

Optimizing Maleic Anhydride Production from Benzene's Cost by Preheating Inlet Air in Fired Heater and Modifying Distillation Column Operating Condition

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Table S1. Heat and material balance of original process using Aspen HYSYS V11

Stream No.	Unit	Benzene	1	Air 1	2	3	4	5
Total Phase Properties								
Phase Temperature (Overall)	C	30.0	30.1	30.0	140.3	140.3	140.0	390.0
Phase Pressure (Overall)	kPa	101.4	301.4	101.4	251.4	301.4	251.4	251.4
Phase Molar Flow (Overall)	kgmole/h	12.4	12.4	825.7	825.7	12.4	838.2	838.2
Phase Mass Flow (Overall)	kg/h	964.1	964.1	23783.6	23783.6	964.1	24747.6	24747.6
Phase Heat Flow (Overall)	kJ/h	580701.6	580998.0	-844011.7	1846719.2	1124512.7	2971231.9	8917458.2
Phase Molecular Weight (Overall)		77.5	77.5	28.8	28.8	77.5	29.5	29.5
Liquid Phase Properties								
Phase Temperature (Mixed Liquid Phase)	C	30.0	30.1	0.0	0.0	0.0	0.0	0.0
Phase Pressure (Liquid Phase)	kPa	101.4	301.4	0.0	0.0	0.0	0.0	0.0
Phase Molar Flow (Liquid Phase)	kgmole/h	12.3	12.3	0.0	0.0	0.0	0.0	0.0
Phase Mass Flow (Liquid Phase)	kg/h	962.0	962.0	0.0	0.0	0.0	0.0	0.0
Phase Heat Flow (Liquid Phase)	kJ/h	613215.2	613497.4	0.0	0.0	0.0	0.0	0.0
Phase Molecular Weight (Liquid Phase)		78.1	78.1	0.0	0.0	0.0	0.0	0.0
Vapour Phase Properties								
Phase Temperature (Vapour Phase)	C	0.0	0.0	30.0	140.3	140.3	140.0	390.0
Phase Pressure (Vapour Phase)	kPa	0.0	0.0	101.4	251.4	301.4	251.4	251.4
Phase Molar Flow (Vapour Phase)	kgmole/h	0.0	0.0	825.7	825.7	12.4	838.2	838.2
Phase Mass Flow (Vapour Phase)	kg/h	0.0	0.0	23783.6	23783.6	964.1	24747.6	24747.6
Phase Heat Flow (Vapour Phase)	kJ/h	0.0	0.0	-844011.7	1846719.2	1124512.7	2971231.9	8917458.2
Phase Molecular Weight (Vapour Phase)		0.0	0.0	28.8	28.8	77.5	29.5	29.5

6	7	8	9	10	11	12	13	14	15
1015.8	54.3	205.9	56.1	56.1	66.2	253.1	217.8	217.8	339.3
250.0	251.4	82.0	82.0	101.3	101.3	101.3	101.3	101.3	101.3
832.6	832.6	841.2	42.0	42.0	0.1	41.9	11.4	0.0	30.6
24747.6	24747.6	29191.0	9639.2	9639.2	3.3	9635.9	1134.6	0.0	8501.4
8917615.5	-19512238.2	24220091.8	30885557.2	-30885360.0	-4914.5	-27064968.1	-4239258.4	-0.2	20616346.0
29.7	29.7	34.7	229.5	229.5	44.1	229.8	99.8	158.4	278.2
0.0	54.3	205.9	56.1	56.1	66.2	253.1	0.0	217.8	339.3
250.0	251.4	82.0	82.0	101.3	101.3	101.3	0.0	101.3	101.3
0.0	10.3	0.0	42.0	42.0	0.0	41.9	0.0	0.0	30.6
0.0	1004.7	0.8	9639.2	9639.2	0.0	9635.9	0.0	0.0	8501.4
0.0	-4675539.0	-2082.4	30885557.2	-30885360.0	-0.4	-27064968.1	0.0	-0.2	20616346.0
30.2	97.6	278.2	229.5	229.5	80.5	229.8	0.0	158.4	278.2
1015.8	54.3	205.9	0.0	0.0	66.2	0.0	217.8	0.0	0.0
250.0	251.4	82.0	0.0	0.0	101.3	0.0	101.3	0.0	0.0
832.6	822.3	841.2	0.0	0.0	0.1	0.0	11.4	0.0	0.0
24747.6	23742.9	29190.2	0.0	0.0	3.3	0.0	1134.6	0.0	0.0
8917615.5	-14836699.2	24218009.3	0.0	0.0	-4914.1	0.0	-4239258.4	0.0	0.0
29.7	28.9	34.7	0.0	0.0	44.0	0.0	99.8	0.0	0.0

