## Mass Transfer: Yesterday, Today and Tomorrow

The concept of separating chemical compounds based on its boiling point has been practiced for several thousands of years. The technology stayed relatively stagnant until the middle ages. At that point, several inventions with significant future impact saw the light. The use of salt to break an azeotrope was first practiced 800 years ago. The use reflux was stumbled upon 500 years ago. The early 1800's saw the introduction of trays, random packing was introduced in the 2$^{nd}$ half of the 1800's and forerunners of modern structured packing was introduced in the first half of the 1900's.

During the last century, the following developments were introduced: improved trays, improved random packing, structured packing, high performance distributors, rotating contactors, extractive and azeotropic distillation, heat pumped systems and dividing wall towers, to mention just a few. The current state of the art is: Trays that use centrifugal motion to generate very high capacity, tray contacting devices that deliver high efficiencies, random packing with high mass transfer coefficients, structured packing that minimize the pressure drop per theoretical stage, dividing wall towers that reduces capital and operating costs, heat pumped systems that reduce energy consumption, innovative solvent systems to deal with difficult separations and the combination of several of these technologies. Even though the technology is considered mature new developments in these fields continue to be introduced.

Mass transfer processes are generally very energy intensive, and the drive to reduce energy consumption will play a significant role in the evolution of mass transfer processes. Several technologies were introduced on the last 40 years with the claim that it will replace distillation. This has not really materialized. The high feed flowrates of conventional distillation systems is one of the reasons why this has not happened. The foreseeable future will most likely see the introduction of new schemes that bring distillation systems closer to the theoretical minimum energy consumption. This could include combinations of internal energy integration, external energy integration, the use of better solvent driven separations, more selective catalysts, and adding unit operations that cannot replace distillation by itself. The digital revolution will also have an impact on the distillation landscape through some form of the internet of things (IOT). Measurement technology will improve, and the ability to generate vast amount of data (big data) will be used with advanced analytics to further drive down the cost of separations. Given the sheer size of the amount of chemicals for consumer goods being produced by distillation, it is highly unlikely that it will be replaced anytime soon, but the cost will be driven down significantly by incremental changes in distillation equipment, reduction in energy consumption, the addition of complementary technologies and optimized operation through IOT, big data and advanced analytics.

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Izak Nieuwoudt is the Chief Technology Officer and Research & Development Director for Koch-Glitsch. He is based at the company headquarters in Wichita, Kansas, USA. He holds bachelors, maters and PhD degrees in chemical engineering and has more than 30 years' experience in the field of mass transfer. He has authored more than 70 papers and book chapters. He is listed as an inventor on more than 20 patents, most of which are commercially exploited by the assignees. He is a visiting professor at the University of Stellenbosch in South Africa. He serves as the chairman of steering committee of the STAR separation technology consortium and on the technical and executive committees of Fractionation Research Inc (FRI).