IHS CHEMICAL

Process Summary—Natural Gas Liquids Separation and Recovery

Process Economics Program Review 2016-05

December 2016

PEP Review 2016-05
Process Summary—Natural Gas Liquids Separation and Recovery

Richard Nielsen
Sr. Principal Analyst
PEP Review 2016-05

Process Summary—Natural Gas Liquids Separation and Recovery

Richard Nielsen, Sr. Principal Analyst

Abstract

Natural gas liquids (NGLs) are the C₂+ liquefied hydrocarbons that are recovered above ground in natural gas field facilities or in gas processing plants. Refineries are a secondary source of some NGLs. The principal NGL products are liquefied petroleum gas, or LPG (a mixture of propane and butane), propane, isobutane, n-butane, ethane, and C₅+ natural gasoline. Besides the growing demand for these NGLs, some NGLs are also extracted from natural gas in order to be able to market the gas by reducing its dew point to below pipeline specification. Some natural gases contain impurities such as hydrogen sulfide that are removed in treaters prior to NGL separation.

Supply of NGLs has grown considerably in North America with the rapid development and application of shale fracking. Recovery of NGLs has provided additional revenue. The United States has switched from a net importer of NGLs to an exporter. US demand for NGLs has lagged behind supply growth, but will significantly increase when ethane steam crackers now under construction or planned for start-up come online. Excess NGL production will be exported.

Worldwide demand for NGLs totaled 410 million metric tons in 2015, about 93.6% of total production of over 438 million metric tons that year. Demand grew an average of 3.43%/yr over 2010 to 2015 from 364 million metric tons. The 3.22%/yr global growth rate of LPG, the NGL product most in demand, over that period exceeded the growth rate of total petroleum demand (about 1.6%/yr). The largest producing regions are North America (about 31% of total production) and the Middle East (about 30% of total production). These two regions account for about 88% of regional surplus NGLs available for export to importing regions. Europe and the Far East have the largest regional deficits of NGLs, accounting for about 37% each of the total regional deficit.

This PEP Review summarizes the process economics and technology of NGL recovery from treated natural gas. Recovering ethane or rejecting ethane (leaving ethane in the natural gas) is presented for each recovery process. Turboexpansion processes are the most prevalent type of recovery processes. Economics are determined for three types of turboexpander processes—the conventional process, a simplified gas subcooled process, and a simplified recycle split vapor process. Economics of a generic NGL fractionation process used to determine the product value of mixed NGL product of the gas separation are also presented.

This process summary highlights the new iPEPSpectra interactive data module with which our clients can quickly compare historical production economics of competing processes in several major global regions. The interactive module, written as an Excel pivot table, is attached with the electronic version of this review. The module provides a powerful interactive tool to compare production economics at various levels, such as variable cost, cash cost, and full production cost. An iPEPSpectra historical economic comparison provides a more comprehensive way of assessing competing technologies, leading to a more valid investment decision.
Contents

1 Executive summary 8
   Introduction 8
   Process overview 9
   Technology 10
   Processes 10
   NGL recovery 11
   NGL fractionation 12
   Licensors 12
   Comparison of process economics 13
   Conclusion 16
   Historical economics comparison—An iPEPSpectra™ analysis 17

2 NGL processes 19
   Introduction 19
   Natural gas processing 19
   Natural gas treating 19
   Natural gas separation 21
   Ethane recovery 23
   Ethane rejection 23
   NGL separation processes 24
   Adsorption 39
   Compression 39
   Membrane process 39
   NGL fractionation 39
   Product specifications 41
   Shipping and storage 42
   Environment impact and safety 42

3 Process economics 43
   NGL recovery 43
   Ethane recovery economics 44
   Contracts 45
   Capital costs 46
   Unit consumption and variable costs 47
   Production costs 51
   NGL fractionation 58
   Capital costs 58
   Unit consumption and variable costs 59
   Production costs 64

4 Market overview 71
   Global NGL supply and demand 72
   Supply 73
   Demand 75
   Ethane 75
   Propane 77
   LPG 77
   Supply 78
   Demand 79
Butanes 80
Natural gasoline 81
End-use markets and demand drivers 81
Ethane 82
Propane 83
LPG 84
Butanes 85
Natural gasoline 86
Price history 87
Ethane 88
Propane 88
LPG 89
Natural gasoline 89
Producers 89
Capacity 90
Fractionators 94
New construction 98
New fractionator plant construction 99

5 Historical economics comparison—An iPEPSpectra™ analysis 100
  Historical NGL prices 100
  Historical process economics comparison—iPEPSpectra™ cost module 101