16	17	DBP	Combustion	Air inlet 2	NG
339.3	296.2	227.0	567.7	30.0	30.0
101.3	101.3	101.3	40040.0	137000.0	40040.0
30.6	50.6	20.1	148.9	121.0	12.5
8501.8	14082.6	5580.9	2926.1	2761.4	164.7
-20617314.5	-35594479.2	14977164.7	-7108260.7	31113.4	-1193095.5
278.2	278.2	278.3	26.0	28.9	30.5
339.3	296.2	227.0	0.0	30.0	30.0
101.3	101.3	101.3	0.0	137000.0	40040.0
30.6	50.6	20.1	0.0	121.0	12.5
8501.8	14082.6	5580.9	0.0	2761.4	164.7
-20617314.5	-35594479.2	14977164.7	0.0	31113.4	-1193095.5
278.2	278.2	278.3	0.0	28.9	30.5
0.0	0.0	0.0	567.7	0.0	0.0
0.0	0.0	0.0	40040.0	0.0	0.0
0.0	0.0	0.0	148.9	0.0	0.0
0.0	0.0	0.0	2926.1	0.0	0.0
0.0	0.0	0.0	-7108260.7	0.0	0.0
0.0	0.0	0.0	26.0	0.0	0.0

Table S2. Heat and material balance of modified process using Aspen HYSYS V11

Stream No.	Unit	Benzene	1	Air 1	2	3	4	5
Total Phase Properties								
Phase Temperature (Overall)	C	30.0	30.1	30.0	140.3	140.3	140.0	155.6
Phase Pressure (Overall)	kPa	101.4	301.4	101.4	251.4	301.4	251.4	251.4
Phase Molar Flow (Overall)	kgmole/h	12.4	12.4	825.7	825.7	12.4	838.2	838.2
Phase Mass Flow (Overall)	kg/h	964.1	964.1	23783.6	23783.6	964.1	24747.6	24747.6
Phase Heat Flow (Overall)	kJ/h	580701.6	580998.0	-844011.7	1846719	1124513	2971232	3379861.3
Phase Molecular Weight (Overall)		77.5	77.5	28.8	28.8	77.5	29.5	29.5
Liquid Phase Properties								
Phase Temperature (Liquid Phase)	C	30.0	30.1	0.0	0.0	0.0	0.0	0.0
Phase Pressure (Liquid Phase)	kPa	101.4	301.4	0.0	0.0	0.0	0.0	0.0
Phase Molar Flow (Liquid Phase)	kgmole/h	12.3	12.3	0.0	0.0	0.0	0.0	0.0
Phase Mass Flow (Liquid Phase)	kg/h	962.0	962.0	0.0	0.0	0.0	0.0	0.0
Phase Heat Flow (Liquid Phase)	kJ/h	613215.2	613497.4	0.0	0.0	0.0	0.0	0.0
Phase Molecular Weight (Liquid Phase)		78.1	78.1	0.0	0.0	0.0	0.0	0.0
Vapour Phase Properties								
Phase Temperature (Vapour Phase)	C	0.0	0.0	30.0	140.3	140.3	140.0	155.6
Phase Pressure (Vapour Phase)	kPa	0.0	0.0	101.4	251.4	301.4	251.4	251.4
Phase Molar Flow (Vapour Phase)	kgmole/h	0.0	0.0	825.7	825.7	12.4	838.2	838.2
Phase Mass Flow (Vapour Phase)	kg/h	0.0	0.0	23783.6	23783.6	964.1	24747.6	24747.6
Phase Heat Flow (Vapour Phase)		0.0	0.0	28.8	28.8	77.5	29.5	29.5
Phase Molecular Weight (Vapour Phase)	kJ/h	0.0	0.0	-844011.7	1846719	1124513	2971231.9	3379861.3

