

## Appendix B

## Toluene Hydrodealkylation Process

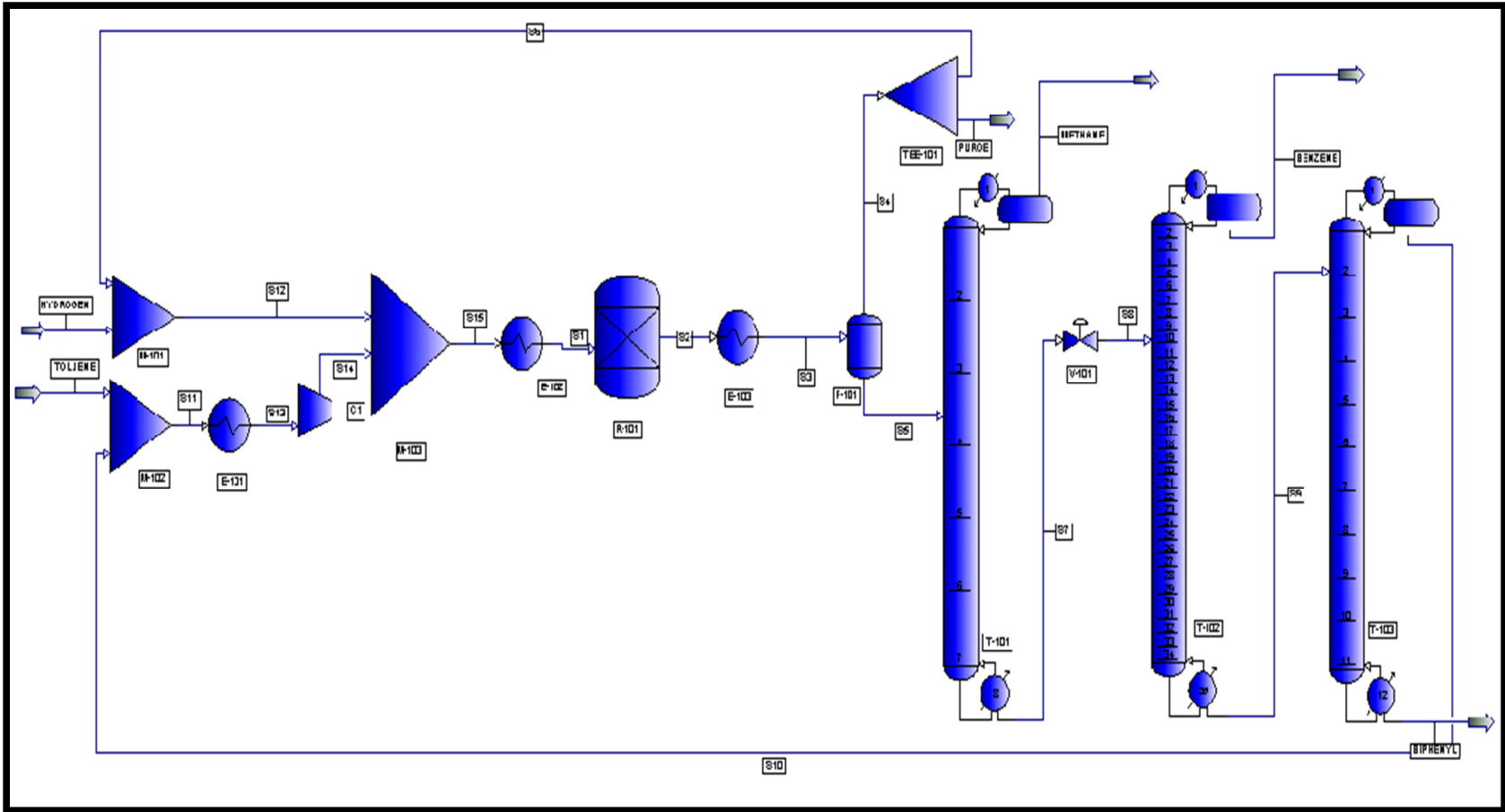


Table B1. Stream summary of toluene hydrodealkylation flowsheet

Stream Name	S1	S2	S3	S4	S5	S6	Purge
Stream Description							
Phase	Vapor	Vapor	Mixed	Vapor	Liquid	Vapor	Vapor
Total Stream							
Rate : KG-MOL/HR	1997.15	1997.15	1997.15	1825.87	171.2802	1606.765	219.1043
KG/HR	32001.52	32001.52	32001.52	18545.35	13456.17	16319.91	2225.442
Std. Liq. Rate : M3/HR	92.56823	93.55526	93.55526	77.96979	15.58548	68.61341	9.356374
Temperature : K	894.11	894.11	300	300	300	300	300
Pressure : ATM	38	38	38	38	38	38	38
Molecular Weight	16.02359	16.02359	16.02359	10.157	78.5623	10.157	10.157
Enthalpy : M*KCAL/HR	17.72779	17.47126	1.168704	0.993965	0.174739	0.874689	0.119276
KCAL/KG	553.967	545.951	36.52028	53.59644	12.98582	53.59644	53.59644
Mole Fraction Liquid	0	0	0.085762	0	1	0	0
Reduced Temperature	5.886793	5.602403	1.87977	2.439569	0.545471	2.439569	2.439569
Reduced Pressure	1.269231	1.172806	1.172806	1.221327	0.823886	1.221327	1.221327
Acentric Factor	-0.07274	-0.06206	-0.06206	-0.08774	0.21175	-0.08774	-0.08774
UOP K factor	16.5026	16.68613	16.68613	21.57945	9.942122	21.57945	21.57945
Std. Liquid Density : KG/M3	345.7073	342.06	342.06	237.8531	863.3781	237.8531	237.8531
Sp. Gravity	0.346049	0.342398	0.342398	0.238088	0.86423	0.238088	0.238088
API Gravity	277.4022	281.7622	281.7622	462.8185	32.22951	462.8185	462.8185
Vapor							
Rate : KG-MOL/HR	1997.15	1997.15	1825.869	1825.87	n/a	1606.765	219.1043
