ABSTRACT

This Review presents a technoeconomic evaluation of an isobutylene from t-butanol (TBA) production process based upon the technical information and data available in patents assigned to LyondellBasell (previously ARCO). The design presented herein differs from an actual commercial LyondellBasell process. However, we firmly believe that the process design and economics presented herein would be a reasonably accurate representation of the actual process when commercialized.

The process primarily consists of liquid-phase dehydration of TBA-rich feed in a shell-and-tube type reactor using a homogenous catalyst, p-toluenesulfonic acid (PTSA). The reaction is endothermic and reaction heat is supplied through the shell side via steam. The conceptual LyondellBasell process is carried out preferably at about 329°F (165°C) and 200–210 psia with a 94.5 wt% purity TBA feedstock assumed to be available from an adjacent propylene oxide (PO) oxirane plant (analyzed in PEP Report 2H). TBA dehydration is a reversible reaction with isobutylene production favored at higher temperatures. The catalyst and reaction conditions selected provide a 73% TBA conversion to isobutylene and water. The reactor product is a vapor mixture of isobutylene, TBA, water and additional impurities. The reactor product is cooled and sent to a three-phase separator to recover isobutylene in vapor form which is further purified via distillation to obtain high-purity isobutylene. The remaining product mixture settles into an organic-phase that is recycled back to the reactor, and a water-phase that is treated to remove isobutanol present as feed impurity. A lower reaction temperature for a liquid-phase reaction as compared to conventional vapor-phase technology is expected to generate fewer by-products and conserve energy. The process design includes careful separation of the TBA/water azeotrope that is recycled back to the reactor and the use of a chemical entrainer to recover isobutanol from the water-rich phase.

Our cost analysis is based on a plant producing 150,000 metric t/yr of high-purity isobutylene at a 0.9 stream factor (equal to an installed capacity of 167,000 metric t/yr). Cost estimates, details thereof and relevant assumptions are provided in this Review.

The Review also compares the economics of six different process configurations to produce high-purity isobutylene. These include three stand-alone isobutylene production routes with varying feed sources (TBA from PO process, TBA from raffinate-1, and MTBE from raffinate-1) and three corresponding integrated processes.
HIGH-PURITY ISOBUTYLENE FROM T-BUTANOL BY LYONDELLBASELL PROCESS

by Sumod Kalakkunnath

February 2013

Santa Clara, California 95054
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.
CONTENTS

REVIEW SUMMARY ........................................................................................................... 1
INTRODUCTION .................................................................................................................. 4
COMMERCIAL OVERVIEW ............................................................................................. 5
TECHNOLOGY OVERVIEW ............................................................................................. 7
Technical Review ............................................................................................................. 7
Reactors and Reaction System ....................................................................................... 8
Catalyst Life ................................................................................................................... 8
PROCESS DESCRIPTION ............................................................................................... 9
Section 100—Isobutylene Production Section .............................................................. 9
PROCESS DISCUSSION .................................................................................................. 14
Feedstock ....................................................................................................................... 14
Catalyst System ............................................................................................................. 14
TBA Dehydration Reactor .............................................................................................. 14
Product Recovery ......................................................................................................... 15
Impurity Recovery ......................................................................................................... 15
Process Waste Effluents ............................................................................................... 15
Materials of Construction ............................................................................................ 15
Process Design Optimization ....................................................................................... 15
COST ESTIMATES ......................................................................................................... 19
Fixed-Capital Costs ....................................................................................................... 19
Production Costs ......................................................................................................... 19
Integrated Plant Economics ........................................................................................ 20
REFERENCES .................................................................................................................. 25
FIGURES

1 High-Purity Isobutylene from t-Butanol by LyondellBasell Process
   Process Flow Diagram .................................................................27

2 High-Purity Isobutylene from t-Butanol by LyondellBasell Process
   Net Production Cost and Product Value of Isobutylene as a Function of TBA
   Price (for Base-Capacity Plant) ..................................................2

3 High-Purity Isobutylene from t-Butanol by LyondellBasell Process
   Comparison of Production Costs (for Base-Capacity Plant) ..............4

4 High-Purity Isobutylene Business Position—Global ..................................6

5 High-Purity Isobutylene from t-Butanol by LyondellBasell Process
   Net Production Cost and Product Value of Isobutylene as a Function of TBA
   Price (for Base-Capacity Plant) ..................................................24

6 High-Purity Isobutylene from t-Butanol by LyondellBasell Process
   Product Value of Isobutylene as a Function of Plant Operating Level and Plant
   Capacity ..........................................................................................24
# TABLES

1. Comparison of Process Economics  
   Total Capital Investment and Production Costs .............................................. 3

2. High-Purity Isobutylene Production by MTBE Cracking  
   Design Bases.................................................................................................. 12

3. High-Purity Isobutylene from t-Butanol by LyondellBasell Process  
   Stream Flows............................................................................................... 13

4. High-Purity Isobutylene Production by MTBE Cracking  
   Major Equipment ......................................................................................... 16

5. High-Purity Isobutylene from t-Butanol by LyondellBasell Process  
   Utilities Summary......................................................................................... 18

6. High-Purity Isobutylene from t-Butanol by LyondellBasell Process  
   Total Capital Investment ............................................................................ 21

7. High-Purity Isobutylene from t-Butanol by LyondellBasell Process  
   Production Costs ......................................................................................... 22