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APPENDIX A

THIN LAYER DRYING RATE DATA AT CONSTANT AIR CONDITIONS

On the following pages are the selected experimental data for samples of rough rice. The data used in evaluating the mathematical models described in this research. Test conditions for all of the tests are given below. The dimensions of the variables are : time, min and average moisture content, gm/gm dry matter.

Explanation of the code :

1^{st} to 2^{nd}	:	Drying air temperature ($^{\circ}C$)
3^{rd} to 5^{th}	:	Relative humidity of air (%)
		Decimal point before the last digit
6^{th} to 9^{th}	:	Initial moisture content of rough rice (% D.B.)
		Decimal point before the last two digits

CODE : 357353740		CODE : 35653700		CODE : 345253680		CODE : 336003736	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	37.40	0	37.00	0	36.80	0	37.36
2	37.00	5	35.30	5	34.80	2	35.90
5	35.80	10	34.00	10	33.42	12	34.21
10	34.80	15	33.10	15	32.41	17	33.19
15	34.00	19	32.21	20	31.22	22	32.48
20	33.00	24	31.76	25	30.61	27	31.90
25	32.80	29	30.87	30	29.90	42	30.48
27	32.58	34	30.51	35	29.19	57	29.25
30	32.21	40	29.99	40	28.39	72	28.00
35	31.79	45	29.30	45	27.80	87	26.97
40	29.99	50	28.82	50	27.20	117	25.16
45	30.90	55	28.39	55	26.60	132	24.28
50	30.50	60	27.99	60	26.10	147	23.55
58	30.00	70	27.00	70	25.02	162	22.79
60	29.75	80	26.20	80	24.10	177	22.25
70	29.00	90	25.40	90	23.24	192	21.62
80	28.35	110	24.10	100	22.41	207	21.10
90	27.75	140	22.50	120	21.00	222	20.71
100	27.18	170	21.13	150	19.41	237	20.22
120	26.10	200	20.00	180	18.00	252	19.83
150	24.65	240	18.90	210	17.00	267	19.43
180	23.30	290	17.74	260	15.80	282	19.09
205	22.34	365	16.59	310	15.00	312	18.38
210	22.09			360	14.30	327	18.10
250	20.93					372	17.54
270	20.37						
300	19.17						
360	18.85						

CODE : 456503570		CODE : 444853589		CODE : 444253556		CODE : 443603544	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	35.70	0	35.89	0	35.56	0	35.44
2	34.22	8	33.20	7	31.98	5	31.27
7	33.28	15	31.20	12	30.98	10	29.83
12	32.40	20	30.20	17	29.40	15	28.78
18	31.45	25	29.45	22	28.52	20	27.90
25	30.45	30	28.62	27	27.81	25	27.16
32	30.00	35	28.01	32	27.20	40	25.20
38	29.12	40	27.42	37	26.51	55	23.66
40	28.89	45	26.98	42	25.83	72	21.99
47	28.26	55	25.99	50	24.80	90	20.63
52	27.92	68	24.86	55	24.44	100	20.05
62	27.01	82	23.62	68	23.32	115	19.19
72	26.24	93	22.95	78	22.41	130	18.41
82	25.45	125	21.01	88	21.81	145	17.73
90	24.83	145	20.06	118	20.00	160	17.08
120	23.12	175	19.00	148	18.42	175	16.60
148	22.00	220	17.88	178	17.39	190	16.09
150	21.63	260	17.15	185	17.00	205	15.62
180	20.99	320	16.78	210	16.4	220	15.30
210	20.22	340	16.59	250	15.49	235	15.02
240	19.64	360	16.51	300	14.97	250	14.78
280	18.99			330	14.81	265	14.55
300	18.77			360	14.81	280	14.33
355	18.39					295	14.11
						315	13.86
						325	13.74
						340	13.59
						355	13.47

