Production of Maleic Anhydride

Background

Maleic anhydride is a versatile chemical intermediate used to make unsaturated polyester resins, lube oil additives, alkyd resins, and a variety of other products. In 1995, global production of maleic anhydride was estimated at 1.8 billion pounds, with an estimated value of $700 million. Over the last five years, world consumption has increased at an average annual rate of 5.8%, with the fastest growth occurring in Asia, where it is used as an intermediate for production of 1,4-butanediol [1]. The goal of this project is to design a grass roots facility that is capable of producing 40 million pounds of maleic anhydride per year from n-butane.

Process Description

Figure 1 shows a PFD for the overall process. Pure butane, Stream 2, and compressed air, Stream 3, are mixed and fed to R-101, an adiabatic reactor, where butane reacts with oxygen to form maleic anhydride. The reaction is exothermic, therefore, one could consider either a fluidized bed reactor or a packed bed reactor with heat removal to stay close to isothermal. The reactor effluent is cooled and sent to T-101, a packed bed absorber, where it is contacted with water, Stream 7, to remove the light gases and all of the maleic anhydride reacts to form maleic acid. The vapor effluent, which consists of non-condensables, Stream 8, must be sent to an after-burner to remove any carbon monoxide prior to venting to the atmosphere. This is not shown here. The liquid effluent, Stream 9, is then cooled and flashed at 101 kPa and 120°C in V-101. The vapor effluent from V-101, Stream 11, is sent to waste treatment. Stream 12, the liquid

effluent, is sent to R-102 where maleic acid is broken down to maleic anhydride and water. The reactor effluent is then sent to distillation column, T-102, where maleic anhydride and water are separated. The distillate, Stream 14, is sent to waste treatment. Stream 15, the bottoms, consists of 99-wt.% maleic anhydride.

Necessary Information and Simulation Hints

The following reactions occur during the reaction of butane with oxygen:

$$C_4H_{10} + 3.5O_2 \rightarrow C_4H_2O_3 + 4H_2O \quad (1)$$

$$C_4H_{10} + 5.5O_2 \rightarrow 2CO + 2CO_2 + 5H_2O \quad (2)$$

$$C_4H_{10} + 3.5O_2 \rightarrow C_3H_4O_2 + CO_2 + 3H_2O \quad (3)$$

$$C_4H_{10} + 6O_2 \rightarrow CH_2O_2 + 3CO_2 + 4H_2O \quad (4)$$

The conversion of butane is assumed to be 82.2%. The selectivity for each reaction is as follows [2]:

(1) maleic anhydride 70.0%

(2) carbon dioxide 1.0%

(3) acrylic acid 1.0%

(4) formic acid 1.0%

Data that may provide reaction kinetics can be found in US patent 4,317,778.

The process was simulated using the Peng-Robinson thermodynamic package for K-values and Peng-Robinson for enthalpy. UNIFAC thermodynamic suggested an azeotrope between maleic andhydride and water, which would not allow purification of the maleic anhydride to the purity obtained here. This should be considered when designing the separation units.

Equipment Summary

C-101	Air Compressor
E-101	Heat Exchanger
E-102	Heat Exchanger
E-103	Condenser
E-104	Reboiler
P-101A/B	Reflux Pump
R-101	Packed Bed Reactor
R-102	Maleic Acid Reactor
T-101	Absorbtion Tower
T-102	Distillation Column
V-101	Flash Vessel
V-102	Reflux Vessel

References

1. http://www-cmrc.sri.com/CIN/JulyAugust96/Article08.html

2. Slindard, W., A. Baylis, U.S. Patent # 4,052,417 “Vapor Phase Oxidation of Butane Producing Maleic Anhydride and Acetic Acid.”

Stream Tables

Stream	1	2	3	4	5	6	7	8
Temp. (°C)	20.0	20.0	147.9	121.0	410.0	95.0	45.0	59.9
Press. (kPa)	275.0	101.0	275.0	275.0	275.0	200.0	170.0	170.0
Vapor Fraction	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0
Total Flow (kg/h)	2000.0	41174.0	41174.0	41174.0	43174.0	43174.0	11216.0	37621.4
Component Flows (kg/h)								
Nitrogen	--	31210.0	31210.0	31210.0	31210.0	31210.0	--	31210.0
Carbon Monoxide	--	--	--	--	21.7	21.7	--	21.7
Oxygen	--	9511.0	9511.0	9511.0	6287.4	6287.4	--	6287.4
Carbon Dioxide	--	--	--	--	102.3	102.3	--	102.3
Butane	2000.0	--	--	--	355.9	355.9	--	--
Water	--	453.0	453.0	453.0	2491.2	2491.2	11216.0	--
Formic Acid	--	--	--	--	17.8	17.8	--	--
Acrylic Acid	--	--	--	--	27.9	27.9	--	--
Maleic Anhydride	--	--	--	--	2659.6	2659.6	--	--
Maleic Acid	--	--	--	--	--	--	--	--