KG/HR	32001.52	32001.52	18545.35	18545.35	n/a	16319.91	2225.442
M3/HR	3904.893	3903.553	1169.706	1169.706	n/a	1029.341	140.3647
Vapor Std Vol Flow : M3/HR	44764.1	44764.1	40925.03	40925.03	n/a	36014.02	4911.003
Molecular Weight	16.02359	16.02359	10.157	10.157	n/a	10.157	10.157
Z (from K)	1.012682	1.012335	0.988897	0.988897	n/a	0.988897	0.988897
Enthalpy : KCAL/KG	553.9671	545.951	53.59644	53.59644	0	53.59644	53.59644
C <sub>p</sub> : KCAL/KG-K	0.982099	0.974241	0.814767	0.814767	n/a	0.814767	0.814767
Density : KG/M3	8.195235	8.198048	15.85472	15.85472	n/a	15.85472	15.85472
Th. Conductivity : Kcal/HR-M-C	0.17931	0.16946	0.064409	0.064409	n/a	0.064409	0.064409
Viscosity : cP	0.022656	0.023667	0.010698	0.010698	n/a	0.010698	0.010698
Liquid							
Rate : KG-MOL/HR	n/a	n/a	171.2802	n/a	171.2802	n/a	n/a
KG/HR	n/a	n/a	13456.16	n/a	13456.17	n/a	n/a
M3/HR	n/a	n/a	15.7202	n/a	15.7202	n/a	n/a
Liquid Std Vol Flow : M3/HR	n/a	n/a	15.58548	n/a	15.58548	n/a	n/a
Molecular Weight	n/a	n/a	78.5623	n/a	78.5623	n/a	n/a
Z (from K)	n/a	n/a	0.156311	n/a	0.156311	n/a	n/a
Enthalpy : KCAL/KG	n/a	n/a	12.98582	n/a	12.98582	n/a	n/a
C <sub>p</sub> : KCAL/KG-K	n/a	n/a	0.385393	n/a	0.385393	n/a	n/a
Density : KG/M3	n/a	n/a	855.9794	n/a	855.9794	n/a	n/a
Surface Tension : DYNE/CM	n/a	n/a	26.46867	n/a	26.46867	n/a	n/a
Th. Conductivity : Kcal/HR-M-C	n/a	n/a	0.119719	n/a	0.119719	n/a	n/a
Viscosity : cP	n/a	n/a	0.505703	n/a	0.505703	n/a	n/a

Table B2. Stream summary of toluene hydrodealkylation flowsheet (cont'd)

