The use of a chemical heat pump to increase the energy efficiency of combined ethanol production

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The concept of using a chemical heat pump is a response to market demand, which was observed by analysing the thermal management of most food plants. A solution was sought for to improve the energy efficiency of the processes, with the potential of application in a wide range of industries.

In the case of the installations which were analyzed in the given study, the installations of the Chemat distillery and the adjacent biogas plant were used. The agricultural distillery produces raw spirit for food purposes, while the adjacent biogas plant produces electricity and heat from plant-based substrates.

The distillery installation has many waste heat streams, in the temperature range of 50-60 degrees. Biogas plants, in turn, are a source of waste heat in the range of 90-120 °C. Excessive low-temperature streams, which are difficult to use in the plant, have resulted in the need to release them into the environment and the loss of thermal energy.

This is where the necessity to raise the parameters of lost streams, appears. Heat pumps offer such an opportunity. They have been selected from among several techniques for heat energy recovery, due to the temperature range of waste streams they can work with. Theoretically, the chemical heat pump is able to raise the stream temperature by 15-50° C. Chemical heat pumps (CPCs) require less electricity, while the water stream for heat extraction can be reused in the ethanol production process. The advantages of CPC are also high energy accumulation and the possibility of its storage, which makes it suitable both for obtaining energy from low-temperature sources and for energy storage.

The opportunity offered by the chemical heat pump has been recognized in the temperature range at which it operates, low electricity demand and a large waste heat stream that the plant has at its disposal. By analyzing various variants of working factors, phosphoric acid (V) was selected as the least aggressive among other inorganic acids.

There was an idea to integrate the distillery, biogas plant and CPC. In addition to the existing cogeneration, the integration of these plants may involve the use of a large waste heat stream from cooling the generator set at the biogas plant and raising its temperature to the temperature of the heating medium used in the distillery installation. In this way, the total demand for thermal energy in the plant would be reduced.

Laboratory tests were undertaken in which the concentration and temperature ranges of the acid, were extended to the values used in the industry. From the point of view of the project, the key factor was the laboratory determination of the heat of dilution and concentration of the acid used under negative pressure.

Preliminary material tests were also carried out during the project. Work was undertaken to assess the suitability of the selected construction materials for the construction of heat pump components, spectrographic and diffraction tests. Material tests gave an overview of the type of materials that can be used in the project.

After the assumptions for the large-laboratory installation were prepared, the technological design of the installation was started. Preparation of the technological project

required the selection of technological devices and their calculations. The ranges of parameters for individual devices have been defined. It was also necessary to provide guidelines for the I&C engineering. Design works included the construction of a pilot installation, along with its structure.

The stage of assembly and welding works on the CPC installation was completed with the tightness tests of the system. A plan of experiments to be carried out at the installation, was drawn up. The planned research has started. The results of the tests were the basis for the verification of the energy efficiency of the analyzed idea.

As a result of the performed experiments, the values of heat fluxes released during the chemical reaction of mixing the acid with water and the values of heat fluxes that were supplied to the system in order to re-concentrate the working medium, were obtained. It was possible to calculate the thermal efficiency of the system and to estimate the energy buffering potential of the operating medium over time. This experimentally verified the potential for increasing the temperature of the waste stream and demonstrated the feasibility of using a chemical heat pump to increase the energy efficiency of combined ethanol production.