CODE : 505803611		CODE : 512903602		CODE : 502903587		CODE : 602953382	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	36.11	0	36.02	0	35.87	0	33.82
2	35.80	10	28.51	2	32.05	5	31.05
7	33.78	15	27.45	7	30.08	10	29.87
12	33.00	20	26.72	12	28.50	15	38.46
17	31.40	25	25.51	17	27.05	20	26.85
20	30.98	30	24.42	22	26.15	30	25.03
25	29.78	35	23.40	27	25.00	30	28.46
32	28.60	45	22.01	32	24.05	35	24.02
35	28.42	50	21.09	37	23.24	40	23.35
40	27.51	60	20.02	52	21.22	45	22.64
45	26.70	70	19.03	68	19.38	55	21.20
52	26.00	80	18.34	82	18.17	65	20.20
55	25.40	90	17.72	97	16.96	75	19.01
70	24.21	100	17.00	112	16.09	85	18.11
85	22.90	120	15.78	127	15.38	90	17.78
90	22.42	150	14.11	142	14.64	100	17.14
125	20.35	160	13.98	157	14.06	120	15.50
140	19.48	180	13.20	172	13.58	130	15.01
150	18.59	200	12.78	187	13.10	150	13.95
190	17.28	210	12.40	202	12.76	180	12.85
210	16.84	240	11.98	217	12.30	210	11.25
230	16.63	250	11.70	232	12.15	230	11.08
250	16.28	270	11.21	247	11.80	250	10.85
280	15.80	300	11.00	270	11.47	270	10.42
300	15.62	330	10.71	277	11.36	300	10.08
355	15.24	365	10.37	293	11.35	362	9.80
		300	18.00	312	10.97		
		310	17.98	322	10.90		
		360	17.55	337	10.73		
				352	10.57		

CODE : 427353610		CODE : 395853626		CODE : 394953625		CODE : 477253550	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	36.10	0	36.26	0	36.25	0	35.50
5	34.59	7	34.00	12	32.76	5	33.78
10	33.81	12	33.06	17	31.31	12	33.41
20	32.10	17	31.35	22	30.37	17	32.67
25	31.37	22	31.36	27	29.42	22	32.12
35	30.04	32	29.79	34	28.30	28	31.25
40	29.58	38	28.87	39	27.68	32	31.00
50	28.00	48	27.65	44	27.21	35	30.46
65	27.52	58	26.57	49	26.42	45	29.52
75	26.89	70	25.20	54	25.86	55	28.40
85	26.32	80	24.40	59	25.23	70	27.40
95	25.64	90	23.90	69	24.21	80	26.50
110	24.83	110	22.63	79	23.42	90	25.98
120	24.43	120	22.06	89	22.52	100	25.62
130	23.95	130	21.81	100	21.67	110	24.98
150	23.20	150	20.90	120	20.36	120	24.71
180	22.30	180	19.98	150	18.90	150	23.42
210	21.59	210	19.40	180	18.00	180	22.39
250	20.70	240	18.81	220	17.04	210	21.81
300	20.10	280	18.21	250	16.60	240	21.30
360	19.75	365	17.60	300	16.00	270	21.11
				340	15.62	300	20.78
				365	15.40	330	20.54
						360	20.50

CODE : 504753608

T(MIN)	$\bar{M}$(%)
0	36.08
5	33.97
12	32.22
15	30.98
20	29.82
27	28.20
30	27.83
35	26.70
40	26.20
45	25.74
52	24.62
57	24.13
62	23.71
67	23.14
80	22.20
90	21.31
95	20.79
120	19.02
135	18.17
150	17.10
180	16.02
200	15.65
210	15.30
250	14.70
300	14.01
350	13.95

CODE : 434252850

T(MIN)	$\bar{M}$(%)
0	28.50
5	28.10
10	27.54
20	26.28
30	25.38
40	24.43
50	23.42
60	22.85
70	21.67
80	21.00
90	20.07
100	19.72
120	18.40
130	17.82
150	17.00
185	16.00
205	15.33
210	15.04
270	13.72
310	12.85
360	12.32

CODE : 515753121

T(MIN)	$\bar{M}$(%)
0	31.21
5	30.92
10	30.60
15	30.27
20	29.95
25	29.80
30	29.32
35	28.50
40	27.63
55	27.16
70	26.00
85	25.00
100	24.14
115	23.27
130	22.80
150	21.40
160	20.98
180	20.20
200	19.43
210	19.20
230	18.40
250	17.81
285	16.83
360	15.41

CODE : 514753123

T(MIN)	$\bar{M}$(%)
0	31.23
7	30.25
12	29.74
17	29.59
22	28.88
27	28.39
32	27.64
37	27.43
42	27.11
47	26.52
57	25.64
67	25.01
87	23.51
97	23.00
121	21.45
151	20.03
181	18.82
211	17.36
251	16.20
301	14.89
361	13.76

