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APPENDIX

APPENDIX A

THE PROPERTIES OF RICE HULL AND RICE HULL CHAR

The chemical properties of rice hull and rice hull char were determined and shown in Table A.1.

Table A.1 Chemical Properties of Rice Hull and Rice Hull Char

Properties	Rice hull	Rice hull char
Moisture content, %	8.49	1.57
Ash, %	13.51	28.29
Fixed carbon, %	19.26	43.55
Volatile matter, %	58.74	26.59
Heating value, kcal/kg	3,629	4,836
Cellulose*, %	42.1-46.6	-
Lignin*, %	22.1-22.8	-
Pentosan*, %	13.9-18.3	-
Starch*, %	7.6-7.9	-
Crude fiber*, %	39.1-41.1	-
Crude protein*, %	1.8-1.9	-
Crude fat*, %	0.28-0.31	-

* From NEIC NEWS 1984.

APPENDIX B

THE EXPERIMENTAL DATA OF RICE HULL PYROLYSIS

The experimental data for various pyrolysis conditions following the procedure in section 3.1.3 were recorded from the batch operation. The collected data were shown in section B.1 and B.2.

B.1 Bulk Density Change

The collected data for bulk density change were shown in Table B.1-B.16 for a moisture content (% wet basis) of 0.11, 8.49, 16.35 and 24.04% and initial bulk density of 113.5, 120.9, 130.2 and 141.4 kg/m^3

Table B.1 Experimental Data for Bulk Density Change during Pyrolysis at 0.11% Moisture Content and 113.5 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	113.5	113.5	113.5	113.5
10	96.1	86.4	77.5	71.4
20	77.1	68.0	60.8	59.8
30	71.5	64.4	59.9	56.5
40	67.9	61.8	58.1	56.4
50	67.2	60.9	58.1	55.8
60	66.0	60.5	57.3	55.5

Table B.2 Experimental Data for Bulk Density Change during Pyrolysis at 0.11% Moisture Content and 120.9 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	120.9	120.9	120.9	120.9
10	102.2	90.5	81.4	74.0
20	84.8	70.2	63.2	58.8
30	77.2	66.7	61.6	58.5
40	72.2	63.9	60.3	58.0
50	69.5	64.1	59.5	56.9
60	69.0	63.1	59.9	57.5

Table B.3 Experimental data for Bulk Density Change during Pyrolysis at 0.11% Moisture Content and 130.2 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	130.2	130.2	130.2	130.2
10	110.7	99.8	87.1	77.8
20	92.9	76.5	68.5	63.6
30	81.3	70.5	64.8	59.2
40	77.2	69.4	63.4	59.1
50	76.8	67.7	63.9	59.6
60	75.2	67.5	62.7	58.8

Table B.4 Experimental Data for Bulk Density Change during Pyrolysis at 0.11% Moisture Content and 141.4 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	141.4	141.4	141.4	141.4
10	120.4	109.3	96.7	86.9
20	98.4	84.2	73.9	67.9
30	90.1	76.4	71.5	63.6
40	86.0	75.8	68.4	64.1
50	84.3	75.1	69.1	63.1
60	83.1	74.4	67.5	63.2

Table B.5 Experimental Data for Bulk Density Change during Pyrolysis at 8.49% Moisture Content and 113.5 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	113.5	113.5	113.5	113.5
10	92.9	85.8	75.4	69.9
20	75.8	65.4	61.1	58.1
30	69.6	59.8	56.6	54.1
40	64.8	59.4	55.6	54.8
50	64.2	58.6	55.9	54.2
60	63.0	58.2	55.6	54.0

Table B.6 Experimental Data for Bulk Density Change during Pyrolysis at 8.49% Moisture Content and 120.9 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	120.9	120.9	120.9	120.9
10	97.9	87.6	80.1	73.6
20	78.8	72.8	61.9	57.5
30	71.4	62.1	59.5	55.8
40	69.7	62.6	58.8	56.2
50	66.8	60.1	57.6	55.9
60	66.7	60.6	57.4	55.5

Table B.7 Experimental Data for Bulk Density Change during Pyrolysis at 8.49% Moisture Content and 130.2 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	130.2	130.2	130.2	130.2
10	106.8	95.8	87.8	79.9
20	87.4	72.2	64.7	59.8
30	79.5	68.4	62.1	57.6
40	72.8	65.5	61.5	58.4
50	72.8	64.8	60.7	57.1
60	71.7	65.1	60.4	57.8

Table B.8 Experimental Data for Bulk Density Change during Pyrolysis at 8.49% Moisture Content and 141.4 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	141.4	141.4	141.4	141.4
10	117.7	104.3	93.9	86.1
20	98.5	79.1	70.9	67.3
30	84.2	73.5	67.6	62.6
40	81.3	72.5	66.4	61.9
50	78.9	71.8	65.5	61.6
60	78.8	70.5	66.0	61.4

Table B.9 Experimental Data for Bulk Density Change during Pyrolysis at 16.35% Moisture Content and 113.5 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	113.5	113.5	113.5	113.5
10	90.8	82.4	78.4	67.9
20	73.2	65.8	58.3	55.5
30	67.1	57.2	55.5	52.6
40	60.6	56.6	53.2	52.8
50	60.7	55.6	53.5	52.4
60	59.1	55.4	53.1	52.3

Table B.10 Experimental Data for Bulk Density Change during Pyrolysis at 16.35% Moisture Content and 120.9 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	120.9	120.9	120.9	120.9
10	95.9	84.5	79.0	72.9
20	80.7	68.9	59.1	57.5
30	68.4	59.1	56.6	53.3
40	65.8	58.4	55.6	53.6
50	63.5	58.3	55.0	53.3
60	62.5	57.8	54.4	52.9

Table B.11 Experimental Data for Bulk Density Change during Pyrolysis at 16.35% Moisture Content and 130.2 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	130.2	130.2	130.2	130.2
10	104.0	94.8	85.4	76.1
20	86.7	75.4	63.3	59.0
30	74.1	64.0	59.3	56.9
40	68.4	62.5	58.2	55.6
50	68.3	60.8	57.6	55.8
60	65.6	60.7	57.4	55.3

Table B.12 Experimental Data for Bulk Density Change during Pyrolysis at 16.35% Moisture Content and 141.4 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	141.4	141.4	141.4	141.4
10	114.5	101.4	94.9	82.9
20	94.1	81.2	71.3	63.1
30	81.7	69.4	63.7	61.7
40	76.4	68.1	64.1	60.6
50	75.6	68.2	63.6	60.1
60	74.3	67.1	63.3	59.8

Table B.13 Experimental Data for Bulk Density Change during Pyrolysis at 24.04% Moisture Content and 113.5 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	113.5	113.5	113.5	113.5
10	88.5	81.6	72.2	68.5
20	71.8	64.1	57.9	53.8
30	62.4	54.9	53.1	50.9
40	57.0	54.1	51.2	51.1
50	56.3	52.8	51.9	51.3
60	55.7	52.4	51.1	50.7

Table B.14 Experimental Data for Bulk Density Change during Pyrolysis at 24.04% Moisture Content and 120.9 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	120.9	120.9	120.9	120.9
10	94.6	84.2	79.8	71.2
20	77.2	62.3	60.8	55.3
30	65.5	56.5	53.7	51.7
40	62.1	56.9	52.8	51.5
50	59.7	55.3	52.4	51.9
60	59.6	55.5	52.1	51.3

Table B.15 Experimental Data for Bulk Density Change during Pyrolysis at 24.04% Moisture Content and 130.2 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	130.2	130.2	130.2	130.2
10	100.9	93.3	81.3	75.5
20	82.6	72.5	63.0	55.9
30	69.9	59.9	57.1	53.9
40	66.1	58.6	56.6	53.8
50	64.1	58.8	55.2	53.7
60	63.0	58.0	54.5	53.3

Table B.16 Experimental Data for Bulk Density Change during Pyrolysis at 24.04% Moisture Content and 141.4 kg/m^3 Initial Bulk Density

Time (min)	Bulk density (kg/m^3)			
	T=350 °C	T=400 °C	T=450 °C	T=500 °C
0	141.4	141.4	141.4	141.4
10	110.7	100.6	90.9	81.3
20	91.6	77.1	65.3	60.6
30	78.7	69.1	61.2	59.2
40	71.7	65.4	59.8	58.5
50	71.4	64.8	60.5	57.4
60	69.1	63.8	59.4	57.3

B.2 Temperature Profiles Inside the Rice Hull Bed during Pyrolysis

The data of temperature change in time at operating condition in section 3.1.4 were shown in Table B.17-B.80.

Table B.17 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	164	25	24	24	31	352	326	324	321
2	276	30	24	24	32	348	326	324	322
3	327	40	26	24	33	352	326	324	322
4	342	59	31	26	34	350	326	325	322
5	346	81	39	30	35	348	326	325	323
6	350	109	47	35	36	351	327	325	323
7	348	142	54	40	37	352	327	325	323
8	351	170	65	45	38	351	328	326	323
9	349	196	77	53	39	349	328	326	324
10	348	218	89	61	40	348	329	326	324
11	352	237	102	70	41	351	329	327	324
12	350	252	113	81	42	350	329	327	324
13	349	268	126	91	43	348	330	327	325
14	348	278	139	103	44	349	330	327	325
15	351	287	154	119	45	352	330	328	325
16	350	294	170	132	46	351	330	328	325
17	349	298	187	151	47	348	331	328	326
18	349	303	202	172	48	349	331	328	326
19	350	309	217	192	49	351	331	329	326
20	349	312	234	213	50	350	332	329	326
21	350	315	250	234	51	351	332	329	327
22	348	318	265	253	52	349	332	329	327
23	352	320	280	271	53	350	333	330	327
24	349	322	292	285	54	348	333	330	328
25	352	324	304	298	55	352	333	330	328
26	349	324	312	307	56	351	334	330	328
27	348	325	318	315	57	348	334	331	329
28	352	325	322	319	58	351	335	331	329
29	348	325	323	321	59	349	335	331	329
30	349	325	323	321	60	350	335	331	329

Table B.18 Experimental Data of Temperature profiles for 0.11% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	165	26	26	26	31	398	368	360	355
2	276	32	26	26	32	400	369	360	356
3	355	45	28	26	33	399	369	360	356
4	384	75	33	28	34	401	369	360	356
5	393	108	42	33	35	398	370	360	357
6	396	149	51	40	36	402	370	361	357
7	399	184	62	49	37	398	370	361	357
8	402	220	78	61	38	402	371	361	358
9	398	251	93	75	39	399	371	361	358
10	400	276	115	90	40	402	372	362	359
11	401	297	137	106	41	398	372	362	359
12	399	310	163	123	42	401	373	362	359
13	400	323	187	148	43	399	373	363	360
14	402	333	212	175	44	401	373	363	360
15	399	340	233	205	45	398	374	364	361
16	402	347	255	237	46	399	374	364	361
17	401	352	282	265	47	400	374	364	362
18	398	355	303	290	48	398	374	365	362
19	400	358	328	319	49	402	375	365	363
20	399	361	345	339	50	400	375	365	363
21	398	363	353	350	51	401	376	365	363
22	401	364	356	352	52	402	376	366	364
23	399	364	358	353	53	398	376	366	364
24	398	365	358	353	54	400	377	366	364
25	402	365	358	353	55	402	377	367	365
26	401	366	358	354	56	400	377	367	365
27	400	366	359	354	57	398	377	368	365
28	400	367	359	354	58	399	378	368	366
29	398	367	359	355	59	402	378	369	366
30	402	368	359	355	60	400	378	369	366

Table B.19 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	167	25	24	24	31	452	406	396	396
2	275	37	24	24	32	450	406	397	397
3	366	51	27	24	33	452	406	398	398
4	422	80	36	26	34	451	407	399	399
5	446	112	46	37	35	450	407	400	400
6	449	156	58	45	36	448	407	401	401
7	451	202	74	54	37	452	408	402	402
8	448	251	92	68	38	449	408	402	402
9	450	289	111	88	39	451	408	403	402
10	449	319	138	109	40	448	409	403	403
11	448	337	168	130	41	450	409	404	403
12	451	355	194	165	42	449	409	404	404
13	449	368	224	199	43	448	410	405	404
14	452	376	258	234	44	451	410	405	405
15	450	383	295	275	45	450	410	406	405
16	448	388	321	309	46	452	410	406	406
17	450	391	348	340	47	450	411	407	406
18	449	394	370	365	48	451	411	407	406
19	451	396	384	381	49	449	411	407	407
20	448	398	391	388	50	449	411	407	407
21	450	399	392	391	51	451	412	407	407
22	452	400	392	391	52	450	412	408	407
23	448	401	393	392	53	452	412	408	407
24	448	402	393	392	54	448	412	408	408
25	450	403	393	392	55	451	413	408	408
26	449	403	393	393	56	451	413	408	408
27	452	404	394	393	57	448	413	408	408
28	449	404	394	394	58	452	413	408	408
29	450	405	394	394	59	448	414	409	408
30	448	405	395	395	60	451	414	409	408

Table B.20 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	164	27	25	25	31	498	455	436	432
2	276	39	25	25	32	502	456	436	432
3	367	56	28	25	33	500	456	437	433
4	428	84	40	31	34	499	457	437	433
5	478	119	53	43	35	501	458	437	433
6	487	163	68	53	36	498	459	437	433
7	496	220	90	67	37	502	459	438	434
8	500	280	112	81	38	498	460	438	434
9	498	326	143	103	39	500	460	438	434
10	499	358	176	131	40	499	461	438	434
11	501	382	217	165	41	501	461	438	434
12	498	397	256	210	42	498	461	439	435
13	500	410	303	272	43	499	462	439	435
14	499	421	348	332	44	502	462	439	435
15	502	432	389	382	45	499	463	439	435
16	500	439	412	408	46	501	463	439	435
17	498	443	423	419	47	498	464	440	435
18	501	445	425	422	48	502	464	440	435
19	499	446	426	422	49	499	465	440	436
20	500	446	426	423	50	501	465	440	436
21	499	447	427	423	51	498	466	440	436
22	502	447	428	424	52	502	466	441	436
23	500	448	429	425	53	498	467	441	436
24	500	449	430	426	54	501	467	441	436
25	498	450	430	427	55	499	467	441	436
26	499	451	432	428	56	502	468	441	437
27	501	452	433	429	57	499	468	441	437
28	498	453	434	430	58	502	468	442	437
29	500	454	435	431	59	499	469	442	437
30	501	455	436	432	60	501	469	442	437

Table B.21 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	165	25	24	24	31	351	331	328	326
2	278	30	24	24	32	350	331	328	326
3	325	38	27	24	33	348	332	329	327
4	343	56	30	26	34	350	332	329	327
5	345	77	37	30	35	349	332	329	327
6	348	106	44	34	36	351	333	330	328
7	351	138	50	38	37	348	333	330	328
8	348	165	61	42	38	351	333	330	328
9	351	189	72	48	39	352	333	330	328
10	349	211	85	56	40	350	334	331	329
11	350	226	98	64	41	348	334	331	329
12	348	247	110	75	42	350	334	331	329
13	350	262	122	86	43	351	334	331	329
14	348	272	136	97	44	352	335	332	330
15	350	280	152	109	45	349	335	332	330
16	349	288	169	125	46	348	335	332	330
17	351	293	185	138	47	350	335	332	330
18	350	299	201	158	48	351	336	333	330
19	352	305	217	182	49	349	336	333	331
20	348	309	235	203	50	352	336	333	331
21	350	313	252	227	51	349	337	333	331
22	351	318	267	250	52	350	337	334	331
23	349	322	284	275	53	352	337	334	332
24	350	325	297	289	54	351	338	334	332
25	351	327	308	302	55	349	338	335	332
26	348	329	315	310	56	352	338	335	332
27	352	330	322	317	57	349	339	335	333
28	351	330	324	322	58	348	339	336	333
29	349	331	326	324	59	352	339	336	333
30	352	331	327	325	60	350	339	336	333

Table B.22 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	164	23	23	23	31	398	372	368	363
2	277	27	23	23	32	402	373	368	363
3	354	37	26	23	33	400	373	368	364
4	383	57	31	25	34	398	373	369	364
5	394	88	38	30	35	402	373	369	364
6	396	126	45	37	36	400	374	369	364
7	400	166	55	43	37	400	374	370	365
8	401	206	69	50	38	402	374	370	365
9	401	240	85	65	39	399	374	370	365
10	398	268	107	79	40	402	375	370	365
11	399	289	131	96	41	401	375	371	365
12	401	305	154	117	42	398	375	371	366
13	402	317	180	138	43	401	375	371	366
14	398	329	204	158	44	402	375	371	366
15	402	339	224	184	45	398	376	372	366
16	401	345	249	212	46	400	376	372	366
17	400	350	271	242	47	402	376	372	367
18	402	355	292	272	48	398	376	372	367
19	398	357	314	299	49	402	377	373	367
20	402	360	339	327	50	401	377	373	367
21	398	363	351	345	51	399	377	373	367
22	402	366	360	354	52	402	377	373	367
23	399	368	364	356	53	401	378	373	368
24	402	369	365	358	54	400	378	374	368
25	399	370	366	359	55	399	378	374	368
26	399	370	366	360	56	400	378	374	368
27	401	371	366	361	57	402	379	374	368
28	398	371	367	362	58	399	379	375	369
29	400	372	367	362	59	400	379	375	369
30	402	372	367	363	60	399	379	375	369

Table B.23 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	166	25	25	25	31	448	406	404	403
2	275	31	25	25	32	452	406	405	403
3	367	44	28	25	33	450	406	405	404
4	423	72	33	27	34	448	407	406	404
5	445	101	42	31	35	452	407	406	404
6	450	143	52	42	36	449	407	406	405
7	449	198	68	50	37	451	408	407	405
8	448	240	89	62	38	452	408	407	405
9	452	283	107	75	39	450	408	407	406
10	450	315	132	93	40	448	409	408	406
11	448	332	160	115	41	452	409	408	406
12	452	346	190	137	42	449	409	408	407
13	451	360	219	172	43	449	410	409	407
14	448	371	248	207	44	452	410	409	407
15	450	378	283	242	45	450	410	409	408
16	452	384	314	282	46	448	411	410	408
17	448	388	340	316	47	452	411	410	408
18	452	392	363	347	48	451	411	410	409
19	449	394	377	370	49	448	412	411	409
20	451	396	388	383	50	450	412	411	409
21	448	398	394	391	51	452	412	411	410
22	449	400	398	395	52	449	413	411	410
23	450	401	400	397	53	450	413	412	410
24	448	402	401	399	54	452	413	412	411
25	452	403	402	400	55	449	413	412	411
26	450	404	402	401	56	448	414	412	411
27	452	404	403	401	57	452	414	413	412
28	449	405	403	402	58	450	414	413	412
29	450	405	403	402	59	448	414	413	412
30	452	405	404	403	60	450	415	413	412

Table B.24 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	165	25	24	24	31	499	461	443	442
2	275	37	24	24	32	500	462	443	442
3	366	54	27	25	33	502	463	444	442
4	427	80	37	30	34	499	463	444	443
5	478	114	50	40	35	501	463	444	443
6	488	158	68	51	36	498	464	445	443
7	496	215	87	64	37	500	464	445	444
8	500	279	111	77	38	501	464	445	444
9	498	321	132	98	39	500	464	445	444
10	499	351	165	125	40	502	465	446	444
11	500	376	208	154	41	498	465	446	445
12	501	391	250	199	42	501	465	446	445
13	502	407	296	256	43	498	465	446	445
14	501	416	343	322	44	502	465	446	445
15	498	427	388	376	45	500	466	447	445
16	499	436	418	408	46	499	466	447	446
17	501	444	431	422	47	502	466	447	446
18	502	448	434	429	48	498	466	447	446
19	500	451	436	432	49	501	466	447	446
20	499	453	437	432	50	499	467	448	446
21	498	454	438	434	51	502	467	448	447
22	502	455	439	435	52	501	467	448	447
23	500	456	440	436	53	498	468	448	447
24	498	457	440	437	54	502	468	448	447
25	501	457	441	438	55	498	468	449	448
26	502	458	441	439	56	500	468	449	448
27	500	458	442	440	57	502	469	449	448
28	498	459	442	440	58	498	469	449	448
29	499	459	442	441	59	502	469	450	449
30	502	460	443	441	60	498	469	450	449

Table B.25 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	163	26	26	26	31	349	332	328	326
2	276	30	26	26	32	350	332	329	328
3	327	34	26	26	33	352	333	330	329
4	341	52	28	26	34	350	333	330	329
5	345	75	35	29	35	348	334	331	330
6	349	102	41	33	36	349	334	331	330
7	351	133	49	37	37	350	334	332	331
8	348	159	56	41	38	352	334	332	331
9	351	185	68	45	39	351	335	333	331
10	349	209	81	50	40	348	335	333	332
11	350	224	93	56	41	349	335	333	332
12	352	241	105	64	42	352	336	334	332
13	348	256	118	75	43	350	336	334	332
14	352	267	132	86	44	348	336	334	333
15	348	273	146	101	45	350	336	334	333
16	351	283	164	116	46	348	337	335	333
17	349	289	180	129	47	351	337	335	333
18	349	294	196	152	48	349	337	335	334
19	352	301	213	175	49	352	337	335	334
20	348	306	229	195	50	350	337	336	334
21	352	310	244	216	51	348	338	336	334
22	351	314	261	236	52	352	338	336	335
23	348	318	275	258	53	350	338	336	335
24	351	321	285	277	54	351	338	336	335
25	352	324	298	291	55	349	339	337	335
26	348	326	306	301	56	348	339	337	336
27	349	328	312	308	57	350	339	337	336
28	352	330	317	314	58	349	339	337	336
29	351	331	321	320	59	352	340	337	336
30	348	331	325	324	60	351	340	337	336

