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APPENDICES

Appendix A Calculations

A.1 Polymer crystallinity

The heat of fusion (ΔH_f) can be converted to the percentage of crystallinity by using the following equation;

$$X\% = 100 \times \frac{\Delta H_f}{\Delta H_f^o}$$

where $X\%$ is the percentage of crystallinity

ΔH_f is the heat of fusion from DSC thermogram

ΔH_f^o is the hypothetical heat of fusion of a perfectly crystalline material

$\cong 290 \text{ J/g}$ (Immergut, 1989)

A.2 Weigh average of standard refinery gas

$$\overline{MW} = \frac{\sum G_i \times (MW)_i}{\sum G_i}$$

From $PV_i = n_i RT$ and $n_i = \frac{G_i}{(MW)_i}$

Thus, $PV_i = \frac{G_i}{(MW)_i} RT$

$$G_i = V_i (MW)_i \times \frac{P}{RT}$$

Hence, $\sum G_i \times (MW)_i = \frac{V_i (MW)_i}{\sum V_i (MW)_i}$

A.3 Response factor (Schomberg, 1990)

Response factors for FID (Flame Ionization Detector) were calculated on the weight basis as shown in the following equation using methane as the standard component.

$$f_i = \frac{A_{std}}{A_i} \times \frac{G_i}{G_{std}} \times f_{std}$$

where f_i is the response factor of the component

f_{std} is the response factor of the standard

A_i is the area of component

A_{std} is the area of the standard

G_i is the mass of the component

G_{std} is the mass of the standard, which is methane in this case

$$\text{From } G_i = V_i(MW)_i \times \frac{P}{RT}$$

$$\text{So, } \frac{G_i}{G_{std}} = \frac{V_i(MW)_i}{V_{std}(MW)_{std}}$$

The mass fraction (m_i) of any component, m_i can be calculated as the following equation

$$m_i = \frac{A_i \times f_i}{\sum A_i \times f_i}$$

$$\text{Thus, } m_i = \frac{A_i \left[\frac{A_{std}}{A_i} \times \frac{G_i}{G_{std}} \times f_{std} \right]}{\sum A_i \left[\frac{A_{std}}{A_i} \times \frac{G_i}{G_{std}} \times f_{std} \right]}$$

Therefore,

$$m_i = \frac{G_i}{\sum G_i}$$

Volume fraction (V)

From $V = \frac{V_i}{\sum V_i}$ and

$$PV_i = \frac{G_i}{(MW)_i} RT$$

$$V_i = \frac{G_i}{(MW)_i} \times \frac{RT}{P}$$

Hence,
$$V = \frac{\frac{G_i}{(MW)_i} \times \frac{RT}{P}}{\sum \frac{G_i}{(MW)_i} \times \frac{RT}{P}}$$

From $m_i = \frac{G_i}{\sum G_i}$

So,

$$V = \frac{\frac{m_i}{(MW)_i}}{\sum \frac{m_i}{(MW)_i}}$$

Appendix B Raw Data

B.1 Mechanical and rheological properties of PP films

Table B1 Tensile strength of PP films.

No.	Tensile Strength (MPa)				
	COPP	CR1PP	CR2PP	CR3PP	CR4PP
1	33.76	31.45	36.65	30.59	32.20
2	32.46	30.57	36.15	31.78	34.45
3.	33.54	32.20	35.15	34.06	34.76
4	32.04	30.28	36.14	33.19	33.30
5	32.30	30.75	35.95	32.56	33.11
6	33.29	32.51	35.52	33.90	34.26
7	-	32.92	36.39	35.13	32.23
8	-	29.45	33.67	38.32	32.91
9	-	30.43	34.53	34.48	33.70
10	-	-	36.11	3.29	32.87
11	-	-	32.39	31.69	33.57
Avg	32.90	31.17	35.33	33.55	33.40
Std	0.722	1.163	1.317	2.074	0.851

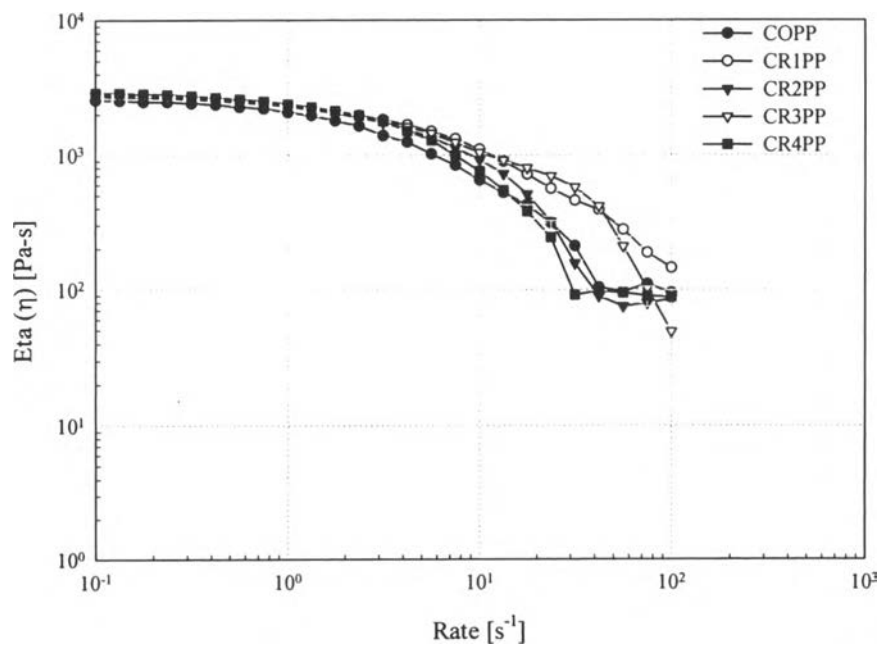


Figure B1 The plot of viscosity versus shear rates from 0.01 to 100 sec⁻¹.

Table B2 Low shear melt viscosity (η) as a function of shear rate

COPP	Viscosity (η) [Pa-s]			CRIPP	Viscosity (η) [Pa-s]		
	Rate [s^{-1}]	1	2		Average	Rate [s^{-1}]	1
0.1000	2576.4600	2542.8400	2559.6500	0.1000	2733.9400	2714.0300	2723.9850
0.1334	2555.0500	2522.7700	2538.9100	0.1334	2723.2400	2692.0700	2707.6550
0.1778	2566.8000	2405.6100	2486.2050	0.1778	2712.4900	2644.1400	2678.3150
0.2371	2538.0400	2423.8200	2480.9300	0.2371	2665.7500	2637.5300	2651.6400
0.3162	2475.3100	2374.7800	2425.0450	0.3162	2642.8500	2556.8200	2599.8350
0.4217	2444.3600	2308.9100	2376.6350	0.4217	2586.8900	2511.2000	2549.0450
0.5623	2324.6500	2231.7600	2278.2050	0.5623	2504.3800	2431.3500	2467.8650
0.7499	2270.6000	2159.8700	2215.2350	0.7499	2440.2600	2364.1800	2402.2200
1.0000	2101.3800	2045.7000	2073.5400	1.0000	2343.7800	2261.1300	2302.4550
1.3335	2001.0500	1936.9400	1968.9950	1.3335	2246.0400	2165.3400	2205.6900
1.7783	1809.7000	1786.0200	1797.8600	1.7783	2136.4000	2047.3500	2091.8750
2.3714	1634.8100	1650.1400	1642.4750	2.3714	2013.5600	1925.6500	1969.6050
3.1623	1425.9600	1355.8500	1390.9050	3.1623	1879.8700	1779.3000	1829.5850
4.2170	1266.3300	1225.4400	1245.8850	4.2170	1729.3200	1615.9400	1672.6300
5.6234	999.4650	1037.3900	1018.4275	5.6234	1555.8500	1441.0700	1498.4600
7.4990	823.0340	852.1220	837.5780	7.4990	1363.4600	1270.2500	1316.8550
10.0000	608.2250	689.0020	648.6135	10.0000	1159.7100	1043.6700	1101.6900
13.3352	496.3410	551.6120	523.9765	13.3352	923.3520	871.9140	897.6330
17.7828	402.3880	447.2190	424.8035	17.7828	711.6080	722.5060	717.0570
23.7138	284.7350	337.4300	311.0825	23.7138	543.6300	580.0170	561.8235
31.6228	178.3430	242.7050	210.5240	31.6228	418.3060	499.4720	458.8890
42.1697	51.7848	155.3800	103.5824	42.1697	341.0980	438.2340	389.6660
56.2342	55.3977	137.8560	96.6269	56.2342	254.6120	301.7810	278.1965
74.9895	60.2242	159.5300	109.8771	74.9895	174.1860	200.1570	187.1715
100.0000	66.1748	123.4330	94.8039	100.0000	168.9200	120.6310	144.7755

CR2PP	Viscosity (η) [Pa-s]		
	Rate [s^{-1}]	1	2
0.1000	2867.6700	2708.9700	2788.3200
0.1334	2836.8500	2663.5500	2750.2000
0.1778	2863.0000	2672.4500	2767.7250
0.2371	2760.1000	2615.1600	2687.6300
0.3162	2725.1700	2573.5000	2649.3350
0.4217	2659.8700	2493.5100	2576.6900
0.5623	2589.0500	2422.0200	2505.5350
0.7499	2480.7700	2333.1600	2406.9650
1.0000	2375.9100	2224.4800	2300.1950
1.3335	2248.1400	2117.7500	2182.9450
1.7783	2122.7700	1981.9600	2052.3650
2.3714	1961.2600	1847.3800	1904.3200
3.1623	1796.4600	1690.3700	1743.4150
4.2170	1567.0700	1510.6500	1538.8600
5.6234	1369.0900	1318.3700	1343.7300
7.4990	1160.9200	1098.7800	1129.8500
10.0000	949.1670	890.7440	919.9555
13.3352	757.5090	693.1580	725.3335
17.7828	502.6730	516.4790	509.5760
23.7138	313.3550	323.9350	318.6450
31.6228	161.2280	151.6930	156.4605
42.1697	87.8933	90.4189	89.1561
56.2342	82.2119	67.8863	75.0491
74.9895	78.9846	79.9866	79.4856
100.0000	81.5907	88.6547	85.1227

