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Determining the Efficiency of Subjecting Finely Dispersed Emulsions to Physical Coagulation in a Packed Layer under Turbulent Conditions

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Abstract—The process through which small droplets contained in emulsions are physically coagulated on the surface of random packing elements is considered. The theory of turbulent migration of a finely dispersed phase is used for determining the coagulation efficiency. Expressions for calculating coagulation efficiency and turbulent transfer rate are obtained by applying models of a turbulent boundary layer. An example of calculating the enlargement of water droplets in hydrocarbon medium represented by a wide fraction of light hydrocarbons (also known as natural gas liquid) is given. The process flowchart of a system for removing petroleum products from effluent waters discharged from the Kazan TETs-1 cogeneration station is considered. Replacement of the mechanical filter by a thin-layer settler with a coagulator is proposed.

Keywords: turbulent migration, droplet enlargement, separation efficiency, settlers, dehydration of hydrocarbons, water treatment at thermal power stations

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Power industry enterprises account for one-third of the total consumption of water and for one-fifth of the total amount of discharged effluent waters. In Russia on the whole, enterprises of the thermal power industry consume around 50% of the entire amount of water taken for industrial purposes from natural sources [1]. It is important to note that the water used at power industry enterprises must be purified from various impurities both prior to enter it into the production cycle and after removing it from the production cycle. Effluent waters contaminated by petroleum products are especially hazardous for the environment. Removal of free water from liquid hydrocarbon mixtures is another important task that has to be dealt with at enterprises of the fuel and energy complex. The list of methods used for purifying liquids includes settling, floatation, filtration, adsorption, and others.

Settling is the simplest and most widely used method for separating impurities from liquids, which precipitate on the settler bottom under gravity or float upward.

More efficient separation of finely dispersed emulsions (containing particles measuring less than 100 μm in size) in settlers can be achieved by installing a coagulator at the location in which the mixture is admitted (Fig. 1). The coagulator serves to enlarge fine droplets to facilitate their subsequent floatation or sedimentation (depending on the difference between the densities of continuous and dispersed phases). A channel filled with fine packing elements can be used as a coagulator. If the packing surface is well wetted by the dispersed phase and poorly wetted by the continuous phase, fine droplets will coagulate on the surface of packing elements with gradually reaching full wetting of the surface as liquid moves on. The droplets leaving the coagulator will have sizes approximately equal to the average stable size for the given two-phase medium.

MIGRATION TRANSFER THEORY AND MATHEMATICAL MODEL FOR CALCULATING PACKED COAGULATORS

As is well known, a turbulent flow mode develops much earlier in a channel containing chaotic packing than it does in the case of flow moving in smooth tubes without packing. The laminar mode boundary corresponds to the Reynolds number $\mathrm{Re_{eq}} = u_{av}d_{eq}/\nu \approx 40$, where u_{av} is the average velocity of liquid (emulsion) in the packing, m/s; $d_{eq} = 4\varepsilon_{fr}/a_V$ is the equivalent packing diameter, m; ε_{fr} is the specific free volume of packings, m^3/m^3; a_V is the specific packing surface area, m^2/m^3; and ν is the kinematic viscosity coefficient of medium, m^2/s [2]. A fully developed turbulent mode occurs at the values of $\mathrm{Re_{eq}}$ ranging from 2000 to 6000.

As flow containing dispersed particles moves over a packing bed, the dispersed phase is separated on the packing surface in different manners. For example, a film will be formed during separation of droplets on the surface of a contact device.