Table B.26 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	163	23	23	23	31	401	374	369	363
2	278	25	23	23	32	399	374	370	363
3	354	35	25	23	33	400	374	370	364
4	384	56	29	24	34	402	375	370	364
5	393	85	35	27	35	399	375	371	364
6	395	124	43	34	36	402	375	371	365
7	398	163	56	40	37	401	375	371	365
8	400	202	69	48	38	398	376	371	365
9	401	236	85	59	39	402	376	372	366
10	402	262	103	74	40	400	376	372	366
11	398	280	125	92	41	399	376	372	366
12	399	297	144	110	42	398	377	372	367
13	402	312	165	127	43	401	377	373	367
14	398	324	189	149	44	402	377	373	367
15	401	334	208	171	45	398	378	373	367
16	402	341	230	195	46	402	378	373	368
17	398	348	251	222	47	401	378	374	368
18	402	353	272	252	48	400	379	374	368
19	399	355	292	280	49	398	379	374	368
20	402	357	312	305	50	401	379	374	369
21	398	361	332	329	51	402	380	375	369
22	402	364	348	346	52	398	380	375	369
23	399	366	359	355	53	401	380	375	369
24	402	368	363	357	54	402	381	375	370
25	398	369	365	358	55	398	381	375	370
26	401	370	366	359	56	402	381	376	370
27	400	371	367	360	57	401	382	376	371
28	401	372	368	361	58	400	382	376	371
29	402	373	368	362	59	398	382	376	371
30	400	373	369	362	60	400	382	376	371

Table B.27 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	164	23	23	23	31	452	406	405	404
2	274	27	23	23	32	448	407	405	404
3	366	38	26	23	33	451	407	405	405
4	424	60	31	25	34	450	408	406	405
5	445	94	41	29	35	450	408	406	406
6	449	134	51	39	36	452	409	406	406
7	451	185	64	48	37	448	409	407	406
8	448	231	82	58	38	451	409	407	407
9	450	269	101	72	39	448	410	408	407
10	449	304	124	90	40	449	410	408	407
11	450	322	153	109	41	451	410	408	408
12	448	336	182	129	42	448	411	409	408
13	452	351	213	158	43	449	411	409	408
14	450	362	241	184	44	450	411	409	409
15	450	373	268	220	45	449	412	410	409
16	448	380	294	260	46	452	412	410	409
17	450	385	322	302	47	448	412	410	410
18	450	390	347	333	48	450	413	411	410
19	448	393	372	366	49	448	413	411	410
20	452	395	386	381	50	452	413	411	410
21	450	397	392	388	51	450	413	412	411
22	449	399	397	393	52	451	414	412	411
23	448	401	399	396	53	450	414	412	411
24	449	402	401	399	54	452	414	413	411
25	450	403	402	400	55	451	415	413	412
26	448	404	403	401	56	450	415	413	412
27	452	404	403	402	57	451	415	413	412
28	448	405	404	402	58	451	416	414	413
29	451	405	404	403	59	448	416	414	413
30	448	406	404	403	60	451	416	414	413

Table B.28 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	164	25	24	24	31	500	466	454	446
2	274	35	24	24	32	498	466	454	446
3	365	53	26	24	33	500	466	455	446
4	427	78	34	29	34	501	467	455	447
5	479	110	44	36	35	502	467	456	447
6	486	149	62	46	36	499	467	456	447
7	497	210	78	57	37	498	468	456	448
8	501	266	99	73	38	500	468	457	448
9	498	314	121	94	39	498	468	457	448
10	499	349	156	121	40	502	469	457	449
11	500	370	195	148	41	500	469	458	449
12	501	385	244	189	42	498	469	458	449
13	499	401	293	248	43	502	470	458	450
14	501	412	337	312	44	501	470	459	450
15	499	423	377	360	45	499	470	459	450
16	498	433	412	402	46	500	470	459	451
17	500	442	426	422	47	502	471	460	451
18	499	447	431	428	48	501	471	460	451
19	501	452	435	432	49	502	471	460	452
20	500	456	439	436	50	499	472	461	452
21	502	458	442	437	51	502	472	461	452
22	501	460	444	439	52	501	472	461	453
23	499	461	446	440	53	498	473	461	453
24	498	462	447	441	54	502	473	462	453
25	500	463	448	442	55	500	473	462	454
26	501	464	449	443	56	499	473	462	454
27	502	464	450	444	57	500	474	463	454
28	499	465	451	444	58	501	474	463	455
29	500	465	452	445	59	501	474	463	455
30	502	465	453	445	60	502	474	463	455

Table B.29 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	165	25	25	25	31	348	333	328	326
2	278	27	25	25	32	352	334	330	328
3	326	31	25	25	33	351	335	331	329
4	342	45	27	25	34	348	335	332	330
5	345	69	32	27	35	352	336	333	331
6	348	96	38	30	36	352	336	334	331
7	349	128	46	34	37	349	337	334	332
8	348	155	53	38	38	350	337	335	332
9	349	178	65	42	39	352	338	335	333
10	351	204	76	49	40	351	338	336	333
11	349	219	89	55	41	350	338	336	333
12	349	236	101	62	42	348	339	337	334
13	350	251	113	72	43	351	339	337	334
14	351	263	126	84	44	352	339	337	334
15	349	271	142	98	45	349	339	338	335
16	352	280	159	114	46	348	340	338	335
17	348	285	176	126	47	349	340	338	335
18	352	291	191	147	48	351	340	339	336
19	350	296	208	170	49	352	340	339	336
20	348	302	224	189	50	350	341	339	336
21	352	306	240	212	51	348	341	339	336
22	349	311	256	234	52	349	341	340	337
23	352	315	271	255	53	351	341	340	337
24	351	318	283	274	54	352	342	340	337
25	348	321	294	288	55	351	342	340	338
26	352	324	303	297	56	348	342	341	338
27	349	327	309	306	57	349	342	341	338
28	348	329	315	312	58	352	343	341	339
29	352	331	320	318	59	350	343	341	339
30	350	332	324	322	60	352	343	341	339

Table B.30 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	164	26	26	26	31	398	375	370	364
2	279	28	26	26	32	402	375	371	365
3	356	32	26	26	33	401	376	372	366
4	384	51	30	27	34	399	376	372	366
5	394	80	33	29	35	402	377	373	367
6	396	116	40	33	36	400	377	373	367
7	398	159	50	39	37	398	378	374	368
8	400	198	60	46	38	402	378	374	368
9	399	232	76	54	39	401	379	375	369
10	401	259	97	71	40	398	379	375	369
11	400	277	116	85	41	400	379	376	369
12	402	292	135	104	42	402	380	376	370
13	398	307	155	121	43	398	380	376	370
14	400	320	173	141	44	401	380	377	370
15	399	331	192	161	45	402	381	377	371
16	398	338	215	187	46	399	381	377	371
17	402	344	237	213	47	398	381	378	371
18	398	349	259	237	48	401	382	378	372
19	402	353	279	260	49	402	382	378	372
20	399	356	299	285	50	398	382	379	372
21	402	359	318	308	51	402	383	379	373
22	398	362	333	328	52	400	383	379	373
23	401	364	343	340	53	401	383	380	373
24	399	366	351	349	54	398	384	380	374
25	402	368	356	354	55	402	384	380	374
26	398	370	360	359	56	401	384	381	374
27	402	371	364	360	57	400	384	381	375
28	400	372	367	361	58	398	385	381	375
29	398	373	368	362	59	401	385	381	375
30	402	374	369	363	60	402	385	381	375

Table B.31 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	165	24	24	24	31	450	408	407	405
2	276	26	24	24	32	449	408	407	406
3	367	34	25	24	33	448	409	408	406
4	423	58	30	24	34	449	409	408	406
5	445	91	39	27	35	450	410	409	407
6	448	129	48	34	36	450	410	409	407
7	450	175	62	45	37	448	410	409	407
8	448	220	77	54	38	451	411	410	408
9	452	259	98	70	39	449	411	410	408
10	449	297	121	86	40	452	411	410	408
11	450	318	142	104	41	450	412	411	409
12	448	332	165	124	42	452	412	411	409
13	450	348	190	141	43	448	412	411	409
14	449	358	216	161	44	451	413	412	410
15	448	365	241	185	45	448	413	412	410
16	450	374	267	214	46	451	413	412	410
17	449	380	292	246	47	450	414	412	411
18	448	385	317	286	48	448	414	413	411
19	450	390	342	329	49	451	414	413	411
20	448	394	367	358	50	450	415	413	412
21	450	396	385	383	51	452	415	413	412
22	452	398	394	391	52	448	415	414	412
23	449	400	398	396	53	452	416	414	413
24	450	402	400	397	54	450	416	414	413
25	448	403	402	400	55	448	416	414	413
26	450	404	403	401	56	452	417	415	414
27	450	405	404	402	57	449	417	415	414
28	449	406	405	403	58	451	417	415	414
29	451	407	406	404	59	449	417	415	414
30	449	407	406	405	60	452	417	415	414

Table B.32 Experimental Data of Temperature Profiles for 0.11% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	163	25	23	23	31	501	469	452	448
2	275	30	23	23	32	501	469	453	449
3	366	51	25	23	33	498	470	453	449
4	428	75	33	27	34	500	470	453	450
5	479	101	42	34	35	499	470	454	450
6	487	138	60	43	36	502	471	454	451
7	498	185	75	53	37	498	471	454	451
8	501	243	96	70	38	502	471	455	452
9	499	296	119	91	39	500	472	455	452
10	500	340	152	114	40	499	472	455	453
11	501	363	190	140	41	502	472	456	453
12	498	379	239	165	42	498	473	456	453
13	500	397	288	202	43	502	473	456	454
14	502	408	332	247	44	498	473	457	454
15	498	417	373	305	45	501	474	457	454
16	499	430	399	357	46	499	474	457	455
17	501	437	417	396	47	502	474	458	455
18	498	443	423	416	48	498	474	458	455
19	500	448	430	424	49	502	475	458	456
20	501	452	436	430	50	499	475	459	456
21	502	456	440	435	51	501	475	459	456
22	498	460	443	438	52	498	476	459	457
23	500	462	446	440	53	502	476	460	457
24	502	464	447	442	54	499	476	460	457
25	498	465	448	443	55	500	477	460	458
26	500	466	449	444	56	498	477	460	458
27	501	467	450	445	57	502	477	461	458
28	498	467	451	446	58	498	478	461	458
29	502	468	451	447	59	501	478	461	459
30	499	468	452	448	60	498	478	461	459

Table B.33 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	168	23	23	23	31	352	322	265	253
2	274	28	23	23	32	348	323	276	269
3	328	47	24	23	33	350	323	288	286
4	342	69	34	26	34	352	324	296	294
5	344	82	58	48	35	351	324	302	300
6	347	90	80	78	36	349	324	305	304
7	349	97	90	90	37	348	324	309	307
8	352	113	93	92	38	350	324	312	310
9	350	132	94	93	39	352	325	314	312
10	351	152	94	94	40	350	325	316	314
11	352	168	94	94	41	351	325	318	315
12	348	182	94	94	42	348	325	319	316
13	351	198	94	94	43	350	325	319	317
14	349	212	94	94	44	352	326	319	317
15	350	226	95	95	45	350	326	319	317
16	352	239	97	95	46	348	326	319	317
17	351	251	102	95	47	352	326	319	317
18	350	262	111	96	48	351	326	320	317
19	348	275	124	96	49	350	326	320	317
20	349	284	133	97	50	348	327	320	317
21	352	292	145	103	51	352	327	320	318
22	351	300	157	112	52	349	327	320	318
23	352	306	169	125	53	350	327	320	318
24	350	310	181	141	54	348	327	321	318
25	349	313	193	157	55	352	328	321	319
26	352	316	205	173	56	350	328	321	319
27	350	318	217	189	57	351	328	321	319
28	351	319	229	205	58	350	328	322	320
29	349	320	241	221	59	349	328	322	320
30	350	321	253	237	60	350	328	322	320

Table B.34 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	168	24	24	24	31	399	363	358	355
2	276	27	24	24	32	398	364	360	357
3	358	46	25	24	33	402	365	360	357
4	381	72	36	28	34	401	365	361	357
5	391	84	65	53	35	399	365	361	358
6	398	92	85	81	36	400	366	361	358
7	402	102	89	88	37	398	366	361	358
8	400	117	92	91	38	399	366	362	358
9	398	138	92	92	39	400	366	362	359
10	401	159	93	93	40	401	367	362	359
11	399	176	93	93	41	399	367	362	359
12	400	197	93	93	42	402	367	363	359
13	398	217	93	93	43	398	367	363	360
14	399	233	94	94	44	400	368	363	360
15	401	250	94	94	45	398	368	363	360
16	399	265	98	94	46	402	368	364	360
17	400	278	102	94	47	399	368	364	360
18	398	290	117	94	48	402	369	364	361
19	400	302	144	102	49	402	369	364	361
20	398	310	165	121	50	398	369	365	361
21	399	318	191	152	51	401	370	365	362
22	402	328	216	189	52	398	370	365	362
23	400	333	241	219	53	402	370	365	362
24	399	337	266	249	54	398	370	365	362
25	400	342	290	282	55	399	371	366	363
26	402	348	314	310	56	402	371	366	363
27	398	352	335	330	57	398	371	366	363
28	401	355	348	344	58	402	371	366	363
29	399	359	353	350	59	399	372	367	363
30	401	362	356	353	60	401	372	367	364

Table B.35 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	166	23	23	23	31	451	406	396	390
2	276	25	23	23	32	448	406	396	390
3	365	47	23	23	33	450	407	397	391
4	422	73	37	26	34	449	407	397	391
5	442	86	65	56	35	448	407	398	391
6	448	93	87	84	36	448	408	398	392
7	451	99	91	90	37	451	408	398	392
8	449	126	92	91	38	448	408	398	392
9	450	163	92	92	39	449	408	399	393
10	451	202	93	92	40	450	409	399	393
11	450	236	93	92	41	452	409	399	393
12	448	262	93	93	42	448	409	399	393
13	448	285	94	93	43	451	410	400	394
14	450	305	102	93	44	450	410	400	394
15	448	320	128	95	45	449	410	400	394
16	450	337	158	98	46	448	411	400	394
17	449	347	187	118	47	450	411	401	394
18	451	356	219	147	48	449	411	401	395
19	450	367	251	194	49	450	411	401	395
20	452	375	283	241	50	448	412	401	395
21	448	382	314	294	51	451	412	402	395
22	449	390	344	338	52	448	412	402	396
23	450	396	370	365	53	450	412	402	396
24	448	400	380	376	54	449	413	402	396
25	450	402	386	382	55	451	413	402	396
26	449	403	389	385	56	450	413	403	396
27	450	404	391	387	57	448	414	403	397
28	448	405	393	388	58	449	414	403	397
29	451	405	394	389	59	452	414	403	397
30	449	406	395	389	60	450	414	403	397

Table B.36 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	22	22	22	22					
1	165	23	22	22	31	501	445	441	436
2	274	26	22	22	32	500	446	441	436
3	366	45	23	22	33	499	446	441	437
4	428	70	28	25	34	501	446	442	437
5	476	96	62	57	35	498	447	442	437
6	488	99	88	88	36	500	447	442	437
7	497	104	92	92	37	498	447	442	438
8	501	143	92	92	38	500	448	442	438
9	498	186	92	92	39	499	448	443	438
10	498	228	94	93	40	498	448	443	438
11	501	270	94	93	41	500	448	443	438
12	500	303	94	94	42	501	449	443	439
13	498	327	98	94	43	502	449	443	439
14	502	349	112	96	44	500	449	444	439
15	500	367	155	115	45	498	449	444	439
16	499	383	209	173	46	499	450	444	439
17	500	397	260	230	47	500	450	444	440
18	498	411	310	288	48	499	450	444	440
19	502	419	359	348	49	501	450	445	440
20	498	426	389	386	50	498	451	445	440
21	499	432	408	405	51	502	451	445	440
22	498	436	421	419	52	500	451	445	441
23	500	438	427	424	53	501	451	445	441
24	499	440	432	429	54	502	451	445	441
25	502	441	435	431	55	499	452	446	441
26	501	442	438	433	56	498	452	446	441
27	499	443	439	434	57	502	452	446	442
28	498	444	440	435	58	500	452	446	442
29	498	444	440	435	59	501	453	446	442
30	499	445	441	436	60	499	453	446	442

Table B.37 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	167	24	24	24	31	351	303	261	248
2	275	28	24	24	32	352	307	274	265
3	330	45	25	24	33	349	312	285	280
4	342	66	34	25	34	348	314	296	291
5	344	79	56	50	35	351	319	305	302
6	348	88	79	76	36	352	320	310	308
7	349	95	90	90	37	351	322	315	312
8	352	105	92	91	38	350	324	319	314
9	352	126	92	92	39	348	325	320	315
10	348	144	93	92	40	352	326	321	316
11	351	161	93	93	41	350	327	322	317
12	349	175	93	93	42	349	327	323	318
13	350	188	93	93	43	348	328	324	318
14	349	199	93	93	44	349	328	324	319
15	350	210	94	93	45	350	329	325	319
16	352	221	95	94	46	352	329	325	320
17	351	230	97	94	47	351	329	325	320
18	349	238	102	95	48	348	330	326	320
19	350	247	110	95	49	348	330	326	321
20	348	253	120	95	50	351	330	327	321
21	352	259	131	97	51	352	331	327	321
22	351	264	144	98	52	350	331	327	321
23	349	269	157	102	53	352	331	327	322
24	352	274	170	115	54	349	331	328	322
25	348	278	183	135	55	351	332	328	322
26	349	282	196	155	56	348	332	328	322
27	352	287	209	174	57	350	332	328	322
28	351	291	222	193	58	352	332	329	323
29	350	296	235	212	59	349	333	329	323
30	348	300	248	231	60	350	333	329	323

Table B.38 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	167	23	23	23	31	399	365	358	354
2	276	25	23	23	32	398	366	361	356
3	356	45	23	23	33	401	367	362	357
4	380	68	36	25	34	399	368	363	358
5	392	86	64	48	35	402	368	364	359
6	398	92	82	78	36	399	369	365	360
7	401	96	90	85	37	400	369	365	360
8	399	108	90	90	38	399	370	366	361
9	400	123	91	91	39	398	370	366	361
10	398	150	92	91	40	401	370	367	362
11	401	173	92	92	41	399	371	367	362
12	398	196	92	92	42	398	371	367	363
13	400	214	92	92	43	400	371	368	363
14	399	234	92	92	44	399	372	368	363
15	401	250	93	92	45	400	372	368	364
16	399	267	97	93	46	401	372	368	364
17	400	281	102	94	47	400	372	369	364
18	401	294	114	95	48	399	373	369	365
19	399	307	139	98	49	398	373	369	365
20	400	314	162	100	50	399	373	369	365
21	398	321	183	131	51	398	373	370	365
22	401	329	211	162	52	400	374	370	366
23	398	334	233	193	53	402	374	370	366
24	400	340	260	227	54	398	374	370	366
25	398	345	283	262	55	401	374	370	366
26	401	352	307	296	56	400	375	371	366
27	398	355	327	323	57	399	375	371	367
28	400	358	344	342	58	400	375	371	367
29	399	361	352	348	59	398	375	371	367
30	401	364	355	352	60	399	375	371	367

Table B.39 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	167	23	23	23	31	450	410	398	394
2	277	25	23	23	32	451	411	399	395
3	366	43	23	23	33	450	411	400	396
4	420	72	34	25	34	448	411	401	397
5	443	86	64	40	35	449	411	401	398
6	450	92	90	75	36	450	412	402	399
7	449	99	93	92	37	452	412	402	400
8	451	124	93	93	38	449	412	402	400
9	450	160	94	93	39	452	413	403	400
10	448	197	94	93	40	450	413	403	401
11	449	233	94	93	41	451	413	403	401
12	450	259	94	94	42	448	413	403	401
13	448	285	95	95	43	452	414	404	401
14	451	308	97	95	44	450	414	404	401
15	450	325	109	96	45	452	414	404	402
16	449	339	127	98	46	450	414	404	402
17	450	351	147	100	47	449	415	404	402
18	452	359	173	113	48	448	415	405	402
19	450	371	204	137	49	451	415	405	403
20	448	380	230	172	50	449	415	405	403
21	451	386	259	212	51	450	416	405	403
22	449	393	292	257	52	451	416	406	403
23	448	398	323	309	53	448	416	406	403
24	450	401	353	345	54	449	416	406	404
25	450	404	373	369	55	448	417	406	404
26	448	406	380	376	56	451	417	407	404
27	450	407	386	382	57	448	417	407	404
28	452	408	391	387	58	450	417	407	404
29	449	409	394	390	59	449	417	407	405
30	452	410	396	392	60	452	417	407	405

Table B.40 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	164	25	24	24	31	502	449	446	444
2	273	28	24	24	32	500	449	447	445
3	367	38	25	24	33	498	450	447	445
4	430	68	28	27	34	501	450	447	445
5	474	89	59	55	35	499	450	447	445
6	485	95	86	85	36	500	451	447	446
7	497	97	92	90	37	502	451	448	446
8	501	130	93	93	38	498	451	448	446
9	500	175	94	93	39	501	451	448	446
10	498	221	94	93	40	498	452	448	447
11	500	261	94	93	41	499	452	448	447
12	499	296	94	94	42	502	452	449	447
13	502	324	97	94	43	499	452	449	447
14	500	347	111	95	44	500	453	449	447
15	498	368	140	98	45	498	453	449	448
16	499	385	181	112	46	500	453	449	448
17	501	399	220	144	47	502	453	450	448
18	499	413	262	193	48	499	454	450	448
19	498	423	308	251	49	500	454	450	448
20	500	433	354	312	50	498	454	450	448
21	498	439	388	360	51	501	454	450	449
22	501	441	411	400	52	498	454	450	449
23	499	443	422	416	53	499	455	451	449
24	498	444	430	425	54	500	455	451	449
25	502	445	436	433	55	498	455	451	449
26	500	446	442	438	56	501	455	451	450
27	501	447	444	441	57	499	456	451	450
28	501	447	445	442	58	500	456	452	450
29	498	448	446	443	59	498	456	452	450
30	501	448	446	444	60	498	456	452	450

Table B.41 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	166	23	23	23	31	352	323	259	243
2	273	26	23	23	32	349	326	273	260
3	327	43	26	23	33	352	329	285	276
4	342	62	34	26	34	350	331	297	289
5	345	77	54	47	35	352	332	311	305
6	348	85	77	73	36	351	333	321	316
7	350	94	86	84	37	349	334	329	327
8	348	100	90	90	38	348	334	332	330
9	350	113	91	91	39	349	335	333	331
10	350	132	92	92	40	352	335	334	332
11	348	152	92	92	41	350	335	334	333
12	352	169	92	92	42	351	336	334	333
13	349	185	92	92	43	349	336	335	334
14	351	196	92	92	44	351	336	335	334
15	348	208	92	92	45	352	336	335	334
16	352	219	94	92	46	351	337	335	334
17	349	228	99	92	47	348	337	335	335
18	352	238	102	93	48	348	337	336	335
19	351	249	107	94	49	350	337	336	335
20	347	258	117	95	50	352	337	336	335
21	350	269	128	96	51	351	337	336	335
22	352	277	141	98	52	352	338	336	336
23	348	285	154	101	53	351	338	336	336
24	351	291	166	114	54	350	338	337	336
25	352	297	180	133	55	348	338	337	336
26	351	304	194	153	56	349	338	337	336
27	348	309	206	171	57	351	338	337	336
28	350	313	218	189	58	352	339	337	337
29	352	317	233	208	59	350	339	338	337
30	351	320	245	228	60	352	339	338	337

