Bentham Corporation
Leading change

Project Specification

1. Design Criteria

Bentham Corporation requires the production of 100 000 te y^{-1} of styrene monomer at purity 99.7 mol%. (See Product Specification Below)

Styrene is a monomer used in the production of polymers including polystyrene, acrylonitrile butadiene styrene (ABS) and styrene-butadiene (SBR). Following fluctuations in the price of polystyrene the board would like a recommendation on which polymer should be produced from the styrene monomer.

2.1 Product Specification
Styrene (Monomer Grade)

Purity:	-	99.7 mol%
Polymers	0.00001	10 max ppm,wt
Color (APHA)	-	10 max
Aldehydes	-	0.01 max %wt
Inhibitor	-	14 – 18 ppm,wt
Total Sulfur (As S)	-	5 max ppm,wt
Ethylbenzene	-	500 max ppm,wt
Specific Gravity (@15°C)	-	0.909 – 0.911

2.2 Proposed Plant Location
The monomer production plant will be situated on a large industrial site in Ordos, China.

2.3 Plant Availability
Plant availability should be at least 8000 hours per year guaranteed operation hours.

2.4 Turndown
The plant must be able to operate at a turndown rate of 70%.

2.5 Feedstock Supply
Bentham Corporation has the option to obtain feedstock in China. The available purity of the feedstock is the same in all locations.

Ethylene Feed Mixture

Gaseous ethylene is available from a pipeline at 40 barg at the battery limit

Average composition:	Ethene	99.5 mole%
	Sulphur	<1ppm
	Water	<10ppm
	Ethane	0.5 mole%

Benzene Feed Mixture

Liquid benzene is available from storage tanks at atmospheric pressure at the battery limit.

Average composition:	Benzene	99.8 wt%
	Water	0.05 wt%
	Toluene	0.15 wt%

3. Services

The following services are available:

Demineralised water (@ Battery Limits) - DW:

Supply Temperature	-	Ambient °C
Supply Pressure	-	15 bar(g)

Chilled water (@ Battery Limits) - CHW:

Supply Temperature	-	10 °C
Return Temperature	-	18 max °C
Supply Pressure	-	8 bar(g)
Return Pressure	-	3 min bar(g)
Chloride Content	-	240 max ppm,wt

Instrument Air (@ Battery Limits) - IA:

Supply Pressure	-	8 bar(g)
Supply Temperature	-	Ambient °C
Dew Point	-	-40 °C
Oil and Ash	-	Nil

L.P. Nitrogen (@ Battery Limits) - LPN:

Supply Pressure	-	5.4 bar(g)
Supply Temperature	-	Ambient °C

H.P. Nitrogen (@ Battery Limits) - HPN:

Supply Pressure	-	35 bar(g)
Supply Temperature	-	Ambient °C

In addition, the following utilities are provided:

Cooling water	Supply Temperature 30°C Return Temperature 40°C Supply Pressure 10 bar(g) Return Pressure 3 bar(g)
I.P. Steam	35 barg, saturated
L.P. Steam	12 barg, saturated

4. Environmental Considerations

Designs should aim to minimise the effects of effluent on the environment using best available technology to minimise solid, liquid and gaseous emissions. Designs should aim to minimise feedstock and energy requirements and maximise the project economic return.

5. Costs Data

Costs	China
Ethylene	7168 Yuan te^{-1}
Benzene	3552 Yuan te^{-1}
Cooling Water	30 Yuan te^{-1}
Chilled Water	115 Yuan te^{-1}
Demineralised Water	200 Yuan te^{-1}
IP Steam	55 Yuan te^{-1}
LP Steam	35 Yuan te^{-1}
Electricity	320 Yuan $(MW\ hr)^{-1}$
Natural Gas	225 Yuan $(MW\ hr)^{-1}$

Wenner and Dybdal* present some product distribution data for styrene production. The reactions they consider are

$$\text{Ethylbenzene} \rightleftharpoons \text{Styrene} + H_2$$

$$\text{Ethylbenzene} \rightarrow \text{Benzene} + C_2H_4$$

$$\text{Ethylbenzene} + H_2 \rightarrow \text{Toluene} + CH_4$$

and points read from their graphs are given in Tables 4.3-4 and 4.3-5. Develop correlations for these data.

* R. W. Wenner and E. C. Dybdal, *Chem. Eng. Prog.*, **44**(4): 275 (1948).

TABLE 4.3-4
Moles of benzene per mole of styrene versus conversion

Mol benzene/mol styrene	0	0.005	0.010	0.020	0.030	0.060	0.100	0.140
Conversion x	0	0.10	0.15	0.20	0.25	0.30	0.35	0.40

From R. W. Wenner and E. C. Dybdal, *Chem. Eng. Prog.*, **44**(4): 275 (1948).

TABLE 4.3-5
Moles of toluene per mole of styrene versus conversion

Mol toluene/mol styrene	0	0.006	0.015	0.030	0.045	0.070	0.110	0.160
Conversion x	0	0.10	0.15	0.20	0.25	0.30	0.35	0.40

From R. W. Wenner and E. C. Dybdal, *Chem. Eng. Prog.*, **44** (4): 275 (1948).

6. Special Considerations

6.1 Safety Considerations

Ethene mixture flash point: Auto ignition temperature- 543₀C. Flammability limits: 2.7-36%(volume in air).

Limitation of the flare is that only gaseous streams may be flared.

6.2 Conversion Table

Felder, R. M.; Rousseau, R. W. (2000). *Elementary Principles of Chemical Processes* (3rd ed.). New York: John Wiley & Sons, Inc.