Stream Name	Methane	S7	S8	Benzene	S9	S10	Biphenyl
Stream Description							
Phase	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Liquid
<b>Total Stream</b>							
<b>Rate : KG-MOL/HR</b>	9.953906	161.3263	161.3263	119.5524	41.77385	40.42879	1.345056
<b>KG/HR</b>	189.0166	13267.15	13267.15	9338.696	3928.452	3723.533	204.9186
<b>Std. Liq. Rate : M3/HR</b>	0.537637	15.04785	15.04785	10.58463	4.463213	4.264032	0.199181
<b>Temperature : K</b>	371.9092	554.1918	425.5198	352.2523	384.9259	383.7963	508.6046
<b>Pressure : ATM</b>	38	38	1	1	1	1	1
<b>Molecular Weight</b>	18.98919	82.23798	82.23798	78.11382	94.04093	92.10102	152.3495
<b>Enthalpy : M*KCAL/HR</b>	0.019373	2.023345	2.023345	0.316387	0.187462	0.175727	0.021739
<b>KCAL/KG</b>	102.4955	152.5079	152.5079	33.87914	47.71912	47.19351	106.0847
<b>Mole Fraction Liquid</b>	0	1	0	1	1	1	1
<b>Reduced Temperature</b>	1.832904	0.969886	0.744699	0.626624	0.643809	0.648613	0.64928
<b>Reduced Pressure</b>	0.878139	0.820757	0.021599	0.020688	0.024712	0.024663	0.026266
<b>Acentric Factor</b>	0.008134	0.224314	0.224314	0.210027	0.265201	0.261971	0.362271
<b>UOP K factor</b>	17.18831	9.838886	9.838886	9.7366	10.08204	10.11256	9.527454
<b>Std. Liquid Density : KG/M3</b>	351.5692	881.6642	881.6642	882.2882	880.1846	873.2422	1028.805
<b>Sp. Gravity</b>	0.351916	0.882534	0.882534	0.883159	0.881053	0.874104	1.02982
<b>API Gravity</b>	270.5844	28.83368	28.83368	28.72029	29.10322	30.38002	5.902626
<b>Vapor</b>							
<b>Rate : KG-MOL/HR</b>	9.953906	n/a	161.3263	n/a	n/a	n/a	n/a
<b>KG/HR</b>	189.0166	n/a	13267.15	n/a	n/a	n/a	n/a
<b>M3/HR</b>	7.719056	n/a	5528.289	n/a	n/a	n/a	n/a
<b>Vapor Std Vol Flow : M3/HR</b>	223.1068	n/a	3615.966	n/a	n/a	n/a	n/a
<b>Molecular Weight</b>	18.98919	n/a	82.23798	n/a	n/a	n/a	n/a
<b>Z (from K)</b>	0.965605	n/a	0.981404	n/a	n/a	n/a	n/a
<b>Enthalpy : KCAL/KG</b>	102.4955	0	152.5079	0	0	0	0
<b>Cp : KCAL/KG-K</b>	0.574427	n/a	0.377169	n/a	n/a	n/a	n/a
<b>Density : KG/M3</b>	24.48701	n/a	2.399865	n/a	n/a	n/a	n/a
<b>Th. Conductivity : Kcal/HR-M-C</b>	0.041207	n/a	0.0188	n/a	n/a	n/a	n/a
<b>Viscosity : cP</b>	0.012826	n/a	0.010494	n/a	n/a	n/a	n/a
<b>Liquid</b>							
<b>Rate : KG-MOL/HR</b>	n/a	161.3263	n/a	119.5524	41.77385	40.42879	1.345056
<b>KG/HR</b>	n/a	13267.15	n/a	9338.696	3928.452	3723.533	204.9186
<b>M3/HR</b>	n/a	24.98074	n/a	11.39836	4.9568	4.739683	0.236758
<b>Liquid Std Vol Flow : M3/HR</b>	n/a	15.04785	n/a	10.58463	4.463213	4.264032	0.199181
<b>Molecular Weight</b>	n/a	82.23798	n/a	78.11382	94.04093	92.10102	152.3495
<b>Z (from K)</b>	n/a	0.177295	n/a	0.003626	0.004236	0.004214	0.004418
<b>Enthalpy : KCAL/KG</b>	n/a	152.5079	n/a	33.87914	47.71912	47.19351	106.0847
<b>Cp : KCAL/KG-K</b>	n/a	1.131455	n/a	0.437109	0.475345	0.477805	0.514868
<b>Density : KG/M3</b>	n/a	531.095	n/a	819.3016	792.5378	785.608	865.5206
<b>Surface Tension : DYNE/CM</b>	n/a	0.937491	n/a	21.23056	18.45507	18.17089	18.8548
<b>Th. Conductivity: KCAL/HR-M-C</b>	n/a	0.087696	n/a	0.109118	0.097259	0.096805	0.099035
<b>Viscosity : cP</b>	n/a	0.060902	n/a	0.318267	0.246998	0.238542	0.284646