Table B.42 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	167	23	23	23	31	399	369	357	352
2	275	24	23	23	32	400	370	361	355
3	357	41	23	23	33	402	371	363	357
4	381	68	36	24	34	398	372	365	359
5	392	84	61	38	35	402	373	366	361
6	399	92	79	62	36	401	374	367	362
7	401	95	91	82	37	398	374	367	363
8	399	99	92	91	38	402	375	368	364
9	400	119	92	92	39	401	375	368	364
10	398	146	92	92	40	399	376	368	365
11	400	169	93	92	41	402	376	369	365
12	402	192	93	93	42	400	376	369	366
13	400	210	93	93	43	401	377	369	366
14	399	231	94	93	44	399	377	369	367
15	400	246	94	93	45	400	377	369	367
16	399	265	94	93	46	402	377	370	367
17	401	282	99	93	47	399	378	370	367
18	400	294	111	94	48	402	378	370	368
19	399	309	136	94	49	400	378	370	368
20	402	316	159	95	50	401	378	370	368
21	398	323	180	103	51	398	378	371	368
22	400	331	207	124	52	400	379	371	368
23	398	336	231	153	53	402	379	371	369
24	401	342	257	188	54	400	379	371	369
25	400	348	281	219	55	401	379	371	369
26	402	352	299	254	56	400	379	372	369
27	398	357	318	292	57	398	380	372	369
28	400	360	336	323	58	400	380	372	370
29	402	363	344	338	59	402	380	372	370
30	398	366	351	347	60	400	380	372	370

Table B.43 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	166	23	23	23	31	451	423	415	412
2	274	24	23	23	32	448	424	417	414
3	368	41	23	23	33	449	424	418	415
4	419	68	30	25	34	450	424	419	416
5	443	94	58	43	35	452	425	420	417
6	449	98	90	78	36	449	425	421	417
7	451	102	93	92	37	451	425	421	418
8	448	119	94	94	38	450	425	422	418
9	450	157	94	94	39	450	426	422	418
10	449	194	94	94	40	449	426	423	419
11	448	224	94	94	41	451	426	423	419
12	452	251	95	94	42	448	426	423	419
13	451	278	95	94	43	451	426	424	419
14	448	302	95	94	44	450	427	424	420
15	449	320	96	95	45	452	427	424	420
16	450	334	120	95	46	451	427	425	420
17	452	349	143	96	47	450	427	425	420
18	449	362	167	99	48	449	427	425	421
19	450	373	195	114	49	452	428	425	421
20	449	383	222	137	50	448	428	426	421
21	449	390	248	174	51	450	428	426	421
22	452	397	272	211	52	449	428	426	422
23	450	403	299	254	53	451	429	426	422
24	448	408	325	301	54	450	429	426	422
25	452	413	353	346	55	451	429	427	422
26	450	417	379	373	56	449	429	427	423
27	451	420	394	388	57	452	430	427	423
28	448	421	404	398	58	448	430	427	423
29	450	422	408	404	59	449	430	427	423
30	449	423	412	409	60	450	430	427	423

Table B.44 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	163	24	24	24	31	502	456	452	449
2	272	27	24	24	32	498	457	453	450
3	365	38	24	24	33	500	457	453	450
4	430	65	27	25	34	502	457	453	450
5	475	87	57	51	35	500	457	454	451
6	484	93	84	83	36	501	458	454	451
7	497	99	90	90	37	499	458	454	451
8	500	127	92	93	38	500	458	454	451
9	499	170	92	93	39	498	458	454	451
10	501	218	93	93	40	502	458	455	452
11	500	257	93	93	41	498	459	455	452
12	499	293	93	93	42	499	459	455	452
13	502	322	94	93	43	500	459	455	452
14	498	351	105	93	44	501	459	455	452
15	500	376	136	94	45	500	459	456	452
16	502	394	178	98	46	502	460	456	453
17	502	407	218	118	47	499	460	456	453
18	500	422	256	154	48	500	460	456	453
19	499	431	305	206	49	498	460	456	453
20	502	435	345	275	50	501	460	456	453
21	498	441	382	334	51	499	461	457	454
22	500	445	405	382	52	502	461	457	454
23	499	448	421	409	53	500	461	457	454
24	502	450	432	426	54	501	461	457	454
25	500	452	438	435	55	499	461	457	454
26	498	453	443	441	56	501	462	457	454
27	502	454	448	445	57	498	462	458	455
28	499	455	450	447	58	500	462	458	455
29	500	455	451	448	59	502	462	458	455
30	498	456	452	449	60	499	462	458	455

Table B.45 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	168	23	23	23	31	352	330	251	177
2	274	26	23	23	32	349	332	265	198
3	326	39	25	23	33	348	333	278	220
4	341	58	34	25	34	350	334	290	241
5	346	75	53	44	35	351	335	301	262
6	348	88	75	63	36	350	336	312	285
7	350	95	87	81	37	348	336	322	303
8	351	99	91	90	38	352	337	330	319
9	348	111	92	91	39	350	337	334	329
10	350	129	92	92	40	349	338	336	332
11	352	147	92	92	41	348	338	337	336
12	349	164	92	92	42	352	338	338	337
13	348	180	92	92	43	351	339	338	338
14	352	194	92	92	44	350	339	338	338
15	349	204	92	92	45	349	339	339	338
16	351	221	93	92	46	350	339	339	339
17	350	233	94	92	47	352	340	339	339
18	348	244	96	92	48	351	340	339	339
19	352	254	102	92	49	350	340	339	339
20	349	264	108	93	50	348	340	340	340
21	351	272	119	93	51	351	341	340	340
22	349	279	130	93	52	350	341	340	340
23	348	288	141	93	53	352	341	340	340
24	352	295	153	94	54	350	341	340	340
25	348	302	166	95	55	348	341	340	340
26	348	308	177	96	56	349	342	341	341
27	352	313	192	101	57	350	342	341	341
28	349	319	208	111	58	352	342	341	341
29	348	323	221	130	59	351	342	341	341
30	350	327	237	154	60	352	342	341	341

Table B.46 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	166	23	23	23	31	399	370	320	307
2	274	23	23	23	32	400	372	339	335
3	355	38	23	23	33	402	374	355	355
4	380	65	26	23	34	398	375	363	361
5	390	81	54	31	35	402	376	367	365
6	397	90	78	59	36	399	377	369	368
7	401	94	90	80	37	401	378	371	370
8	398	98	92	92	38	398	378	372	371
9	399	116	92	92	39	401	379	373	372
10	400	141	93	92	40	400	379	374	373
11	401	160	93	92	41	399	380	374	373
12	399	179	93	93	42	401	380	375	373
13	398	201	93	93	43	398	380	375	374
14	400	224	93	93	44	401	381	376	374
15	402	243	94	93	45	400	381	376	374
16	398	264	95	93	46	399	381	376	374
17	400	282	99	93	47	398	381	377	375
18	398	297	109	94	48	401	382	377	375
19	402	310	118	94	49	399	382	377	375
20	399	318	131	94	50	400	382	378	375
21	400	325	142	95	51	398	382	378	376
22	399	332	156	95	52	399	383	378	376
23	401	338	174	96	53	402	383	378	376
24	399	344	191	100	54	398	383	379	376
25	400	349	207	112	55	400	383	379	376
26	398	354	226	143	56	400	384	379	377
27	399	358	244	176	57	398	384	379	377
28	401	361	263	206	58	400	384	379	377
29	398	364	281	237	59	402	384	380	377
30	400	367	299	273	60	400	384	380	377

Table B.47 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	169	24	24	24	31	448	425	420	416
2	275	25	24	24	32	452	426	422	420
3	364	39	24	24	33	449	426	424	422
4	423	65	26	24	34	451	427	425	423
5	444	90	55	29	35	448	427	426	424
6	449	98	87	65	36	450	428	427	425
7	451	101	93	92	37	451	428	427	426
8	450	117	94	94	38	449	428	428	426
9	448	146	94	94	39	452	429	428	427
10	451	182	94	94	40	449	429	428	427
11	449	210	94	94	41	452	429	429	427
12	450	237	94	94	42	448	430	429	428
13	448	272	94	94	43	452	430	429	428
14	452	302	94	94	44	450	430	429	428
15	450	326	97	94	45	452	430	429	428
16	451	343	108	94	46	449	431	430	429
17	449	356	129	94	47	452	431	430	429
18	450	367	149	95	48	448	431	430	429
19	449	379	172	97	49	452	431	430	429
20	451	388	201	105	50	448	431	430	429
21	451	395	227	123	51	451	432	431	430
22	450	402	258	153	52	451	432	431	430
23	451	406	286	191	53	450	432	431	430
24	452	410	315	235	54	452	432	431	430
25	448	414	342	279	55	449	432	431	430
26	451	417	368	327	56	452	433	432	431
27	449	420	389	375	57	450	433	432	431
28	450	422	401	394	58	452	433	432	431
29	451	423	408	403	59	451	433	432	431
30	449	424	415	411	60	448	433	432	431

Table B.48 Experimental Data of Temperature Profiles for 8.49% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	167	23	23	23	31	498	459	454	451
2	270	26	23	23	32	500	460	455	452
3	364	35	23	23	33	501	460	455	452
4	429	60	25	25	34	498	461	455	452
5	474	85	41	40	35	500	461	456	453
6	486	93	74	72	36	499	462	456	453
7	498	102	90	89	37	500	462	456	453
8	501	125	92	90	38	501	463	456	453
9	498	168	92	92	39	502	463	457	453
10	500	214	92	92	40	498	463	457	454
11	499	251	93	92	41	499	463	457	454
12	498	286	93	92	42	500	464	457	454
13	501	321	95	92	43	502	464	457	454
14	499	354	99	93	44	498	464	458	454
15	500	372	125	96	45	502	464	458	454
16	498	392	171	100	46	501	464	458	454
17	502	408	216	126	47	500	465	458	455
18	500	419	259	177	48	502	465	458	455
19	501	433	308	238	49	498	465	459	455
20	502	440	353	318	50	502	465	459	455
21	500	444	385	376	51	498	465	459	455
22	498	448	410	406	52	499	466	459	455
23	500	451	425	421	53	501	466	459	456
24	502	453	434	432	54	499	466	460	456
25	502	455	441	439	55	500	466	460	456
26	500	456	446	444	56	499	466	460	456
27	499	457	450	447	57	502	467	460	456
28	498	458	452	449	58	500	467	460	456
29	501	458	453	450	59	502	467	461	456
30	501	459	454	451	60	499	467	461	456

Table B.49 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	165	26	26	26	31	351	318	174	132
2	278	30	26	26	32	349	320	188	155
3	328	41	26	26	33	348	322	206	178
4	344	57	30	26	34	352	323	222	199
5	346	75	41	33	35	351	324	238	221
6	348	89	57	50	36	350	325	256	245
7	350	93	76	71	37	351	325	274	268
8	348	95	87	84	38	352	326	290	284
9	351	96	90	89	39	348	326	304	299
10	349	96	91	90	40	350	327	310	307
11	350	104	91	91	41	351	327	314	310
12	348	117	91	91	42	348	327	316	313
13	352	132	91	91	43	351	328	317	315
14	349	148	91	91	44	352	328	318	316
15	350	163	91	91	45	348	328	319	317
16	352	181	91	91	46	351	329	319	318
17	350	197	91	91	47	352	329	319	318
18	348	211	92	91	48	350	329	320	318
19	349	223	92	91	49	351	330	320	318
20	350	235	92	92	50	348	330	320	319
21	352	246	92	92	51	352	330	320	319
22	349	257	93	92	52	351	330	321	319
23	350	266	94	92	53	349	331	321	319
24	351	275	96	92	54	352	331	321	319
25	352	284	101	93	55	348	331	321	320
26	350	292	109	93	56	350	331	322	320
27	351	300	118	93	57	348	331	322	320
28	349	306	130	96	58	349	332	322	320
29	348	311	143	102	59	351	332	322	320
30	350	315	158	114	60	348	332	322	320

Table B.50 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	166	26	26	26	31	402	364	357	352
2	276	29	26	26	32	399	365	359	355
3	355	52	28	26	33	402	366	360	357
4	384	76	41	28	34	400	367	361	358
5	392	88	62	49	35	401	367	362	359
6	396	92	81	74	36	399	368	363	360
7	401	92	89	88	37	400	368	363	361
8	399	93	91	90	38	398	368	364	361
9	401	94	91	90	39	402	369	364	362
10	398	108	91	90	40	399	369	364	362
11	400	127	91	90	41	401	369	365	362
12	398	146	91	90	42	402	370	365	363
13	402	170	92	90	43	398	370	365	363
14	398	190	92	90	44	401	370	365	363
15	398	211	92	91	45	399	370	366	363
16	401	231	92	91	46	400	371	366	364
17	402	247	92	91	47	402	371	366	364
18	400	265	92	91	48	400	372	366	364
19	401	280	106	91	49	399	372	367	364
20	402	296	126	93	50	400	372	367	364
21	402	309	151	97	51	398	372	367	365
22	401	322	176	107	52	401	373	367	365
23	401	331	199	133	53	400	373	368	365
24	402	338	221	163	54	402	373	368	365
25	398	346	247	198	55	400	373	368	365
26	400	351	268	232	56	402	374	368	366
27	399	357	291	261	57	399	374	369	366
28	404	360	316	296	58	402	374	369	366
29	401	362	338	326	59	401	374	369	366
30	400	363	352	346	60	399	374	369	366

Table B.51 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	166	25	25	25	31	451	403	395	393
2	272	27	25	25	32	448	403	395	393
3	365	48	25	25	33	452	404	395	394
4	423	71	36	27	34	449	404	396	394
5	444	91	63	51	35	451	404	396	395
6	447	95	85	78	36	450	405	396	395
7	451	97	89	88	37	452	405	396	395
8	448	98	91	90	38	450	405	397	395
9	450	101	91	90	39	448	406	397	395
10	448	119	92	90	40	452	406	397	395
11	451	141	92	91	41	449	406	397	396
12	448	169	92	91	42	448	406	398	396
13	450	195	95	91	43	450	407	398	396
14	452	223	99	92	44	448	407	398	396
15	449	245	106	94	45	452	407	398	396
16	450	271	121	95	46	448	407	399	397
17	448	295	142	107	47	451	407	399	397
18	452	313	165	124	48	452	408	399	397
19	450	327	192	148	49	448	408	399	397
20	448	341	215	180	50	449	408	399	398
21	452	353	243	213	51	450	408	400	398
22	450	365	270	248	52	452	408	400	398
23	449	374	298	285	53	449	409	400	398
24	450	382	321	316	54	450	409	400	399
25	452	388	352	346	55	448	409	400	399
26	448	394	372	368	56	452	409	401	399
27	450	397	384	381	57	450	410	401	399
28	452	399	392	389	58	449	410	401	400
29	450	401	393	391	59	450	410	401	400
30	449	402	394	392	60	448	410	401	400

Table B.52 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	163	26	26	26	31	502	443	440	438
2	275	28	26	26	32	498	443	441	438
3	367	49	27	26	33	502	443	441	439
4	428	71	33	29	34	501	444	441	439
5	478	91	61	53	35	498	444	442	439
6	484	95	85	83	36	502	444	442	440
7	496	103	91	88	37	501	444	442	440
8	501	135	92	92	38	499	445	442	440
9	498	175	92	92	39	500	445	442	440
10	500	221	92	92	40	499	445	443	441
11	499	257	93	93	41	501	445	443	441
12	498	293	95	93	42	498	446	443	441
13	499	321	100	94	43	500	446	443	441
14	500	344	116	94	44	502	446	444	442
15	502	364	142	99	45	498	446	444	442
16	498	381	174	120	46	500	447	444	442
17	499	395	208	156	47	498	447	444	442
18	502	405	242	191	48	502	447	444	442
19	501	415	282	238	49	500	447	445	443
20	499	422	318	284	50	501	447	445	443
21	500	429	350	326	51	499	448	445	443
22	498	435	388	377	52	502	448	445	443
23	502	438	408	401	53	502	448	445	444
24	499	439	422	415	54	501	448	446	444
25	500	440	427	424	55	499	448	446	444
26	499	441	432	429	56	502	449	446	444
27	502	441	435	432	57	502	449	446	444
28	500	442	438	435	58	501	449	446	445
29	498	442	439	436	59	499	449	447	445
30	501	442	440	437	60	502	449	447	445

Table B.53 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	168	25	25	25	31	352	320	176	111
2	277	28	25	25	32	349	322	192	127
3	326	39	25	25	33	348	324	213	153
4	342	55	27	25	34	351	325	230	182
5	345	69	35	28	35	352	326	249	213
6	350	84	52	46	36	350	327	267	242
7	348	90	70	64	37	349	327	286	273
8	352	90	84	79	38	350	328	301	298
9	349	91	90	89	39	352	328	312	310
10	350	92	90	90	40	352	328	318	316
11	351	99	90	90	41	351	329	322	320
12	348	113	91	90	42	348	329	324	322
13	350	129	91	90	43	350	329	325	323
14	348	144	91	91	44	349	330	326	324
15	348	161	91	91	45	352	330	326	325
16	351	176	92	91	46	350	330	327	325
17	349	189	92	91	47	351	330	327	325
18	352	207	92	91	48	348	331	327	326
19	351	222	92	92	49	349	331	328	326
20	350	237	92	92	50	351	331	328	326
21	352	250	92	92	51	350	331	328	326
22	348	263	93	92	52	352	332	328	327
23	350	273	93	92	53	350	332	329	327
24	352	283	93	92	54	351	332	329	327
25	350	292	97	92	55	350	332	329	327
26	348	299	104	92	56	349	333	329	328
27	352	305	116	93	57	350	333	330	328
28	349	310	129	94	58	348	333	330	328
29	348	314	141	97	59	351	333	330	328
30	350	317	159	101	60	352	333	330	328

Table B.54 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	167	26	26	26	31	400	374	351	343
2	275	29	26	26	32	399	375	366	362
3	356	50	26	26	33	402	376	371	368
4	383	76	37	29	34	398	377	374	371
5	392	88	58	49	35	402	377	375	373
6	395	91	78	67	36	400	378	376	374
7	400	91	86	81	37	401	378	376	375
8	399	92	89	87	38	402	379	377	375
9	398	92	90	90	39	398	379	377	376
10	399	95	90	90	40	402	380	377	376
11	402	109	90	90	41	402	380	378	376
12	400	129	90	90	42	398	380	378	377
13	398	153	91	90	43	401	380	378	377
14	400	176	91	91	44	400	381	378	377
15	402	198	91	91	45	398	381	379	377
16	398	224	91	91	46	402	381	379	378
17	401	246	93	91	47	400	381	379	378
18	399	271	95	91	48	399	381	379	378
19	399	293	106	91	49	402	382	379	378
20	402	308	124	92	50	400	382	380	379
21	398	322	141	92	51	401	382	380	379
22	401	332	162	93	52	402	382	380	379
23	399	342	184	93	53	400	383	380	379
24	402	348	205	95	54	398	383	380	380
25	398	353	228	105	55	400	383	381	380
26	402	358	248	127	56	401	383	381	380
27	398	364	268	161	57	398	384	381	380
28	402	367	291	218	58	402	384	381	381
29	399	370	312	269	59	401	384	382	381
30	402	372	334	314	60	398	384	382	381

Table B.55 Experimental data of Temperature Profiles for 16.35% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	167	24	24	24	31	448	414	392	388
2	274	27	24	24	32	449	415	398	396
3	366	46	24	24	33	452	415	404	401
4	424	66	32	26	34	450	416	408	404
5	446	84	59	52	35	449	416	411	407
6	449	92	80	78	36	450	416	413	410
7	451	94	88	86	37	451	417	414	411
8	448	95	90	89	38	448	417	415	412
9	450	98	90	90	39	451	417	416	413
10	449	114	91	90	40	448	418	416	414
11	451	137	91	90	41	450	418	417	415
12	450	163	92	90	42	451	418	417	415
13	452	189	92	91	43	449	418	417	415
14	449	217	92	91	44	450	418	417	416
15	450	242	93	91	45	449	419	418	416
16	448	274	103	91	46	450	419	418	416
17	451	297	112	92	47	451	419	418	416
18	450	318	125	93	48	449	419	418	417
19	448	339	145	98	49	451	420	418	417
20	450	351	167	103	50	448	420	418	417
21	449	362	195	114	51	450	420	419	417
22	450	375	222	135	52	449	420	419	418
23	452	385	247	152	53	450	421	419	418
24	448	392	271	181	54	450	421	419	418
25	449	398	293	218	55	448	421	419	418
26	450	403	314	254	56	449	421	420	418
27	448	407	335	289	57	450	421	420	419
28	451	410	354	322	58	452	422	420	419
29	450	412	367	351	59	451	422	420	419
30	451	413	381	374	60	450	422	420	419

Table B.56 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	165	26	26	26	31	498	461	449	445
2	274	26	26	26	32	501	462	449	446
3	368	43	26	26	33	502	463	450	447
4	426	69	33	27	34	498	464	450	447
5	476	90	56	45	35	499	464	451	448
6	486	96	74	66	36	501	465	451	448
7	495	98	83	81	37	498	465	451	449
8	499	104	89	88	38	501	465	452	449
9	501	135	92	90	39	502	465	452	449
10	498	179	93	91	40	499	466	452	449
11	502	218	93	91	41	502	466	452	450
12	500	254	93	92	42	501	466	453	450
13	499	289	96	92	43	498	466	453	450
14	502	327	99	92	44	500	467	453	450
15	498	353	107	92	45	501	467	454	451
16	500	379	129	95	46	498	467	454	451
17	502	396	156	98	47	504	467	454	451
18	500	410	195	114	48	500	468	454	451
19	498	421	232	156	49	501	468	455	451
20	498	430	270	210	50	502	468	455	452
21	501	434	306	262	51	498	468	455	452
22	500	441	347	317	52	500	468	455	452
23	502	446	381	362	53	499	469	456	452
24	499	451	413	405	54	502	469	456	453
25	500	454	432	429	55	502	469	456	453
26	500	456	441	437	56	499	469	456	453
27	499	457	444	440	57	501	470	457	453
28	498	458	446	442	58	498	470	457	454
29	502	459	447	443	59	502	470	457	454
30	500	460	448	444	60	498	470	457	454