CR3PP	Viscosity (η) [Pa-s]		
	Rate [s^{-1}]	1	2
0.1000	2814.9900	2770.0300	2792.5100
0.1334	2785.1400	2709.2900	2747.2150
0.1778	2769.4600	2715.3500	2742.4050
0.2371	2696.7900	2653.3900	2675.0900
0.3162	2653.9200	2604.8200	2629.3700
0.4217	2601.2500	2555.1500	2578.2000
0.5623	2516.7400	2462.5600	2489.6500
0.7499	2429.8200	2374.8400	2402.3300
1.0000	2326.2700	2277.5200	2301.8950
1.3335	2217.8800	2158.2800	2188.0800
1.7783	2098.2500	2039.6100	2068.9300
2.3714	1966.4600	1891.3300	1928.8950
3.1623	1826.3700	1772.3000	1799.3350
4.2170	1656.5000	1595.1500	1625.8250
5.6234	1468.8600	1423.7300	1446.2950
7.4990	1247.5200	1227.2800	1237.4000
10.0000	1025.0700	1054.5400	1039.8050
13.3352	884.5220	943.9790	914.2505
17.7828	790.4270	811.9790	801.2030
23.7138	690.2270	699.9640	695.0955
31.6228	591.9280	558.1470	575.0375
42.1697	478.4440	351.9200	415.1820
56.2342	221.5610	196.1710	208.8660
74.9895	101.0910	101.4450	101.2680
100.0000	51.3652	46.3292	48.8472

CR4PP	Viscosity (η) [Pa-s]		
	1	2	Average
0.1000	2961.6500	2830.3900	2896.0200
0.1334	2967.1900	2794.2700	2880.7300
0.1778	2911.2400	2790.0600	2850.6500
0.2371	2908.0500	2718.8500	2813.4500
0.3162	2832.1600	2658.5700	2745.3650
0.4217	2756.8600	2607.3600	2682.1100
0.5623	2676.4300	2528.6700	2602.5500
0.7499	2584.1000	2432.2600	2508.1800
1.0000	2465.5800	2325.7300	2395.6550
1.3335	2340.9700	2201.4300	2271.2000
1.7783	2184.8600	2075.3400	2130.1000
2.3714	2022.1900	1913.4900	1967.8400
3.1623	1806.8900	1756.4200	1781.6550
4.2170	1552.8200	1461.1400	1506.9800
5.6234	1310.4500	1262.6600	1286.5550
7.4990	1009.2100	971.1040	990.1570
10.0000	768.8020	741.8200	755.3110
13.3352	564.6050	527.3950	546.0000
17.7828	411.8630	347.7110	379.7870
23.7138	299.6500	187.0430	243.3465
31.6228	87.6037	94.6430	91.1234
42.1697	97.9126	97.9138	97.9132
56.2342	102.3340	86.5734	94.4537
74.9895	100.4000	79.0510	89.7255
100.0000	95.5287	80.6274	88.0781

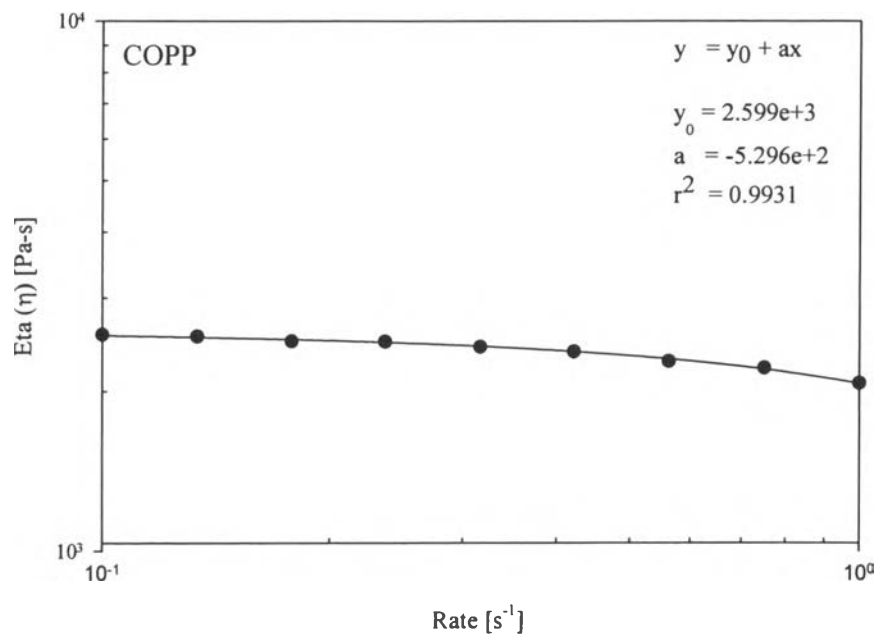


Figure B2 The plot of viscosity versus shear rates from 0.01 to 1 sec^{-1} of virgin PP film (COPP) with an equation of a fitted curve.

	Equation	R^2	η (rate = 10^{-2})
COPP	$y = 2599 - 529.6x$	0.9931	2593.704
CR1PP	$y = 2761 - 476.6x$	0.9917	2756.234
CR2PP	$y = 2831 - 552.8x$	0.9877	2825.472
CR3PP	$y = 2819 - 544.1x$	0.9858	2813.559
CR4PP	$y = 2943 - 571.0x$	0.9916	2937.290

B.2 Thermal properties of PP films

Table B3 Melting temperature and percentage of crystallinity of PP film

	T_m ($^{\circ}C$)	ΔH_f (J/g)	% Crystallinity
COPP	165.166	85.152	29.363
CR1PP	164.666	86.242	29.739
CR2PP	165.333	86.938	29.979
CR3PP	165.166	87.994	30.343
CR4PP	163.666	89.007	30.692

B.3 Gas chromatography calibration

Table B4 Standard refinery gas mixture

% Volume	Gas
15	hydrogen
15	nitrogen
5	carbon dioxide
5	carbon monoxide
5	methane
1	ethylene
10	ethane
1	propylene
5	propane
10	iso-butane
5	n-butane
10	1-butene
5	trans-2-butene
5	cis-2-butene
1	n-Pentane
2	iso-pentane

Table B5 Standard liquid mixture

% Volume	% Assay	Density	Liquid
2.5	99.00	0.6260	n-pentane
2.5	99.00	0.6590	n-hexane
2.5	99.70	0.6840	n-heptane
2.5	99.85	0.6919	iso-octane

Table B6 Normalization composition and molecular weight of standard refinery gas that can be detected by FID

% Normalized volume	Gas	MW	Gi	\overline{MW}
8.33	methane	16.043	0.02782	-
1.67	ethylene	28.0542	0.00975	-
16.67	ethane	30.0701	0.10436	-
1.67	propylene	42.0813	0.01463	-
8.33	propane	44.0972	0.07647	-
16.67	iso-butane	58.1243	0.20172	56.9899
8.33	n-butane	58.1243	0.10080	
16.67	1-butene	56.1084	0.19472	
8.33	trans-2-butene	56.1084	0.09730	
8.33	cis-2-butene	56.1084	0.09730	
1.67	n-pentane	72.1514	0.02509	72.1514
3.33	iso-pentane	72.1514	0.05002	

Table B7 Normalization composition of standard liquid mixture

% Normalized volume	Liquid
24.75	n-pentane
24.75	n-hexane
24.93	n-heptane
24.96	iso-octane

Table B8 GC calibration of standard refinery gas

$$f_{\text{std}} = 1.00000$$

$$G_{\text{std}} = 133.63844$$

No.	Gas	A _i	G _i	f _i
1	methane	2534.80762	133.63844	1.00000
	ethylene	938.52789	46.85048	0.94685
	ethane	9408.39551	501.26890	1.01058
	propylene	1367.15015	70.27572	0.97500
	propane	7037.36670	367.32976	0.99006
	C ₄	64150.20000	3324.21814	0.98289
	C ₅	6978.22314	360.75695	0.98058
2	methane	3044.79272	133.63844	1.00000
	ethylene	1127.59814	46.85048	0.94664
	ethane	11305.60000	501.26890	1.01019
	propylene	1643.56897	70.27572	0.97419
	propane	8455.52148	367.32976	0.98979
	C ₄	77043.20000	3324.21814	0.98306
	C ₅	8350.40918	360.75695	0.98431
3	methane	2639.10034	133.63844	1.00000
	ethylene	977.14130	46.85048	0.94685
	ethane	9802.079100	501.2689	1.00990
	propylene	1424.68665	70.27572	0.97412
	propane	7326.83057	367.32976	0.99007
	C ₄	66788.40000	3324.21814	0.98291
	C ₅	7240.13037	360.75695	0.98399
4	methane	1669.47742	133.63844	1.00000
	ethylene	616.98907	46.85048	0.94861
	ethane	6198.93506	501.26890	1.01019
	propylene	900.68207	70.27572	0.97473
	propane	4636.31494	367.32976	0.98977
	C ₄	42267.00000	3324.21814	0.98251
	C ₅	4579.24023	360.75695	0.98417
5	methane	3401.62866	133.63844	1.00000
	ethylene	1260.78638	46.85048	0.94586
	ethane	12629.90000	501.26890	1.01024
	propylene	1836.68420	70.27572	0.97393
	propane	9444.68652	367.32976	0.98997
	C ₄	86087.20000	3324.21814	0.98289
	C ₅	9332.23730	360.75695	0.98398

6	methane	3509.58398	133.63844	1.00000
	ethylene	1299.26294	46.85048	0.94698
	ethane	13015.90000	501.26890	1.01139
	propylene	1891.21228	70.27572	0.97586
	propane	9732.12598	367.32976	0.99123
	C ₄	88710.70000	3324.21814	0.98410
	C ₅	9610.22656	360.75695	0.98584
7	methane	4271.41553	133.63844	1.00000
	ethylene	1582.31653	46.85048	0.94637
	ethane	15847.40000	501.26890	1.01100
	propylene	2305.71704	70.27572	0.97418
	propane	11867.60000	367.32976	0.98931
	C ₄	108025.00000	3324.21814	0.98357
	C ₅	11705.60000	360.75695	0.98506
8	methane	1955.63562	133.63844	1.00000
	ethylene	722.90826	46.85048	0.94839
	ethane	7261.38965	501.26890	1.01020
	propylene	1055.85986	70.27572	0.97399
	propane	5425.79248	367.32976	0.99072
	C ₄	49532.90000	3324.21814	0.98209
	C ₅	5370.14844	360.75695	0.98307
9	methane	2334.90796	133.63844	1.00000
	ethylene	863.35187	46.85048	0.94812
	ethane	8661.98633	501.26890	1.01109
	propylene	1259.66797	70.27572	0.97474
	propane	6477.30762	367.32976	0.99083
	C ₄	59082.90000	3324.21814	0.98303
	C ₅	6407.53906	360.75695	0.98370
10	methane	1586.39600	133.63844	1.00000
	ethylene	584.31897	46.85048	0.95180
	ethane	5868.78613	30.07012	1.01392
	propylene	851.95776	42.08127	0.97919
	propane	4376.33594	367.32976	0.99638
	C ₄	39892.40000	3324.21814	0.98919
	C ₅	4312.21582	360.75695	0.99310

Table B9 GC calibration of standard liquid mixture using pentane as the standard component

