ANALYSIS OF THE ZONE CONNECTING CONSECUTIVE SECTORS IN GENERALIZED DISTILLATION COLUMNS BY USING THE PONCHON-SAVARIT METHOD

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Abstract— Ponchon-Savarit is a classical graphical method for the design of binary distillation columns. This method is still widely used, mainly with didactical purposes, though it is also valid for preliminary calculations. Nevertheless, no complete description has been found in books and situations such as different thermal feed conditions, multiple feeds, possibilities to extract by-products or to add or remove heat, are not always considered. In this work we provide, a systematic analysis of the Ponchon-Savarit method by developing generalized equations for the operating lines or difference points, as well as a consistent analysis of what may happen in the zone between two consecutive trays of the corresponding sectors separated by a lateral stream of feed, product, or a heat removal or addition. The graphical interpretation of all situations shown allows a clarifying view of the different possibilities in the rectifying column and completes the existing literature about this method.

Keywords— Distillation; Side Stream; Process Design; Heat Stages; Lateral Product.

I. INTRODUCTION

Many references dealing with the design of binary distillation columns, describe the Ponchon-Savarit and the McCabe-Thiele methods. Equations for the operating lines (OL) and difference points (DP) are always developed for columns with single or multiple feed additions but product extractions and heat additions or withdrawals are not always considered.

Furthermore, when a feed stream is considered, whatever its physical condition, it is commonly assumed to be introduced to a single tray where it perfectly mixes with the vapor of the tray below and with the liquid of the tray above. The streams leaving this feeding stage are considered to be in equilibrium, as in any other theoretical stage. This separation between the liquid and vapor portions is considered to have a small influence in the calculations of the number of trays. Consequently, the equation that defines the change between two consecutive sectors in a column is not usually developed and the zone of such change of sector is not represented. Nevertheless, some authors have pointed out the necessity of incorporating the considerations of those partly vapor feeds to the graphical methods to develop generalized equations. Although it is not the general trend, some references consider the zone between consecutive sectors for a two phase feed introduction to a distillation column (Ledanois and Olivera Fuentes, 1984; Wankat, 2012).

Additionally some references can be found in the literature dealing with the advantages of using the Ponchon-Savarit method and its geometrical concepts in particular cases, where molar latent heat depends on composition and heat of mixing is considerable, such as: multicomponent distillation, reactive distillation, quaternary liquid-liquid extraction, minimum reflux calculations and internal heat integrated distillation columns (HIDiC) (Reyes-Labarta et al., 2012; Lee et al., 2000; Marcilla et al., 1997; 1999; Reyes et al., 2000; Ho et al., 2010; Wakabayashi and Hasebe, 2013).

In previous works (Reyes-Labarta et al., 2014a), generalized equations for OL were systematically developed and analyzed for sectors and zones connecting consecutive sectors due to feeds, products or heat removals or additions on the McCabe-Thiele method, using a Generalized Feed Operating Line (GFOL) approach. In this paper, equations for OL and DP are systematically developed for the Ponchon-Savarit method with different side streams (feeds, products and/or heat removals or additions). This work widens the academic literature dealing with this subject. All the streams involved in the stages corresponding to the zones connecting consecutive sectors, as well as the corresponding DP, are unambiguously located in the enthalpy-composition diagrams.

II. GENERALISED EQUATIONS

A generalised distillation column has a total condenser and several sectors, which are adiabatic zones without lateral feed or products streams. Two consecutive sectors \( k \) and \( k+1 \), are separated by a generalised feed \( GF_k \) and we consider that only a single \( GF_k \) can be added or removed between two consecutive steps. The \( GF_2 \) can be either a mass stream or an enthalpy stream. In the first case, we consider \( M_{GF} \) the mass flow rate, \( z_{GF} \) the molar fraction, and \( H_{GF} \) the specific enthalpy of such stream. In the case where there is not a net mass flow in or out the column, we consider that \( E_{GF} \) is the heat flow added or removed to the column by an intermediate heat exchanger.

Considering all the possibilities, as a summary the generalised in or out feed considered and their character-