Table B.57 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	164	24	24	24	31	348	326	172	103
2	276	26	24	24	32	350	327	191	118
3	328	38	24	24	33	352	328	212	142
4	344	53	26	24	34	350	328	233	169
5	346	68	32	26	35	352	329	256	201
6	349	82	46	38	36	349	329	279	244
7	351	91	61	52	37	351	329	296	286
8	350	91	75	68	38	350	330	308	304
9	348	92	88	81	39	348	330	317	315
10	351	92	90	88	40	350	330	323	321
11	349	100	90	90	41	349	330	326	324
12	348	111	90	90	42	351	331	328	326
13	350	125	90	90	43	348	331	329	327
14	349	137	90	90	44	350	331	330	327
15	352	151	90	90	45	352	331	330	327
16	349	167	91	90	46	351	332	330	328
17	350	186	91	90	47	350	332	331	328
18	351	200	91	90	48	349	332	331	328
19	348	218	92	90	49	351	332	331	328
20	349	237	92	90	50	348	333	331	328
21	352	254	92	90	51	350	333	331	329
22	350	269	92	91	52	348	333	332	329
23	349	284	92	91	53	349	333	332	329
24	350	296	92	91	54	352	334	332	329
25	352	305	93	91	55	350	334	332	330
26	350	312	98	91	56	352	334	332	330
27	348	316	111	91	57	351	334	333	330
28	350	320	123	92	58	351	334	333	330
29	352	323	137	93	59	350	334	333	331
30	351	325	154	97	60	351	334	333	331

Table B.58 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	164	24	24	24	31	402	375	332	312
2	274	28	24	24	32	398	376	354	343
3	354	48	24	24	33	400	377	367	362
4	382	72	35	26	34	400	378	373	370
5	392	86	56	46	35	399	378	376	374
6	395	90	73	63	36	402	379	377	376
7	399	90	85	78	37	399	379	378	377
8	400	91	88	88	38	400	380	379	378
9	398	91	90	90	39	402	380	379	378
10	402	92	91	90	40	399	380	380	378
11	399	98	91	90	41	398	381	380	379
12	399	122	91	90	42	402	381	380	379
13	398	149	91	90	43	400	381	381	379
14	400	171	91	90	44	398	382	381	379
15	399	194	91	91	45	401	382	381	380
16	402	220	91	91	46	402	382	381	380
17	398	241	91	91	47	400	383	382	380
18	400	267	91	91	48	398	383	382	380
19	399	288	91	91	49	402	383	382	381
20	402	313	93	91	50	400	383	382	381
21	398	330	109	91	51	398	384	383	381
22	399	345	126	91	52	400	384	383	381
23	401	356	148	91	53	402	384	383	381
24	400	362	167	94	54	398	384	383	381
25	399	365	192	99	55	399	385	383	382
26	400	368	214	119	56	402	385	384	382
27	398	369	233	147	57	401	385	384	382
28	402	371	262	183	58	398	385	384	382
29	400	373	285	224	59	400	386	384	382
30	398	374	311	268	60	401	386	384	382

Table B.59 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	168	26	26	26	31	448	416	389	386
2	273	28	26	26	32	452	417	404	402
3	364	42	28	26	33	448	418	410	406
4	423	60	35	27	34	450	418	413	410
5	445	79	54	42	35	448	419	415	412
6	448	92	69	59	36	451	419	416	413
7	452	93	84	74	37	452	419	416	414
8	449	93	90	89	38	450	419	417	414
9	450	94	92	90	39	451	420	417	415
10	448	108	92	91	40	449	420	417	415
11	452	133	92	91	41	452	420	417	415
12	450	156	93	91	42	449	420	418	416
13	449	183	93	92	43	452	421	418	416
14	450	211	93	92	44	449	421	418	416
15	448	237	93	92	45	451	421	418	416
16	451	264	93	92	46	449	421	419	417
17	452	291	93	92	47	452	422	419	417
18	450	315	95	92	48	450	422	419	417
19	448	342	114	92	49	451	422	419	417
20	451	358	132	92	50	450	422	420	418
21	452	369	155	93	51	452	422	420	418
22	450	380	179	94	52	451	422	420	418
23	449	388	203	96	53	449	423	420	418
24	452	396	228	108	54	452	423	420	419
25	448	401	250	135	55	448	423	421	419
26	450	405	273	178	56	450	423	421	419
27	452	409	297	231	57	451	424	421	419
28	448	412	323	289	58	450	424	421	420
29	452	414	345	330	59	448	424	421	420
30	449	415	368	364	60	452	424	421	420

Table B.60 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	164	23	23	23	31	499	466	460	457
2	273	25	23	23	32	502	467	462	460
3	366	43	23	23	33	498	467	463	461
4	427	63	29	25	34	502	467	464	462
5	477	85	48	40	35	498	467	465	463
6	485	90	67	56	36	502	468	465	463
7	495	94	79	72	37	498	468	466	463
8	500	94	86	88	38	500	468	466	464
9	498	97	91	90	39	499	468	466	464
10	501	116	91	91	40	499	469	467	464
11	498	143	92	91	41	501	469	467	464
12	501	175	92	91	42	498	469	467	465
13	499	211	92	92	43	502	469	468	465
14	502	253	92	92	44	498	470	468	465
15	498	294	92	92	45	502	470	468	465
16	500	341	95	92	46	498	470	468	466
17	500	380	102	93	47	502	470	469	466
18	499	411	116	94	48	500	471	469	466
19	498	431	141	97	49	502	471	469	466
20	501	442	183	118	50	500	471	469	467
21	502	451	228	145	51	499	471	470	467
22	500	456	273	192	52	502	472	470	467
23	498	459	312	244	53	498	472	470	467
24	502	462	348	295	54	502	472	470	468
25	500	463	384	347	55	498	472	471	468
26	499	464	408	394	56	501	473	471	468
27	502	465	431	424	57	499	473	471	468
28	498	465	444	440	58	502	473	471	469
29	501	466	453	447	59	498	473	471	469
30	498	466	457	453	60	501	473	471	469

Table B.61 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	166	25	25	25	31	349	328	173	90
2	277	27	25	25	32	352	329	194	92
3	329	34	25	25	33	349	330	218	97
4	344	49	26	25	34	350	331	237	108
5	347	65	30	26	35	351	331	257	145
6	350	78	42	34	36	352	332	281	200
7	349	88	57	48	37	352	332	298	268
8	350	90	72	64	38	350	332	316	308
9	348	91	86	78	39	349	333	322	317
10	352	92	90	86	40	350	333	325	322
11	350	94	90	89	41	352	333	327	324
12	351	103	90	90	42	348	333	328	325
13	349	119	90	90	43	352	334	329	326
14	350	133	90	90	44	348	334	330	327
15	352	145	90	90	45	348	334	331	328
16	350	163	90	90	46	349	334	331	328
17	348	178	90	90	47	350	334	332	329
18	351	196	90	90	48	351	335	332	329
19	349	213	90	90	49	350	335	332	329
20	350	232	90	90	50	352	335	333	330
21	351	249	90	90	51	351	335	333	330
22	348	268	90	90	52	350	335	333	330
23	349	286	91	90	53	350	336	334	331
24	352	299	91	90	54	349	336	334	331
25	350	309	92	90	55	348	336	334	331
26	348	315	95	90	56	352	336	334	331
27	351	319	103	90	57	350	336	334	332
28	352	322	117	90	58	349	337	335	332
29	348	325	134	90	59	350	337	335	332
30	350	327	156	90	60	352	337	335	332

Table B.62 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	166	26	26	26	31	402	383	296	212
2	276	28	26	26	32	399	384	321	268
3	356	48	26	26	33	398	384	345	326
4	383	73	33	27	34	402	384	368	356
5	392	89	54	44	35	398	384	379	374
6	396	90	71	62	36	402	385	382	380
7	399	91	89	79	37	401	385	383	381
8	401	91	90	90	38	398	385	383	381
9	398	92	91	90	39	402	385	383	382
10	399	92	91	90	40	401	385	384	382
11	400	96	91	90	41	398	386	384	382
12	398	114	91	91	42	402	386	384	383
13	402	144	91	91	43	402	386	384	383
14	399	165	92	91	44	398	386	384	383
15	401	192	92	91	45	400	386	385	383
16	399	218	92	91	46	402	387	385	384
17	398	247	92	91	47	399	387	385	384
18	402	273	92	92	48	398	387	385	384
19	398	298	92	92	49	402	387	385	384
20	400	320	92	92	50	401	387	385	384
21	399	339	94	92	51	398	388	386	385
22	398	355	108	92	52	400	388	386	385
23	402	364	124	92	53	402	388	386	385
24	400	372	142	92	54	400	388	386	385
25	402	377	161	92	55	398	388	386	385
26	399	380	181	94	56	401	389	387	386
27	402	381	201	96	57	402	389	387	386
28	398	382	225	99	58	400	389	387	386
29	402	383	248	115	59	398	389	387	386
30	399	383	272	158	60	402	389	387	386

Table B.63 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	166	23	23	23	31	450	422	394	386
2	273	25	23	23	32	448	423	408	402
3	366	37	25	23	33	451	423	413	409
4	424	56	32	25	34	451	424	416	412
5	446	74	50	40	35	452	424	418	413
6	449	89	67	57	36	450	424	419	414
7	451	92	82	74	37	449	425	420	415
8	448	92	91	88	38	451	425	421	415
9	450	93	92	89	39	452	425	421	415
10	448	100	92	91	40	448	425	421	416
11	451	115	92	91	41	451	426	422	416
12	449	136	92	91	42	450	426	422	416
13	450	168	92	92	43	449	426	422	416
14	448	197	92	92	44	452	426	422	417
15	452	228	92	92	45	449	427	423	417
16	451	263	92	92	46	448	427	423	417
17	448	296	92	92	47	452	427	423	417
18	449	322	92	92	48	448	427	423	417
19	452	346	93	92	49	452	428	423	418
20	448	362	93	92	50	450	428	424	418
21	450	375	99	92	51	449	428	424	418
22	448	388	128	92	52	451	428	424	418
23	452	397	158	95	53	452	429	424	419
24	448	404	188	98	54	448	429	425	419
25	451	410	223	109	55	450	429	425	419
26	448	413	251	129	56	448	429	425	419
27	452	416	283	162	57	449	430	425	420
28	448	418	316	216	58	451	430	426	420
29	452	420	343	284	59	452	430	426	420
30	449	421	371	354	60	451	430	426	420

Table B.64 Experimental Data of Temperature Profiles for 16.35% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	163	24	24	24	31	498	469	464	462
2	274	24	24	24	32	499	470	466	464
3	367	32	24	24	33	502	470	467	465
4	426	58	26	26	34	498	470	468	466
5	476	82	44	34	35	501	471	468	467
6	486	88	63	53	36	499	471	468	467
7	496	92	82	70	37	502	471	469	467
8	499	92	89	84	38	498	471	469	468
9	498	94	91	89	39	502	472	469	468
10	500	99	91	90	40	499	472	469	468
11	498	112	91	90	41	502	472	470	468
12	499	136	91	91	42	498	472	470	469
13	499	172	91	91	43	499	473	470	469
14	500	208	92	92	44	500	473	470	469
15	498	244	92	92	45	502	473	471	469
16	500	286	92	92	46	500	473	471	469
17	499	324	93	92	47	499	474	471	470
18	501	359	95	92	48	498	474	471	470
19	501	396	100	92	49	501	474	471	470
20	499	429	124	94	50	499	474	472	470
21	500	447	165	103	51	502	475	472	470
22	502	459	214	140	52	500	475	472	470
23	498	463	261	193	53	498	475	472	471
24	499	465	305	250	54	501	475	473	471
25	502	466	349	314	55	498	476	473	471
26	501	467	388	366	56	502	476	473	471
27	498	468	423	417	57	499	476	473	471
28	502	468	445	441	58	501	476	474	472
29	499	469	456	453	59	500	477	474	472
30	500	469	461	459	60	498	477	474	472

Table B.65 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	166	23	23	23	31	350	317	160	99
2	276	27	23	23	32	349	319	176	107
3	325	34	23	23	33	348	322	196	126
4	343	52	25	23	34	352	323	215	147
5	345	71	36	27	35	349	324	234	175
6	347	86	52	46	36	350	324	253	209
7	350	93	71	65	37	348	324	269	245
8	351	94	86	80	38	350	325	287	276
9	350	94	90	86	39	351	325	300	294
10	349	95	90	89	40	348	325	308	304
11	348	97	91	90	41	350	325	313	309
12	351	107	91	90	42	352	326	315	312
13	350	121	91	90	43	350	326	316	314
14	348	136	91	90	44	352	326	317	315
15	351	150	92	90	45	350	326	317	315
16	349	166	92	91	46	349	326	318	316
17	350	182	92	91	47	351	327	318	316
18	348	198	92	91	48	350	327	318	317
19	353	215	92	91	49	348	327	318	317
20	349	228	92	91	50	349	327	319	317
21	350	240	92	91	51	351	327	319	318
22	348	252	92	91	52	349	328	319	318
23	348	263	94	91	53	348	328	319	318
24	352	272	94	92	54	350	328	319	318
25	351	281	97	92	55	352	328	320	318
26	352	289	99	92	56	351	328	320	319
27	352	296	103	93	57	350	329	320	319
28	348	304	114	93	58	352	329	320	319
29	350	309	129	93	59	351	329	321	319
30	352	313	144	94	60	349	329	321	319

Table B.66 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	166	26	26	26	31	398	363	337	328
2	275	30	26	26	32	399	364	345	342
3	356	49	26	26	33	402	364	354	351
4	382	72	38	28	34	400	364	358	355
5	391	90	58	47	35	402	365	361	359
6	397	91	78	65	36	399	365	362	360
7	401	91	90	79	37	398	365	363	361
8	398	91	91	86	38	401	365	363	362
9	400	91	91	90	39	400	366	364	362
10	399	92	91	90	40	401	366	364	362
11	401	97	91	90	41	401	366	364	363
12	398	110	92	90	42	398	366	364	363
13	400	134	92	90	43	402	367	365	363
14	399	159	92	91	44	401	367	365	363
15	402	184	92	91	45	399	367	365	364
16	401	211	92	91	46	402	367	365	364
17	399	232	93	91	47	400	368	365	364
18	402	254	95	92	48	398	368	366	364
19	400	276	99	92	49	402	368	366	364
20	402	296	105	92	50	400	368	366	365
21	399	310	113	92	51	399	369	366	365
22	401	323	125	94	52	402	369	367	365
23	400	330	145	98	53	399	369	367	365
24	398	338	173	103	54	398	369	367	365
25	400	346	200	119	55	402	370	367	366
26	402	351	227	146	56	400	370	367	366
27	399	355	252	182	57	398	370	368	366
28	402	358	276	226	58	401	370	368	366
29	398	361	299	262	59	402	371	368	366
30	401	362	321	299	60	402	371	368	366

Table B.67 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	169	26	26	26	31	452	401	393	392
2	273	29	26	26	32	448	401	394	393
3	365	46	26	26	33	451	402	395	394
4	422	64	34	28	34	449	402	395	394
5	444	87	54	45	35	450	402	396	394
6	449	90	72	65	36	451	403	396	395
7	451	90	87	82	37	452	403	396	395
8	448	92	91	89	38	450	403	397	395
9	450	98	91	90	39	452	404	397	396
10	449	115	91	90	40	449	404	397	396
11	451	133	92	91	41	452	404	397	396
12	450	155	92	91	42	448	404	398	396
13	449	182	92	91	43	450	405	398	397
14	448	206	94	92	44	452	405	398	397
15	450	234	101	92	45	450	405	398	397
16	452	263	111	92	46	449	405	399	397
17	451	284	131	92	47	451	406	399	398
18	449	306	157	94	48	451	406	399	398
19	448	322	187	102	49	450	406	399	398
20	450	337	211	123	50	449	406	399	398
21	452	348	239	150	51	448	407	400	399
22	449	359	268	188	52	451	407	400	399
23	452	368	294	229	53	450	407	400	399
24	450	376	319	280	54	448	407	400	399
25	448	385	350	328	55	452	408	401	399
26	452	391	369	362	56	450	408	401	400
27	451	395	381	376	57	452	408	401	400
28	450	398	388	384	58	449	408	401	400
29	452	399	391	389	59	450	409	402	400
30	448	400	392	391	60	448	409	402	400

Table B.68 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 113.5 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	163	25	25	25	31	501	442	438	436
2	274	29	25	25	32	498	442	439	436
3	366	51	27	25	33	499	443	439	437
4	427	79	32	27	34	500	443	440	437
5	477	90	56	51	35	501	443	440	438
6	486	90	72	70	36	499	444	440	438
7	497	92	87	81	37	501	444	441	439
8	501	97	90	89	38	500	444	441	439
9	498	116	90	90	39	498	445	441	439
10	500	155	91	91	40	499	445	442	440
11	499	205	91	92	41	502	445	442	440
12	502	250	91	92	42	500	445	442	440
13	500	292	94	92	43	502	446	443	441
14	498	326	100	92	44	498	446	443	441
15	500	353	122	96	45	501	446	443	441
16	499	374	154	107	46	499	446	443	442
17	501	390	186	128	47	501	447	444	442
18	500	403	220	153	48	498	447	444	442
19	498	413	258	196	49	500	447	444	442
20	501	420	296	238	50	501	447	444	443
21	502	426	333	284	51	499	448	445	443
22	498	431	364	328	52	499	448	445	443
23	499	435	392	368	53	498	448	445	443
24	500	438	413	402	54	500	448	445	444
25	501	439	423	419	55	498	449	446	444
26	498	440	429	427	56	502	449	446	444
27	500	440	433	430	57	499	449	446	444
28	499	441	435	433	58	502	449	446	445
29	498	441	437	434	59	498	450	447	445
30	500	442	438	435	60	499	450	447	445

Table B.69 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	165	26	26	26	31	350	320	142	97
2	278	27	26	26	32	348	323	161	99
3	328	31	26	26	33	352	326	185	109
4	343	49	28	26	34	349	328	207	127
5	346	68	35	28	35	351	329	228	151
6	348	82	53	44	36	348	330	251	196
7	351	90	69	63	37	350	331	271	239
8	348	92	85	78	38	352	331	289	274
9	350	92	89	86	39	349	332	304	298
10	349	92	90	88	40	351	332	312	310
11	351	95	90	90	41	348	332	316	314
12	348	103	91	90	42	350	333	320	318
13	350	115	91	90	43	352	333	323	319
14	352	131	91	91	44	350	333	324	320
15	348	148	91	91	45	352	333	325	321
16	352	166	91	91	46	350	334	325	321
17	350	182	91	91	47	348	334	326	322
18	351	199	92	91	48	349	334	326	322
19	348	217	92	91	49	350	334	327	323
20	352	233	92	92	50	351	335	327	323
21	351	245	92	92	51	350	335	327	323
22	348	259	92	92	52	352	335	328	324
23	350	270	92	92	53	350	335	328	324
24	351	281	94	92	54	348	336	328	324
25	348	288	94	92	55	349	336	328	324
26	350	296	97	92	56	352	336	329	325
27	352	302	100	93	57	350	336	329	325
28	348	309	107	94	58	352	337	329	325
29	350	313	116	94	59	351	337	329	325
30	352	317	128	94	60	349	337	329	325

Table B.70 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	167	26	26	26	31	399	376	331	261
2	276	29	26	26	32	402	377	352	314
3	355	47	26	26	33	398	377	364	351
4	384	68	34	27	34	402	378	370	364
5	393	86	55	44	35	400	378	373	368
6	396	90	76	66	36	399	379	374	371
7	400	91	88	83	37	402	379	375	373
8	399	92	91	89	38	398	379	376	374
9	398	92	91	90	39	402	380	376	375
10	401	92	92	90	40	398	380	377	375
11	398	95	92	90	41	399	380	377	376
12	400	104	92	91	42	402	380	377	376
13	399	129	92	91	43	398	381	378	376
14	402	155	92	91	44	402	381	378	377
15	398	180	93	91	45	401	381	378	377
16	402	208	93	91	46	398	381	378	377
17	401	235	93	92	47	402	382	379	377
18	402	260	93	92	48	400	382	379	377
19	400	285	93	92	49	398	382	379	378
20	402	303	97	92	50	402	382	379	378
21	399	318	104	92	51	400	382	380	378
22	399	331	117	92	52	399	383	380	378
23	402	342	136	92	53	402	383	380	378
24	398	351	157	93	54	401	383	380	379
25	401	359	179	95	55	398	383	381	379
26	399	362	204	98	56	400	384	381	379
27	402	367	226	104	57	402	384	381	379
28	399	372	253	119	58	398	384	381	380
29	402	374	279	147	59	399	384	382	380
30	401	375	307	204	60	400	384	382	380

Table B.72 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 120.9 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	163	25	25	25	31	498	459	455	452
2	276	27	25	25	32	499	459	456	453
3	368	50	26	25	33	502	460	456	453
4	428	79	35	27	34	500	460	457	454
5	479	88	61	51	35	498	460	457	454
6	488	90	79	70	36	501	460	457	454
7	496	90	85	83	37	499	461	458	455
8	501	96	90	89	38	501	461	458	455
9	498	112	90	90	39	501	461	458	455
10	500	147	90	90	40	498	461	459	456
11	499	194	91	90	41	501	462	459	456
12	500	238	91	91	42	499	462	459	456
13	502	281	93	91	43	500	462	459	456
14	498	319	95	91	44	501	462	460	457
15	500	355	104	92	45	498	463	460	457
16	500	380	135	94	46	501	463	460	457
17	498	398	168	99	47	502	463	460	457
18	499	407	208	105	48	498	463	461	457
19	501	419	252	135	49	502	464	461	458
20	498	428	291	178	50	500	464	461	458
21	502	435	328	231	51	501	464	461	458
22	499	441	366	289	52	499	464	461	458
23	500	446	394	346	53	500	465	462	459
24	498	450	416	389	54	501	465	462	459
25	499	454	433	418	55	500	465	462	459
26	502	456	442	434	56	502	465	462	459
27	498	457	448	443	57	498	466	462	460
28	502	458	451	448	58	502	466	463	460
29	501	458	453	450	59	499	466	463	460
30	500	459	454	451	60	498	466	463	460

