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Optimizing ethane recovery in turboexpander processes

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ABSTRACT

Optimization of ethane recovery using the CRR process shows that, except for the case of lean gas at low demethanizer pressure, the CRR process reduces to GSP, in which there is no reflux stream and therefore no added cryogenic compression and heat exchange equipment. Adding a second cold separator, operating at lower temperature, in GSP is found to lead to more or less recovery depending on the NGL content of the feed gas and the demethanizer pressure. GSP is also compared with the conventional turboexpander process. Optimization shows that adding more equipment or even flow splitting may lead to less ethane recovery.

1. Introduction

There are many extraction processes for natural gas liquids which include Joule–Thompson (JT) expansion, refrigeration using propane in a chiller, and turboexpansion. More often than not, all three processes are used at once. Mixed refrigerants can also be used [1] but the most popular process in the natural gas liquids (NGL)-recovery industry is turboexpansion. A review of NGL recovery can be found in Manning and Thompson [1], McKee [2], Pitman et al. [3], GPSA [4], Chebbi et al. [5,6], Mehrpooya et al. [7] and in the references therein. The optimized conventional process for ethane recovery [5], to which the present results are compared, is shown in Fig. 1. The cold residue recycle (CRR) process, examined in this paper (Fig. 2), is claimed to provide very high ethane recovery, above 98% [4]. The CRR process [3,4,8] is built upon the gas subcooled process (GSP). In the GSP [4], the gas leaving the separator is split, with one fraction subcooled by heat exchange with the overhead stream from the demethanizer, and the other fraction entering the turboexpander. The fraction subcooled by the demethanizer overhead stream is flashed in a valve and fed to the tower as reflux [4]. The GSP process is considered in the present work (Fig. 3). The process in Fig. 4, referred to as GSP with cold separator in the rest of the manuscript, has a cold separator operating at a lower temperature than the chiller temperature. The CRR process has one addition when compared to the GSP process (Fig. 3): a reflux stream to rectify the vapors in the demethanizer tower in order to minimize the amount of ethane and other heavier hydrocarbons that leave with the overhead. A compressor is used to boost part of the demethanizer overhead stream to a slightly higher pressure so that a fraction of the methane could be liquefied by the flashed stream and sent to the top stage of the demethanizer (see Fig. 2). The flashed feed to the demethanizer would condense some of the ethane from the turboexpander outlet vapor and the liquid reflux stream would condense some of the remaining ethane vapors at the top of the tower.

Maximum ethane recovery can be carried out by changing a select number of design variables. Ethane and NGL recovery problems are characterized by a large number of design variables affecting ethane and NGL recovery that include, but are not limited to demethanizer pressure and split ratio(s) if any.

The present paper considers the effect of demethanizer pressure on maximum ethane recovery for the CRR process as compared to a conventional turboexpander process [5]. Furthermore, GSP (without or with cold separator) is considered and its performance compared to both the CRR process and the conventional turboexpander process [5] for a lean and a rich feed gas at different demethanizer pressures. Optimization is performed by maximizing the percent ethane recovery. Ethane recovery as a function of demethanizer pressure is then reported and analyzed for the two types of feed. Feed composition, flow rates, temperature and pressure are identical to the values used in Bandoni et al. [9], and Chebbi et al. [5,6] for feeds A and D.

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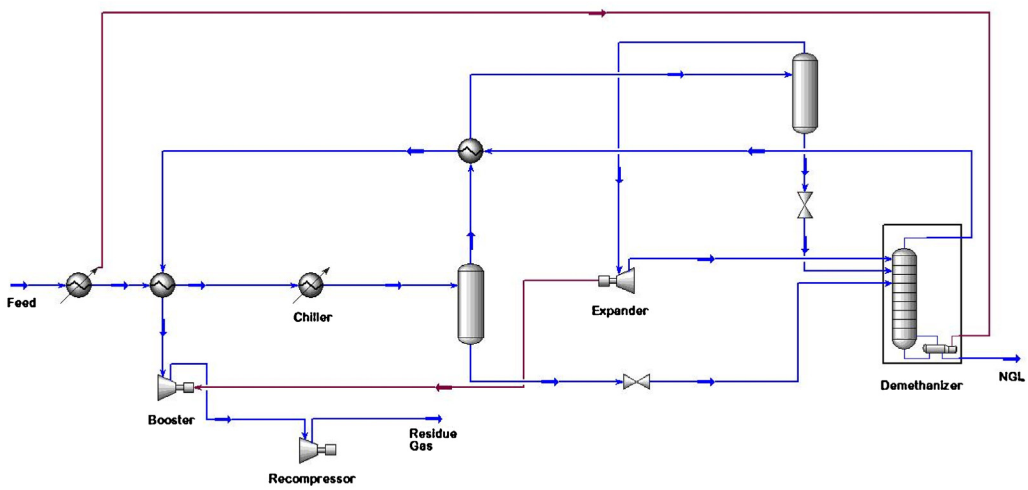

Fig. 1. Conventional ethane recovery process optimized for maximum ethane recovery in [5].