6	7	DBP	8	9	10	11	12	13	14	15
827.1	54.3	308.0	205.3	55.6	55.6	67.1	249.1	215.1	339.9	339.9
250.0	251.4	101.3	82.0	82.0	101.3	101.3	101.3	101.3	101.3	101.3
832.6	832.6	20.8	842.2	35.6	35.6	0.1	35.5	11.2	24.3	24.3
24747.6	24747.6	5575.7	29210.2	7881.0	7881.0	8.4	7872.6	1111.3	6761.3	6767.8
3379917.1	19275645.1	14135829.6	24239254.8	25570270.6	-25570109.7	2141.3	-22506158.3	-4194713.3	-16383190.1	16399060.9
29.7	29.7	267.5	34.7	221.4	221.4	62.0	222.0	99.5	278.3	278.3
827.1	54.3	308.0	205.3	55.6	55.6	67.1	249.1	0.0	339.9	339.9
250.0	251.4	101.3	82.0	82.0	101.3	101.3	101.3	0.0	101.3	101.3
0.0	10.2	20.8	0.0	35.6	35.6	0.0	35.5	0.0	24.3	24.3
0.0	992.5	5575.7	0.7	7881.0	7881.0	0.0	7872.6	0.0	6761.3	6767.8
0.0	-4615222.8	14135829.6	-2044.0	25570270.6	-25570109.7	1.2	-22506158.3	0.0	-16383190.1	16399060.9
31.9	97.6	267.5	278.0	221.4	221.4	77.9	222.0	0.0	278.3	278.3
827.1	54.3	0.0	205.3	0.0	0.0	67.1	0.0	215.1	0.0	0.0
250.0	251.4	0.0	82.0	0.0	0.0	101.3	0.0	101.3	0.0	0.0
832.6	822.5	0.0	842.2	0.0	0.0	0.1	0.0	11.2	0.0	0.0
24747.6	23755.1	0.0	29209.4	0.0	0.0	8.4	0.0	1111.3	0.0	0.0
29.7	28.9	0.0	34.7	0.0	0.0	62.0	0.0	99.5	0.0	0.0
3379917.1	14660422.3	0.0	24237210.7	0.0	0.0	2140.1	0.0	-4194713.3	0.0	0.0

16	Air 2	NG	Combustion	Out2
324.8	30.0	30.0	986.2	250.0
101.3	137000.0	40040.0	40040.0	137000.0
45.2	121.0	12.5	148.9	121.0
12343.5	3490.9	381.1	3872.0	3490.9
-30534890.5	31113.4	-1193095.5	-4783059.0	999946.7
273.3	28.9	30.5	26.0	28.9
324.8	30.0	30.0	0.0	250.0
101.3	137000.0	40040.0	0.0	137000.0
44.7	121.0	12.5	0.0	121.0
12250.0	3490.9	381.1	0.0	3490.9
-30308661.4	31113.4	-1193095.5	0.0	999946.7
273.8	28.9	30.5	0.0	28.9
324.8	0.0	0.0	986.2	0.0
101.3	0.0	0.0	40040.0	0.0
0.4	0.0	0.0	148.9	0.0
93.5	0.0	0.0	3872.0	0.0
223.1	0.0	0.0	26.0	0.0
-226229.1	0.0	0.0	-4783059.0	0.0