Table B.73 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	164	25	25	25	31	351	326	134	95
2	277	25	25	25	32	352	328	158	96
3	327	28	25	25	33	348	330	182	101
4	343	46	27	25	34	349	331	208	113
5	345	64	32	27	35	352	332	232	142
6	348	78	47	40	36	350	332	258	187
7	350	89	62	54	37	348	333	279	233
8	351	91	79	72	38	352	333	296	272
9	348	91	89	84	39	350	334	313	300
10	350	92	90	89	40	352	334	322	316
11	348	92	90	90	41	349	334	327	323
12	352	95	90	90	42	350	334	329	326
13	349	108	91	90	43	348	335	330	327
14	351	127	91	91	44	352	335	331	328
15	348	142	91	91	45	350	335	332	329
16	351	161	91	91	46	348	335	332	329
17	350	176	91	91	47	350	336	333	330
18	352	194	92	91	48	349	336	333	330
19	348	214	92	92	49	349	336	333	330
20	350	230	92	92	50	348	336	334	331
21	348	245	92	92	51	350	337	334	331
22	352	261	92	92	52	351	337	334	331
23	352	275	92	92	53	352	337	334	331
24	350	286	92	92	54	350	337	335	332
25	351	294	93	92	55	349	338	335	332
26	350	303	93	92	56	348	338	335	332
27	349	307	94	92	57	350	338	335	332
28	352	313	99	93	58	352	338	336	333
29	350	318	107	93	59	351	339	336	333
30	348	322	117	93	60	351	339	336	333

Table B.74 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	26	26	26	26					
1	164	26	26	26	31	398	380	318	258
2	278	28	26	26	32	400	381	341	311
3	357	43	26	26	33	402	381	361	348
4	383	61	31	28	34	399	382	368	363
5	392	78	48	41	35	400	382	373	370
6	397	87	64	56	36	398	382	375	373
7	402	90	78	72	37	402	382	377	374
8	398	92	89	86	38	400	383	378	375
9	400	92	91	90	39	401	383	379	376
10	399	93	91	90	40	398	383	380	376
11	398	93	91	91	41	400	383	380	377
12	400	98	91	91	42	399	384	381	377
13	398	118	92	91	43	400	384	381	378
14	399	145	92	91	44	402	384	381	378
15	402	174	92	92	45	400	384	382	378
16	399	205	92	92	46	402	384	382	378
17	400	231	92	92	47	399	384	382	379
18	398	260	93	92	48	398	385	382	379
19	402	285	93	92	49	400	385	382	379
20	400	309	93	92	50	401	385	383	379
21	399	326	93	92	51	398	385	383	380
22	400	338	98	92	52	400	385	383	380
23	401	349	109	92	53	399	386	383	380
24	398	357	123	93	54	402	386	383	380
25	400	366	145	95	55	399	386	384	380
26	399	372	174	97	56	400	386	384	381
27	402	376	201	101	57	398	386	384	381
28	401	378	233	116	58	402	387	384	381
29	398	379	262	142	59	399	387	384	381
30	399	380	292	198	60	399	387	384	381

Table B.75 Experimental data of Temperature Profiles for 24.04% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	166	24	24	24	31	451	419	410	404
2	273	26	24	24	32	448	420	413	409
3	364	41	24	24	33	452	421	415	412
4	423	58	26	24	34	449	421	416	413
5	445	78	45	33	35	451	422	417	414
6	449	89	66	55	36	449	422	417	414
7	451	91	85	76	37	450	422	418	415
8	448	91	90	89	38	452	423	418	415
9	450	93	91	90	39	448	423	418	415
10	452	101	91	90	40	451	423	419	416
11	448	117	91	90	41	452	423	419	416
12	448	141	92	90	42	449	424	419	416
13	450	169	92	90	43	450	424	419	416
14	449	196	92	90	44	451	424	420	417
15	452	224	92	90	45	448	424	420	417
16	449	256	92	90	46	450	424	420	417
17	452	281	92	91	47	451	425	420	417
18	450	306	94	91	48	449	425	421	418
19	452	327	106	91	49	450	425	421	418
20	449	343	127	91	50	452	425	421	418
21	452	358	162	95	51	450	426	421	418
22	450	369	194	98	52	448	426	421	418
23	449	380	226	108	53	452	426	422	419
24	448	387	257	127	54	450	426	422	419
25	448	395	289	155	55	449	426	422	419
26	449	401	316	196	56	450	427	422	419
27	448	407	345	259	57	452	427	422	420
28	452	412	372	330	58	448	427	423	420
29	450	416	389	372	59	452	427	423	420
30	451	418	403	394	60	450	427	423	420

Table B.76 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 130.2 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	165	24	24	24	31	498	459	456	451
2	275	26	24	24	32	498	460	457	452
3	367	48	26	24	33	500	460	457	453
4	430	77	36	26	34	501	460	458	453
5	475	89	59	49	35	499	460	458	454
6	485	90	77	68	36	500	461	458	454
7	496	92	86	79	37	502	461	459	454
8	501	93	91	88	38	498	461	459	455
9	499	99	91	90	39	502	461	459	455
10	500	126	91	90	40	499	462	459	455
11	501	169	91	90	41	501	462	459	456
12	500	214	91	90	42	498	462	460	456
13	499	261	92	90	43	499	462	460	456
14	500	303	92	90	44	502	462	460	456
15	502	349	92	91	45	498	463	460	457
16	498	381	96	92	46	502	463	460	457
17	499	402	105	93	47	499	463	461	457
18	500	415	121	93	48	501	463	461	457
19	502	425	162	98	49	499	464	461	458
20	498	435	197	103	50	502	464	461	458
21	499	443	239	123	51	498	464	461	458
22	502	448	284	192	52	500	464	462	458
23	500	452	322	269	53	499	465	462	459
24	499	455	356	332	54	502	465	462	459
25	501	456	392	388	55	499	465	462	459
26	498	457	416	412	56	499	465	462	459
27	498	458	436	433	57	502	466	463	460
28	500	458	448	446	58	499	466	463	460
29	499	459	453	448	59	501	466	463	460
30	501	459	455	450	60	500	466	463	460

Table B.77 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 350 °C

TIME	T=350°C				TIME	T=350°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	165	23	23	23	31	349	331	110	92
2	276	23	23	23	32	350	332	139	92
3	325	25	23	23	33	348	333	172	94
4	342	43	25	23	34	352	334	202	99
5	345	61	30	26	35	350	335	231	114
6	349	76	44	38	36	352	335	263	147
7	351	89	59	51	37	348	336	289	195
8	349	91	76	69	38	349	336	309	252
9	350	92	88	83	39	350	336	324	313
10	349	92	91	88	40	351	337	330	326
11	350	92	91	91	41	349	337	332	329
12	352	92	91	91	42	350	337	333	330
13	349	92	91	91	43	352	337	334	331
14	350	104	91	91	44	351	338	334	331
15	349	118	91	91	45	348	338	335	331
16	352	137	91	91	46	351	338	335	332
17	350	159	91	91	47	352	338	335	332
18	349	186	92	91	48	350	338	336	332
19	351	210	92	91	49	348	339	336	333
20	348	232	92	91	50	350	339	336	333
21	350	249	92	91	51	348	339	336	333
22	352	266	92	91	52	352	339	336	334
23	348	280	92	91	53	350	339	337	334
24	350	291	92	91	54	352	340	337	334
25	352	301	92	91	55	351	340	337	334
26	351	309	93	92	56	350	340	337	334
27	349	316	93	92	57	350	340	337	335
28	350	322	93	92	58	348	340	338	335
29	351	326	93	92	59	350	341	338	335
30	352	330	98	92	60	349	341	338	335

Table B.78 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 400 °C

TIME	T=400°C				TIME	T=400°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	24	24	24	24					
1	165	24	24	24	31	401	385	285	171
2	276	26	24	24	32	398	385	321	232
3	356	41	24	24	33	400	386	357	299
4	383	59	27	26	34	402	386	372	361
5	392	76	45	36	35	400	386	377	373
6	396	84	61	52	36	398	386	379	376
7	400	89	75	69	37	402	387	380	378
8	398	92	89	84	38	401	387	381	379
9	402	92	90	89	39	400	387	382	379
10	399	92	91	90	40	398	387	382	380
11	400	94	91	90	41	402	387	383	380
12	401	95	91	90	42	401	388	383	380
13	400	107	91	90	43	400	388	383	380
14	401	133	91	90	44	399	388	384	381
15	399	164	91	90	45	402	388	384	381
16	398	202	92	91	46	400	388	384	381
17	400	234	92	91	47	401	388	384	381
18	398	265	92	91	48	399	389	384	381
19	402	292	92	91	49	400	389	385	382
20	400	315	92	91	50	401	389	385	382
21	401	330	92	91	51	399	389	385	382
22	398	343	92	91	52	402	389	385	382
23	398	355	92	91	53	400	389	386	382
24	400	364	94	91	54	398	390	386	383
25	401	371	101	91	55	400	390	386	383
26	398	377	112	91	56	399	390	386	383
27	400	381	132	91	57	402	390	386	383
28	401	383	172	92	58	400	390	387	383
29	398	384	211	96	59	399	391	387	384
30	400	385	251	112	60	401	391	387	384

Table B.79 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 450 °C

TIME	T=450°C				TIME	T=450°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	23	23	23	23					
1	168	23	23	23	31	448	420	412	402
2	275	25	23	23	32	450	421	416	411
3	366	39	23	23	33	452	421	418	415
4	422	63	25	23	34	448	422	419	417
5	448	84	42	30	35	448	422	420	418
6	450	89	63	52	36	451	423	420	418
7	448	90	82	73	37	449	423	421	419
8	452	92	90	87	38	451	423	421	419
9	450	92	90	90	39	450	424	421	419
10	449	98	90	90	40	452	424	422	420
11	451	109	90	90	41	450	424	422	420
12	448	132	91	90	42	452	424	422	420
13	450	162	91	90	43	448	425	422	420
14	449	189	91	90	44	451	425	423	421
15	448	220	91	90	45	449	425	423	421
16	449	251	91	91	46	452	425	423	421
17	451	279	91	91	47	450	425	423	421
18	452	306	92	91	48	449	426	423	421
19	448	330	92	91	49	451	426	424	422
20	450	350	99	91	50	449	426	424	422
21	449	365	113	91	51	450	426	424	422
22	450	378	138	91	52	451	426	424	422
23	451	390	163	92	53	450	427	424	422
24	449	397	196	94	54	452	427	425	423
25	450	405	238	104	55	448	427	425	423
26	448	408	279	136	56	449	427	425	423
27	450	412	316	192	57	451	427	425	423
28	451	415	357	263	58	449	428	425	423
29	449	418	388	334	59	450	428	426	424
30	452	419	407	388	60	449	428	426	424

Table B.80 Experimental Data of Temperature Profiles for 24.04% Moisture Content, 141.4 kg/m^3 Initial Bulk Density and Pyrolysis Temperature at 500 °C

TIME	T=500°C				TIME	T=500°C			
(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm	(min)	R=4.8 cm	R=3.2 cm	R=1.6 cm	R=0.0 cm
0	25	25	25	25					
1	164	25	25	25	31	500	464	459	455
2	275	27	25	25	32	498	464	459	456
3	366	48	26	25	33	502	464	460	456
4	429	71	34	27	34	501	464	460	457
5	478	88	56	46	35	498	465	460	457
6	487	92	74	65	36	502	465	461	457
7	498	92	83	80	37	499	465	461	458
8	502	92	89	89	38	499	465	461	458
9	499	98	90	89	39	502	465	462	458
10	500	107	90	90	40	500	466	462	458
11	498	153	91	90	41	498	466	462	459
12	502	199	91	90	42	499	466	462	459
13	500	246	91	90	43	501	466	463	459
14	499	288	91	90	44	502	466	463	459
15	501	326	91	91	45	500	467	463	459
16	500	364	91	91	46	501	467	463	460
17	501	395	94	91	47	498	467	463	460
18	502	418	99	91	48	502	467	464	460
19	500	433	118	91	49	498	467	464	460
20	498	443	153	93	50	501	468	464	460
21	499	453	191	96	51	499	468	464	461
22	501	458	240	106	52	501	468	464	461
23	500	460	292	156	53	499	468	465	461
24	498	461	341	227	54	502	468	465	461
25	500	462	392	321	55	501	469	465	461
26	502	462	429	401	56	500	469	465	462
27	500	463	447	435	57	501	469	465	462
28	499	463	454	451	58	500	469	466	462
29	498	463	457	453	59	502	469	466	462
30	502	464	458	454	60	499	469	466	462

APPENDIX C

THE EXPERIMENTAL DATA OF RICE HULL HEAT CAPACITY

The experimental data for heat capacity following the procedure in section 3.2 were shown in Figure C.1 and Table C.1-C.6.

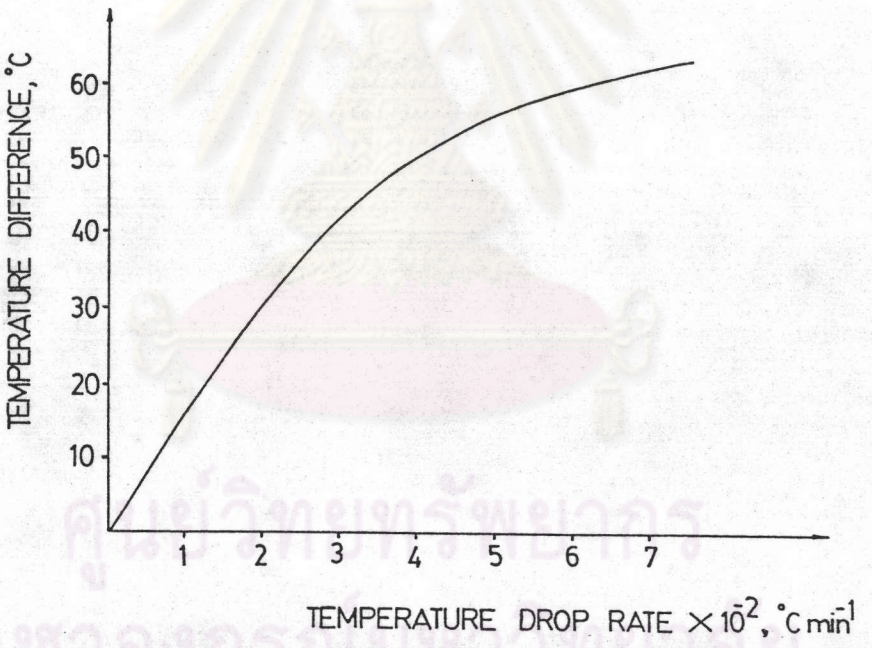

Figure C.1 Heat Loss Curve for Heat Capacity Calorimeter

Table C.1 Data for Heat Capacity Constant (H_c) of the Calorimeter

No	Weight of hot water (g)	Initial temp of hot water (°C)	Weight of cold water (g)	Initial temp of cold water (°C)	Equilibrium temp of mixture (°C)	Heat capacity constant (cal/°C)
1	248.6	33	284.9	17	25	36.30
2	249.0	36	285.9	18	27	36.90
3	234.9	41	290.2	10	25	37.16
4	246.3	43	301.5	10	26	37.46
5	211.4	47	337.4	7	24	37.98
					average	37.16

Table C.2 Data for Heat Capacity Determination of Rice Hull at 0.11% Moisture Content

No	Room temp (°C)	Weight of rice hull (g)	Initial temp of rice hull (°C)	Weight of cold water (g)	Initial temp of cold water (°C)	Equilibrium temp of mixture (°C)
1	23	44.02	32	54.02	17	24
2	25	46.27	40	51.92	15	27
3	24	43.35	46	53.06	10	27
4	24	45.40	56	55.42	11	32

Table C.3 Data for Heat Capacity Determination of Rice Hull at 8.49% Moisture Content

No	Room temp (°C)	Weight of rice hull (g)	Initial temp of rice hull (°C)	Weight of cold water (g)	Initial temp of cold water (°C)	Equilibrium temp of mixture (°C)
1	24	48.92	28	50.11	18	23
2	26	47.64	40	55.01	17	28
3	25	46.06	46	56.63	10	27
4	24	47.25	52	51.47	8	30

Table C.4 Data for Heat Capacity Determination of Rice Hull at 16.35% Moisture Content

No	Room temp (°C)	Weight of rice hull (g)	Initial temp of rice hull (°C)	Weight of cold water (g)	Initial temp of cold water (°C)	Equilibrium temp of mixture (°C)
1	24	47.20	31	52.13	17	24
2	23	46.49	40	52.81	10	25
3	25	44.83	46	55.40	9	27
4	24	43.22	56	55.07	7	31

Table C.5 Data for Heat Capacity Determination of Rice Hull at 24.04% Moisture Content

No	Room temp (°C)	Weight of rice hull (g)	Initial temp of rice hull (°C)	Weight of cold water (g)	Initial temp of cold water (°C)	Equilibrium temp of mixture (°C)
1	25	46.94	31	54.32	17	24
2	23	47.53	43	52.39	10	27
3	22	45.95	51	50.79	7	30
4	26	44.92	55	53.60	6	31

Table C.6 Data for Heat Capacity Determination of Rice Hull Char

No	Room temp (°C)	Weight of rice hull char (g)	Initial temp of rice hull char (°C)	Weight of cold water (g)	Initial temp of cold water (°C)	Equilibrium temp of mixture (°C)
1	25	47.30	32	53.74	17	24
2	24	44.57	41	53.30	11	25
3	23	46.06	47	52.70	11	28
4	25	45.48	54	51.37	8	30

APPENDIX D

DETERMINATION OF PYROLYSIS PARAMETERS FROM MATHEMATICAL MODEL BY FINITE DIFFERENCE METHODS

Finite difference methods provide a means for obtaining numerical solutions with simple geometrical shapes. Derivatives in the mathematical model equation is replaced by discrete differences. This leads to an algebraic equation which must be solved simultaneously at discrete time levels.

In order to simplify the evaluation of pyrolysis parameters, the problem will be considered in two parts. One part deals with the evaluation of transient thermal conductivity and the other part deals with the evaluation of kinetic parameters.

D.1 Determination of the Transient Thermal Conductivity

The governing partial differential equation (PDE) for transient thermal conductivity is given in chapter 4 as follows :

$$\frac{1}{r}\frac{\partial(q_r r)}{\partial r} + Q\left(\frac{\partial \rho}{\partial t}\right) = \frac{\partial(\rho C_p T)}{\partial t} \qquad (D.1)$$

Substitution of Fourier's Law and thermal conductivity as a function of bulk density and local temperature is shown in equation (D.2)

$$k = k_o + a(\rho - 0.15) + b(T - 20) \qquad (D.2)$$

equation (D.1) gives the following differential equation

$$\frac{\partial \rho}{\partial t} = \frac{k\frac{\partial^2 T}{\partial r^2} + (a\frac{\partial \rho}{\partial r} + \frac{k}{r})(\frac{\partial T}{\partial r}) + b(\frac{\partial T}{\partial r})^2 - \rho C_p \frac{\partial T}{\partial t}}{(C_p T - Q)} \qquad (D.3)$$

This equation is solved by substituting known values and estimating the unknown values (k_o, a, b) with march in time starting at an initial condition. The derivative is evaluated in the interval between t to t+Δt and r to r$\pm\Delta$r as

$$\frac{\partial^2 T(r,t)}{\partial r^2} = \frac{T_{i,j+1} - 2T_{i,j} + T_{i,j-1}}{\Delta r^2} \qquad (D.4)$$

$$\frac{\partial T(r,t)}{\partial r} = \frac{T_{i,j+1} - T_{i,j-1}}{2\Delta r} \qquad (D.5)$$

$$\frac{\partial T(r,t)}{\partial t} = \frac{T_{i+1,j} - T_{i,j}}{\Delta t} \qquad (D.6)$$

$$\frac{\partial \rho(r,t)}{\partial r} = \frac{\rho_{i,j+1} - \rho_{i,j-1}}{2\Delta r} \qquad (D.7)$$

$$\frac{\partial \rho(r,t)}{\partial t} = \frac{\rho_{i+1,j} - \rho_{i,j}}{\Delta t} \qquad (D.8)$$

where i refers to time and j refers to radial distance. Finally the bulk density at various times and positions is obtained. The average bulk density at various times is evaluated and compared with measured average bulk density by a Gauss Newton optimization technique (see Appendix E) where the unknown values (k_o, a, b) in the thermal conductivity term are available.