CODE : 50385360

T(MIN)	$\bar{M}$(%)
0	36.00
4	33.40
10	31.50
15	30.00
20	28.74
25	27.42
31	26.21
35	25.40
40	24.81
45	24.10
50	23.50
57	22.53
62	21.90
72	20.79
80	20.20
90	18.90
110	17.83
120	17.21
140	16.01
155	15.31
180	14.50
230	13.41
250	13.10
300	12.70
350	12.01
362	12.01

CODE : 613802178		CODE : 602852195		CODE : 377253040	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	21.78	0	21.95	0	30.40
5	21.00	10	19.00	2	30.26
10	19.85	20	18.20	7	30.00
15	19.60	25	18.00	12	29.46
20	18.62	30	17.45	17	29.18
30	18.23	40	16.84	22	28.85
35	18.02	50	16.25	27	28.42
40	17.67	60	15.90	32	28.03
45	17.53	70	15.20	37	27.85
50	17.37	80	14.90	44	27.29
55	17.20	90	14.26	52	26.85
60	16.89	100	14.00	57	26.65
70	16.26	110	13.81	68	26.00
80	16.00	120	13.36	82	25.19
90	15.73	150	12.90	95	24.40
110	15.00	160	12.85	110	23.82
120	14.84	180	12.40	120	23.13
150	14.30	210	12.14	150	22.00
180	13.98	250	11.63	180	21.00
210	13.47	305	11.30	210	20.17
250	13.18	360	11.24	260	18.91
300	13.00			300	18.37
360	12.85			360	17.42

CODE : 384853247		CODE : 467352848		CODE : 456452845		CODE : 444802846	
T(MIN	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	32.47	0	28.48	0	28.45	0	28.46
2	31.05	5	28.35	5	28.27	5	28.16
12	30.23	10	28.00	10	27.89	12	27.54
17	29.56	15	27.75	20	27.12	17	27.00
22	29.19	20	27.30	25	26.80	22	26.80
27	28.67	30	26.52	35	26.08	28	26.12
42	27.21	42	26.00	40	25.93	37	25.33
50	26.62	52	25.46	50	25.24	47	24.61
55	26.24	62	24.97	55	25.03	57	23.63
60	25.84	72	24.42	60	24.52	67	23.11
75	24.53	82	24.05	70	23.90	77	22.44
85	23.77	92	23.61	80	23.81	87	21.76
95	23.00	102	23.38	90	23.08	122	20.00
115	21.83	122	22.64	100	22.43	152	18.79
135	20.62	152	21.85	125	21.08	182	17.90
155	19.61	182	20.85	155	20.07	212	16.99
210	17.55	212	20.02	185	19.22	275	15.33
255	16.08	280	18.92	220	18.43	305	15.00
305	14.82	310	18.27	250	17.80	350	14.32
360	13.88	360	17.80	305	16.87		
				340	16.21		
				365	16.12		

CODE : 513803122		CODE : 503053123		CODE : 603753140		CODE : 592853143	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	31.22	0	31.23	0	31.40	0	31.43
5	30.78	7	29.84	8	29.43	5	31.00
10	30.20	12	29.22	15	28.85	10	28.44
15	29.63	17	28.16	20	28.24	15	27.60
20	28.89	22	27.56	25	27.63	20	27.03
25	28.43	27	26.63	30	27.02	30	25.00
30	28.00	37	25.32	35	26.43	40	23.92
35	27.00	47	24.00	40	25.45	50	22.67
40	26.26	57	23.07	45	25.02	60	21.26
45	25.82	67	21.99	55	24.00	70	20.34
55	25.43	87	20.01	60	23.42	80	19.42
65	24.00	97	19.22	70	22.26	100	17.89
75	23.11	130	17.00	80	21.70	120	16.22
85	22.37	150	15.63	95	20.37	150	14.42
95	21.52	180	14.32	125	18.32	180	13.37
125	19.57	210	13.08	155	16.73	200	12.68
155	17.84	280	11.26	175	15.90	230	11.45
185	16.52	330	10.26	175	15.01	260	10.95
215	15.32	360	10.00	205	14.83	300	10.34
255	13.97			320	12.10	330	10.10
305	12.63			360	12.00	360	9.98
365	11.98						