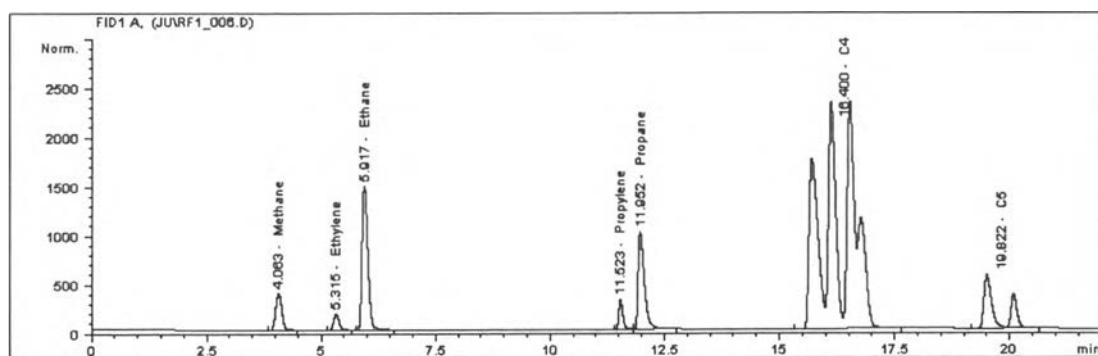
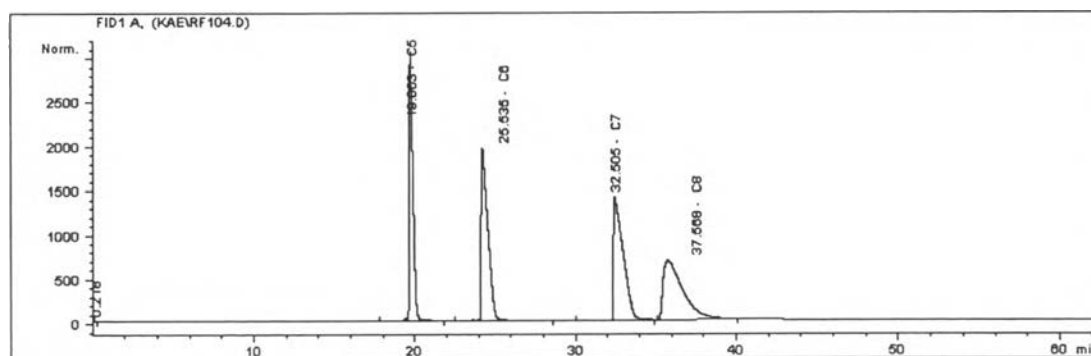
$$f_{\text{std}} = 0.98411$$

$$G_{\text{std}} = 15.49350$$

No.	Liquid	A_i	G_i	f_i
1	C ₅	45306.20000	15.49350	0.98411
	C ₆	49823.00000	16.31025	0.94207
	C ₇	54036.30000	17.04870	0.90794
	C ₈	51225.30000	17.27155	0.97028
2	C ₅	45374.50000	15.49350	0.98411
	C ₆	50004.60000	16.31025	0.94006
	C ₇	53982.00000	17.04870	0.91022
	C ₈	50879.50000	17.27155	0.97835
3	C ₅	45701.40000	15.49350	0.98411
	C ₆	50062.00000	16.31025	0.94575
	C ₇	52741.50000	17.04870	0.93834
	C ₈	51112.90000	17.27155	0.98090
4	C ₅	49069.30000	15.49350	0.98411
	C ₆	54269.70000	16.31025	0.93671
	C ₇	57877.80000	17.04870	0.91809
	C ₈	56170.00000	17.27155	0.95837
5	C ₅	43738.60000	15.49350	0.98411
	C ₆	48590.60000	16.31025	0.93254
	C ₇	51728.90000	17.04870	0.91562
	C ₈	50204.60000	17.27155	0.95576

Table B10 Response factors

	f_i	Std
Methane	1.00000	0.00000
Ethylene	0.94654	0.00217
Ethane	1.00996	0.00247
Propylene	0.97351	0.00324
Propane	0.98920	0.00390
C ₄	0.98242	0.00397
C ₅	0.98411	0.00472
C ₆	0.93943	0.00452

**Figure B3** Chromatogram of standard refinery gas calibration.**Figure B4** Chromatogram of standard liquid mixture.

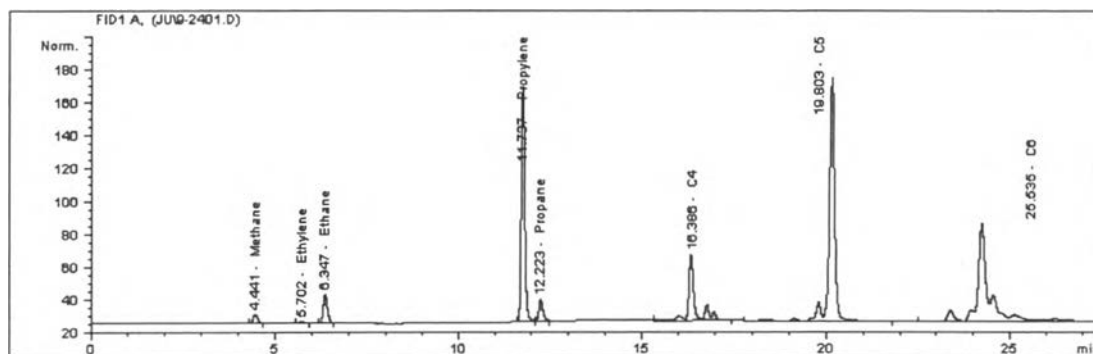


Figure B5 An example of Chromatogram of pyrolysed gas (from commercial PP film with 4% sulfate of sulfated zirconia at C/P ratio = 0.17).

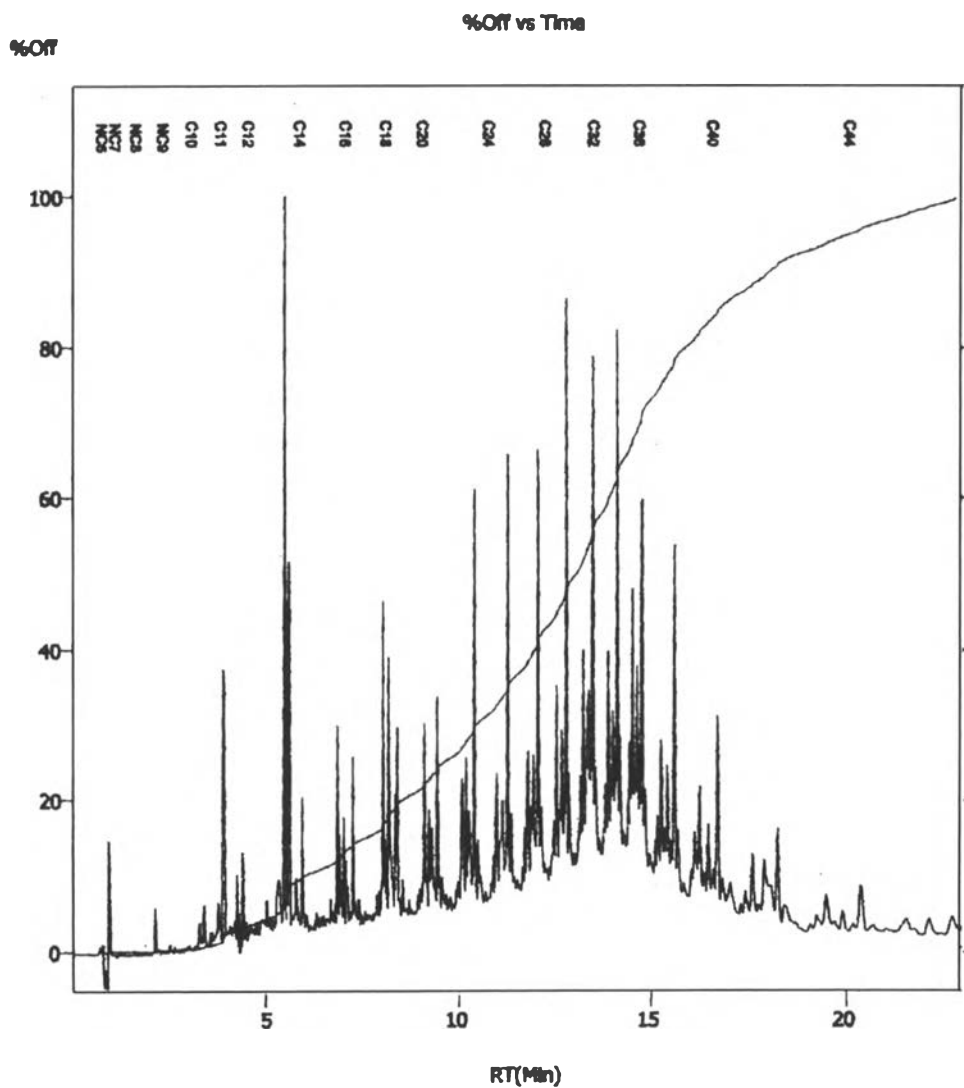


Figure B6 An example of Chromatogram of pyrolysed liquid (from commercial PP film with 4% sulfate of sulfated zirconia at C/P ratio = 0.17).

Table B11 ASTM Method D2887 Column Test Mixture

Component	Carbon number	% by Weight	Boiling Point (°C)
n-hexane	6	6.0	68.9
n-heptane	7	6.0	97.8
n-octane	8	8.0	126.1
n-nonane	9	8.0	151.1
n-decane	10	12.0	173.9
n-undecane	11	12.0	196.1
n-dodecane	12	12.0	216.1
n-tetradecane	14	12.0	253.9
n-hexadecane	16	10.0	287.2
n-octadecane	18	5.0	316.1
n-eicosane	20	2.0	343.9
n-tetracosane	24	2.0	391.1
n-octacosane	28	1.0	431.1
n-dotriacontane	32	1.0	466.1
n-hexatriacontane	36	1.0	496.1
n-tetracontane	40	1.0	522.2
n-tetratetracontane	44	1.0	545

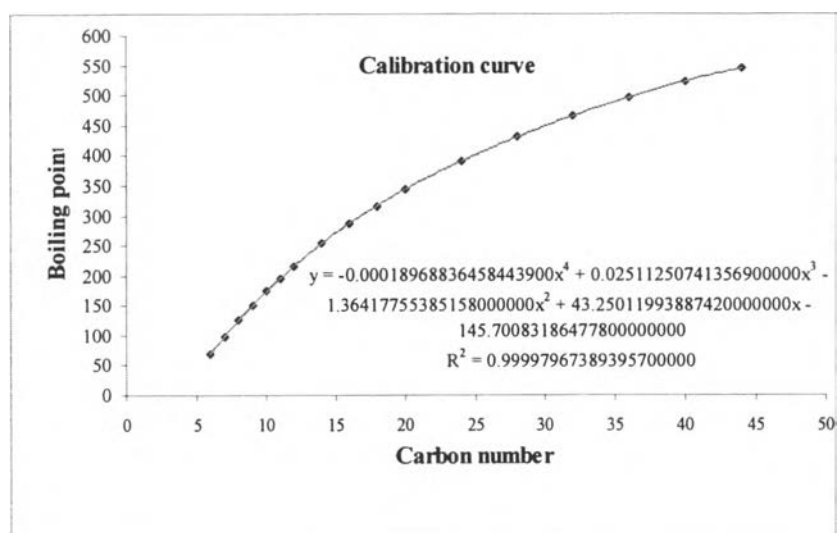
**Figure B7** GC calibration curve of ASTM Method D2887 Column Test Mixture with the equation of fitted curve.