The program to determine thermal conductivity during pyrolysis is presented in below.

```
10 CLEAR
20 OPTION BASE 0
30 DIM T(50,3), AYEXP(50), YCAL(500,3), YCALDK(500,3), YCALDA(500,3), YCALDB(500
,3), TSTEP(500,3), Y(500,3), AYCAL(50), AYCALDK(50), AYCALDA(50), AYCALDB(50)
40 INPUT "DATAFILE : ", A$
50 A1$ = "B:" + A$ + ".PRN"
60 OPEN "I", #1, A1$
70 INPUT #1, K0, A, B, DINI, CP, NO
80 FOR I = 0 TO NO
90 INPUT #1, T(I,3), T(I,2), T(I,1), T(I,0), AYEXP(I)
100 NEXT I
110 CLOSE #1
120 D0 = .15 : T0 = 20 : DELT = 3 : DELR = 1.6
130 FOR J = 0 TO 3
140 YCAL(0,J) = DINI
150 YCALDK(0,J) = DINI
160 YCALDA(0,J) = DINI
170 YCALDB(0,J) = DINI
180 TSTEP(0,J) = T(0,J)
190 NEXT J
200 FOR I = 1 TO NO
210 FOR K = 1 TO 20
220 FOR J = 0 TO 3
230 TSTEP(20*(I-1)+K,J) = (T(I,J)-T(I-1,J))*K/20 + T(I-1,J)
240 NEXT J
250 NEXT K
260 NEXT I
270 FOR J = 0 TO 3
280 Y(0,J) = YCAL(0,J)
290 NEXT J
300 GOSUB 1040
310 FOR I = 0 TO NO*20
320 FOR J = 0 TO 3
330 YCAL(I,J) = Y(I,J)
340 NEXT J
350 NEXT I
360 K = K*1.01
370 GOSUB 1040
380 FOR I = 0 TO NO*20
390 FOR J = 0 TO 3
400 YCALDK(I,J) = Y(I,J)
410 NEXT J
420 NEXT I
430 A = A*1.01 : K = K/1.01
440 GOSUB 1040
450 FOR I = 0 TO NO*20
460 FOR J = 0 TO 3
470 YCALDA(I,J) = Y(I,J)
480 NEXT J
490 NEXT I
500 B = B*1.01 : A = A/1.01
```

```
510 GOSUB 1040
520 FOR I = 0 TO NO*20
530 FOR J = 0 TO 3
540 YCALDB(I,J) = Y(I,J)
550 NEXT J
560 NEXT I
570 B = B/1.01
580 ESP = 0 : AA = 0 : BB = 0 : CC = 0 : DD = 0 : EE = 0 : FF = 0 : GG = 0 : HH
= 0 : II = 0 : JJ = 0 : KK = 0 : LL = 0
590 FOR I = 0 TO NO
600 AYCAL(I) = (YCAL(20*I,1) + YCAL(20*I,2))/2
610 AYCALDK(I) = (YCALDK(20*I,1)+YCALDK(20*I,2))/2
620 AYCALDA(I) = (YCALDA(20*I,1)+YCALDA(20*I,2))/2
630 AYCALDB(I) = (YCALDB(20*I,1)+YCALDB(20*I,2))/2
640 DYDK = (AYCALDK(I)-AYCAL(I))/.01
650 DYDA = (AYCALDA(I)-AYCAL(I))/.01
660 DYDB = (AYCALDB(I)-AYCAL(I))/.01
670 ESP = ESP + (AYEXP(I)-AYCAL(I))^2
680 EDC = AYEXP(I) - AYCAL(I)
690 AA = AA + DYDA^2
700 EE = EE + DYDB^2
710 II = II + DYDK^2
720 BB = BB + DYDB*DYDA
730 CC = CC + DYDK*DYDA
740 FF = FF + DYDK*DYDB
750 JJ = JJ + ECD*DYDA
760 KK = KK + EDC*DYDB
770 LL = LL + EDC*DYDK
780 NEXT I
790 DD = BB : GG = CC : HH = FF
800 LPRINT "DATAFILE = ", A$
810 LPRINT "AA =", AA, "BB =", BB, "CC =", CC, "JJ =", JJ
820 LPRINT "DD =", DD, "EE =", EE, "FF =", FF, "KK =", KK
830 LPRINT "GG =", GG, "HH =", HH, "II =", II, "LL =", LL
840 LPRINT "ESP =", ESP, "k0 =", K0, "a =", A, "b = ", B
850 INPUT "DO YOU INPUT  DATAFILE ? (Y or N)   ", B$
860 IF B$ = "Y" GOTO 10
870 IF B$ = "N" GOTO 880
880 INPUT "TAA,TBB,TCC,TJJ   ", TAA, TBB, TCC, TJJ
890 INPUT "TDD,TEE,TFF,TKK   ", TDD, TEE, TFF, TKK
900 INPUT "TGG,THH,TII,TLL   ", TGG, THH, TII, TLL
910 INPUT "TESP   ", TESP
920 DET = (TAA*TEE*TII) + (TBB*TFF*TGG) + (TCC*TDD*THH) - (TGG*TEE*TCC) - (THH*T
FF*TAA) - (TII*TDD*TBB)
930 PRINT "DET = ", DET
940 IF ABS(DET) <= .000001 THEN END
950 DA = ((TJJ*TEE*TII)+(TBB*TFF*TLL)+(TCC*TKK*THH)-(TLL*TEE*TCC)-(THH*TFF*TJJ)-
(TII*TKK*TBB))/DET
960 DB = ((TAA*TKK*TII)+(TJJ*TFF*TGG)+(TCC*TDD*TLL)-(TGG*TKK*TCC)-(TLL*TFF*TAA)-
(TII*TDD*TJJ))/DET
970 DB = ((TAA*TEE*TLL)+(TBB*TKK*TGG)+(TJJ*TDD*THH)-(TGG*TEE*TJJ)-(THH*TKK*TAA)-
(TLL*TDD*TBB))/DET
980 LPRINT "DK =", DK, "DA =", DA, "DB =", DB
990 K0 = K0 + DK : A = A + DA : B = B + DB
1000 LPRINT "K0 =", K0, "a =", A, "b =", B
1010 IF TESP <= .0001 THEN END
```

```
1020 GOTO 10
1030 END
1040 FOR I = 0 TO NO*20-1
1050 FOR J = 1 TO 2
1060 A0 = CP*Y(I,J)*(TSTEP(I+1,J)-TSTEP(I,J))/DELT
1070 B0 = ((TSTEP(I,J+1)-TSTEP(I,J-1))/2/DELR)^2*B
1080 C0 = (K0 + A*(Y(I,J)-D0) + B*(TSTEP(I,J)-T0))/DELR/J
1090 D00 = A*(Y(I,J+1)-Y(I,J-1))/2/DELR
1100 E0 = (D00+C0)*(TSTEP(I,J+1)-TSTEP(I,J-1))/2/DELR
1110 F0 = (K0 + A*(Y(I,J)-D0) + B*(TSTEP(I,J)-T0))*(TSTEP(I,J+1)-2*TSTEP(I,J)+TS
TEP(I,J-1))/(DELR^2)
1120 IF TSTEP(I,J) < 200 THEN Q = -2.76*TSTEP(I,J) + 2518.4 : GOTO 1240
1130 IF TSTEP(I,J) < 225 THEN Q = -2.25*TSTEP(I,J) + 837.5 : GOTO 1240
1140 IF TSTEP(I,J) < 250 THEN Q = -1.75*TSTEP(I,J) + 725 : GOTO 1240
1150 IF TSTEP(I,J) < 275 THEN Q = -1.5*TSTEP(I,J) + 662.5 : GOTO 1240
1160 IF TSTEP(I,J) < 300 THEN Q = -1.4*TSTEP(I,J) + 635 : GOTO 1240
1170 IF TSTEP(I,J) < 325 THEN Q = -1.1*TSTEP(I,J) + 545 : GOTO 1240
1180 IF TSTEP(I,J) < 350 THEN Q = -1*TSTEP(I,J) + 512.5 : GOTO 1240
1190 IF TSTEP(I,J) < 375 THEN Q = -.85*TSTEP(I,J) + 460 : GOTO 1240
1200 IF TSTEP(I,J) < 400 THEN Q = -.65*TSTEP(I,J) + 385 : GOTO 1240
1210 IF TSTEP(I,J) < 425 THEN Q = -.5*TSTEP(I,J) + 325 : GOTO 1240
1220 IF TSTEP(I,J) < 450 THEN Q = -.25*TSTEP(I,J) + 197.5 : GOTO 1240
1230 IF TSTEP(I,J) < 500 THEN Q = -.15*TSTEP(I,J) + 175 : GOTO 1240
1240 G = CP*TSTEP(I,J) - Q
1250 Y(I+1,J) = DELT*(F0+E0+B0-A0)/G + Y(I,J)
1260 NEXT J
1270 Y(I+1,0) = (4*Y(I+1,1)-Y(I+1,2))/3
1280 Y(I+1,3) = (4*Y(I+1,2)-Y(I+1,1))/3
1290 FOR K = 0 TO 3
1300 IF Y(I+1,K) > Y(I,K) THEN Y(I+1,K) = Y(I,K)
1310 NEXT K
1320 NEXT I
1330 RETURN
```

D.2 Determination of the Kinetic Parameters

Equation (D.3) is rearranged as

$$\frac{\partial T}{\partial t} = \frac{k\frac{\partial^2 T}{\partial r^2} + (a\frac{\partial \rho}{\partial r} + \frac{k}{r})(\frac{\partial T}{\partial r}) + b(\frac{\partial T}{\partial r})^2 + (C_p T - Q)(-\frac{\partial \rho}{\partial t})}{\rho C_p} \qquad (D.9)$$

where the pyrolysis rate is expressed as

$$-\frac{\partial \rho}{\partial t} = \begin{cases} -k\,\frac{\partial T}{\partial r}/\lambda L \\ \\ A\exp(-\frac{E}{R_g T})\,(\rho-\rho_\infty) \end{cases} \qquad (D.10)$$

Equation (D.9) is solved and the kinetic parameters are available by optimization.

The program to determine kinetic parameters is presented in below.

```
10 CLEAR
20 OPTION BASE 0
30 DIM T(50,3), ABULKD(50), YCAL(500,3), YCALDP(500,3), YCALDE(500,3), DCAL(500,
3), YEXP(500,3), Y(500,3), AYCAL(50), AYCALDP(50), AYCALDE(50), AYEXP(50)
40 INPUT "DATAFILE : ",A$
50 A1$ = "B:" + A$ + ".PRN"
60 OPEN "I", #1, A1$
70 INPUT #1, KO, A, B, PRE, E
80 INPUT #1, DINI, DFIN, CP, NO
90 FOR I = 0 TO NO
100 INPUT #1, T(I,3), T(I,2), T(I,1), T(I,0), ABULKD(I)
110 NEXT I
120 CLOSE #1
130 DO = .15 : TO = 20 : DELT = 3 : DELR = 1.6 : RG = 8.314
140 FOR J = 0 TO 3
150 YCAL(0,J) = T(0,J)
160 YCALDP(0,J) = T(0,J)
170 YCALDE(0,J) = T(0,J)
180 DCAL(0,J) = DINI
190 NEXT J
200 FOR I = 1 TO NO
210 FOR K = 1 TO 20
220 FOR J = 0 TO 3
230 YEXP(20*(I-1)+K,J) = (T(I,J)-T(I-1,J))*K/20 + T(I-1,J)
240 NEXT J
250 NEXT K
260 NEXT I
270 FOR I = 1 TO NO*20
280 Y(I,3) = YEXP(I,3)
290 NEXT I
300 FOR J = 0 TO 3
310 Y(0,J) = YCAL(0,J)
320 NEXT J
330 GOSUB 920
340 FOR I = 0 TO NO*20
350 FOR J = 0 TO 3
360 YCAL(I,J) = Y(I,J)
370 NEXT J
380 NEXT I
390 PRE = PRE*1.01
400 GOSUB 920
410 FOR I = 0 TO NO*20
420 FOR J = 0 TO 3
430 YCALDP(I,J) = Y(I,J)
440 NEXT J
450 NEXT I
```

```
460 E = E*1.01 : PRE = PRE/1.01
470 GOSUB 920
480 FOR I = 0 TO NO*20
490 FOR J = 0 TO 3
500 YCALDE(I,J) = Y(I,J)
510 NEXT J
520 NEXT I
530 E = E/1.01
540 ESP = 0 : AA = 0 : BB = 0 : CC = 0 : DD = 0 : EE = 0 : FF = 0
550 FOR I = 0 TO NO
560 AYCAL(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YCAL(20*I,0)) + (3.1416*(2.4^2-.
8^2)*YCAL(20*I,1)) + (3.1416*(4^2-2.4^2)*YCAL(20*I,2)) + (3.1416*(4.8^2-4^2)*YCA
L(20*I,3)))
570 AYCALDP(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YCALDP(20*I,0)) + (3.1416*(2.4
^2-.8^2)*YCALDP(20*I,1)) + (3.1416*(4^2-2.4^2)*YCALDP(20*I,2)) + (3.1416*(4.8^2-
4^2)*YCALDP(20*I,3)))
580 AYCALDE(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YCALDE(20*I,0)) + (3.1416*(2.4
^2-.8^2)*YCALDE(20*I,1)) + (3.1416*(4^2-2.4^2)*YCALDE(20*I,2)) + (3.1416*(4.8^2-
4^2)*YCALDE(20*I,3)))
590 AYEXP(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YEXP(20*I,0)) + (3.1416*(2.4^2-.
8^2)*YEXP(20*I,1)) + (3.1416*(4^2-2.4^2)*YEXP(20*I,2)) + (3.1416*(4.8^2-4^2)*YEX
P(20*I,3)))
600 DYDP = (AYCALDP(I) - AYCAL(I))/.01
610 DYDE = (AYCALDE(I) - AYCAL(I))/.01
620 ESP = ESP + (AYEXP(I) - AYCAL(I))^2
630 EDC = AYEXP(I) - AYCAL(I)
640 AA = AA + DYDP^2
650 DD = DD + DYDE^2
660 BB = BB + DYDP*DYDE
670 EE = EE + EDC*DYDP
680 FF = FF + EDC*DYDE
690 NEXT I
700 CC = BB
710 LPRINT "DATAFILE = ", A$
720 LPRINT "AA =", AA, "BB =", BB, "EE =", EE
730 LPRINT "CC =", CC, "DD =", DD, "FF =", FF
740 LPRINT "ESP =", ESP, "Pre-exponential =", PRE, "E =", E
750 INPUT "DO YOU INPUT DATAFILE ? (Y or N)  ", B$
760 IF B$ = "Y" GOTO 10
770 IF B$ = "N" GOTO 780
780 INPUT "TAA,TBB,TEE   ", TAA, TBB, TEE
790 INPUT "TCC,TDD,TFF   ", TCC, TDD, TFF
800 INPUT "TESP   ", TESP
810 DET = TAA*TDD - TBB*TCC
820 PRINT "DET = ", DET
830 IF ABS(DET) <= .0001 THEN END
840 DP = (TEE*TDD - TFF*TBB)/DET
850 DE = (TAA*TFF - TEE*TCC)/DET
860 LPRINT "DP =", DP, "DE =", DE
870 PRE = PRE + DP : E = E + DE
880 LPRINT "PRE-EXPONENTIAL =", PRE, "E =", E
890 IF TESP <= .0001 THEN END
900 GOTO 10
910 END
920 FOR I = 0 TO NO*20-1
```

```
930 FOR J = 1 TO 2
940 IF Y(I,J) < 200 THEN M = (K0 + A*(DCAL(I,J)-D0) + B*(Y(I,J)-T0))*(Y(I,J+1)-Y
(I,J-1))/2/DELR/7.6/(-2.76*Y(I,J) + 2518.4) : GOTO 960
950 M = PRE*EXP(-E/RG/Y(I,J))*(DCAL(I,J) - DFIN)
960 IF Y(I,J) < 200 THEN Q = -2.76*Y(I,J) + 2518.4 : GOTO 1080
970 IF Y(I,J) < 225 THEN Q = -2.25*Y(I,J) + 837.5 : GOTO 1080
980 IF Y(I,J) < 250 THEN Q = -1.75*Y(I,J) + 725 :-GOTO 1080
990 IF Y(I,J) < 275 THEN Q = -1.5*Y(I,J) + 662.5 : GOTO 1080
1000 IF Y(I,J) < 300 THEN Q = -1.4*Y(I,J) + 635 : GOTO 1080
1010 IF Y(I,J) < 325 THEN Q = -1.1*Y(I,J) + 545 : GOTO 1080
1020 IF Y(I,J) < 350 THEN Q = -1*Y(I,J) + 512.5 : GOTO 1080
1030 IF Y(I,J) < 375 THEN Q = -.85*Y(I,J) + 460 : GOTO 1080
1040 IF Y(I,J) < 400 THEN Q = -.65*Y(I,J) + 385 : GOTO 1080
1050 IF Y(I,J) < 425 THEN Q = -.5*Y(I,J) + 325 : GOTO 1080
1060 IF Y(I,J) < 450 THEN Q = -.25*Y(I,J) + 197.5 : GOTO 1080
1070 IF Y(I,J) < 500 THEN Q = -.15*Y(I,J) + 175 : GOTO 1080
1080 N = (CP*Y(I,J)-Q)*M
1090 Q = ((Y(I,J+1)-Y(I,J-1))/2/DELR)^2*B
1100 P = (K0 + A*(DCAL(I,J)-D0) + B*(Y(I,J)-T0))/DELR/J
1110 QQ = A*(DCAL(I,J+1)-DCAL(I,J-1))/2/DELR
1120 R = (P+QQ)*(Y(I,J+1)-Y(I,J-1))/2/DELR
1130 S = (K0 + A*(DCAL(I,J)-D0) + B*(Y(I,J)-T0))*(Y(I,J+1)-2*Y(I,J)+Y(I,J-1))/(D
ELR^2)
1140 Y(I+1,J) = DELT*(S+R+Q+N)/DCAL(I,J)/CP + Y(I,J)
1150 DCAL(I+1,J) = DELT*(-M) + DCAL(I,J)
1160 NEXT J
1170 Y(I+1,0) = (4*Y(I+1,1)-Y(I+1,2))/3
1180 DCAL(I+1,0) = (4*DCAL(I+1,1)-DCAL(I+1,2))/3
1190 DCAL(I+1,3) = (4*DCAL(I+1,2)-DCAL(I+1,1))/3
1200 FOR K = 0 TO 3
1210 IF Y(I+1,K) < Y(I,K) THEN Y(I+1,K) = Y(I,K)
1220 IF DCAL(I+1,K) > DCAL(I,K) THEN DCAL(I+1,K) = DCAL(I,K)
1230 NEXT K
1240 NEXT I
1250 RETURN
```

