Project RSF 18-79-10136-P

Theoretical methods for modeling and developing energy-efficient import-substituting apparatus for cleaning and deep processing of hydrocarbon raw materials at enterprises of the fuel and energy complex

(Years 2021-2023)

Year 2 Summary

The project solves a number of important research and scientific & technical problems with the use and development of methods of mathematical modeling and experimental research.

Based on the approximate method of mathematical modeling of momentum and heat transfer in heat exchangers with surface intensifiers, expressions for the average coefficients of friction and heat transfer are obtained. The results of calculations and comparison with known experimental data are presented. Methods are developed to intensify transport phenomena in media with increased viscosity to enhance the efficiency of heat exchangers using the Ingehim packings and significantly reduce their weight and size. The packings provide a transition from laminar to turbulent regime in the pipe at Reynolds numbers over 50-150 and a significant increase in α (by 15-20 times). Expressions for the Nusselt number are given. Due to the volumetric intensifier, the heat transfer surface area is reduced by up to 17 times. The results of the numerical solution of the heat transfer equation and comparison of the obtained temperature profiles with experimental data are presented.

The scientific & technical problem of calculating film cooling towers and scrubbers is solved. Expressions are obtained for the Nusselt and Sherwood numbers for contact devices of various designs. Solutions to the system of equations and comparison of temperature and moisture content profiles along the packing height with experimental data are given. Conclusions are drawn about the most efficient designs of packings in terms of thermal-hydraulic characteristics.

An algorithm for calculating the regime and design characteristics of bubble trays for cooling and purifying gases is obtained using the results of hydraulic studies. Numerical solution to the system of equations for temperature fields, moisture content, particle concentration and comparison with experimental data are given.

The advantage of the concurrent mode in gas cleaning with strong interaction of gas with a liquid film in a rough channel is shown. The particle deposition efficiency is calculated for the regimes of weak and strong interaction of the film with the gas flow. Recommendations are given on the regime and design parameters that ensure the gas cleaning efficiency of 99%.

The mass transfer and hydraulic characteristics of a tubular film packing in a polyethylene apparatus with a discretely rough surface for cooling towers and scrubbers are experimentally obtained.

The process of obtaining heavy vacuum gas oil to the requirements of oil production by the distillation method is experimentally studied. The thermal stability of the bottom product of the column is evaluated. Investigations of the parameters of the optimal technological regime and the main design characteristics are carried out. A structured segmented corrugated packing "Ingehim" with a roughness applied to the surface is used. An industrial column implemented at an oil & gas processing enterprise is developed.

Experimental studies of the effect of flow pulsations on heat transfer in a pipe bundle are carried out. The regularities of heat transfer in a bundle of pipes are experimentally obtained under a pulsating flow regime. The maximum intensification of heat transfer is increased by 3.23 times. The numerical experiment is carried out using the Ansys Fluent software package. The decrease in the heat exchange surface area of the oil cooler with flow pulsations is estimated.

The possibility of using carbonate sludge from TPP water treatment as a sorption material for the extraction of anionic synthetic surfactants from industrial wastewater is experimentally established. Granules of carbonate sludge with the use of liquid sodium glass (11.2 mg/g) and paraffin (10.79 mg/g) as a binder have the best adsorption capacity. The process of adsorption drying of natural gas by the developed granular material based on chemical water treatment sludge from Kazan CHPP-1 is considered. It is shown that the adsorption capacity of the material in terms of moisture reaches a maximum value of 2.4 g/g. A process flow scheme of a recuperative adsorption plant for drying natural gas is proposed.

The implementation of scientific & technical developments in the purification of natural gas at production sites is noted.

Experimental results on the volumetric mass transfer coefficient for film apparatuses, which are in satisfactory agreement with the calculation by the mathematical model, are obtained. The results obtained can be used in the design of packed scrubbers and film cooling towers, as well as absorbers.

An adsorption technology for purification of reverse osmosis plant concentrate from sulfate and chloride ions by wastes from power engineering facilities is presented.

The proposed sorption method for cleaning gas mixtures makes it possible to minimize the anthropogenic impact of gas emissions on the atmosphere by extracting nitrogen dioxide from them.

Experimental data on the release of commercial ethylene glycol from a 36% water-glycol solution are obtained. The resulting regenerated ethylene glycol is a clear liquid with a concentration of 99.54 wt%.

The problem of sewage pollution with anionic synthetic surfactants, as well as the possibility of using various sorption materials as secondary energy resources (SER) are considered.

The possibility of technological purification of a reverse osmosis concentrate of an industrial enterprise with granular sorption material is shown. Cleaning efficiency is over 98%.

Methods for treating oil- and petroleum-containing wastewater are developed. It is proposed to use a 2-stage purification technology, which includes separation of emulsified drops and adsorption post-treatment.

A mathematical model of the extraction process for the purification of hydrocarbon mixtures in a packed extractor with a thin-layer sedimentation tank is obtained. Implemented developed extractors and thin-layer sedimentation tanks ensure high efficiency of the processes.

An approximate method for modeling the momentum and heat transfer in channels with surface intensifiers is obtained. The Deissler and van Driest model is used. The adequacy of the developed mathematical model is shown.

The scientific & technical problem of development and implementation at industrial enterprises of a heavy vacuum gas oil separation unit is solved. As a result of the implementation of the developed scientific & technical solutions after the industrial operational unit, compliance with the requirements to the design specification is established.

Experimental data on the separation of a multicomponent mixture by distillation are obtained. As a result, the agreement of the experiment with the data of mathematical modeling is established.

The scientific & technical problem of mathematical modeling and modernization of an industrial distillation column is solved. The implementation of the packing "Ingehim" in the modernized column ensures the desired quality of separation of the mixture.

A numerical method is used to study heat transfer in a pipe with a pulsating oil flow. The reduction in the heat exchange area of the oil cooler is up to 9%.

A numerical method is used to study heat transfer during pulsations of the coolant flow. The effective mode of intensification is 0.5 Hz.

A technology for the treatment of oil- and petroleum-containing wastewater, including the separation of wastewater and subsequent adsorption post-treatment, is proposed. As a result, the anthropogenic impact on the environment is reduced.

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