Table B12 Boiling point of hydrocarbons (C_6 to C_{49}) using the equation in Figure B7

Carbon number	Boiling point (°C)	Carbon number	Boiling point (°C)
6	69.9	28	430.5
7	98.4	29	439.6
8	125.1	30	448.4
9	150.1	31	457.0
10	173.6	32	465.4
11	195.6	33	473.5
12	216.3	34	481.3
13	235.8	35	489.0
14	254.0	36	496.4
15	271.3	37	503.5
16	287.5	38	510.4
17	302.8	39	517.0
18	317.4	40	523.2
19	331.1	41	529.1
20	344.2	42	534.7
21	356.6	43	539.8
22	368.5	44	544.5
23	379.9	45	548.6
24	390.8	46	552.2
25	401.2	47	555.2
26	411.3	48	557.5
27	421.0	49	559.1

B.4 Effect of film reprocessing on pyrolysed products

Table B13 Pyrolysed product yield of PP film

Product (%wt)	VPP	COPP	CR1PP	CR2PP	CR3PP	CR4PP
Residue	0.00	0.00	0.00	0.00	0.00	0.93
Gas	36.66	36.78	48.08	42.62	34.14	34.15
Liquid	63.34	63.22	51.92	57.38	65.86	64.92

Table B14 Pyrolysed gas products of PP films

	% Mass					
	VPP	COPP	CR1PP	CR2PP	CR3PP	CR4PP
Methane	1.148	1.432	1.387	1.245	1.353	1.531
Ethylene	0.1744	0.1950	0.1872	0.1719	0.1699	0.3246
Ethane	3.695	4.447	4.238	3.825	4.177	4.817
Propylene	26.02	31.34	30.40	27.50	29.80	32.50
Propane	1.779	2.199	2.111	1.888	2.116	2.257
C ₄	6.922	7.907	7.866	7.328	8.113	7.470
C ₅	33.86	32.92	33.91	35.43	34.77	31.98
C ₆	26.41	19.56	19.91	22.62	19.50	19.11

	% Volume					
	VPP	COPP	CR1PP	CR2PP	CR3PP	CR4PP
Methane	4.074	4.798	4.689	4.339	4.593	5.059
Ethylene	0.3538	0.3735	0.3620	0.3425	0.3298	0.6132
Ethane	6.997	7.948	7.646	7.108	7.565	8.489
Propylene	35.20	40.03	39.19	36.53	38.57	40.93
Propane	2.297	2.680	2.597	2.393	2.613	2.713
C ₄	6.915	7.456	7.488	7.187	7.754	6.947
C ₅	26.72	24.52	25.50	27.44	26.25	23.49
C ₆	17.45	12.20	12.53	14.67	12.32	11.76

Table B15 % Accumulation and boiling point of pyrolysed liquid product of virgin PP pellets, reprocessed and virgin PP films

VPP

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	134.6	34	350.7	68	473.1
1	134.8	35	362.5	69	475.7
2	135.2	36	366.1	70	476.0
3	150.9	37	370.1	71	477.2
4	176.6	38	373.9	72	480.3
5	190.5	39	374.4	73	484.7
6	191.2	40	380.1	74	486.6
7	192.0	41	389.5	75	491.1
8	205.2	42	392.6	76	491.9
9	215.0	43	397.7	77	492.5
10	232.4	44	398.1	78	494.3
11	235.9	45	400.5	79	498.8
12	236.3	46	408.8	80	500.6
13	236.8	47	412.4	81	503.1
14	237.9	48	416.1	82	505.2
15	239.0	49	419.6	83	505.6
16	239.4	50	420.0	84	508.4
17	244.3	51	421.7	85	513.2
18	249.6	52	426.5	86	516.0
19	266.7	53	432.6	87	520.5
20	274.9	54	435.0	88	521.1
21	278.9	55	439.6	89	523.5
22	285.7	56	440.2	90	526.7
23	290.0	57	440.6	91	528.8
24	304.8	58	442.9	92	531.4
25	308.0	59	449.6	93	532.6
26	311.5	60	452.4	94	537.0
27	312.7	61	455.3	95	540.0
28	317.2	62	458.7	96	545.1
29	318.6	63	459.1	97	546.5
30	331.6	64	459.7	98	551.8
31	338.5	65	462.2	99	557.1
32	343.2	66	468.1	100	559.3
33	347.6	67	470.2		

COPP

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	115.9	34	309.5	68	460.5
1	133.5	35	311.9	69	464.3
2	134.5	36	316.2	70	469.7
3	134.7	37	318.3	71	471.8
4	134.8	38	329.8	72	475.6
5	135.0	39	338.6	73	476.0
6	135.1	40	344.1	74	477.5
7	135.4	41	347.8	75	481.8
8	135.8	42	354.3	76	485.7
9	138.9	43	365.2	77	488.8
10	153.3	44	368.8	78	491.8
11	175.5	45	373.9	79	492.6
12	188.7	46	374.5	80	495.0
13	190.7	47	381.9	81	499.5
14	191.3	48	390.0	82	501.8
15	191.9	49	394.7	83	505.1
16	201.3	50	398.0	84	505.6
17	206.1	51	400.0	85	508.9
18	221.3	52	408.3	86	513.8
19	235.6	53	412.8	87	517.1
20	236.1	54	417.4	88	520.7
21	236.5	55	419.8	89	522.5
22	236.8	56	420.7	90	526.1
23	237.9	57	425.7	91	528.7
24	239.0	58	432.8	92	530.8
25	239.4	59	435.8	93	531.9
26	240.1	60	440.0	94	535.4
27	249.2	61	440.5	95	539.8
28	264.3	62	442.7	96	545.1
29	275.0	63	449.3	97	547.4
30	279.0	64	452.5	98	552.7
31	286.1	65	455.2	99	557.1
32	293.8	66	458.6	100	559.6
33	307.6	67	459.2		

CRIPP

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	63.5	34	247.6	68	447.8
1	65.7	35	253.6	69	452.4
2	114.6	36	274.1	70	455.7
3	132.3	37	276.7	71	458.8
4	134.4	38	283.6	72	459.5
5	134.5	39	290.3	73	461.8
6	134.6	40	307.3	74	468.4
7	134.7	41	309.4	75	471.1
8	134.9	42	311.9	76	475.6
9	135.0	43	316.6	77	476.1
10	135.1	44	319.1	78	477.8
11	135.2	45	335.1	79	483.5
12	135.4	46	340.8	80	486.0
13	135.6	47	347.4	81	489.8
14	135.8	48	349.4	82	491.9
15	136.0	49	362.6	83	493.5
16	141.8	50	367.6	84	497.5
17	153.1	51	372.6	85	500.7
18	172.8	52	374.3	86	504.5
19	185.9	53	378.6	87	505.5
20	190.6	54	389.6	88	508.7
21	191.2	55	393.7	89	514.3
22	191.8	56	397.9	90	520.1
23	199.6	57	399.7	91	521.5
24	205.8	58	408.4	92	525.9
25	219.4	59	413.0	93	529.1
26	234.2	60	418.5	94	531.5
27	235.9	61	419.9	95	534.4
28	236.4	62	421.9	96	539.8
29	236.7	63	429.3	97	545.3
30	237.8	64	433.5	98	549.2
31	238.9	65	439.1	99	556.1
32	239.2	66	440.3	100	558.9
33	239.7	67	442.0		

CR2PP

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	81.1	34	294.6	68	458.8
1	115.5	35	307.6	69	459.5
2	134.4	36	309.1	70	461.2
3	134.6	37	311.8	71	467.3
4	134.7	38	314.3	72	470.3
5	134.9	39	317.8	73	474.0
6	135.1	40	322.1	74	475.9
7	135.2	41	335.7	75	476.6
8	135.4	42	340.0	76	479.7
9	135.6	43	345.0	77	484.9
10	135.8	44	348.0	78	487.2
11	135.9	45	353.5	79	491.6
12	138.3	46	365.0	80	492.2
13	149.2	47	368.3	81	493.8
14	172.0	48	373.1	82	497.7
15	177.6	49	374.3	83	500.6
16	190.7	50	377.9	84	503.6
17	191.3	51	388.9	85	505.4
18	191.8	52	392.8	86	506.6
19	195.2	53	397.8	87	512.0
20	205.8	54	398.6	88	514.9
21	220.9	55	405.1	89	520.5
22	235.8	56	412.6	90	521.2
23	236.4	57	416.9	91	524.4
24	236.7	58	419.9	92	527.5
25	237.8	59	421.2	93	531.2
26	238.9	60	427.0	94	531.9
27	239.5	61	433.3	95	536.5
28	240.2	62	437.7	96	540.6
29	249.5	63	440.3	97	545.5
30	267.3	64	441.1	98	548.5
31	275.3	65	445.9	99	556.1
32	279.4	66	452.2	100	558.5
33	286.2	67	455.0		

CR3PP

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	113.9	34	304.8	68	446.2
1	128.1	35	308.0	69	452.1
2	134.4	36	310.9	70	454.7
3	134.6	37	311.9	71	458.5
4	134.7	38	315.1	72	459.2
5	134.9	39	317.7	73	460.7
6	135.0	40	322.0	74	466.0
7	135.1	41	335.0	75	470.1
8	135.5	42	338.8	76	473.5
9	135.9	43	343.2	77	475.9
10	139.3	44	347.6	78	476.7
11	158.7	45	349.4	79	480.8
12	176.3	46	358.8	80	485.7
13	190.4	47	365.4	81	489.1
14	191.1	48	368.5	82	491.9
15	191.8	49	372.9	83	493.4
16	201.2	50	374.2	84	497.5
17	207.4	51	376.7	85	500.8
18	223.4	52	385.0	86	505.0
19	235.7	53	390.3	87	505.5
20	236.3	54	394.4	88	509.4
21	236.6	55	397.9	89	514.3
22	236.9	56	398.6	90	519.4
23	237.9	57	404.4	91	521.2
24	239.0	58	412.1	92	525.2
25	239.4	59	415.2	93	528.6
26	240.0	60	419.6	94	531.3
27	248.8	61	420.0	95	533.0
28	258.0	62	422.4	96	538.9
29	273.4	63	430.3	97	544.9
30	276.1	64	433.6	98	548.0
31	279.3	65	438.7	99	555.2
32	286.0	66	440.2	100	558.4
33	290.3	67	441.5		