CODE : 554903020		CODE : 543853022		CODE : 552953022	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	30.20	0	30.22	0	30.22
2	29.62	7	29.27	5	29.58
10	28.83	12	28.43	10	28.72
20	27.94	17	27.86	15	28.00
30	27.22	22	27.54	20	27.38
40	25.63	27	26.62	25	27.00
50	25.00	32	26.22	30	26.28
60	23.82	37	25.48	35	26.00
70	23.46	42	25.23	40	24.92
80	22.40	57	23.22	45	24.54
90	21.63	67	22.18	50	23.42
100	21.12	77	21.55	60	22.63
120	20.00	87	20.64	70	21.58
150	18.36	127	18.22	80	20.32
180	17.45	157	16.69	90	19.63
210	16.24	187	15.30	100	18.76
250	15.12	217	14.42	110	18.00
290	14.40	247	13.68	120	17.22
330	13.98	307	12.18	140	15.34
360	13.80	367	12.00	170	13.70
				210	12.00
				270	10.80
				300	10.43
				365	10.00

CODE : 467152387		CODE : 456152413		CODE : 434752400		CODE : 444302408	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	23.87	0	24.13	0	24.00	0	24.08
5	23.80	5	23.62	5	23.70	5	23.65
10	23.60	12	23.16	10	23.54	10	23.40
17	23.00	17	23.00	15	22.95	15	22.80
25	22.51	20	22.81	20	22.60	20	22.00
30	22.40	27	22.40	25	22.20	25	21.46
37	22.01	30	22.00	30	21.96	30	21.40
40	21.95	35	21.97	35	21.63	35	21.01
45	21.80	40	21.83	40	21.12	40	20.22
50	21.51	45	21.71	50	20.84	45	20.03
60	20.92	50	21.15	60	20.00	50	19.82
70	20.90	55	21.00	70	19.61	60	19.03
80	20.78	60	20.63	80	19.20	80	17.83
90	20.23	70	20.36	90	18.87	90	17.63
100	20.00	80	20.21	120	17.43	100	17.03
120	19.67	90	19.83	150	16.65	120	16.00
150	18.93	100	10.24	180	15.87	130	15.84
180	18.43	120	16.88	210	15.60	150	15.34
210	18.06	150	17.87	240	14.98	180	14.22
260	17.37	180	17.25	280	14.63	210	13.61
305	17.08	210	17.00	300	14.23	250	12.95
360	16.87	250	16.41	355	13.90	310	12.35
		320	15.88			360	12.08
		365	15.61				

CODE : 544952150		CODE : 543852145		CODE : 552952140		CODE : 503952408	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	21.50	0	21.45	0	21.40	0	24.08
5	21.00	7	20.95	4	20.90	5	23.45
10	20.85	12	20.37	9	20.78	10	23.15
15	20.50	17	19.17	14	19.05	15	23.10
30	18.56	22	18.47	24	17.22	20	22.86
45	17.93	27	18.24	29	16.74	25	22.48
55	17.38	32	17.89	34	16.62	30	22.08
60	17.10	37	17.21	39	16.00	35	21.70
75	16.39	42	17.05	50	15.20	40	21.11
90	15.85	47	16.62	60	14.61	45	21.00
105	15.27	52	16.47	70	14.09	50	20.43
120	15.08	57	16.00	80	13.46	55	20.12
150	14.20	62	15.73	90	13.24	60	19.96
165	14.01	80	15.00	100	13.03	70	19.13
180	13.82	90	14.65	120	12.02	80	18.59
230	13.43	100	14.22	150	11.61	90	17.88
250	13.02	120	13.62	180	11.00	100	17.28
300	13.00	150	12.75	210	10.65	120	16.44
365	13.00	180	12.20	250	10.10	150	15.27
		210	12.00	305	10.00	180	14.08
		300	11.40			210	13.40
		360	11.20			250	12.81
						300	12.00
						350	11.65

