Industrial tests on vessels subjected to the following processes: absorption of NO\textsubscript{x} by nitric acid, and SO\textsubscript{3} by sulfuric acid; desulfurization of flue gases by a calcareous solution during both low and high gas-flow rates; cleaning gases of harmful components (SO\textsubscript{2}, NO\textsubscript{x}, H\textsubscript{2}S, HF); and dust collection.

Counterflow interaction between the gaseous and liquid phases in an absorber with a three-phase fluidized bed is a possible alternate scheme of a three-phase fluidized bed. The following vessels are utilized to accomplish the process in question: a turbulent-contact absorber (TCA), and absorbers with a fluidized and a moving packing.

Owing to the distribution of lightweight elements of a moving packing over the plate of the absorber, they are set in vigorous motion during counterflow circulation of the gaseous and liquid phases, resulting in strong turbulization and intermixing of the flows. Under these conditions, the area of the interphase surface increases, and it is possible to obtain high kinetic mass-exchange coefficients.

Industrial absorbers with a fluidized bed are both circular, or rectangular in section. In the case of a heavy gas load, the sectioning problem is easily resolved in vessels with a rectangular section (when bed uniformity is ensured).

The portion of the free-flow section of the plate (grid) is an important factor since the optimal performance of the absorber, and also the maximum surface area of the interphase contact will depend on it. From the hydrodynamic standpoint, the possibility of stable absorber operation exists over a broad range of relative liquid-to-gas flow rates.

Studies of the hydrodynamics of vessels with a three-phase fluidized bed and plates with small flow sections are of interest when investigating bed behavior under such atypical conditions [1], especially in the case when moving vessels are employed in absorption processes involving the cleaning of industrial gases [2–7].

To achieve a highly efficient cleaning process, for example, the desulfurization of flue gases, the vessel constructed should fulfill the following two conditions: ensure a high carrying capacity with respect to the gaseous phase (economic requirements), and also the required time of contact between the liquid and gaseous phases on the plates (production requirements, which are met by use of plates with a free-flow section of 0.2–0.4 of the total section).

Due to the self-cleaning packing, vessels with a three-phase fluidized bed are used primarily for the cleaning of industrial gases contaminated with solid particles. The mobility of the packing in the absorbers eliminates problems associate with clogging of the vessels. Self-cleaning of the moving packing makes it possible to increase the content of circulating suspension, and simultaneously ensuring that the gas is cleaned not only of harmful components, but also dust.

Absorption is accompanied by the liberation of a certain amount of heat, which is characteristic of this process; this will cause the temperature of the gaseous phase, and also the absorbent to rise. The temperature in the volume of the vessel...
depends not only on the amount of heat that has been liberated, but also on the heat capacity of both phases. The excess heat should be removed to maintain the required temperature level.

Absorption processes for which the problem of heat removal assumes paramount significance are known in chemical engineering. The technology employed to produce nitric and sulfuric acids are classed among these processes. In the production of nitric acid, for example, 20–25% of the overall cost of the plant is earmarked for absorption subassemblies. Thus, the design solution for this section of the industrial plant, including the removal of significant amounts of heat of absorption, exerts a major influence on the cost of the plant on the whole.

Vessels with a turbulent three-phase fluidized bed may provide for a significant increase in process efficiency in the absorption subassemblies of production plants utilized to produce sulfuric and nitric acids, and similar gas-liquid processes with high heat liberation [8–13].

The simplest alternate scheme of heat-exchange vessel with a three-phase fluidized bed is an absorber in which the external wall bounding the fluidized bed serves as the surface of heat exchange between the bed and coolant. A relatively high area of heat-exchange surface is therefore provided for a given cross-sectional area of the absorber. In a vessel with a circular cross section, the gas and liquid proceed into the internal portion of the unit, while the coolant is delivered to a jacket placed around the working chamber [14].

In large industrial vessels, it is possible to employ additionally vertical sectioning, where the coolant will also proceed into the space between the walls separating the individual sections. It is expedient to use an absorber with a rectangular cross section for the vertical sectioning of a fluidized bed utilizing a coil heat exchanger.

**Intensification of NO\textsubscript{x} Absorption by Nitric Acid.** This process may be intensified in working units by modernizing vessels of the absorption subassembly.

Industrial tests were conducted on a column 0.4 m in diameter with ten plates and a three-phase fluidized bed. Spheres with a diameter $d_s = 20$ mm and bulk density $\rho_b = 600$ or $750$ kg/m\textsuperscript{3} were used in this column as packing. The free-flow section was 0.2–0.3 of the total section. All plates were equipped with cooling jackets. The cooling rate was monitored in order that the absorption process proceed under isothermal conditions.

The following results relative to intensification of NO\textsubscript{x} absorption by nitric acid were obtained in the column under investigation:

- the gas velocity is increased by a factor of 2 (up to 0.8–1.0 m/sec); this makes it possible reduce the diameter of the columns;
- the efficiency of NO\textsubscript{x} absorption on plates with a three-phase fluidized bed is increased by 30% on average as compared with bubbling plates; this permits a reduction in the number of plates; and
- the rate of oxidation of nitric oxide to nitrogen dioxide is increased in the fluidized bed; this, in turn, elevates the overall efficiency of the absorption process.

Under industrial conditions involving the production of nitric acid, the above-enumerated factors make it possible to reduce the diameter of the absorption columns by 25%.