Stream	9	10	11	12	13	14	15
Temp. (°C)	60.0	40.0	120.0	120.0	160.0	97.1	162.0
Press. (kPa)	170.0	101.0	101.0	101.0	101.0	101.0	101.0
Vapor Fraction	0.0	0.0	1.0	0.0	0.7	0.0	0.0
Total Flow (kg/h)	16768.5	16768.5	13639.7	3128.8	3128.8	602.5	2526.3
Component Flows (kg/h)							
Nitrogen	--	--	--	--	--	--	--
Carbon Monoxide	--	--	--	--	--	--	--
Oxygen	--	--	--	--	--	--	--
Carbon Dioxide	--	--	--	--	--	--	--
Butane	355.9	355.9	355.9	0.1	0.1	0.1	--
Water	2491.2	2491.2	13206.0	12.6	496.0	491.5	4.5
Formic Acid	17.8	17.8	17.6	0.2	0.2	0.2	0.1
Acrylic Acid	27.9	27.9	26.6	1.4	1.4	0.6	0.8
Maleic Anhydride	2659.6	2659.6	--	--	2631.2	110.2	2521.0
Maleic Acid	--	--	33.6	3114.6	--	--	--

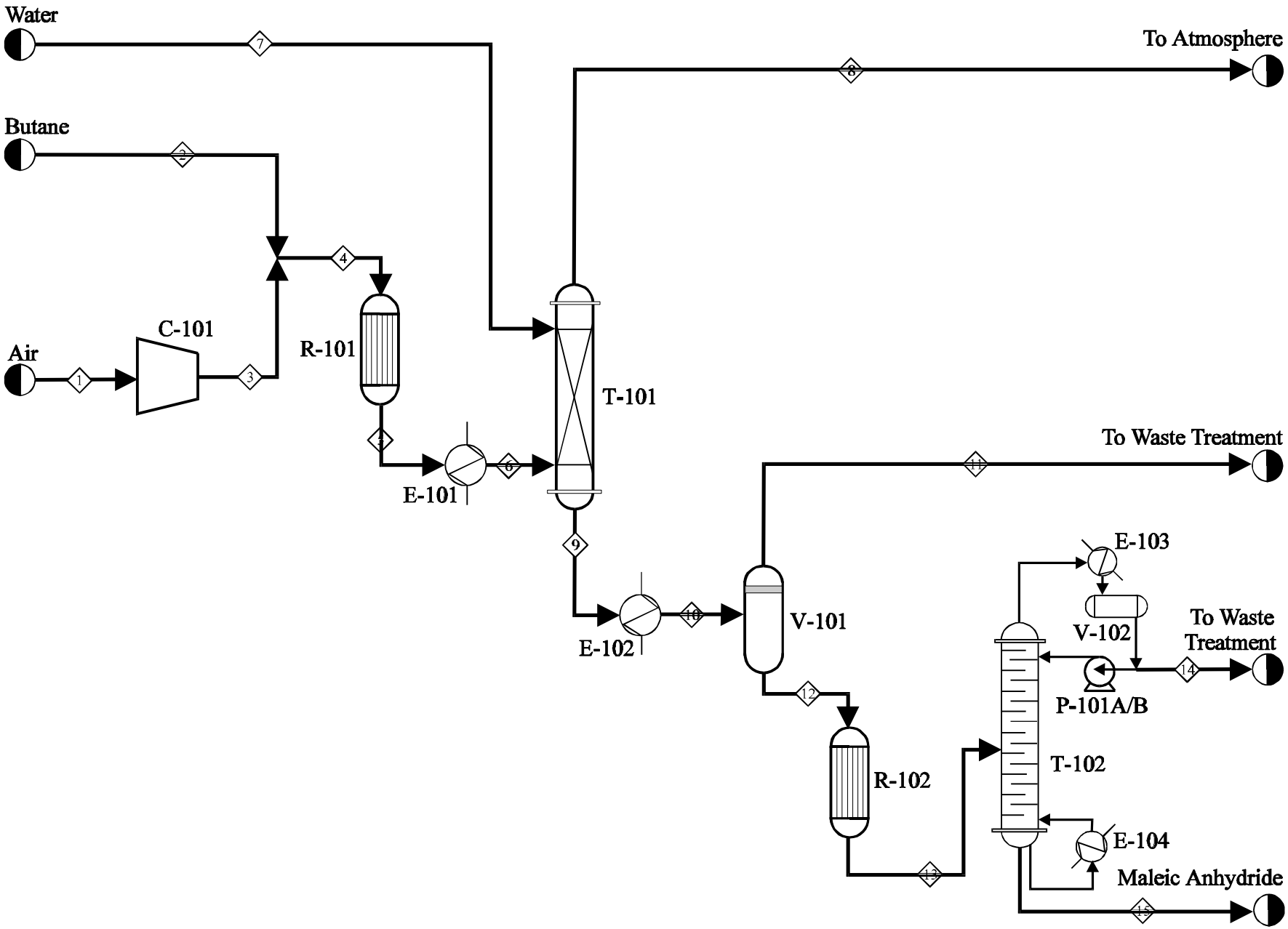

Figure 1: PFD for Maleic Anhydride Production