Table B3. Stream summary of toluene hydrodealkylation flowsheet (cont'd)

Stream Name	Hydrogen	Toluene	S11	S12	S13	S14	S15
Stream Description							
Phase	Vapor	Liquid	Liquid	Vapor	Vapor	Vapor	Mixed
Total Stream							
Rate : KG-MOL/HR	226.1247	123.831	164.2598	1832.89	164.2598	164.2598	1997.15
KG/HR	548.2234	11409.85	15133.39	16868.13	15133.39	15133.39	32001.52
Std. Liq. Rate : M3/HR	6.624264	13.06653	17.33056	75.23768	17.33056	17.33056	92.56823
Temperature : K	303.15	303.15	324.5059	299.9317	450	591.1362	399.0196
Pressure : ATM	39.12645	1	1	38	1	38	38
Molecular Weight	2.42443	92.14052	92.1308	9.203027	92.1308	92.1308	16.0236
Enthalpy : M*KCAL/HR	0.032721	0.137928	0.313655	0.90741	2.422614	3.044523	3.951933
KCAL/KG	59.68537	12.0885	20.726	53.79433	160.0841	201.1792	123.492
Mole Fraction Liquid	0	1	1	0	0	0	0.036828
Reduced Temperature	8.025423	0.512251	0.548356	2.666972	0.760418	0.998912	2.627133
Reduced Pressure	2.81427	0.024677	0.024674	1.310779	0.024674	0.937606	1.269231
Acentric Factor	-0.20937	0.262122	0.262085	-0.10275	0.262085	0.262085	-0.07274
UOP K factor	41.74393	10.11354	10.1133	22.23481	10.1133	10.1133	16.5026
Std. Liquid Density : KG/M3	82.75991	873.2123	873.2197	224.198	873.2197	873.2197	345.7074
Sp. Gravity	0.082842	0.874074	0.874082	0.224419	0.874082	0.874082	0.346049
API Gravity	1576.579	30.38557	30.3842	499.0163	30.3842	30.3842	277.4021
Vapor							
Rate : KG-MOL/HR	226.1247	n/a	n/a	1832.89	164.2598	164.2598	1923.599
KG/HR	548.2234	n/a	n/a	16868.13	15133.39	15133.39	25515.46
M3/HR	146.6703	n/a	n/a	1180.645	5943.492	106.7559	1659.38
Vapor Std Vol Flow : M3/HR	5068.356	n/a	n/a	41082.38	3681.718	3681.718	43115.53
Molecular Weight	2.42443	n/a	n/a	9.203027	92.1308	92.1308	13.26444
Z (from K)	1.020209	n/a	n/a	0.994549	0.979896	0.509142	1.001158
Enthalpy : KCAL/KG	59.68537	n/a	n/a	53.79433	160.0841	201.1792	140.6593
Cp : KCAL/KG-K	2.88429	n/a	n/a	0.879703	0.40825	0.958362	0.747315
Density : KG/M3	3.737794	n/a	n/a	14.28722	2.546211	141.7569	15.3765
Th. Conductivity : KCAL/HR-M-C	0.148037	n/a	n/a	0.071378	0.02188	0.035552	0.084579
Viscosity : cP	0.009191	n/a	n/a	0.010589	0.010377	0.013192	0.012669
Liquid							
Rate : KG-MOL/HR	n/a	123.831	164.2598	n/a	n/a	n/a	73.55107
KG/HR	n/a	11409.85	15133.39	n/a	n/a	n/a	6486.061
M3/HR	n/a	13.25335	17.96706	n/a	n/a	n/a	8.565394
Liquid Std Vol Flow : M3/HR	n/a	13.06653	17.33056	n/a	n/a	n/a	7.536906
Molecular Weight	n/a	92.14052	92.1308	n/a	n/a	n/a	88.18444
Z (from K)	n/a	0.004875	0.004649	n/a	n/a	n/a	0.152116
Enthalpy : KCAL/KG	n/a	12.0885	20.726	n/a	n/a	n/a	55.95795
Cp : KCAL/KG-K	n/a	0.393499	0.415387	n/a	n/a	n/a	0.495791
Density : KG/M3	n/a	860.9036	842.285	n/a	n/a	n/a	757.2401
Surface Tension : DYNE/CM	n/a	27.33304	24.83731	n/a	n/a	n/a	15.75414
Th. Conductivity : KCAL/HR-M-C	n/a	0.113368	0.108984	n/a	n/a	n/a	0.09359
Viscosity : CP	n/a	0.518273	0.419823	n/a	n/a	n/a	0.176552

