A Course on

SEPARATION PROCESSES

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ONE FASCINATING ASPECT of chemical engineering is the tremendously wide variety of regions of interest which are incorporated as part of the general field. Two broad areas of interest serve to distinguish the chemical engineer from chemists and other engineers: the ability to design processes involving chemical reactors and separation processes. Indeed the cost of most chemical and petroleum plants (exclusive of utilities) are principally attributable to these two categories. In many cases plant costs will be 5-20 percent for reactors and 80-95 percent for a variety of separation processes including feed preparation and product recovery.

There are a large number of basic separation processes and a much larger number of generic names applied in the field. There appears to be no limit in the variations that can be applied to develop new processes that are basically different or to improve existing processes. Indeed, the field of separation processes has been called an "inventor's paradise."

DESIGN OF SEPARATION processes involves a considerable amount of ingenuity and synthesis. Many of the basic principles to be applied are currently taught under the general headings of heat, mass and momentum transfer. However, other aspects of equal importance are not usually taught in basic courses. For example, one must consider how a small separation achieved in one unit can be increased to attain a product of specified purity. Cascading and compounding of separation units involve knowledge and experience beyond that of basic fundamentals. As mentioned, design of separation processes involves both synthesis and ingenuity. Therefore a course in the subject should properly stress the former and illustrate the latter. The courses in separation processes at the University of Michigan are designed to achieve these objectives.

Rather than teach how to design a number of different separation processes, an attempt is made to teach an approach to the design of separation processes in general. The procedure is broken down into two aspects: 1) mathematical modeling of the fundamental process unit taking into account its mode of operation; 2) methods of increasing the separation achieved either by joining together a number of process units (cascading) or incorporating some procedure to enhance the separation achieved within a single unit (complexing).

Modeling. Emphasis is placed on an under standing of the basic principle underlying the separation and the constraints imposed on the separation by the mode of operation. Several broad classifications are developed to stress different types of basic principles. For example, it is generally important to recognize whether the basic separation takes place within a single phase or results from a concentration difference between two phases in equilibrium. In combination, one must consider whether or not a barrier is required to achieve the separation. For example, thermal diffusion is one example of a separation that occurs within a single phase without using

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a barrier whereas gaseous diffusion and permeation are single-phase processes that require a barrier. Similarly distillation does not utilize a barrier but depends on a difference in concentration between two phases. Filtration is a two-phase separation process that makes use of a barrier. Modeling of a variety of processes in each category emphasizes a general approach.

Mathematical modeling of individual units is also influenced a great deal by the mode of operation. The mathematical constraints that are applied to satisfy the mass, energy, and momentum balances will depend on whether the process is batch and transient, a flow process at steady state or a hybrid involving unsteady-state operation of a flow process. In all cases it is desirable to develop a mathematical model of the basic unit that yields a descriptive equation of reasonable form. This is especially important if the individual units are to be joined into a cascade. Therefore a number of simplifying assumptions that have proven to yield suitable design equations are summarized in general form and emphasized by applying to a number of different processes with various modes of operation.

In most separation processes, the basic effect is insufficient to produce the desired separation. Therefore some processing scheme must be developed to enhance the separation and mathematical techniques need to be developed to permit estimation of the total separation achieved and to apply optimization techniques if necessary. In many cases individual basic units are joined together. The most familiar example is a series of distillation stages joined to form a distillation column. The use of reflux and the concepts of limitations such as minimum stages and minimum reflux are developed. In some cases such as gaseous diffusion the separations achieved in any stage are so small, the time to achieve operating conditions with the usual cascading arrangements are so long and the costs so high that advanced cascade theory must be applied to attain a workable design. Such an application is illustrated emphasizing general principles of advanced cascade design.

It is sometimes possible to enhance a separation within a single unit. This usually involves countercurrent flow within the unit. Packed column absorption and extraction provide illustration of such techniques involving contacting of two phases. Fixed bed operation including chromatographic separations are considered in this same category. Application of these general principles to separations achieved within one phase usually involves laminar flow brought about by density differences within the single phase in combination with a gravitational or centrifugal field and are therefore subject to mathematical analysis. Thermogravitational thermal diffusion and gas centrifugation illustrate this approach.

SEPARATION PROCESSES involve a bewildering variety of approaches both from the point of view of the basic principles to be applied, and the mode of operation including the possibilities of cascading and complexing. Therefore it is usually possible to illustrate the principles of a general approach to the design of separation processes by providing examples and home problems based on a wide variety of basic techniques. During the course, examples are drawn from filtration, leaching, extraction, distillation, absorption, adsorption, permeation, gaseous diffusion, crystallization, thermal diffusion, chromatography, etc. Examinations are designed to test the students' ability to synthesize a solution to a problem involving a basic approach and/or mode of operation which has not been treated in the lectures, home problems or outside reading. The response has been most gratifying.

Up until the past year the graduate course on separation processes has been elective with good attendance. At present the course is required of all first year graduate students.

ERRATA

SOME CURRENT STUDIES IN LIQUID STATE PHYSICS

DIELECTRIC AND CRITICAL STATE PHENOMENA

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In Table I of the paper, "Some Current Dielectric Studies in Liquid State Physics, 2. Dielectric and Critical State Phenomena," by C. J. Pings [CEE, 4, 98 (1970)], the second row of entries should be labeled "Primitive Expt.," and the fourth row should be "Refined Expt."

Also the following footnote was omitted:

Work supported by the Chemistry Directorate of the Air Force Office of Scientific Research.