6 Detailed process economics 105

7 Cost bases 115
  Capital investment 115
  Production costs 115
  Effect of operating level on production costs 116

Appendix A—Cited references 117
Appendix B—Product yields 122

Tables

Table 1.1 Three types of separation processes 11
Table 1.2 Selected commercial NGL recovery processes 13
Table 1.3 Battery limits investment, off-sites investment, and total fixed cost 14
Table 1.4 Comparison of technologies—Return on investment, fourth quarter 2015 price scenario 16
Table 1.5 Comparison of technologies—Return on investment, first quarter 2014 price scenario 16
Table 2.1 Recovery of NGL by process 22
Table 2.2 Plant technology limits of NGL recovery by type of process 23
Table 3.1 Natural gas feedstock compositions 44
Table 3.2 Capital costs of NGL recovery processes 46
Table 3.3 Values of feedstocks, products, and utilities 47
Table 3.4 Variable costs of C_{2+} NGL recovery by process for Rich B feed gas—Low crude oil price case 47
Table 3.5 Variable costs of C_{3+} NGL recovery by process for Rich B feed gas—Low crude oil price case 48
Table 3.6 Variable costs of C_{2+} NGL recovery by process for Rich B feed gas—100 $/barrel crude oil price case 48
Table 3.7 Variable costs of C_{3+} NGL recovery by process for Rich B feed gas—100 $/barrel crude oil price case 49
Table 3.8 Variable costs of C_{2+} NGL recovery by feed gas using conventional turboexpansion—Low crude oil price case 49
Table 3.9 Variable costs of C_{3+} NGL recovery by feed gas using conventional turboexpansion—Low crude oil price case 50
Table 3.10 Variable costs of C2+ NGL recovery by feed gas using GSP turboexpansion—Low crude oil price case 50
Table 3.11 Variable costs of C2+ NGL recovery by feed gas using GSP turboexpansion—Low crude oil price case 50
Table 3.12 Variable costs of C2+ NGL recovery by feed gas using RSV turboexpansion—Low crude oil price case 51
Table 3.13 Variable costs of C3+ NGL recovery by feed gas using RSV turboexpansion—Low crude oil price case 51
Table 3.14 Production costs of C2+ NGL recovery by process for Rich B feed gas—Low crude oil price case 52
Table 3.15 Production costs of C3+ NGL recovery by process for Rich B feed gas—Low crude oil price case 52
Table 3.16 Production costs of C2+ NGL recovery by process for Rich B feed gas—100 $/barrel crude oil price case 53
Table 3.17 Production costs of C3+ NGL recovery by process for Rich B feed gas—100 $/barrel crude oil price case 54
Table 3.18 Production costs of C2+ NGL recovery by feed gas using conventional turboexpansion—Low crude oil price case 55
Table 3.19 Production costs of C3+ NGL recovery by feed gas using conventional turboexpansion—Low crude oil price case 55
Table 3.20 Production costs of C2+ NGL recovery by feed gas using GSP turboexpansion—Low crude oil price case 56
Table 3.21 Production costs of C3+ NGL recovery by feed gas using GSP turboexpansion—Low crude oil price case 56
Table 3.22 Production costs of C2+ NGL recovery by feed gas using RSV turboexpansion—Low crude oil price case 57
Table 3.23 Production costs of C3+ NGL recovery by feed gas using RSV turboexpansion—Low crude oil price case 57
Table 3.24 Capital cost of NGL fractionation process 59
Table 3.25 Variable costs of fractionation of Rich B C2+ NGL—Low crude oil price case 60
Table 3.26 Variable costs of Rich B C2+ NGL fractionation—Low crude oil price case 60
Table 3.27 Variable costs of Rich B C2+ NGL fractionation—100 $/barrel crude oil price case 61
Table 3.28 Variable costs of Rich B C3+ NGL fractionation—100 $/barrel crude oil price case 61
Table 3.29 Variable costs of fractionation of C2+ NGL by conventional turboexpansion—Low crude oil price case 62
Table 3.30 Variable costs of fractionation of C3+ NGL by conventional turboexpansion—Low crude oil price case 62
Table 3.31 Variable costs of fractionation of C2+ NGL by GSP turboexpansion—Low crude oil price case 63
Table 3.32 Variable costs of fractionation of C3+ NGL by GSP turboexpansion—Low crude oil price case 63
Table 3.33 Variable costs of fractionation of C2+ NGL by RSV turboexpansion—Low crude oil price case 64
Table 3.34 Variable costs of fractionation of C3+ NGL by RSV turboexpansion—Low crude oil price case 64
Table 3.35 Production costs of C2+ NGL fractionation for Rich B feed gas—Low crude oil price case 65
Table 3.36 Production costs of C3+ NGL fractionation for Rich B feed gas—Low crude oil price case 65
Table 3.37 Production costs of C2+ NGL fractionation for Rich B feed gas—100 $/barrel crude oil price case 66
Table 3.38 Production costs of C3+ NGL fractionation for Rich B feed gas—100 $/barrel crude oil price case 66
Table 3.39 Production costs of C2+ NGL fractionation by conventional turboexpansion—Low crude oil price case 67
Table 3.40 Production costs of C3+ NGL fractionation by conventional turboexpansion—Low crude oil price case 68
Table 3.41 Production costs of $C_2^+$ NGL fractionation by GSP turboexpansion—Low crude oil price case
Table 3.42 Production costs of $C_3^+$ NGL fractionation by GSP turboexpansion—Low crude oil price case
Table 3.43 Production costs of $C_2^+$ NGL fractionation by RSV turboexpansion—Low crude oil price case
Table 3.44 Production costs of $C_3^+$ NGL fractionation by RSV turboexpansion—Low crude oil price case
Table 4.1 Air pollutant emissions, lb per billion Btus
Table 4.2 Top 10 countries with technically recoverable shale gas reserves
Table 4.3 NGL characteristics of North American shale gas and oil fields
Table 4.4 Major importers of US ethane
Table 4.5 World NGL demand by region—2015
Table 4.6 US NGL demand (ca 2011)
Table 4.7 Major reactions of ethylene, products, and derivatives
Table 4.8 World LPG end uses
Table 4.9 Estimated fractionation plus transportation costs to market hubs (2012)
Table 4.10 Ethane transportation fees to Mont Belvieu, Texas hub (2013)
Table 4.11 Capacity of United States fractionation facilities
Table 4.12 Capacity of Canadian fractionation facilities
Table 4.13 New gas plant construction
Table 4.14 New North American NGL fractionator construction
Table 6.1 NGLs by conventional turboexpander process
Table 6.2 NGLs by gas subcooled (GSP) turboexpander process
Table 6.3 NGLs by recycle split vapor (RSV) turboexpander process
Table 6.4 NGL separation by generic fractionation process