CR4PP

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	131.9	34	331.8	68	469.7
1	134.4	35	338.6	69	471.7
2	134.6	36	343.6	70	475.7
3	134.8	37	347.8	71	476.0
4	135.0	38	351.4	72	477.0
5	135.2	39	364.0	73	480.6
6	135.5	40	367.2	74	485.1
7	135.9	41	371.1	75	487.1
8	145.6	42	374.1	76	491.5
9	167.2	43	375.5	77	492.0
10	176.8	44	383.5	78	493.1
11	190.5	45	390.1	79	495.5
12	191.3	46	394.3	80	499.5
13	192.0	47	397.9	81	501.4
14	205.1	48	398.3	82	505.0
15	217.8	49	403.5	83	505.4
16	235.6	50	411.9	84	506.8
17	236.3	51	414.8	85	512.2
18	236.7	52	419.5	86	514.6
19	237.8	53	420.0	87	520.1
20	239.0	54	421.6	88	520.9
21	239.5	55	427.2	89	522.6
22	244.6	56	433.0	90	526.2
23	251.8	57	436.1	91	528.5
24	271.6	58	440.1	92	531.3
25	276.1	59	440.4	93	531.9
26	280.0	60	442.3	94	535.1
27	286.4	61	448.3	95	539.6
28	299.1	62	452.3	96	544.3
29	307.8	63	455.1	97	545.9
30	310.9	64	458.7	98	550.6
31	312.1	65	459.3	99	556.8
32	316.8	66	460.4	100	559.1
33	318.5	67	464.2		

Table B16 Fitted equations and parameters of pyrolysed liquid product of virgin PP pellets, reprocessed and virgin PP films

$y = y_0 + \frac{a}{[1 + e^{-\frac{(x-x_0)}{b}}]^c}$	Parameter	Value	r^2
VPP	a	1.19E+02	0.9984
	b	1.03E+01	
	c	4.39E-02	
	x_0	5.47E+02	
	y_0	-1.86E+01	
COPP	a	9.36E+02	0.9957
	b	1.67E+02	
	c	4.73E-01	
	x_0	1.24E+03	
	y_0	-3.41E+01	
CR1PP	a	8.94E+02	0.9920
	b	5.09E+02	
	c	1.26E+00	
	x_0	1.13E+03	
	y_0	-5.38E+01	
CR2PP	a	1.66E+03	0.9957
	b	2.69E+02	
	c	6.66E-01	
	x_0	1.54E+03	
	y_0	-4.25E+01	
CR3PP	a	1.11E+03	0.9978
	b	3.13E+02	
	c	6.76E-01	
	x_0	1.42E+03	
	y_0	-6.21E+01	
CR4PP	a	5.89E+02	0.9974
	b	1.03E+02	
	c	3.67E-01	
	x_0	9.91E+02	
	y_0	-2.24E+01	

Table B17 % Accumulation and % Mass of pyrolysed liquid product of virgin PP pellets, reprocessed and virgin PP films

VPP

Carbon number	% Accumulation	% Mass
8 [*]	1.04	1.04
9	3.26	2.22
10	5.57	2.31
11	7.96	2.39
12	10.42	2.46
13	12.94	2.52
14	15.50	2.57
15	18.11	2.61
16	20.75	2.64
17	23.42	2.67
18	26.11	2.69
19	28.82	2.71
20	31.55	2.73
21	34.29	2.74
22	37.04	2.76
23	39.81	2.77
24	42.60	2.79
25	45.40	2.80
26	48.22	2.82
27	51.07	2.84
28	53.93	2.86
29	56.81	2.89
30	59.72	2.91
31	62.65	2.93
32	65.61	2.95
33	68.58	2.97
34	71.56	2.98
35	74.54	2.98
36	77.52	2.98
37	80.46	2.95
38	83.36	2.89
39	86.15	2.79
40	88.79	2.64
41	91.21	2.42
42	93.34	2.13
43	95.11	1.77
44	96.51	1.40
45	97.55	1.04
46	98.29	0.74
47	98.79	0.51
48	99.12	0.33
49	99.32	0.19
50 ⁺	100.00	0.68

COPP

Carbon number	% Accumulation	% Mass
7	2.65	2.65
8	5.54	2.89
9	8.46	2.92
10	11.40	2.93
11	14.33	2.93
12	17.26	2.93
13	20.17	2.91
14	23.05	2.89
15	25.91	2.86
16	28.73	2.82
17	31.52	2.79
18	34.27	2.75
19	36.99	2.71
20	39.67	2.68
21	42.31	2.64
22	44.92	2.61
23	47.49	2.58
24	50.04	2.55
25	52.57	2.52
26	55.07	2.50
27	57.55	2.48
28	60.01	2.47
29	62.47	2.45
30	64.90	2.44
31	67.33	2.42
32	69.74	2.41
33	72.13	2.39
34	74.51	2.38
35	76.86	2.36
36	79.19	2.33
37	81.48	2.29
38	83.73	2.25
39	85.92	2.19
40	88.05	2.13
41	90.09	2.04
42	92.03	1.94
43	93.86	1.82
44	95.54	1.68
45	97.05	1.52
46	98.38	1.33
47	99.49	1.11
48 ⁺	100.00	0.51

CR1PP

Carbon number	% Accumulation	% Mass
6	2.38	2.38
7	6.01	3.63
8	9.59	3.59
9	13.13	3.54
10	16.61	3.47
11	20.01	3.40
12	23.33	3.32
13	26.57	3.24
14	29.73	3.16
15	32.80	3.07
16	35.78	2.98
17	38.67	2.89
18	41.48	2.81
19	44.21	2.73
20	46.87	2.65
21	49.45	2.58
22	51.96	2.51
23	54.42	2.45
24	56.81	2.40
25	59.15	2.34
26	61.45	2.29
27	63.70	2.25
28	65.91	2.21
29	68.08	2.17
30	70.21	2.14
31	72.32	2.10
32	74.39	2.07
33	76.42	2.04
34	78.42	2.00
35	80.38	1.96
36	82.31	1.92
37	84.18	1.88
38	86.01	1.82
39	87.77	1.76
40	89.46	1.69
41	91.08	1.62
42	92.60	1.53
43	94.03	1.42
44	95.33	1.30
45	96.50	1.17
46	97.52	1.02
47	98.37	0.85
48	99.02	0.66
49	99.47	0.45
50 ⁺	100.00	0.53

CR2PP

Carbon number	% Accumulation	% Mass
6	0.77	0.77
7	3.93	3.15
8	7.09	3.16
9	10.24	3.16
10	13.38	3.14
11	16.50	3.12
12	19.58	3.08
13	22.62	3.04
14	25.62	2.99
15	28.56	2.94
16	31.45	2.89
17	34.29	2.84
18	37.07	2.78
19	39.80	2.73
20	42.48	2.68
21	45.11	2.63
22	47.69	2.58
23	50.23	2.54
24	52.74	2.50
25	55.20	2.47
26	57.64	2.44
27	60.05	2.41
28	62.43	2.38
29	64.79	2.36
30	67.13	2.34
31	69.45	2.32
32	71.74	2.30
33	74.02	2.28
34	76.27	2.25
35	78.50	2.22
36	80.69	2.19
37	82.84	2.15
38	84.95	2.11
39	86.99	2.05
40	88.98	1.98
41	90.87	1.90
42	92.67	1.80
43	94.36	1.69
44	95.92	1.55
45	97.32	1.40
46	98.54	1.22
47	99.56	1.02
48 ⁺	100.00	0.44

CR3PP

Carbon number	% Accumulation	% Mass
7	0.59	0.59
8	4.26	3.67
9	7.89	3.63
10	11.48	3.58
11	15.00	3.52
12	18.45	3.46
13	21.84	3.38
14	25.15	3.31
15	28.38	3.23
16	31.53	3.15
17	34.60	3.07
18	37.60	3.00
19	40.52	2.92
20	43.37	2.85
21	46.16	2.79
22	48.88	2.72
23	51.55	2.67
24	54.16	2.61
25	56.73	2.57
26	59.25	2.52
27	61.73	2.48
28	64.18	2.45
29	66.59	2.41
30	68.97	2.38
31	71.32	2.35
32	73.64	2.32
33	75.94	2.29
34	78.20	2.26
35	80.42	2.22
36	82.60	2.18
37	84.74	2.14
38	86.83	2.08
39	88.85	2.02
40	90.80	1.95
41	92.66	1.86
42	94.42	1.76
43	96.07	1.65
44	97.59	1.51
45	98.95	1.36
46 [†]	100.00	1.05

CR4PP

Carbon number	% Accumulation	% Mass
7	1.89	1.89
8	4.32	2.43
9	6.82	2.50
10	9.37	2.55
11	11.97	2.60
12	14.61	2.63
13	17.26	2.66
14	19.94	2.67
15	22.62	2.68
16	25.30	2.68
17	27.98	2.68
18	30.66	2.67
19	33.32	2.67
20	35.98	2.66
21	38.62	2.65
22	41.26	2.64
23	43.89	2.63
24	46.51	2.62
25	49.12	2.62
26	51.74	2.61
27	54.35	2.61
28	56.96	2.61
29	59.57	2.61
30	62.19	2.62
31	64.81	2.62
32	67.43	2.62
33	70.05	2.62
34	72.67	2.62
35	75.28	2.61
36	77.87	2.59
37	80.43	2.57
38	82.96	2.53
39	85.44	2.48
40	87.85	2.41
41	90.18	2.33
42	92.40	2.22
43	94.50	2.09
44	96.44	1.94
45	98.19	1.75
46	99.73	1.54
47 [†]	100.00	0.27

B.5 Effect of catalyst to polymer ratio on pyrolysis products

Table B18 Pyrolysed product yield of commercial PP film with 4% sulfate on $\text{SO}_4^{2-}/\text{ZrO}_2$ at various catalysts to polymer ratio (C/P)

C/P	0.00	0.17	0.50	1.00
Residue	0.00	0.00	0.00	0.00
Gas	50.29	41.05	35.81	29.13
Liquid	49.71	58.95	64.19	70.87

Table B19 Pyrolysed gas product of commercial PP film with 4% sulfate on $\text{SO}_4^{2-}/\text{ZrO}_2$ at various catalysts to polymer ratio (C/P)

