free silicon dioxide.

Frequent burning of fuel oil can affect the reliability of the energy supply in the most undesirable way. This is explained not only by the danger of corrosion, which shortens the overhaul period of the heating surfaces of boilers, but also by the formation of sooty deposits that impede the operation of boilers and clog tubular air heaters and lead to an explosion of electrostatic precipitators.

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