Figures

Figure 1.1 Overview of natural gas and NGL processing
Figure 1.2 Comparison of technologies—Capital intensity
Figure 1.3 Comparison of technologies—Production costs, ethane recovered
Figure 1.4 Comparison of technologies—Production costs, ethane rejected
Figure 1.5 Margin for ethane recovery compared with rejection for combined conventional turboexpander—Fractionation process for feed gases Rich B and Rich C
Figure 2.1 General configuration of non-associated natural gas processing
Figure 2.2 Acid gas removal processes
Figure 2.3 Joule-Thomson process block diagram
Figure 2.4 IPOR℠ process block diagram
Figure 2.5 PRICO-NGL® process block diagram
Figure 2.6 Conventional turboexpander process block diagram
Figure 2.7 Gas subcooled turboexpander process block diagram
Figure 2.8 Cold residue recycle process block diagram
Figure 2.9 Recycle split vapor process block diagram
Figure 2.10 IPSI-1 process block diagram
Figure 2.11 IPSI-2 process block diagram
Figure 2.12 Generic NGL fractionation process block diagram
Figure 3.1 Effect of ethane price on optimal ethane recovery based on gross plant revenue
Figure 4.1 NGL supply by region
Figure 4.2 Worldwide demand for NGL by region
Figure 4.3 World propane supply and demand
Figure 4.4 World LPG production by source—2015  78
Figure 4.5 World butane supply  80
Figure 4.6 US petrochemical demand for ethane and propane  83
Figure 4.7 World propane uses—2015  83
Figure 4.8 World LPG demand by use—2015  84
Figure 4.9 World butane uses—2015  86
Figure 4.10 US NGL price history  87
Figure 4.11 Natural gas processing plant capacity number distribution  94
Figure 4.12 Natural gas processing plant location capacity volume distribution  94
Figure 4.13 NGL fractionation plant capacity—Number distribution  97
Figure 4.14 NGL fractionation plant capacity—Volume distribution  97
Figure 5.1 Historical NGL component market prices  100
Figure 5.2 Effect of feed gases on margins for ethane recovery by the conventional turboexpander combined with the fractionation process  102
Figure 5.3 Effect of turboexpander process type on ethane recovery margins for Rich B feed gas  103
Figure 5.4 Effect of turboexpander process type on ethane rejection margins for Rich B feed gas  103
Figure 5.5 Margin for ethane recovery compared with rejection for combined conventional turboexpander—Fractionation process for feed gases Rich B and Rich C  104