C/P	0.00		0.17		0.50		1.00	
	% Mass	Std	% Mass	Std	% Mass	Std	% Mass	Std
Methane	1.08719	0.02063	1.07374	0.01633	0.88092	0.00203	0.40029	0.00687
Ethylene	0.18470	0.00336	0.25028	0.00355	0.88092	0.00203	0.40029	0.00687
Ethane	3.45682	0.05132	3.47578	0.05551	2.92435	0.01319	1.30291	0.02330
Propylene	23.12319	0.35046	20.31709	0.35634	18.13516	0.08420	11.08673	0.16188
Propane	1.81261	0.01231	2.64752	0.04568	2.15586	0.04297	1.24778	0.02570
C ₄	6.84009	0.21034	9.94404	0.19801	12.26104	0.14901	24.23054	0.39394
C ₅	34.63067	0.32122	34.79681	0.45484	35.14097	0.10086	34.44939	0.21352
C ₆	28.86473	0.78495	27.49474	0.87283	28.27679	0.31142	27.28235	0.66570

C/P	0.00		0.17		0.50		1.00	
	% Vol.	Std	% Vol.	Std	% Vol.	Std	% Vol.	Std
Methane	3.95161	0.05519	3.91246	0.04121	3.28738	0.00772	1.57989	0.02140
Ethylene	0.38390	0.00506	0.52152	0.00539	0.47997	0.00084	0.00000	0.00000
Ethane	6.70354	0.06624	6.75693	0.07320	5.82225	0.01993	2.74356	0.03894
Propylene	32.04209	0.32573	28.23161	0.35027	25.80053	0.07807	16.68217	0.18162
Propane	2.39700	0.00517	3.50725	0.04380	2.92683	0.05353	1.79168	0.03095
C ₄	6.99850	0.18123	10.20932	0.15802	12.88019	0.13551	26.92165	0.33840
C ₅	27.98895	0.12086	28.20019	0.23988	29.15856	0.03454	30.23318	0.08506
C ₆	19.53441	0.60886	18.66073	0.67064	19.64428	0.24342	20.04787	0.54894

Table B20 % Off and boiling point of pyrolysed liquid product of commercial PP film with 4% sulfate on $\text{SO}_4^{2-}/\text{ZrO}_2$ at various catalysts to polymer ratio (C/P)

C/P = 0.0

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	135.5	34	346.7	68	459.6
1	172.4	35	348.3	69	461.8
2	189.2	36	354.7	70	467.5
3	191.2	37	364.4	71	470.2
4	191.9	38	366.9	72	472.7
5	201.1	39	370.0	73	474.7
6	206.2	40	373.7	74	476.0
7	221.6	41	374.3	75	476.8
8	232.1	42	378.1	76	480.5
9	236.2	43	387.2	77	484.7
10	236.5	44	390.5	78	486.8
11	236.7	45	394.0	79	489.1
12	237.7	46	397.3	80	491.7
13	238.7	47	398.1	81	492.6
14	239.5	48	400.5	82	496.3
15	239.9	49	407.3	83	499.6
16	244.5	50	412.3	84	501.9
17	249.5	51	414.9	85	504.2
18	264.3	52	417.2	86	505.5
19	274.7	53	419.7	87	508.2
20	276.5	54	420.4	88	513.3
21	280.7	55	423.0	89	516.7
22	286.2	56	429.8	90	520.4
23	292.3	57	433.2	91	522.5
24	304.9	58	436.2	92	526.4
25	308.0	59	438.8	93	529.3
26	310.5	60	440.2	94	531.3
27	312.0	61	440.9	95	533.5
28	314.4	62	444.5	96	539.4
29	317.8	63	450.3	97	544.2
30	321.5	64	452.7	98	548.1
31	333.4	65	455.3	99	555.4
32	338.5	66	457.1	100	558.9
33	342.3	67	459.0		

C/P = 0.17

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	172.1	34	395.9	68	487.2
1	184.5	35	398.2	69	489.1
2	191.7	36	401.4	70	491.4
3	202.8	37	407.3	71	492.3
4	218.7	38	412.0	72	494.2
5	231.2	39	414.9	73	497.1
6	236.2	40	418.0	74	499.3
7	236.8	41	419.9	75	500.8
8	239.2	42	422.2	76	502.5
9	241.4	43	426.7	77	504.2
10	250.0	44	431.3	78	505.4
11	264.2	45	434.0	79	506.8
12	274.8	46	437.0	80	509.6
13	279.6	47	439.8	81	512.6
14	286.3	48	440.6	82	514.5
15	296.0	49	443.3	83	517.0
16	306.1	50	447.7	84	519.5
17	309.3	51	451.0	85	521.1
18	312.5	52	453.2	86	523.2
19	317.0	53	455.6	87	525.0
20	322.3	54	457.5	88	527.1
21	332.2	55	459.1	89	528.8
22	338.5	56	459.9	90	530.2
23	343.4	57	462.5	91	531.6
24	347.8	58	466.4	92	533.8
25	352.7	59	469.2	93	537.6
26	361.1	60	470.9	94	540.2
27	365.9	61	473.1	95	543.6
28	369.7	62	475.2	96	546.3
29	373.9	63	476.1	97	550.5
30	376.1	64	477.5	98	554.3
31	382.1	65	480.1	99	558.5
32	388.7	66	483.3	100	560.7
33	392.3	67	485.6		

C/P = 0.50

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	134.8	34	365.4	68	475.8
1	144.0	35	369.0	69	477.1
2	172.5	36	372.9	70	479.9
3	184.9	37	375.3	71	483.4
4	190.8	38	380.4	72	485.9
5	194.1	39	386.4	73	488.3
6	203.1	40	390.4	74	490.8
7	212.7	41	394.2	75	492.2
8	223.3	42	397.8	76	494.3
9	231.7	43	400.3	77	497.4
10	235.8	44	404.9	78	499.7
11	236.8	45	410.0	79	501.5
12	239.1	46	413.3	80	503.5
13	241.7	47	416.6	81	505.3
14	249.1	48	419.6	82	506.6
15	258.7	49	421.6	83	509.7
16	268.4	50	425.5	84	513.1
17	274.9	51	430.1	85	515.5
18	279.4	52	433.4	86	518.5
19	285.9	53	436.5	87	520.9
20	291.9	54	439.6	88	523.0
21	300.4	55	440.7	89	525.3
22	306.9	56	444.0	90	527.5
23	309.6	57	448.3	91	529.6
24	312.5	58	451.8	92	531.4
25	316.7	59	454.3	93	533.3
26	321.2	60	456.6	94	537.5
27	328.5	61	458.8	95	540.8
28	335.8	62	459.8	96	544.6
29	340.2	63	462.6	97	547.6
30	344.6	64	466.5	98	553.0
31	348.3	65	469.6	99	557.5
32	353.9	66	471.7	100	560.4
33	360.8	67	474.1		

C/P = 1.00

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	132.3	34	344.4	68	459.7
1	146.0	35	348.4	69	462.8
2	165.3	36	352.5	70	466.0
3	177.2	37	356.6	71	468.9
4	185.5	38	360.7	72	471.8
5	191.9	39	364.6	73	474.6
6	198.0	40	368.3	74	477.6
7	205.1	41	371.9	75	480.6
8	212.1	42	375.5	76	483.6
9	217.9	43	379.2	77	486.5
10	224.0	44	382.9	78	489.3
11	230.0	45	386.5	79	492.4
12	234.2	46	390.1	80	496.1
13	238.4	47	393.5	81	498.4
14	243.4	48	396.8	82	500.8
15	249.2	49	400.1	83	503.5
16	255.3	50	403.5	84	506.3
17	261.6	51	406.8	85	509.8
18	267.8	52	410.1	86	513.4
19	273.4	53	413.3	87	516.9
20	278.6	54	416.5	88	520.8
21	283.8	55	419.7	89	523.7
22	289.1	56	422.8	90	526.2
23	294.3	57	426.0	91	528.7
24	299.5	58	429.2	92	531.1
25	304.4	59	432.4	93	533.8
26	308.6	60	435.5	94	537.5
27	312.7	61	438.6	95	540.7
28	317.0	62	441.7	96	544.8
29	321.7	63	444.8	97	548.6
30	326.4	64	448.0	98	553.0
31	331.2	65	451.1	99	557.5
32	335.8	66	454.1	100	560.1
33	340.1	67	456.8		

Table B21 Fitted equation and parameters of pyrolysed liquid product of commercial PP film with 4% sulfate on $\text{SO}_4^{2-}/\text{ZrO}_2$ at various catalysts to polymer ratio (C/P)

$y = y_0 + \frac{a}{[1 + e^{-\frac{(x-x_0)}{b}}]}^c$	Parameter	Value	r^2
C/P = 0.00	a	1.34E+02	0.9984
	b	1.37E+01	
	c	4.96E-02	
	x_0	5.39E+02	
	y_0	-3.31E+01	
C/P = 0.17	a	1.09E+02	0.9993
	b	1.15E+01	
	c	7.30E-02	
	x_0	5.44E+02	
	y_0	-8.51E+00	
C/P = 0.50	a	1.19E+02	0.9995
	b	9.32E+00	
	c	4.18E-02	
	x_0	5.47E+02	
	y_0	-1.89E+01	
C/P = 1.00	a	1.50E+02	0.9999
	b	5.09E+01	
	c	1.98E-01	
	x_0	5.64E+02	
	y_0	-2.93E+01	

Table B22 % Accumulation and % Mass of pyrolysed liquid product of commercial PP film with 4% sulfate on $\text{SO}_4^{2-}/\text{ZrO}_2$ at various catalysts to polymer ratio (C/P)

C/P = 0.00

Carbon number	% Accumulation	% Mass
10	2.58	2.58
11	5.54	2.96
12	8.54	3.00
13	11.58	3.03
14	14.63	3.05
15	17.70	3.07
16	20.77	3.07
17	23.84	3.07
18	26.91	3.07
19	29.98	3.06
20	33.03	3.05
21	36.08	3.05
22	39.11	3.04
23	42.14	3.03
24	45.17	3.02
25	48.19	3.02
26	51.21	3.02
27	54.23	3.02
28	57.26	3.03
29	60.28	3.03
30	63.32	3.03
31	66.36	3.04
32	69.39	3.04
33	72.43	3.03
34	75.44	3.01
35	78.42	2.98
36	81.34	2.92
37	84.16	2.83
38	86.85	2.68
39	89.34	2.49
40	91.57	2.23
41	93.50	1.93
42	95.10	1.60
43	96.37	1.27
44	97.34	0.97
45	98.06	0.72
46	98.58	0.52
47	98.95	0.36
48	99.19	0.24
49	99.34	0.15
50*	100.0	0.66

