Distillation Engineering

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Preface to German Edition

Distillation and its related separation methods are undoubtedly the most predominant of the basic thermal process engineering operations, and the amount of literature on this subject has greatly increased recently. The need for a uniform summary of the various fields of distillation is apparent. It would not be expedient to extensively cover the whole field of distillation in one book, because of the great number of special problems which exist. A book is therefore needed which is both technical in its approach and orientated towards application, whereby focal points can be seen, in theory, for example, in particular consideration of phase equilibrium, as well as in the construction and planning of distillation installations for industrial application. This book is intended to give an introduction to the latter, while the theory is dealt with only from the viewpoint of practice-related tasks and problems.

The various problems in industrial distillation mostly require individual treatment of the questions connected with calculation and construction. For example, optimization of the process and the installation is now made absolutely necessary by the application of more expensive materials, or the strict observance of particular operating conditions, whether they be the need for minimal product temperature in the distillation equipment of a separation column for the least possible residence time of the product, or a limited heating medium temperature. Particular attention is therefore directed to considering the choice of the optimum separation apparatus for a particular separation problem, and to investigating the optimum operating conditions. Also taken into account is that the chemical decomposition and polymerization of materials require a transfer of the chemical compound separation through distillation in the field of lower pressures, frequently under application of special apparatus.

Where separation column internals are concerned, only those which have prominently stood the test in recent years in the most varied separation processes of the chemical and allied industries and which are also therefore more frequently used, are dealt with in greater detail. In order to make some judgment on them from both cost and process engineering points of view, the result of an extensive study is presented here. This study was practicable only on the basis of numerous experimental investigations. Consequently, an evaluation of separation installations from the points of view of operation, process engineering and cost, became possible.

In addition to the findings obtained both through theory and practice, easily-applied calculation methods are suggested. Where possible, representation and utilization have been simplified if the effect of such simplification on the results obtained is unimportant when practically applied.

Where it is of importance for the construction of industrial distillation installations, methods for transferring results received either directly, or through simulation, to

full-scale installations, are detailed and shown during the course of laboratory distillation.

In the section dealing with accessories for distillation installations, measurement and control equipment is also detailed. In order to give some examples of application, the suitability of various types of control for a separation column is explained through the discussion of superior aspects.

The use of computers for industrial application is discussed only in so far as it is relevant to the object of this book.

The numerical examples of particular chapters have been selected so that the material presented can be better understood, and to illustrate the application of this material in the construction and operation of distillation installations.

Ludwigshafen, July 1972 R. Billet

Preface to American Edition

In the past, the theory of distillation and rectification has appeared in great detail in the form of both single publications and monographies. However, until now, this particular field has lacked a book on thermal separation processes which concentrates on the practical application, design and planning of total plants from an industrial point of view. It was therefore the author's aim in writing "Distillation Engineering" to cover the industrial side of distillation and rectification. Following publication of the German edition in 1973, the great demand for this book confirmed that this intention was right.

The increasing use of distillation apparatus and plants in the field of technology and environmental protection, particularly in the chemical and allied industries, justified the inclusion in the American edition of a complete chapter concerning distillation technology in environmental protection. Furthermore, the author also felt it necessary to discuss Vacuum Distillation in greater detail. In addition to this, certain chapters have been extended in this edition in order to include new industrially significant findings which have been revealed in the light of further developments during the last five years.

Bochum, June 1978 R. Billet

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I The Thermal Separation of Liquids

The field of distillation engineering, as presented here, is comprised of the currently prevalent practices for thermal splitting as based on known facts of simple distillation theory. Many chemical reactions supply liquid or gas mixtures that have to be decomposed by heat. Some mixtures occurring in nature must be broken down to recover specific constituents, such as aromatics, petroleum distillates serving as fuels, air liquefied to produce nitrogen, oxygen and rare gases, or water distilled for use in nuclear installations.

Obviously, the many uses of distillation justify a broad coverage of its fundamentals.

The primary operations in the thermal separation of liquids are distillation and rectification[3]. While simple distillation will generally achieve a rough separation of constituents, because the vapors arising from a mixture will have a composition different from that of the mother liquid, rectification provides a better separation and a recovery of virtually pure components.

Essentially, in rectification the vapor mixture generated by distilling a liquid mixture is passed counter to a stream of condensed vapor in such a way that an intimate contact of the liquid and vapor phases occurs. The exchange of materials thus brought about will effectively achieve a decomposition of the mixture.

In accordance with this, there will have to be an evaporator to supply the vapor mixture. The mixture will go to a rectifier where its components will separate, after

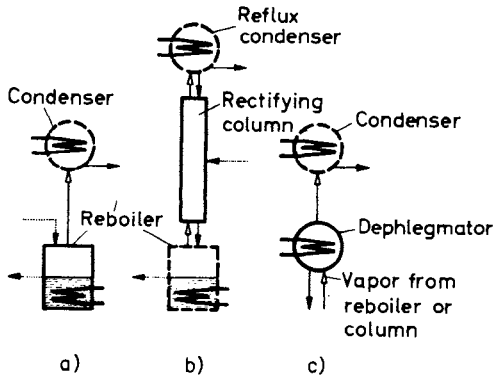

Fig 1.1 is a schematic presentation of separations by distillation; a) Partial distillation, b) Rectification, c) Partial condensation.

Fig. 1.2 shows the corresponding equipment as a part of an up-to-date chemical production plant.

which a condenser will liquefy the low-boiling fractions from the rectifier. Part of the condensate formed is recycled as reflux. Part is recovered as product, and part is reused to serve as coolant in the final cooling stage. The residue from rectification is the high-boiling fraction; this may undergo reworking for secondary products if desired.

Splitting up of mixed vapors by means of partial condensation is of secondary significance. It may be regarded as partial distillation in reverse. It may be combined with the aforementioned separation method by allowing only that part of the vapor

needed for refluxing to be liquefied, while the balance of vapor is recovered in a secondary, subordinate condenser.

Such separations may take place on a continuous or discontinuous basis. Both methods will be discussed after the physical fundamentals have been reviewed. Furthermore, there is a semi-continuous mode of operation which results from the origin of the mixture on the one hand, and its integration with the separation scheme on the other.

While rectifiers of the kind under discussion work adiabatically, a nonadiabatic mode of operation is available for specific separations, characterized by a lateral vaporization and condensation superimposed on a counterflow scheme for the liquid and vapor phases.

Finally, a direct, partial-condensation process may serve to achieve an effectual separation.