Production of Styrene from the Dehydrogenation of Ethylbenzene

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Introduction

Why Styrene? Key building block in the creation of many consumer and industrial products

Location: Edmonton, AB

Plant Capacity: 105 kilotonnes per year

Market Growth: CAGR of 5.64% from 2021 to 2030

Innovation

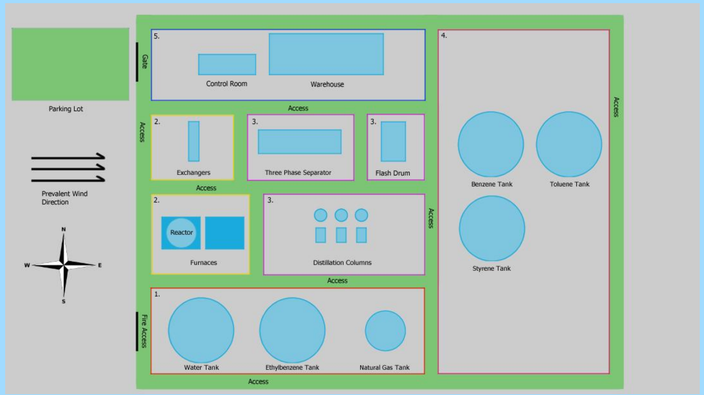
Multi-tube, isothermal reactor

- Better conversion compared to conventional adiabatic design
- Reduced utility and separation load compared to steam injection

Compressor-based heat integration

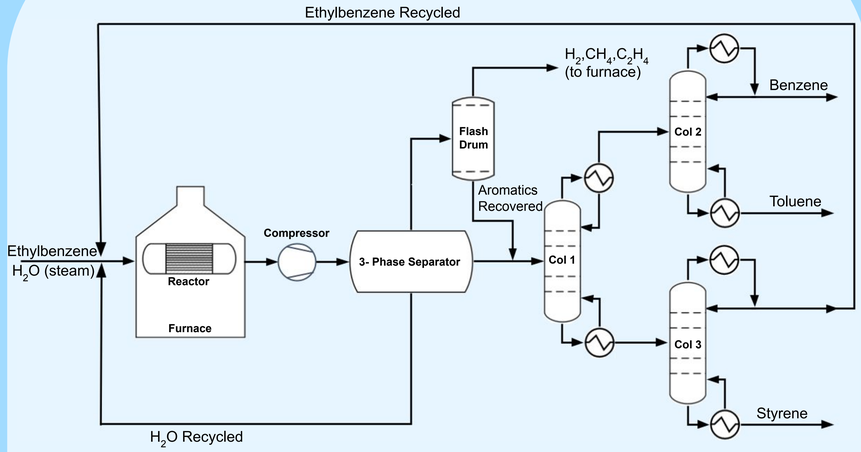
- Better heat transfer, lower capital cost, lower carbon emissions
- More energy and cost efficient than vacuum steam generation proposed in literature

Plant Layout



1. Feed Storage
2. Reactor and Heat Integration
3. Separation
4. Product Storage
5. Administration, Workhouse, and Warehouse

Process Description



Feed Preparation

- Water and ethylbenzene are mixed and heated to 640°C via a furnace. The water to ethylbenzene ratio is maintained using a ratio controller
- The recycled water from the three phase separator and recycled ethylbenzene from the third distillation column are mixed with the fresh feed before entering the process again

Catalytic Reactor

- Mixed feed is fed into a multi-tube, fixed bed, catalytic reactor, within a furnace to operate isothermally
- The main reaction will be endothermic dehydrogenation of ethylbenzene producing styrene, along with side reactions producing benzene, toluene, methane, hydrogen, and ethylene
- The reactor effluent is compressed and fed to the heat exchanger

Three Phase Separation

- The product stream from the heat exchanger is fed to the three phase separator
- The bottom stream mostly consisting of water is recycled back into the process
- The middle stream contains aromatics and most of our valuable products and by-products and is sent to the first distillation column
- The top stream is mostly composed of light gases and is sent to the flash drum

Distillation

- The first column separates benzene and toluene from ethylbenzene and styrene
- The second column separates benzene from toluene which are both temporarily stored and sold for profit
- The third column separates ethylbenzene from styrene. Ethylbenzene is recycled back into the process and the styrene will be temporarily stored and sold

Environmental

Process Aromatics: Styrene, ethylbenzene, toluene, benzene

Environmental Impact

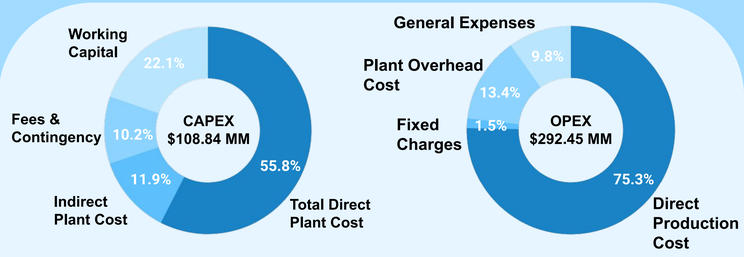
- Toxic, volatile, and flammable
- All aromatics are recycled or sold
- In case of spill, may contaminate soil and sediment

Impactful Units: Heat exchangers, furnace, and compressor

Environmental Assessment

- Cooling water is not contaminated
- Steam in reaction recycled
- SOx and NOx are 2.4 and 2.8 ppm
- eCO_2 is 33 kilotonne/year, within 100 kilotonne/year regulation of Alberta's TIER

Economics



Revenue: $327.98 MM

Payback Period: 16 years

Selling Price: $2.95/kg

Interest Rate: 9.7%

Plant Lifetime: 30 years

ROROI: 17.5%

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