Equations (D.9) and (D.10) are solved again by substituting the thermal conductivity, pre-exponential factor and activation energy obtained from section D.1 and D.2. By the optimization technique for this step, the heat conduction term, the pre-exponential and activation energy term are the best value available as shown in this program below.

```
10 CLEAR
20 OPTION BASE 0
30 DIM T(50,3), ABULKD(50), YTCAL(300,3), YTCALDK(300,3), YTCALDA(300,3), YTCALD
B(300,3), YTCALDP(300,3), YTCALDE(300,3), YDCAL(300,3), YT(300,3), AYTEXP(50), A
YTCAL(50), AYTCALDK(50), AYTCALDA(50), AYTCALDB(50), AYTCALDP(50), AYTCALDE(50)
40 INPUT "DATAFILE : ", A$
50 A1$ = "B:" + A$ + ".PRN"
60 OPEN "I", #1, A1$
70 INPUT #1, K0, A, B, PRE, E
80 INPUT #1, DINI, DFIN, CP, NO
90 FOR I = 0 TO NO
100 INPUT #1, T(I,3), T(I,2), T(I,1), T(I,0), ABULKD(I)
110 NEXT I
120 CLOSE #1
130 D0 = .15 : T0 = 20 : DELT = 3 : DELR = 1.6 : RG = 8.314
140 FOR J = 0 TO 3
150 YT(0,J) = T(0,J)
160 YDCAL(0,J) = DINI
170 NEXT J
180 FOR I = 1 TO NO
190 FOR K = 1 TO 20
200 YT(20*(I-1)+K,3) = (T(I,3)-T(I-1,3))*K/20 + T(I-1,3)
210 NEXT K
220 NEXT I
230 GOSUB 1840
240 FOR I = 0 TO NO*20
250 FOR J = 0 TO 3
260 YTCAL(I,J) = YT(I,J)
270 NEXT J
280 NEXT I
290 K0 = K0*1.01
300 GOSUB 1840
310 FOR I = 0 TO NO*20
320 FOR J = 0 TO 3
330 YTCALDK(I,J) = YT(I,J)
340 NEXT J
350 NEXT I
360 A = A*1.01 : K0 = K0/1.01
370 GOSUB 1840
380 FOR I = 0 TO NO*20
390 FOR J = 0 TO 3
400 YTCALDA(I,J) = YT(I,J)
410 NEXT J
420 NEXT I
430 B = B*1.01 : A = A/1.01
440 GOSUB 1840
450 FOR I = 0 TO NO*20
460 FOR J = 0 TO 3
470 YTCALDB(I,J) = YT(I,J)
480 NEXT J
490 NEXT I
500 PRE = PRE*1.01 : B = B/1.01
510 GOSUB 1840
520 FOR I = 0 TO NO*20
530 FOR J = 0 TO 3
540 YTCALDP(I,J) = YT(I,J)
```

```
550 NEXT J
560 NEXT I
570 E = E*1.01 : PRE = PRE/1.01
580 GOSUB 1840
590 FOR I = 0 TO NO*20
600 FOR J = 0 TO 3
610 YTCALDE(I,J) = YT(I,J)
620 NEXT J
630 NEXT I
640 E = E/1.01
650 ESP = 0 : MA = 0 : MB = 0 : MC = 0 : MD = 0 : ME = 0 : MF = 0 : MG = 0 : MH
= 0 : MI = 0 : MJ = 0 :MK = 0 : ML = 0 : MM = 0 : MN = 0 : MO = 0
660 MP = 0 : MQ = 0 : MR = 0 : MS = 0 : MT = 0 : MU = 0 : MV = 0 : MW = 0 : MX =
 0 : MY = 0 : MZ = 0 : MAA = 0 : MBB =0 : MCC = 0 : MDD = 0
670 FOR I = 0 TO NO
680 AYTEXP(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*T(I,0)) + (3.1416*(2.4^2-.8^2)*
T(I,1)) + (3.1416*(4^2-2.4^2)*T(I,2)) + (3.1416*(4.8^2-4^2)*T(I,3)))
690 AYTCAL(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YTCAL(I,0)) + (3.1416*(2.4^2-.8
^2)*YTCAL(I,1)) + (3.1416*(4^2-2.4^2)*YTCAL(I,2)) + (3.1416*(4.8^2-4^2)*YTCAL(I,
3)))
700 AYTCALDK(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YTCALDK(I,0)) + (3.1416*(2.4^
2-.8^2)*YTCALDK(I,1)) + (3.1416*(4^2-2.4^2)*YTCALDK(I,2)) + (3.1416*(4.8^2-4^2)*
YTCALDK(I,3)))
710 AYTCALDA(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YTCALDA(I,0)) + (3.1416*(2.4^
2-.8^2)*YTCALDA(I,1)) + (3.1416*(4^2-2.4^2)*YTCALDA(I,2)) + (3.1416*(4.8^2-4^2)*
YTCALDA(I,3)))
720 AYTCALDB(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YTCALDB(I,0)) + (3.1416*(2.4^
2-.8^2)*YTCALDB(I,1)) + (3.1416*(4^2-2.4^2)*YTCALDB(I,2)) + (3.1416*(4.8^2-4^2)*
YTCALDB(I,3)))
730 AYTCALDP(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YTCALDP(I,0)) + (3.1416*(2.4^
2-.8^2)*YTCALDP(I,1)) + (3.1416*(4^2-2.4^2)*YTCALDP(I,2)) + (3.1416*(4.8^2-4^2)*
YTCALDP(I,3)))
740 AYTCALDE(I) = (1/(3.1416*4.8^2))*((3.1416*.8^2*YTCALDE(I,0)) + (3.1416*(2.4^
2-.8^2)*YTCALDE(I,1)) + (3.1416*(4^2-2.4^2)*YTCALDE(I,2)) + (3.1416*(4.8^2-4^2)*
YTCALDE(I,3)))
750 DYDK = (AYTCALDK(I)-AYTCAL(I))/.01
760 DYDA = (AYTCALDA(I)-AYTCAL(I))/.01
770 DYDB = (AYTCALDB(I)-AYTCAL(I))/.01
780 DYDP = (AYTCALDP(I)-AYTCAL(I))/.01
790 DYDE = (AYTCALDE(I)-AYTCAL(I))/.01
800 ESP = ESP + (AYTEXP(I)-AYTCAL(I))^2
810 EDC = AYTEXP(I) - AYTCAL(I)
820 MA = MA + DYDA^2
830 MG = MG + DYDB^2
840 MM = MM + DYDK^2
850 MS = MS + DYDP^2
860 MY = MY + DYDE^2
870 MB = MB + DYDA*DYDB
880 MC = MC + DYDA*DYDK
890 MD = MD + DYDA*DYDP
900 ME = ME + DYDA*DYDE
910 MH = MH + DYDB*DYDK
920 MI = MI + DYDB*DYDP
930 MJ = MJ + DYDB*DYDE
940 MN = MN + DYDK*DYDP
950 MO = MO + DYDK*DYDE
```

```
960 MT = MT + DYDP*DYDE
970 MZ = MZ + ECD*DYDA
980 MAA = MAA + ECD*DYDB
990 MBB = MBB + ECD*DYDK
1000 MCC = MCC + ECD*DYDP
1010 MDD = MDD + ECD*DYDE
1020 NEXT I
1030 MF = MB : MK = MC : MP = MD : ML = MH : MU = ME : MQ = MI : MV = MJ : MR =
MN : MW = MO : MX = MT
1040 LPRINT "DATAFILE = ", A$
1050 LPRINT "A B C D E Z", MA, MB, MC, MD, ME, MZ
1060 LPRINT "F G H I J AA", MF, MG, MH, MI, MJ, MAA
1070 LPRINT "K L M N O BB", MK, ML, MM, MN, MO, MBB
1080 LPRINT "P Q R S T CC", MP, MQ, MR, MS, MT, MCC
1090 LPRINT "U V W X Y DD", MU, MV, MW, MX, MY, MDD
1100 LPRINT "ESP =", ESP, "k0 =", K0, "a =", A, "b =", B, "Pre-exponential =", P
RE, "E =", E
1110 INPUT "DO YOU INPUT DATAFILE ? (Y or N)", B$
1120 IF B$ = "Y" GOTO 10
1130 IF B$ = "N" GOTO 1140
1140 INPUT "TA,TB,TC,TD,TE,TZ   ", TA, TB, TC, TD, TE, TZ
1150 INPUT "TF,TG,TH,TI,TJ,TAA  ", TF, TG, TH, TI, TJ, TAA
1160 INPUT "TK,TL,TM,TN,TO,TBB  ", TK, TL, TM, TN, TO, TBB
1170 INPUT "TP,TQ,TR,TS,TT,TCC  ", TP, TQ, TR, TS, TT, TCC
1180 INPUT "TU,TV,TW,TX,TY,TDD  ", TU, TV, TW, TX, TY, TDD
1190 INPUT "TESP  ", TESP
1200 Z1=AA*(GG*(MM*SS*YY+NN*TT*WW+OO*RR*XX-WW*SS*OO-XX*TT*MM-YY*RR*NN)-HH*(LL*SS
*YY+NN*TT*VV+OO*QQ*XX-VV*SS*OO-XX*TT*LL-YY*QQ*NN)+II*(LL*RR*YY+MM*TT*VV+OO*QQ*WW
-VV*RR*OO-WW*TT*LL-YY*QQ*MM)-JJ*(LL*RR*XX+MM*SS*VV+NN*QQ*WW-VV*RR*NN-WW*SS*LL-XX
*QQ*MM))
1210 Z2=-BB*(FF*(MM*SS*YY+NN*TT*WW+OO*RR*XX-WW*SS*OO-XX*TT*MM-YY*RR*NN)-HH*(KK*S
S*YY+NN*TT*UU+OO*PP*XX-UU*SS*OO-XX*TT*KK-YY*PP*NN)+II*(KK*RR*YY+MM*TT*UU+OO*PP*W
W-UU*RR*OO-WW*TT*KK-YY*PP*MM)-JJ*(KK*RR*XX+MM*SS*UU+NN*PP*WW-UU*RR*NN-WW*SS*KK-X
X*PP*MM))
1220 Z3=CC*(FF*(LL*SS*YY+NN*TT*VV+OO*QQ*XX-VV*SS*OO-XX*TT*LL-YY*QQ*NN)-GG*(KK*SS
*YY+NN*TT*UU+OO*PP*XX-UU*SS*OO-XX*TT*KK-YY*PP*NN)+II*(KK*QQ*YY+LL*TT*UU+OO*PP*VV
-UU*QQ*OO-VV*TT*KK-YY*PP*LL)-JJ*(KK*QQ*XX+LL*SS*UU+NN*PP*VV-UU*QQ*NN-VV*SS*KK-XX
*PP*LL))
1230 Z4=-DD*(FF*(LL*RR*YY+MM*TT*VV+OO*QQ*WW-VV*RR*OO-WW*TT*LL-YY*QQ*MM)-GG*(KK*R
R*YY+MM*TT*UU+OO*PP*WW-UU*RR*OO-WW*TT*KK-YY*PP*MM)+HH*(KK*QQ*YY+LL*TT*UU+OO*PP*V
V-UU*QQ*OO-VV*TT*KK-YY*PP*LL)-JJ*(KK*QQ*WW+LL*RR*UU+MM*PP*VV-UU*QQ*MM-VV*RR*KK-W
W*PP*LL))
1240 Z5=EE*(FF*(LL*RR*XX+MM*SS*VV+NN*QQ*WW-VV*RR*NN-WW*SS*LL-XX*QQ*MM)-GG*(KK*RR
*XX+MM*SS*UU+NN*PP*WW-UU*RR*NN-WW*SS*KK-XX*PP*MM)+HH*(KK*QQ*XX+LL*SS*UU+NN*PP*VV
-UU*QQ*NN-VV*SS*KK-XX*PP*LL)-II*(KK*QQ*WW+LL*RR*UU+MM*PP*VV-UU*QQ*MM-VV*RR*KK-WW
*PP*LL))
1250 DET = Z1 + Z2 + Z3 + Z4 + Z5
1260 PRINT "DET =", DET
1270 IF ABS(DET) <= .0001 THEN END
1280 Z6=ZZ*(GG*(MM*SS*YY+NN*TT*WW+OO*RR*XX-WW*SS*OO-XX*TT*MM-YY*RR*NN)-HH*(LL*SS
*YY+NN*TT*VV+OO*QQ*XX-VV*SS*OO-XX*TT*LL-YY*QQ*NN)+II*(LL*RR*YY+MM*TT*VV+OO*QQ*WW
-VV*RR*OO-WW*TT*LL-YY*QQ*MM)-JJ*(LL*RR*XX+MM*SS*VV+NN*QQ*WW-VV*RR*NN-WW*SS*LL-XX
*QQ*MM))
1290 Z7=AAA*(MM*SS*YY+NN*TT*WW+OO*RR*XX-WW*SS*OO-XX*TT*MM-YY*RR*NN)-HH*(BBB*SS*Y
Y+NN*TT*DDD+OO*CCC*XX-DDD*SS*OO-XX*TT*BBB-YY*CCC*NN)+II*(BBB*RR*YY+MM*TT*DDD+OO*
CCC*WW-DDD*RR*OO-WW*TT*BBB-YY*CCC*MM)
```

```
1300 Z77=-BB*(Z7-JJ*(BBB*RR*XX+MM*SS*DDD+NN*CCC*WW-DDD*RR*NN-WW*SS*BBB-XX*CCC*MM
))
1310 Z8=AAA*(LL*SS*YY+NN*TT*VV+OO*QQ*XX-VV*SS*OO-XX*TT*LL-YY*QQ*NN)-GG*(BBB*SS*Y
Y+NN*TT*DDD+OO*CCC*XX-DDD*SS*OO-XX*TT*BBB-YY*CCC*NN)+II*(BBB*QQ*YY+LL*TT*DDD+OO*
CCC*VV-DDD*QQ*OO-VV*TT*BBB-YY*CCC*LL)
1320 Z88=CC*(Z8-JJ*(BBB*QQ*XX+LL*SS*DDD+NN*CCC*VV-DDD*QQ*NN-VV*SS*BBB-XX*CCC*LL)
)
1330 Z9=AAA*(LL*RR*YY+MM*TT*VV+OO*QQ*WW-VV*RR*OO-WW*TT*LL-YY*QQ*MM)-GG*(BBB*RR*Y
Y+MM*TT*DDD+OO*CCC*WW-DDD*RR*OO-WW*TT*BBB-YY*CCC*MM)+HH*(BBB*QQ*YY+LL*TT*DDD+OO*
CCC*VV-DDD*QQ*OO-VV*TT*BBB-YY*CCC*LL)
1340 Z99=-DD*(Z9-JJ*(BBB*QQ*WW+LL*RR*DDD+MM*CCC*VV-DDD*QQ*MM-VV*RR*BBB-WW*CCC*LL
))
1350 Z10=AAA*(LL*RR*XX+MM*SS*VV+NN*QQ*WW-VV*RR*NN-WW*SS*LL-XX*QQ*MM)-GG*(BBB*RR*
XX+MM*SS*DDD+NN*CCC*WW-DDD*RR*NN-WW*SS*BBB-XX*CCC*MM)+HH*(BBB*QQ*XX+LL*SS*DDD+NN
*CCC*VV-DDD*QQ*NN-VV*SS*BBB-XX*CCC*LL)
1360 Z100=EE*(Z10-II*(BBB*QQ*WW+LL*RR*DDD+MM*CCC*VV-DDD*QQ*MM-VV*RR*BBB-WW*CCC*L
L))
1370 DETDA = (Z6+Z77+Z88+Z99+Z100)/DET
1380 Z11=AAA*(MM*SS*YY+NN*TT*WW+OO*RR*XX-WW*SS*OO-XX*TT*MM-YY*RR*NN)-HH*(BBB*SS*
YY+NN*TT*DDD+OO*CCC*XX-DDD*SS*OO-XX*TT*BBB-YY*CCC*NN)+II*(BBB*RR*YY+MM*TT*DDD+OO
*CCC*WW-DDD*RR*OO-WW*TT*BBB-YY*CCC*MM)
1390 Z111=AA*(Z11-JJ*(BBB*RR*XX+MM*SS*DDD+NN*CCC*WW-DDD*RR*NN-WW*SS*BBB-XX*CCC*M
M))
1400 Z12=-ZZ*(FF*(MM*SS*YY+NN*TT*WW+OO*RR*XX-WW*SS*OO-XX*TT*MM-YY*RR*NN)-HH*(KK*
SS*YY+NN*TT*UU+OO*PP*XX-UU*SS*OO-XX*TT*KK-YY*PP*NN)+II*(KK*RR*YY+MM*TT*UU+OO*PP*
WW-UU*RR*OO-WW*TT*KK-YY*PP*MM)-JJ*(KK*RR*XX+MM*SS*UU+NN*PP*WW-UU*RR*NN-WW*SS*KK-
XX*PP*MM))
1410 Z13=FF*(BBB*SS*YY+NN*TT*DDD+OO*CCC*XX-DDD*SS*OO-XX*TT*BBB-YY*CCC*NN)-AAA*(K
K*SS*YY+NN*TT*UU+OO*PP*XX-UU*SS*OO-XX*TT*KK-YY*PP*NN)+II*(KK*CCC*YY+BBB*TT*UU+OO
*PP*DDD-UU*CCC*OO-DDD*TT*KK-YY*PP*BBB)
1420 Z133=CC*(Z13-JJ*(KK*CCC*XX+BBB*SS*UU+NN*PP*DDD-UU*CCC*NN-DDD*SS*KK-XX*PP*BB
B))
1430 Z14=FF*(BBB*RR*YY+MM*TT*DDD+OO*CCC*WW-DDD*RR*OO-WW*TT*BBB-YY*CCC*MM)-AAA*(K
K*RR*YY+MM*TT*UU+OO*PP*WW-UU*RR*OO-WW*TT*KK-YY*PP*MM)+HH*(KK*CCC*YY+BBB*TT*UU+OO
*PP*DDD-UU*CCC*OO-DDD*TT*KK-YY*PP*BBB)
1440 Z144=-DD*(Z14-JJ*(KK*CCC*WW+BBB*RR*UU+MM*PP*DDD-UU*CCC*MM-DDD*RR*KK-WW*PP*B
BB))
1450 Z15=FF*(BBB*RR*XX+MM*SS*DDD+NN*CCC*WW-DDD*RR*NN-WW*SS*BBB-XX*CCC*MM)-AAA*(K
K*RR*XX+MM*SS*UU+NN*PP*WW-UU*RR*NN-WW*SS*KK-XX*PP*MM)+HH*(KK*CCC*XX+BBB*SS*UU+NN
*PP*DDD-UU*CCC*NN-DDD*SS*KK-XX*PP*BBB)
1460 Z155=EE*(Z15-JJ*(KK*CCC*WW+BBB*RR*UU+MM*PP*DDD-UU*CCC*MM-DDD*RR*KK-WW*PP*BB
B))
1470 DETDB = (Z111+Z12+Z133+Z144+Z155)/DET
1480 Z16=GG*(BBB*SS*YY+NN*TT*DDD+OO*CCC*XX-DDD*SS*OO-XX*TT*BBB-YY*CCC*NN)-AAA*(L
L*SS*YY+NN*TT*VV+OO*QQ*XX-VV*SS*OO-XX*TT*LL-YY*QQ*NN)+II*(LL*CCC*YY+BBB*TT*VV+OO
*QQ*DDD-VV*CCC*OO-DDD*TT*LL-YY*QQ*BBB)
1490 Z17=FF*(BBB*SS*YY+NN*TT*DDD+OO*CCC*XX-DDD*SS*OO-XX*TT*BBB-YY*CCC*NN)-AAA*(K
K*SS*YY+NN*TT*UU+OO*PP*XX-UU*SS*OO-XX*TT*KK-YY*PP*NN)+II*(KK*CCC*YY+BBB*TT*UU+OO
*PP*DDD-UU*CCC*OO-DDD*TT*KK-YY*PP*BBB)
1500 Z177=-BB*(Z17-JJ*(KK*CCC*XX+BBB*SS*UU+NN*PP*DDD-UU*CCC*NN-DDD*SS*KK-XX*PP*B
BB))
1510 Z18=ZZ*(FF*(LL*SS*YY+NN*TT*VV+OO*QQ*XX-VV*SS*OO-XX*TT*LL-YY*QQ*NN)-GG*(KK*S
S*YY+NN*TT*UU+OO*PP*XX-UU*SS*OO-XX*TT*KK-YY*PP*NN)+II*(KK*QQ*YY+LL*TT*UU+OO*PP*V
V-UU*QQ*OO-VV*TT*KK-YY*PP*LL)-JJ*(KK*QQ*XX+LL*SS*UU+NN*PP*VV-UU*QQ*NN-VV*SS*KK-X
X*PP*LL))
```

```
1520 Z19=FF*(LL*CC*YY+BBB*TT*VV+OO*QQ*DDD-VV*CCC*OO-DDD*TT*LL-YY*QQ*BBB)-GG*(KK*
CCC*YY+BBB*TT*UU+OO*PP*DDD-UU*CCC*OO-DDD*TT*KK-YY*PP*BBB)+AAA*(KK*QQ*YY+LL*TT*UU
+OO*PP*VV-UU*QQ*OO-VV*TT*KK-YY*PP*LL)
1530 Z199=-DD*(Z19-JJ*(KK*QQ*DDD+LL*CCC*UU+BBB*PP*VV-UU*QQ*BBB-VV*CCC*KK-DDD*PP*
LL))
1540 Z20=FF*(LL*CCC*XX+BBB*SS*VV+NN*QQ*DDD-VV*CCC*NN-DDD*SS*LL-XX*QQ*BBB)-GG*(KK
*CCC*XX+BBB*SS*UU+NN*PP*DDD-UU*CCC*NN-DDD*SS*KK-XX*PP*BBB)+AAA*(KK*QQ*XX+LL*SS*U
U+NN*PP*VV-UU*QQ*NN-VV*SS*KK-XX*PP*LL)
1550 Z200=EE*(Z20-II*(KK*QQ*DDD+LL*CCC*UU+BBB*PP*VV-UU*QQ*BBB-VV*CCC*KK-DDD*PP*L
L))
1560 DETDK = (Z166+Z177+Z18+Z199+Z200)/DET
1570 Z21=GG*(MM*CCC*YY+BBB*TT*WW+OO*RR*DDD-WW*CCC*OO-DDD*TT*MM-YY*RR*BBB)-HH*(LL
*CCC*YY+BBB*TT*VV+OO*QQ*DDD-VV*CCC*OO-DDD*TT*LL-YY*QQ*BBB)+AAA*(LL*RR*YY+MM*TT*V
V+OO*QQ*WW-VV*RR*OO-WW*TT*LL-YY*QQ*MM)
1580 Z211=AA*(Z21-JJ*(LL*RR*DDD+MM*CCC*VV+BBB*QQ*WW-VV*RR*BBB-WW*CCC*LL-DDD*QQ*M
M))
1590 Z22=FF*(MM*CCC*YY+BBB*TT*WW+OO*RR*DDD-WW*CCC*OO-DDD*TT*MM-YY*RR*BBB)-HH*(KK
*CCC*YY+BBB*TT*UU+OO*PP*DDD-UU*CCC*OO-DDD*TT*KK-YY*PP*BBB)+AAA*(KK*RR*YY+MM*TT*U
U+OO*PP*WW-UU*RR*OO-WW*TT*KK-YY*PP*MM)
1600 Z222=-BB*(Z22-JJ*(KK*RR*DDD+MM*CCC*UU+BBB*PP*WW-VV*RR*BBB-WW*CCC*KK-DDD*PP*
MM))
1610 Z23=FF*(LL*CCC*YY+BBB*TT*VV+OO*QQ*DDD-VV*CCC*OO-DDD*TT*LL-YY*QQ*BBB)-GG*(KK
*CCC*YY+BBB*TT*UU+OO*PP*DDD-UU*CCC*OO-DDD*TT*KK-YY*PP*BBB)+AAA*(KK*QQ*YY+LL*TT*U
U+OO*PP*VV-UU*QQ*OO-VV*TT*KK-YY*PP*LL)
1620 Z233=CC*(Z23-JJ*(KK*QQ*DDD+LL*CCC*UU+BBB*PP*VV-UU*QQ*BBB-VV*CCC*KK-DDD*PP*L
L))
1630 Z24=-ZZ*(FF*(LL*RR*YY+MM*TT*VV+OO*QQ*WW-VV*RR*OO-WW*TT*LL-YY*QQ*MM)-GG*(KK*
RR*YY+MM*TT*UU+OO*PP*WW-UU*RR*OO-WW*TT*KK-YY*PP*MM)+HH*(KK*QQ*YY+LL*TT*UU+OO*PP*
VV-UU*QQ*OO-VV*TT*KK-YY*PP*LL)-JJ*(KK*QQ*WW+LL*RR*UU+MM*PP*VV-UU*QQ*MM-VV*RR*KK-
WW*PP*LL))
1640 Z25=FF*(LL*RR*DDD+MM*CCC*VV+BBB*QQ*WW-VV*RR*BBB-WW*CCC*LL-DDD*QQ*MM)-GG*(KK
*RR*DDD+MM*CCC*UU+BBB*PP*WW-UU*RR*BBB-WW*CCC*KK-DDD*PP*MM)+HH*(KK*QQ*DDD+LL*CCC*
UU+BBB*PP*VV-UU*QQ*BBB-VV*CCC*KK-DDD*PP*LL)
1650 Z255=EE*(Z25-AAA*(KK*QQ*WW+LL*RR*UU+MM*PP*VV-UU*QQ*MM-VV*RR*KK-WW*PP*LL))
1660 DETDP = (Z211+Z222+Z233+Z24+Z255)/DET
1670 Z26=GG*(MM*SS*DDD+NN*CCC*WW+BBB*RR*XX-WW*SS*BBB-XX*CCC*MM-DDD*RR*NN)-HH*(LL
*SS*DDD+NN*CCC*VV+BBB*QQ*XX-VV*SS*BBB-XX*CCC*LL-DDD*QQ*NN)+II*(LL*RR*DDD+MM*CCC*
VV+BBB*QQ*WW-VV*RR*BBB-WW*CCC*LL-DDD*QQ*MM)
1680 Z266=AA*(Z26-AAA*(LL*RR*XX+MM*SS*VV+NN*QQ*WW-VV*RR*NN-WW*SS*LL-XX*QQ*MM))
1690 Z27=FF*(MM*SS*DDD+NN*CCC*WW+BBB*RR*XX-WW*SS*BBB-XX*CCC*MM-DDD*RR*NN)-HH*(KK
*SS*DDD+NN*CCC*UU+BBB*PP*XX-UU*SS*BBB-XX*CCC*KK-DDD*PP*NN)+II*(KK*RR*DDD+MM*CCC*
UU+BBB*PP*WW-UU*RR*BBB-WW*CCC*KK-DDD*PP*MM)
1700 Z277=-BB*(Z27-AAA*(KK*RR*XX+MM*SS*UU+NN*PP*WW-UU*RR*NN-WW*SS*KK-XX*PP*MM))
1710 Z28=FF*(LL*SS*DDD+NN*CCC*VV+BBB*QQ*XX-VV*SS*BBB-XX*CCC*LL-DDD*QQ*NN)-GG*(KK
*SS*DDD+NN*CCC*UU+BBB*PP*XX-UU*SS*BBB-XX*CCC*KK-DDD*PP*NN)+II*(KK*QQ*DDD+LL*CCC*
UU+BBB*PP*VV-UU*QQ*BBB-VV*CCC*KK-DDD*PP*LL)
1720 Z288=CC*(Z28-AAA*(KK*QQ*XX+LL*SS*UU+NN*PP*VV-UU*QQ*NN-VV*SS*KK-XX*PP*LL))
1730 Z29=FF*(LL*RR*DDD+MM*CCC*VV+BBB*QQ*WW-VV*RR*BBB-WW*CCC*LL-DDD*QQ*MM)-GG*(KK
*RR*DDD+MM*CCC*UU+BBB*PP*WW-UU*RR*BBB-WW*CCC*KK-DDD*PP*MM)+HH*(KK*QQ*DDD+LL*CCC*
UU+BBB*PP*VV-UU*QQ*BBB-VV*CCC*KK-DDD*PP*LL)
1740 Z299=-DD*(Z29-AAA*(KK*QQ*WW+LL*RR*UU+MM*PP*VV-UU*QQ*MM-VV*RR*KK-WW*PP*LL))
1750 Z30=FF*(LL*RR*XX+MM*SS*VV+NN*QQ*WW-VV*RR*NN-WW*SS*LL-XX*QQ*MM)-GG*(KK*RR*XX
+MM*SS*UU+NN*PP*WW-UU*RR*NN-WW*SS*KK-XX*PP*MM)+HH*(KK*QQ*XX+LL*SS*UU+NN*PP*VV-UU
*QQ*NN-VV*SS*KK-XX*PP*LL)
1760 Z300=ZZ*(Z30-II*(KK*QQ*WW+LL*RR*UU+MM*PP*VV-UU*QQ*MM-VV*RR*KK-WW*PP*LL))
1770 DETDE = (Z266+Z277+Z288+Z299+Z300)/DET
```

```
1780 LPRINT "DA =", DA, "DB =", DB, "DK =", DK, "DP =", DP, "DE =", DE
1790 K0 = K0 + DK : A = A + DA : B = B + DB : PRE = PRE + DP : E = E + DE
1800 LPRINT "k0 =", K0, "a =", A, "b =", B, "Pre-exponential =", PRE, "E =", E
1810 IF TESP <= .0001 THEN END
1820 GOTO 10
1830 END
1840 FOR I = 0 TO NO*20-1
1850 FOR J = 1 TO 2
1860 IF YT(I,J) < 200 THEN M = (K0 + A*(YDCAL(I,J)-D0) + B*(YT(I,J)-T0))*(YT(I,J
+1)-YT(I,J-1))/2/DELR/7.6/(-2.76*YT(I,J)+2518.4) : GOTO 1880
1870 M = PRE*EXP(-E/RG/YT(I,J))*(YDCAL(I,J)-DFIN)
1880 IF YT(I,J) < 200 THEN Q = -2.76*YT(I,J) +2518.4 : GOTO 2000
1890 IF YT(I,J) < 225 THEN Q = -2.25*YT(I,J) + 837.5 : GOTO 2000
1900 IF YT(I,J) < 250 THEN Q = -1.75*YT(I,J) + 725 : GOTO 2000
1910 IF YT(I,J) < 275 THEN Q = -1.5*YT(I,J) + 662.5 : GOTO 2000
1920 IF YT(I,J) < 300 THEN Q = -1.4*YT(I,J) + 635 : GOTO 2000
1930 IF YT(I,J) < 325 THEN Q = -1.1*YT(I,J) + 545 : GOTO 2000
1940 IF YT(I,J) < 350 THEN Q = -1*YT(I,J) + 512.5 : GOTO 2000
1950 IF YT(I,J) < 375 THEN Q = -.85*YT(I,J) + 460 : GOTO 2000
1960 IF YT(I,J) < 400 THEN Q = -.65*YT(I,J) + 385 : GOTO 2000
1970 IF YT(I,J) < 425 THEN Q = -.5*YT(I,J) + 325 : GOTO 2000
1980 IF YT(I,J) < 450 THEN Q = -.25*YT(I,J) + 197.5 : GOTO 2000
1990 IF YT(I,J) < 500 THEN Q = -.15*YT(I,J) + 175 : GOTO 2000
2000 N = (CP*YT(I,J)-Q)*M
2010 Q = ((YT(I,J+1)-YT(I,J-1))/2/DELR)^2*B
2020 P = (K0 + A*(YDCAL(I,J)-D0) + B*(YT(I,J)-T0))/DELR/J
2030 QQ = A*(YDCAL(I,J+1)-YDCAL(I,J-1))/2/DELR
2040 R = (P+QQ)*(YT(I,J+1)-YT(I,J-1))/2/DELR
2050 S = (K0 + A*(YDCAL(I,J)-D0) + B*(YT(I,J)-T0))*(YT(I,J+1)-2*YT(I,J)+YT(I,J-1
))/(DELR^2)
2060 YT(I+1,J) = DELT*(S+R+Q+N)/YDCAL(I,J)/CP + YT(I,J)
2070 YDCAL(I+1,J) = DELT*(-M) + YDCAL(I,J)
2080 NEXT J
2090 YT(I+1,0) = (4*YT(I+1,1)-YT(I+1,2))/3
2100 YDCAL(I+1,0) = (4*YDCAL(I+1,1)-YDCAL(I+1,2))/3
2110 YDCAL(I+1,3) = (4*YDCAL(I+1,2)-YDCAL(I+1,1))/3
2120 FOR K = 0 TO 3
2130 IF YT(I+1,K) < YT(I,K) THEN YT(I+1,K) = YT(I,K)
2140 IF YDCAL(I+1,K) > YDCAL(I,K) THEN YDCAL(I+1,K) = YDCAL(I,K)
2150 NEXT K
2160 NEXT I
2170 RETURN
```