C/P = 0.17

Carbon number	% Accumulation	% Mass
9	0.52	0.52
10	1.97	1.45
11	3.54	1.57
12	5.23	1.69
13	7.03	1.80
14	8.93	1.91
15	10.94	2.01
16	13.05	2.11
17	15.25	2.20
18	17.54	2.29
19	19.91	2.37
20	22.36	2.45
21	24.89	2.53
22	27.50	2.61
23	30.18	2.69
24	32.95	2.76
25	35.79	2.84
26	38.71	2.92
27	41.71	3.00
28	44.80	3.09
29	47.97	3.17
30	51.22	3.25
31	54.56	3.34
32	57.98	3.42
33	61.48	3.50
34	65.04	3.57
35	68.66	3.62
36	72.32	3.65
37	75.97	3.65
38	79.57	3.60
39	83.06	3.49
40	86.34	3.28
41	89.31	2.97
42	91.88	2.57
43	94.00	2.11
44	95.65	1.65
45	96.87	1.23
46	97.75	0.88
47	98.36	0.61
48	98.76	0.40
49	99.00	0.24
50*	100.0	1.00

C/P = 0.50

Carbon number	% Accumulation	% Mass
9	1.30	1.30
10	3.54	2.24
11	5.87	2.33
12	8.27	2.40
13	10.75	2.47
14	13.28	2.53
15	15.86	2.58
16	18.48	2.62
17	21.14	2.66
18	23.82	2.69
19	26.54	2.72
20	29.28	2.74
21	32.04	2.76
22	34.83	2.78
23	37.63	2.80
24	40.46	2.83
25	43.31	2.85
26	46.18	2.87
27	49.08	2.90
28	52.01	2.93
29	54.97	2.96
30	57.96	2.99
31	60.97	3.02
32	64.01	3.04
33	67.08	3.07
34	70.17	3.08
35	73.26	3.09
36	76.35	3.09
37	79.43	3.07
38	82.45	3.03
39	85.39	2.94
40	88.19	2.80
41	90.78	2.58
42	93.05	2.28
43	94.94	1.89
44	96.42	1.48
45	97.51	1.08
46	98.26	0.75
47	98.76	0.50
48	99.07	0.32
49	99.26	0.18
50*	100.00	0.74

C/P = 1.00

Carbon number	% Accumulation	% Mass
9	0.47	0.47
10	3.32	2.85
11	6.25	2.93
12	9.23	2.98
13	12.26	3.03
14	15.33	3.07
15	18.42	3.09
16	21.53	3.11
17	24.64	3.12
18	27.76	3.12
19	30.88	3.12
20	33.99	3.11
21	37.09	3.10
22	40.18	3.09
23	43.25	3.07
24	46.31	3.06
25	49.34	3.04
26	52.36	3.02
27	55.35	2.99
28	58.32	2.97
29	61.26	2.94
30	64.16	2.90
31	67.02	2.86
32	69.82	2.81
33	72.57	2.75
34	75.25	2.68
35	77.85	2.60
36	80.36	2.51
37	82.76	2.40
38	85.05	2.29
39	87.21	2.16
40	89.22	2.02
41	91.09	1.87
42	92.80	1.71
43	94.34	1.54
44	95.71	1.37
45	96.91	1.19
46	97.91	1.01
47	98.73	0.82
48	99.35	0.62
49	99.77	0.42
50*	100.00	0.23

B.6 Effect of amount of sulfate loaded on zirconia on pyrolysis products

Table B23 Pyrolysed product yield of commercial PP film with and without catalyst ($\text{SO}_4^{2-}/\text{ZrO}_2$)

	Product (%wt)			
	No.	Residue	Gas	Liquid
Without catalyst	1	0.00	50.29	49.71
+ 0% sulfate	1	0.00	44.98	55.02
	2	0.00	40.32	59.69
	Average	0.00	42.65	57.35
+ 2% sulfate	1	0.00	40.63	59.37
	2	0.00	39.30	60.70
	Average	0.00	39.96	60.04
+ 4% sulfate	1	0.00	41.90	58.10
	2	0.00	40.21	59.79
	Average	0.00	41.05	58.95
+ 6% sulfate	1	0.00	35.48	64.52
	2	0.00	37.48	62.52
	Average	0.00	36.48	63.52
+ 8% sulfate	1	0.00	42.58	57.42
	2	0.00	36.58	63.42

Table B24 Pyrolysed gas product of commercial PP film with and without catalyst (SO₄²⁻/ZrO₂)

		Methane	Ethylene	Ethane	Propylene	Propane	C ₄	C ₅	C ₆
Without catalyst	%Mass	08719	0.18470	3.45682	23.12319	1.81261	6.8400	34.63067	28.86473
	Std	0.02063	0.00336	0.05132	0.35046	0.01231	0.21034	0.32122	0.78495
+ 0 % sulfate	%Mass	1.13743	0.19771	3.65807	22.34683	2.18989	6.88414	35.08870	28.49723
	Std	0.01770	0.00412	0.06732	0.45260	0.03887	0.26258	0.53862	1.11813
+ 2 % sulfate	%Mass	1.14068	0.23023	3.71431	21.58486	2.69613	7.51453	34.70897	28.41028
	Std	0.01469	0.00465	0.05132	0.31298	0.03340	0.23129	0.31076	0.72281
+ 4 % sulfate	%Mass	1.07374	0.25028	3.47578	20.31709	2.64752	9.94404	34.79681	27.49474
	Std	0.01633	0.00355	0.05551	0.35634	0.04568	0.19801	0.45484	0.87283
+ 6 % sulfate	%Mass	1.03730	0.22613	3.34908	20.34238	2.25251	9.41987	35.13486	28.23786
	Std	0.01472	0.00480	0.05157	0.30236	0.02396	0.23436	0.41077	0.81866
+ 8 %	%Mass	1.00991	0.26948	3.09730	17.45859	2.81227	12.32246	35.53223	27.49777

		Methane	Ethylene	Ethane	Propylene	Propane	C ₄	C ₅	C ₆
Without catalyst	%Volume	3.95161	0.38390	6.70354	32.04209	2.39700	6.99850	27.98895	19.53441
	Std	0.05519	0.00506	0.06624	0.32573	0.00517	0.18123	0.12086	0.60886
+ 0 % sulfate	%Volume	4.12423	0.40981	7.07804	30.88003	2.89275	7.02387	28.32021	19.27107
	Std	0.03894	0.00584	0.08469	0.42376	0.03396	0.22151	0.25854	0.85076
+ 2 % sulfate	%Volume	4.13462	0.47715	7.18330	29.83003	3.55471	7.66663	27.97624	19.17732
	Std	0.03713	0.00732	0.06613	0.29488	0.02689	0.19993	0.15513	0.55555
+ 4 % sulfate	%Volume	3.91246	0.52152	6.75693	28.23161	3.50725	10.20932	28.20019	18.66073
	Std	0.04121	0.00539	0.07320	0.35027	0.04380	0.15802	0.23988	0.67064
+ 6 % sulfate	%Volume	3.80617	0.47452	6.55577	28.45569	3.00762	9.73522	28.66899	19.29601
	Std	0.03863	0.00792	0.06893	0.28520	0.01829	0.20202	0.20256	0.62925
+ 8 %	%Volume	3.73644	0.56979	6.11440	24.66258	3.77698	12.87618	29.27822	18.98540

Table B25 % Off and boiling point of pyrolysed liquid product of commercial PP film with and without catalyst ($\text{SO}_4^{2-}/\text{ZrO}_2$)

0% sulfate

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	139.4	34	415.0	68	499.8
1	185.8	35	416.8	69	500.8
2	191.7	36	419.7	70	502.2
3	205.4	37	422.6	71	503.0
4	229.0	38	429.9	72	504.3
5	235.7	39	433.3	73	505.4
6	236.5	40	436.2	74	506.9
7	237.8	41	437.4	75	510.5
8	239.3	42	440.1	76	512.9
9	242.9	43	442.4	77	514.5
10	255.8	44	448.7	78	516.2
11	274.3	45	452.2	79	517.6
12	279.0	46	454.0	80	519.4
13	286.1	47	455.8	81	520.9
14	301.7	48	457.3	82	522.7
15	308.0	49	459.0	83	525.1
16	311.6	50	461.0	84	526.6
17	313.8	51	466.2	85	527.6
18	318.4	52	469.3	86	529.1
19	334.0	53	470.7	87	529.8
20	340.0	54	472.8	88	531.4
21	344.3	55	473.6	89	532.5
22	349.7	56	475.6	90	535.4
23	362.5	57	476.4	91	538.2
24	366.9	58	479.6	92	539.8
25	370.3	59	483.1	93	542.1
26	374.0	60	485.5	94	543.7
27	379.8	61	486.5	95	545.6
28	389.5	62	488.4	96	548.6
29	393.1	63	489.1	97	553.3
30	395.4	64	491.1	98	556.8
31	398.2	65	492.2	99	559.7
32	405.9	66	494.7	100	561.0
33	412.1	67	498.1		

2% sulfate

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	135.8	34	411.9	68	498.4
1	174.9	35	414.6	69	500.3
2	191.0	36	416.8	70	501.1
3	199.9	37	419.6	71	502.7
4	222.3	38	421.2	72	503.7
5	235.6	39	427.2	73	505.2
6	236.6	40	432.2	74	505.9
7	238.9	41	434.4	75	508.7
8	240.1	42	436.9	76	511.9
9	254.3	43	440.4	77	514.1
10	274.2	44	443.6	78	515.4
11	279.0	45	449.2	79	517.4
12	286.2	46	452.3	80	519.2
13	301.0	47	454.2	81	520.9
14	307.9	48	455.9	82	522.5
15	311.5	49	457.6	83	524.4
16	313.5	50	459.2	84	526.3
17	317.9	51	460.7	85	527.5
18	328.6	52	465.0	86	529.1
19	338.2	53	468.6	87	530.0
20	342.6	54	470.4	88	531.5
21	347.3	55	472.4	89	532.8
22	351.7	56	473.5	90	536.1
23	362.7	57	475.5	91	539.0
24	366.6	58	476.2	92	540.9
25	370.1	59	478.3	93	542.9
26	373.8	60	482.6	94	545.5
27	376.7	61	485.0	95	547.8
28	386.1	62	486.3	96	552.7
29	390.5	63	488.4	97	556.4
30	394.0	64	489.5	98	559.4
31	397.2	65	491.6	99	561.0
32	398.8	66	492.5	100	
33	406.2	67	495.3		

