Process Economics Program

Review 2014-08
Ethylbenzene by Badger EBMaxSM
Liquid Phase Alkylation Process

By Mike Kelly
IHS Chemical agrees to assign professionally qualified personnel to the preparation of the Process Economics Program’s reports and will perform the work in conformance with generally accepted professional standards. No other warranties expressed or implied are made. Because the reports are of an advisory nature, neither IHS Chemical nor its employees will assume any liability for the special or consequential damages arising from the Client’s use of the results contained in the reports. The Client agrees to indemnify, defend, and hold IHS Chemical, its officers, and employees harmless from any liability to any third party resulting directly or indirectly from the Client’s use of the reports or other deliverables produced by IHS Chemical pursuant to this agreement.

For detailed marketing data and information, the reader is referred to one of the IHS Chemical programs specializing in marketing research. THE IHS CHEMICAL ECONOMICS HANDBOOK Program covers most major chemicals and chemical products produced throughout the world. In addition the IHS DIRECTORY OF CHEMICAL PRODUCERS services provide detailed lists of chemical producers by company, product, and plant for the United States, Europe, East Asia, China, India, South & Central America, the Middle East & Africa, Canada, and Mexico.
Abstract

Commercial production of ethylbenzene was dominated by liquid-phase aluminum chloride catalyzed processes until the early 1980s when the first vapor-phase zeolite-based process was introduced. The zeolite vapor-phase technology subsequently achieved much commercial success as it proved more efficient and avoided the difficulty of handling aluminum chloride. However, vapor-phase processes operate at high temperatures and produce considerable by-products. While improvements were made over the years, it was not until the arrival of liquid-phase processes in the early 1990s that zeolite-based technologies could produce a high-purity ethylbenzene product.

This review presents a techno-economic evaluation of zeolite-based ethylbenzene production via the Badger EBMaxSM liquid-phase alkylation process. The analysis that follows is based on a plant with an annual capacity to produce 1,150 million pounds of ethylbenzene. In the process, polymer grade ethylene is reacted with benzene that is in stoichiometric excess under liquid-phase conditions in a fixed-bed, five stage alkylation reactor. Ethylene conversion is essentially complete, with selectivity to ethylbenzene in the alkylation reaction at over 90%. Unreacted benzene is separated and recycled back to the reaction section. Ethylbenzene product is recovered from polyethylbenzenes, the latter of which is fed to a single fixed-bed transalkylation reactor and converted into additional ethylbenzene product by reacting with excess benzene. The molar yield of ethylbenzene for the overall process exceeds 99.5% relative to both ethylene and benzene.
Table of contents

Introduction ................................................................................................................................................... 1
Review summary ........................................................................................................................................ 2
Industry status ........................................................................................................................................ 6
Technology overview ............................................................................................................................... 7
  Chemistry ............................................................................................................................................. 7
  Process description ............................................................................................................................. 9
    Section 100—alkylation and transalkylation ............................................................................... 9
    Section 200—ethylbenzene recovery .......................................................................................... 10
Process discussion .................................................................................................................................. 17
  Design conditions ............................................................................................................................... 17
  Feedstock .......................................................................................................................................... 17
  Reactors .......................................................................................................................................... 18
  Product purification ............................................................................................................................ 19
  Design optimization ........................................................................................................................... 19
  Waste effluents ................................................................................................................................. 19
  Materials of construction .................................................................................................................. 19
Cost estimates ......................................................................................................................................... 20
  Capital costs .................................................................................................................................... 20
  Production costs ............................................................................................................................... 21
References ............................................................................................................................................... 26
Tables

Table 1: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Comparison of process economics
Table 2: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Design basis
Table 3: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Stream flows
Table 4: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Major equipment
Table 5: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Utilities summary
Table 6: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Total capital investment
Table 7: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Capital investment by section
Table 8: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Production costs

Figures

Figure 1: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Process flow diagram
Figure 2: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Effect of plant capacity on investment costs
Figure 3: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Net production cost and product value of ethylbenzene as a function of ethylene price
Figure 4: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Net production cost and product value of ethylbenzene as a function of benzene price
Figure 5: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Net production cost of ethylbenzene as a function of operating level and plant capacity
Figure 6: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Product value of ethylbenzene as a function of operating level and plant capacity
Figure 7: Ethylbenzene by Badger EBMaxSM Liquid Phase Alkylation Process Comparison of production costs (for base capacity plant)