APPENDIX E

THE GAUSS NEWTON OPTIMIZATION TECHNIQUE

This method solves for the coefficients in a multivariable, nonlinear regression equation

$$\hat{Y} = F(X_1, X_2, \ldots\ldots, X_K ; \hat{A}_1, \hat{A}_2, \ldots\ldots, \hat{A}_M) \qquad (E.1)$$

utilizing N data points for Y_i and $X_{k,i}$, $i = 1,2,\ldots\ldots,N$; $k = 1,2, \ldots\ldots,K$.

E.1 Method

The procedure is based on a linearization of the proposed model. A least squares objective function is utilized. The algorithm proceeds as follows :

1. The model is linearized by expanding $\hat{Y}_i$ in a Taylor series about current trial values for the coefficients and retaining the linear terms only,

$$\hat{Y}_i = \hat{Y}_i^* + \left[\frac{\partial \hat{Y}_i}{\partial \hat{A}_1}\right]^* \Delta\hat{A}_1 + \left[\frac{\partial \hat{Y}_i}{\partial \hat{A}_2}\right]^* \Delta\hat{A}_2 + \ldots + \left[\frac{\partial \hat{Y}_i}{\partial \hat{A}_M}\right]^* \Delta\hat{A}_M \qquad (E.2)$$

where

$$\Delta\hat{A}_j = [\hat{A}_j - \hat{A}_j^*], \; j = 1, 2, \ldots, M. \qquad (E.3)$$

The asterisk designates quantities evaluated at the initial trial values

2. A least squares objective function is formulated, and $S = \sum_{i=1}^{N} (Y_i - \hat{Y}_i)^2$ is minimized.

3. The linearized model is substituted into the objective function and the "normal equations" formed by setting the partial derivatives of the objective function with respect to each coefficient equal to zero :

$$\frac{\partial S}{\partial \hat{A}_j} = 0, \quad j = 1, 2, \ldots, M . \tag{E.4}$$

The resulting normal equations will be of the form

$$(\underline{A}^t \underline{A})\ \underline{\Delta \hat{A}} = \underline{A}^t (\underline{Y} - \underline{\hat{Y}}^*) \tag{E.5}$$

where

$$\underline{A} = \begin{bmatrix} \frac{\partial \hat{Y}_1}{\partial \hat{A}_1} & \frac{\partial \hat{Y}_1}{\partial \hat{A}_2} & \cdots & \frac{\partial \hat{Y}_1}{\partial \hat{A}_M} \\ \frac{\partial \hat{Y}_2}{\partial \hat{A}_1} & \frac{\partial \hat{Y}_2}{\partial \hat{A}_2} & & \frac{\partial \hat{Y}_2}{\partial \hat{A}_M} \\ \vdots & \vdots & & \vdots \\ \frac{\partial \hat{Y}_N}{\partial \hat{A}_1} & \frac{\partial \hat{Y}_N}{\partial \hat{A}_2} & \cdots & \frac{\partial \hat{Y}_N}{\partial \hat{A}_M} \end{bmatrix}^*$$

$$\underline{\Delta\hat{A}} = \begin{bmatrix} (\hat{A}_1 - \hat{A}_1^*) \\ (\hat{A}_2 - \hat{A}_2^*) \\ \vdots \\ (\hat{A}_M - \hat{A}_M^*) \end{bmatrix} , \qquad (\underline{Y - \hat{Y}^*}) = \begin{bmatrix} (Y_1 - \hat{Y}_1^*) \\ (Y_2 - \hat{Y}_2^*) \\ \vdots \\ (Y_N - Y_N^*) \end{bmatrix}$$

A^t is the transpose of the $\underline{A}$ matrix. The derivatives in the $\underline{A}$ matrix may be evaluated analytically or numerically.

4. The normal equations are a system of linear algebraic equations and are solved by an appropriate technique for $\underline{\Delta\hat{A}}$. The $\underline{\Delta\hat{A}}$ vector and S will approach zero as convergence is achieved. If convergence is achieved, the final coefficients are calculated from

$$\hat{A}_j = \hat{A}_j^* + \Delta\hat{A}_j, \qquad j = 1, 2, \ldots, M . \tag{E.6}$$

If convergence is not achieved, $\underline{\hat{A}}^*$ is updated by replacing the old values by the new values and the process repeated.

A flow sheet illustrating the above procedure is given in Figure E.1.

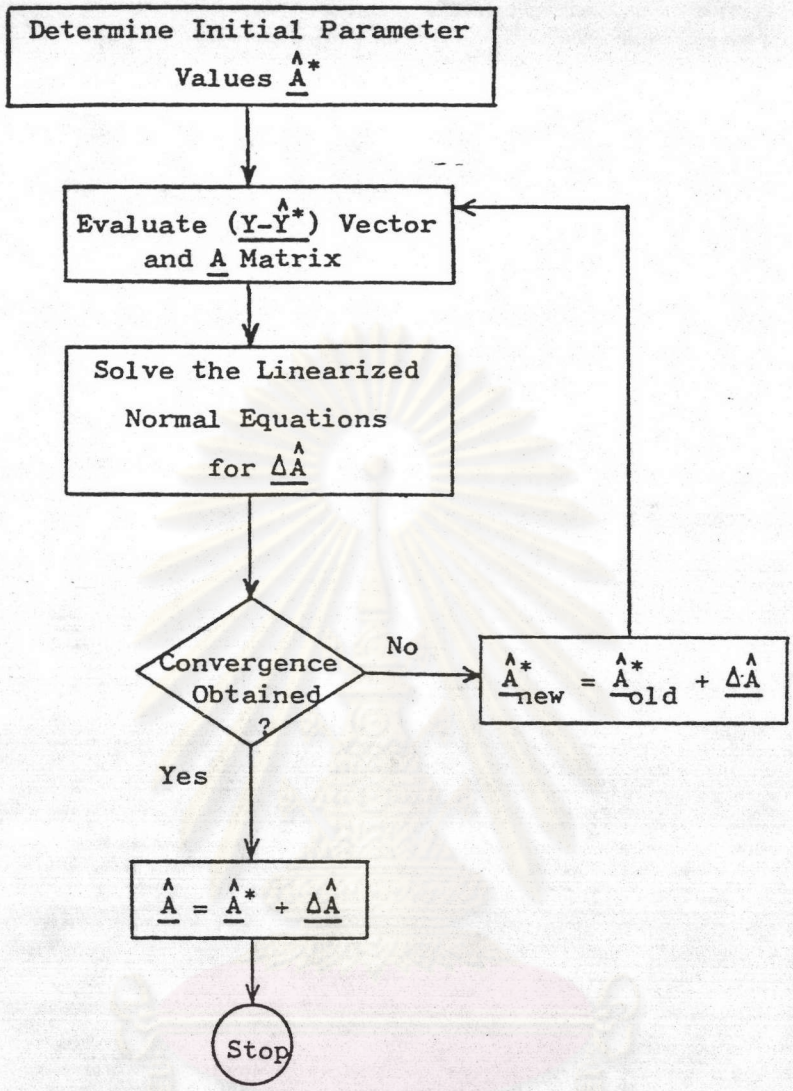

Figure E.1 Gauss Newton Logic Diagram

APPENDIX F

SAMPLE CALCULATION FOR HEAT CAPACITY MEASUREMENT

F.1 Determine the Heat Capacity Constant (H_c)

The heat capacity constant was computed using experiment No 3 in Table C.1. From equation (3.2)

$$H_c = \frac{C_{pw} W_c \Delta T_c - C_{pw} W_h \Delta T_h}{\Delta T_f}$$

where

C_{pw} = heat capacity of water = 1.00 cal/g °C

W_c = weight of cold water = 290.2 g

W_h = weight of hot water = 234.9 g

ΔT_c = difference in temperature of cold water

= 25-10 = 15 °C

ΔT_h = difference in temperature of hot water

= 41-25 = 16 °C

ΔT_f = difference in temperature of calorimeter

= 41-25 = 16 °C

Thus

$$H_c = \frac{1 \times 290.2 \times 15 - 1 \times 234.9 \times 16}{16}$$

$$= 37.16 \text{ cal/°C}$$

F.2 Determine the Heat Capacity of Rice Hull

The heat capacity of rice hull was computed using experiment No 3 in Table C.2. From equation (3.1)

$$C_{ps}W_s(\Delta T_s - \theta R_c) = C_{pw}W_w(\Delta T_w + \theta R_c) - H_c(\Delta T_f - \theta R_c)$$

where

C_{ps} = heat capacity of the sample, cal/g°C

C_{pw} = heat capacity of water = 1 cal/g°C

W_s = Weight of sample = 43.25 g

W_w = Weight of water = 53.06 g

R_c = heat loss rate = 0.2×10^{-2} °C/min

θ = time of cooling the sample = 2 min

ΔT_s = initial temperature of sample minus the equilibrium temperature of mixture

= 46 - 27 = 19 °C

ΔT_w = equilibrium temperature minus initial temperature of water

= 27 - 10 = 17 °C

ΔT_f = initial temperature of calorimeter minus equilibrium temperature

= 46 - 27 = 19 °C

H_c = heat capacity constant of the calorimeter

= 37.16 cal/°C

Thus

$$C_{p_m} \times 43.35 \times (19 - 2 \times 0.2 \times 10^{-2}) = 1 \times 53.06 \times (17 + 2 \times 0.2 \times 10^{-2}) - 37.16 \times (19 - 2 \times 0.2 \times 10^{-2})$$

$$C_{p_m} = 0.2384 \text{ cal/g}^{\circ}\text{C}$$

APPENDIX G

PROPERTIES OF SATURATED STEAM

Table G.1 Properties of Saturated Steam ; Temperature Table

Temp. °F (T)	Abs. press. psia (P)	Specific vol., ft³/lb$_m$		Enthalpy, Btu/lb$_m$		
		Sat. liq. (v_w)	Sat. vap. (v_s)	Sat. liq. (h_w)	Evap. Δh_{vap}	Sat. vap. (h_s)
32	0.08854	0.01602	3306	0.00	1075.8	1075.8
35	0.09995	0.01602	2947	3.02	1074.1	1077.1
40	0.12170	0.01602	2444	8.05	1071.3	1079.3
45	0.14752	0.01602	2036.4	13.06	1068.4	1081.5
50	0.17811	0.01603	1703.2	18.07	1065.6	1083.7
60	0.2563	0.01604	1206.7	28.06	1059.9	1088.0
70	0.3631	0.01606	867.9	38.04	1054.3	1092.3
80	0.5069	0.01608	633.1	48.02	1048.6	1096.6
90	0.6982	0.01610	468.0	57.99	1042.9	1100.9
100	0.9492	0.01613	350.4	67.97	1037.2	1105.2
110	1.2748	0.01617	265.4	77.94	1031.6	1109.5
120	1.6924	0.01620	203.27	87.92	1025.8	1113.7
130	2.2225	0.01625	157.34	97.90	1020.0	1117.9
140	2.8886	0.01629	123.01	107.89	1014.1	1122.0
150	3.718	0.01634	97.07	117.89	1008.2	1126.1
160	4.741	0.01639	77.29	127.89	1002.3	1130.2
170	5.992	0.01645	62.06	137.90	996.3	1134.2
180	7.510	0.01651	50.23	147.92	990.2	1138.1
190	9.339	0.01657	40.96	157.95	984.1	1142.0
200	11.526	0.01663	33.64	167.99	977.9	1145.9
210	14.123	0.01670	27.82	178.05	971.6	1149.7
212	14.696	0.01672	26.80	180.07	970.3	1150.4
220	17.186	0.01677	23.15	188.13	965.2	1153.4
230	20.780	0.01684	19.382	198.23	958.8	1157.0
240	24.969	0.01692	16.323	208.34	952.2	1160.5
250	29.825	0.01700	13.821	216.48	945.5	1164.0
260	35.429	0.01709	11.763	228.64	938.7	1167.3
270	41.858	0.01717	10.061	238.84	931.8	1170.6
280	49.203	0.01726	8.645	249.06	924.7	1173.8
290	57.556	0.01735	7.461	259.31	917.5	1176.8
300	67.013	0.01745	6.466	269.59	910.1	1179.7
310	77.68	0.01755	5.626	279.92	902.6	1182.5
320	89.66	0.01765	4.914	290.28	894.9	1185.2
330	103.06	0.01776	4.307	300.68	887.0	1187.7
340	118.01	0.01787	3.788	311.13	879.0	1190.1
350	134.63	0.01799	3.342	321.63	870.7	1192.3
360	153.04	0.01811	2.957	332.18	862.2	1194.4
370	173.37	0.01823	2.625	342.79	853.5	1196.3
380	195.77	0.01836	2.335	353.45	844.6	1198.1
390	220.37	0.01850	2.0836	364.17	835.4	1199.6

APPENDIX H

OTHER UTILIZATIONS OF RICE HULL CHARS AND RESIDUES

Whenever rice hulls are converted to energy a residue remains. At the lowest level, this can be the percentage of ash in the variety being converted, usually 17 to 22% of the rice hull weight. The upper limit of this residue is about 35 of the initial weight, it represents conversion only of the volatiles present in the raw hull and the retention of the full content of carbon.

The utilization of the char/ash residue has taken many varied paths. In each rice producing country there is some utilization made of the residue, the degree of utilization varies from almost zero upwards. Table H.1 summarizes some technical commercial opportunities for rice hull ash and char utilization.

Table H.1 Technical/Commercial Opportunities for Rice Hull Ash and Char Utilization[a]

Category	Form	Technical Status			Commercial Status	
		Proved	Possible	Conceptual	Proved	Possible
ABSORBENT						
Marine spills	LC			+		
Oil absorbent (Greasweep)	LC	+			xo	
Sweeping & floor cleaning (Greasweep)	LC					
BUILDING MATERIAL COMPONENT						
Calcium heterolsilicate brick (Silicior)	LC	+				o
Cement (impingement process)	LC		+			o
Concrete (acid-resistant)	HC		+			o
Concrete blocks	LC	+				o
Lightweight concrete	LC	+				o
CARBON SOURCE						
Fine filter media (water purification)	HC		+			o
Activated carbon	HC	+				o
Decolorizing charcoal	HC	+				o
Adsorption media (water purification)	HC		+			
Coagulant aid (water purification)	HC		+			
CARRIER						
Catalyst	LC		+			
FERTILIZER						
Anti-caking agent	LC	+			xo	
Coating for prills	LC		+			o
FILTER MEDIA						
Liquid, gas or oil	LC	+				o
Solids removal	LC	+				o
FILLER MATERIAL						
Rubber compounding (as carbon silica)	HC		+			x
Silica aerogel insecticides	LC			+		
Grit toothpaste	LC	+			o	
Rubber compounding (as silica)	LC		+			x
HYDROPONIC MEDIA						
Ash media	LC	+				o
INSULATION USES						
Hot tops (steel plant)	LC	+			o	
Bridge undercoat, steel beams, etc.	LC	+				o
Ingot insulation (steel plant)	HC	+			xo	

Table H.1 Technical/Commercial Opportunities for Rice Hull Ash and Char Utilization (cont.)

Category	Form	Technical Status			Commercial Status	
		Proved	Possible	Conceptual	Proved	Possible
PIGMENT						
Varnish - shoe polish	HC			+		
Paint				+		
Porcelain enamel suspension agent	LC			+		
Carbon paper, ink extender	HC			+		
REFRACTORIES						
Heat-insulation brick from ash	LC	+			o	
Porous media (Ontario Research)	LC	+				o
Ceramics	LC	+			o	
Insulating brick (Medium Temperature)	LC	+			o	
SILICA SOURCE						
Silicon tetrachloride	LC		+			
Silicon carbide nitride	LC		+			
For production of sodium silicate	LC		+			o
Dehydrating agent	LC			+		
Thickening agent	LC			+		
Dessicant and deodorizer	LC			+		
Fumed silica				+		
Finely divided silica			+			o
Silica coating (welding electrode)	LC			+		
Silica rocks for landscaping effects	LC	+				o
Silica source for glass manufacture	LC		+			o
Sintered glass material				+		
SOAP MANUFACTURING						
Soap ingredient from ash	LC	+			o	
SOIL USE						
Silica regeneration in silica-deficient soils	LC		+			o
Mulch media for surface control	HC	+			xo	

LEGEND

FORM OF HUSK PRODUCT: LC = Low-Carbon Ash
HC = High-Carbon Ash

STATUS: + = Techincal feasibility
o = Commercial, small use
x = Commercial, extensive use

* From Beagle 1978.

AUTOBIOGRAPHY

Amorn Putiphrawan was born on December 11, 1963 in Chumporn, Thailand. He attended Debsirin High School in Bangkok and graduated in 1982. He received his Bachelor of Science Degree in Chemical Engineering from Chulalongkorn University, Thailand, in April 1986. He continued his Master's study at Chulalongkorn University in the same year. He was granted a Master's Degree in Chemical Engineering in April 1990.