6% sulfate

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	135.2	34	386.5	68	485.2
1	168.2	35	390.5	69	486.8
2	187.8	36	394.3	70	488.8
3	191.8	37	397.8	71	490.8
4	205.0	38	399.8	72	492.0
5	218.8	39	405.1	73	493.8
6	230.6	40	410.7	74	496.9
7	235.7	41	413.8	75	499.2
8	236.6	42	416.8	76	500.8
9	238.9	43	419.6	77	502.6
10	239.7	44	421.2	78	504.2
11	248.5	45	425.4	79	505.4
12	259.2	46	430.6	80	507.1
13	270.4	47	433.5	81	510.6
14	276.2	48	436.5	82	513.4
15	281.5	49	439.2	83	515.7
16	288.1	50	440.4	84	518.2
17	298.2	51	442.9	85	520.7
18	306.6	52	447.4	86	522.5
19	309.3	53	451.0	87	524.6
20	312.2	54	453.3	88	526.8
21	316.6	55	455.7	89	528.6
22	321.3	56	457.9	90	530.3
23	330.5	57	459.2	91	531.7
24	337.8	58	460.8	92	534.0
25	342.0	59	464.2	93	537.7
26	347.0	60	468.0	94	540.0
27	350.6	61	470.1	95	542.8
28	358.4	62	472.3	96	545.7
29	364.9	63	474.1	97	549.0
30	368.3	64	475.8	98	553.5
31	371.7	65	476.7	99	557.8
32	374.3	66	479.3	100	560.5
33	379.2	67	482.8		

8% sulfate

% OFF	B.P.(°C)	% OFF	B.P.(°C)	% OFF	B.P.(°C)
0	135.0	34	387.7	68	487.3
1	152.0	35	391.9	69	489.0
2	177.0	36	395.4	70	491.0
3	189.3	37	398.8	71	493.0
4	193.4	38	403.6	72	495.9
5	202.4	39	408.8	73	497.9
6	215.8	40	412.6	74	499.7
7	227.2	41	415.8	75	501.3
8	232.4	42	418.7	76	502.9
9	235.7	43	421.6	77	504.5
10	237.4	44	425.7	78	506.1
11	239.3	45	430.0	79	508.6
12	244.5	46	433.3	80	511.4
13	252.4	47	436.1	81	513.9
14	264.4	48	438.6	82	515.9
15	273.7	49	440.9	83	518.1
16	278.9	50	444.2	84	520.6
17	285.5	51	447.9	85	522.8
18	294.2	52	451.1	86	524.6
19	303.5	53	453.5	87	526.5
20	308.1	54	455.6	88	528.2
21	311.9	55	457.6	89	529.8
22	316.3	56	459.5	90	531.4
23	322.8	57	462.1	91	533.5
24	332.0	58	465.2	92	536.5
25	338.5	59	468.1	93	539.3
26	343.6	60	470.2	94	541.8
27	348.6	61	472.3	95	544.5
28	355.8	62	474.0	96	547.2
29	363.1	63	475.8	97	550.9
30	367.6	64	477.8	98	555.0
31	371.3	65	480.4	99	558.8
32	375.5	66	483.1	100	560.8
33	381.5	67	485.4		

Table B26 Fitted equation and parameters of pyrolysed liquid product of commercial PP film with and without catalyst ($\text{SO}_4^{2-}/\text{ZrO}_2$)

$y = y_0 + \frac{a}{[1 + e^{-\frac{(x-x_0)}{b}}]^c}$	Parameter	Value	r^2
w/o catalyst	a	1.34E+02	0.9984
	b	1.37E+01	
	c	4.96E-02	
	x_0	5.39E+02	
	y_0	-3.31E+01	
+ 0% sulfate	a	1.02E+02	0.9986
	b	7.18E+00	
	c	5.47E-02	
	x_0	5.48E+02	
	y_0	-2.46E+00	
+ 2% sulfate	a	1.05E+02	00.9995
	b	9.39E+00	
	c	6.83E-02	
	x_0	5.47E+02	
	y_0	-4.59E+00	
+ 4% sulfate	a	1.09E+02	0.9993
	b	1.15E+01	
	c	7.30E-02	
	x_0	5.44E+02	
	y_0	-8.51E+00	
+ 6% sulfate	a	1.12E+02	0.9993
	b	1.09E+01	
	c	6.22E-02	
	x_0	5.46E+02	
	y_0	-1.08E+01	
+ 8% sulfate	a	1.09E+02	0.9988
	b	8.79E+00	
	c	5.12E-02	
	x_0	5.48E+02	

Table B27 % Accumulation and % Mass of pyrolysed liquid product of commercial PP film with and without catalyst ($\text{SO}_4^{2-}/\text{ZrO}_2$)

+ 0% sulfate

Carbon number	% Accumulation	% Mass
6 ⁻	0.21	0.21
7	0.86	0.65
8	1.60	0.75
9	2.46	0.86
10	3.43	0.97
11	4.50	1.08
12	5.69	1.19
13	7.00	1.30
14	8.41	1.42
15	9.94	1.53
16	11.57	1.63
17	13.31	1.74
18	15.16	1.85
19	17.11	1.95
20	19.16	2.05
21	21.31	2.15
22	23.57	2.25
23	25.92	2.36
24	28.38	2.46
25	30.94	2.56
26	33.61	2.67
27	36.39	2.78
28	39.29	2.89
29	42.29	3.01
30	45.42	3.12
31	48.66	3.24
32	52.02	3.36
33	55.49	3.47
34	59.08	3.59
35	62.77	3.69
36	66.55	3.78
37	70.40	3.85
38	74.30	3.90
39	78.22	3.91
40	82.08	3.86
41	85.79	3.72
42	89.22	3.43
43	92.19	2.97
44	94.55	2.36
45	96.26	1.71
46	97.40	1.14
47	98.11	0.71
48	98.53	0.42
49	98.76	0.23
50 ⁺	100.00	1.24

+ 2% sulfate

Carbon number	% Accumulation	% Mass
8 ⁻	0.31	0.31
9	1.29	0.98
10	2.39	1.10
11	3.60	1.21
12	4.93	1.33
13	6.37	1.44
14	7.93	1.56
15	9.60	1.67
16	11.38	1.78
17	13.27	1.88
18	15.25	1.99
19	17.34	2.09
20	19.53	2.19
21	21.81	2.28
22	24.19	2.38
23	26.67	2.48
24	29.24	2.58
25	31.92	2.68
26	34.70	2.78
27	37.58	2.88
28	40.57	2.99
29	43.66	3.10
30	46.87	3.21
31	50.18	3.32
32	53.61	3.43
33	57.14	3.53
34	60.77	3.63
35	64.50	3.73
36	68.30	3.80
37	72.16	3.85
38	76.03	3.87
39	79.86	3.83
40	83.57	3.71
41	87.04	3.48
42	90.15	3.11
43	92.78	2.62
44	94.85	2.07
45	96.39	1.54
46	97.46	1.08
47	98.18	0.72
48	98.64	0.46
49	98.91	0.27
50 ⁺	100.00	1.09

+ 6% sulfate

Carbon number	% Accumulation	% Mass
9	0.92	0.92
10	2.60	1.68
11	4.39	1.79
12	6.29	1.90
13	8.29	2.00
14	10.39	2.09
15	12.57	2.18
16	14.83	2.26
17	17.17	2.34
18	19.58	2.41
19	22.05	2.47
20	24.59	2.54
21	27.19	2.60
22	29.85	2.66
23	32.56	2.72
24	35.34	2.77
25	38.17	2.83
26	41.06	2.89
27	44.02	2.96
28	47.04	3.02
29	50.12	3.08
30	53.27	3.15
31	56.48	3.21
32	59.75	3.27
33	63.08	3.33
34	66.46	3.38
35	69.88	3.42
36	73.32	3.44
37	76.75	3.44
38	80.15	3.40
39	83.45	3.30
40	86.58	3.13
41	89.45	2.87
42	91.98	2.53
43	94.09	2.11
44	95.76	1.67
45	97.02	1.26
46	97.93	0.91
47	98.56	0.63
48	98.97	0.41
49	99.22	0.25
50*	100.00	0.78

+ 8% sulfate

Carbon number	% Accumulation	% Mass
8	1.03	1.03
9	2.47	1.45
10	4.04	1.56
11	5.71	1.67
12	7.49	1.78
13	9.37	1.88
14	11.35	1.97
15	13.41	2.06
16	15.55	2.14
17	17.77	2.22
18	20.06	2.29
19	22.42	2.36
20	24.84	2.42
21	27.33	2.48
22	29.87	2.55
23	32.48	2.61
24	35.14	2.67
25	37.87	2.73
26	40.66	2.79
27	43.51	2.85
28	46.43	2.92
29	49.41	2.98
30	52.46	3.05
31	55.57	3.11
32	58.75	3.18
33	61.99	3.24
34	65.28	3.29
35	68.62	3.34
36	72.00	3.38
37	75.39	3.39
38	78.77	3.38
39	82.10	3.33
40	85.33	3.22
41	88.36	3.03
42	91.10	2.74
43	93.43	2.34
44	95.30	1.87
45	96.70	1.40
46	97.68	0.98
47	98.33	0.65
48	98.75	0.41
49	98.99	0.24
50*	100.00	1.01

Table B28 Pyrolysed liquid product fractions from pyrolysis of virgin PP pellets, virgin and reprocessed PP films

	% Mass				
	Gasoline	Kerosene	Gas oil	Fuel oil	Heavy vacuum gas oil
VPP	3.16	9.28	18.86	6.35	62.36
COPP	8.33	11.26	19.83	6.06	54.52
CR1PP	12.97	12.97	20.69	5.87	47.50
CR2PP	10.10	11.93	20.21	6.01	51.75
CR3PP	7.73	13.44	21.94	6.35	50.54

Table B29 Pyrolysed liquid product fractions from catalytic pyrolysis of commercial PP film using $\text{SO}_4^{2-}/\text{ZrO}_2$ at various amounts of sulfate loading

C/P Ratio	% Mass				
	Gasoline	Kerosene	Gas oil	Fuel oil	Heavy vacuum gas oil
0.00	0.00	10.97	21.78	7.02	60.23
0.17	0.46	6.20	15.47	5.94	71.93
0.50	1.20	9.05	18.78	6.40	64.57

Table B30 Pyrolysed liquid product fractions from catalytic pyrolysis of commercial PP film with and without catalyst ($\text{SO}_4^{2-}/\text{ZrO}_2$) at various amounts of sulfate loading

	% Mass				
	Gasoline	Kerosene	Gas oil	Fuel oil	Heavy vacuum gas oil
w/o	-	10.97	21.78	7.02	60.23
0S ^a Z ^b	2.42	4.31	12.24	5.10	75.93
2SZ	1.25	4.83	13.24	5.40	75.28
4SZ	0.46	6.20	15.47	5.94	71.93
6SZ	0.85	7.04	16.47	6.07	69.57
8SZ	2.40	6.59	15.63	5.81	69.57

^a percentage of sulfate loading

^b Zirconia

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