**Table B4.** Stream summary of toluene hydrodealkylation flowsheet with utilities system for mass and energy balance

Stream Name	S1	S2	S3	S4	S5	S6	Purge
Stream Description							
Phase	Vapor	Vapor	Mixed	Vapor	Liquid	Vapor	Vapor
Temperature : K	894.11	894.11	300	300	300	300	300
Pressure : ATM	38	38	38	38	38	38	38
Enthalpy : M*KCAL/HR	17.72779	17.47126	1.168704	0.993965	0.174739	0.874689	0.119276
Molecular Weight	16.02359	16.02359	16.02359	10.157	78.5623	10.157	10.157
Mole Fraction Vapor	1	1	0.914238	1	0	1	1
Mole Fraction Liquid	0	0	0.085762	0	1	0	0
Rate : KG-MOL/HR	1997.15	1997.15	1997.15	1825.87	171.2802	1606.765	219.1043
Fluid Rates : KG-MOL/HR							
BENZENE	6.841109	127.8621	127.8621	7.638055	120.224	6.721488	0.916567
TOLUENE	164.8405	41.21013	41.21013	0.797355	40.41277	0.701673	0.095683
H <sub>2</sub>	927.2976	804.9719	804.9719	804.2715	0.700432	707.7589	96.51257
BIPHENYL	0.001352	1.306067	1.306067	5.20E-05	1.306015	4.57E-05	6.23E-06
METHANE	898.1691	1021.8	1021.8	1013.163	8.636936	891.5831	121.5795

**Table B5.** Stream summary of toluene hydrodealkylation flowsheet with utilities system for mass and energy balance (cont'd)

Stream Name	Methane	S7	S8	Benzene	S9	S10	Biphenyl
Stream Description							
Phase	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Liquid
Temperature : K	371.9092	554.1918	425.5198	352.2523	384.9259	383.7963	508.6046
Pressure : ATM	38	38	1	1	1	1	1
Enthalpy : M*KCAL/HR	0.019373	2.023345	2.023345	0.316387	0.187462	0.175727	0.021739
Molecular Weight	18.98919	82.23798	82.23798	78.11382	94.04093	92.10102	152.3495
Mole Fraction Vapor	1	0	1	0	0	0	0
Mole Fraction Liquid	0	1	0	1	1	1	1
Rate : KG-MOL/HR	9.953906	161.3263	161.3263	119.5524	41.77385	40.42879	1.345056
Fluid Rates : KG-MOL/HR							
BENZENE	0.601118	119.6229	119.6229	119.5033	0.119621	0.119621	2.95E-08
TOLUENE	0.024175	40.3886	40.3886	0.040388	40.34822	40.30787	0.040348
H <sub>2</sub>	0.700311	0.000121	0.000121	0.000121	0	0	0
BIPHENYL	5.48E-08	1.306015	1.306015	1.72E-23	1.306015	0.001306	1.304709
METHANE	8.628303	0.008635	0.008635	0.008635	0	0	0

**Table B6.** Stream summary of toluene hydrodealkylation flowsheet with utilities system for mass and energy balance (cont'd)

C	Hydrogen	Toluene	S11	S12	S13	S14	S15
Stream Description							
Phase	Vapor	Liquid	Liquid	Vapor	Vapor	Vapor	Mixed
Temperature : K	303.15	303.15	324.5059	299.9317	450	591.1362	399.0196
Pressure : ATM	39.12645	1	1	38	1	38	38
Enthalpy : M*KCAL/HR	0.032721	0.137928	0.313655	0.90741	2.422614	3.044523	3.951933
Molecular Weight	2.42443	92.14052	92.1308	9.203027	92.1308	92.1308	16.0236
Mole Fraction Vapor	1	0	0	1	1	1	0.963172
Mole Fraction Liquid	0	1	1	0	0	0	0.036828
Rate : KG-MOL/HR	226.1247	123.831	164.2598	1832.89	164.2598	164.2598	1997.15
Fluid Rates : KG-MOL/HR							
BENZENE	0	0	0.119621	6.721488	0.119621	0.119621	6.841109
TOLUENE	0	123.831	164.1389	0.701673	164.1389	164.1389	164.8405
H <sub>2</sub>	219.5385	0	0	927.2974	0	0	927.2975
BIPHENYL	0	0	0.001306	4.57E-05	0.001306	0.001306	0.001352
METHANE	6.586156	0	0	898.1693	0	0	898.1693