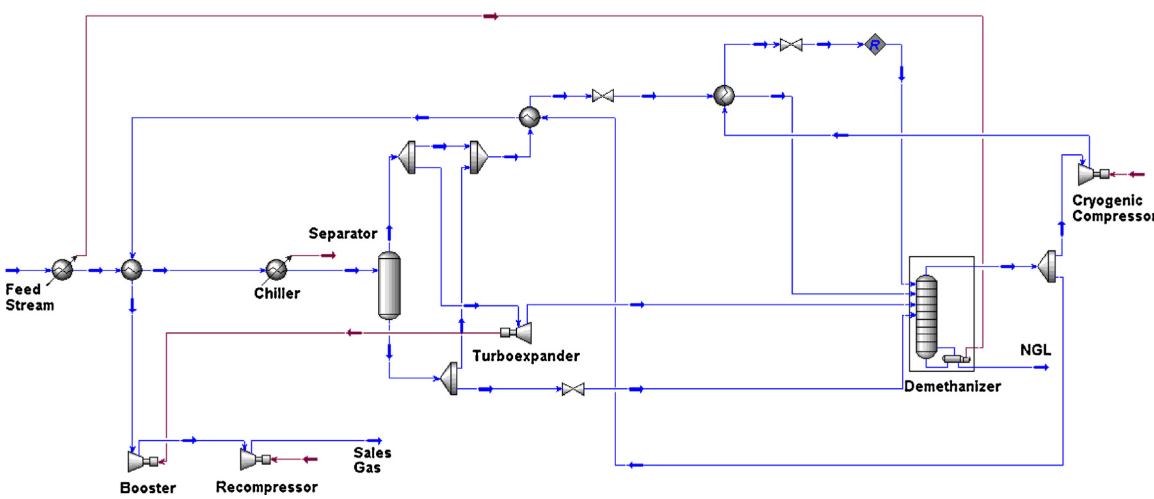

Fig. 2. CRR process flow sheet.

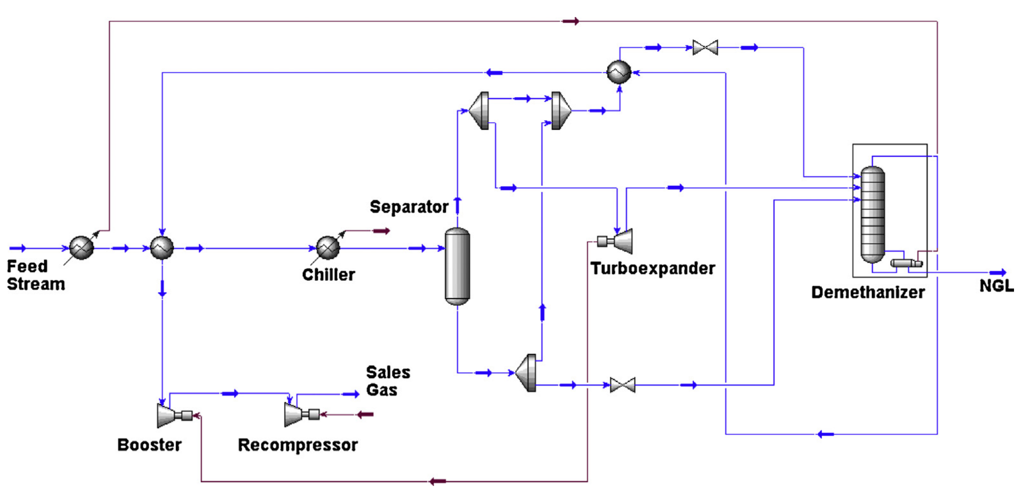

Fig. 3. Gas subcooled process (GSP) flow sheet.

2. Simulation and optimization

2.1. CRR process

The study was conducted by first simulating the CRR process. Fig. 2 demonstrates the process flow sheet for the CRR process. The figure does not depict the refrigeration loop, which is connected to the main process through the chiller. The feed is first cooled by providing the duty necessary for the reboiler, and further cooling of the feed is achieved by heat exchange with the residue gas. The four demethanizer pressures considered are 100, 215, 335, and 450 psia as in [5,6]. The pressures are grouped as low (100 psia),