CODE : 443602661		CODE : 515752410		CODE : 504852400		CODE : 512852420	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	26.61	0	24.10	0	24.00	0	24.20
2	24.56	10	23.38	5	23.60	7	23.37
7	23.46	15	23.31	10	23.28	12	22.64
12	22.88	20	23.21	15	23.20	17	22.18
17	22.41	35	22.35	27	22.14	20	22.00
22	22.04	40	22.18	32	21.85	25	21.63
37	20.86	45	22.03	37	21.62	30	21.02
52	20.05	55	21.47	42	21.54	35	20.68
67	19.31	60	21.14	50	21.09	40	20.00
82	18.64	70	20.60	55	20.93	45	19.68
97	18.04	80	20.32	60	20.63	50	19.10
112	17.58	90	19.93	70	20.05	60	18.13
127	17.14	100	19.45	85	19.43	70	17.45
142	16.7	120	18.59	95	18.92	80	16.80
157	16.37	150	18.08	120	17.83	90	16.24
172	16.17	180	17.04	150	16.65	120	14.49
187	15.98	210	16.50	180	15.57	150	13.34
202	15.82	240	16.08	210	15.00	180	12.38
217	15.65	255	15.94	250	14.20	210	11.62
232	15.57	300	15.63	305	13.80	250	11.03
247	15.37	355	15.40	355	13.38	300	10.63
262	15.22	370	15.40			360	10.15
277	15.11						
296	14.98						
302	14.91						
307	14.91						
322	14.78						
337	14.73						

CODE : 555003475

T(MIN)	$\bar{M}$(%)
0	34.75
2	32.94
10	30.62
15	29.21
20	28.03
30	26.14
35	25.26
40	24.53
50	23.16
55	22.45
60	22.01
70	21.06
80	20.05
90	19.39
110	18.00
120	17.43
130	17.01
150	16.24
180	15.21
210	14.55
250	13.97
300	13.28
360	13.02

CODE : 552953477

T(MIN)	$\bar{M}$(%)
0	34.77
5	28.87
9	27.36
15	25.78
20	24.39
26	23.21
31	22.13
36	21.38
41	20.74
46	19.78
51	18.99
57	18.32
70	16.62
80	15.67
90	14.68
120	13.02
150	11.84
190	10.99
240	10.32
300	9.98
330	9.96
365	9.81

CODE : 553803469

T(MIN)	$\bar{M}$(%)
0	34.69
2	32.94
7	30.41
12	28.53
17	27.52
22	26.20
27	25.09
32	24.19
37	23.29
42	28.35
67	19.19
72	18.62
82	17.75
97	16.58
112	15.66
127	14.86
142	14.18
157	13.32
207	12.42
217	12.42
232	12.03
247	11.82
262	11.66
277	11.57
292	11.32

CODE : 613853400

T(MIN)	$\bar{M}$(%)
0	34.00
7	31.91
10	31.65
15	30.05
20	28.82
25	28.00
35	29.01
30	27.22
40	25.81
45	25.00
50	24.45
55	23.48
60	23.10
65	22.61
70	22.52
75	21.62
80	21.25
85	20.80
90	20.39
110	18.80
120	18.05
150	16.10
180	14.90
200	13.75
220	13.60
250	12.80
280	12.05
300	11.95
330	11.75
360	11.40

CODE : 453602882		CODE : 417252341		CODE : 415952341		CODE : 385152342	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	28.82	0	23.41	0	23.41	0	23.42
5	26.45	5	23.29	5	23.21	7	23.09
10	25.64	10	23.20	10	23.17	12	22.47
15	25.16	17	22.83	18	22.53	15	22.39
20	24.66	22	22.58	23	22.34	20	22.00
25	24.30	27	22.48	25	22.21	25	21.85
30	23.80	32	22.38	35	21.71	30	21.36
35	23.35	37	22.27	40	21.45	35	21.10
40	23.00	42	22.00	45	21.30	40	21.00
55	22.13	47	21.98	50	21.13	45	21.90
70	21.31	55	21.87	55	20.93	50	20.42
85	20.63	60	21.60	60	20.80	60	20.01
100	19.91	70	21.45	70	20.28	70	19.50
115	19.40	80	21.36	80	20.01	80	19.08
130	18.93	100	21.00	90	19.84	90	18.89
145	18.49	120	20.35	100	19.26	100	18.31
160	18.09	150	19.92	120	18.93	120	17.85
175	17.74	180	19.61	130	18.80	150	16.60
190	17.32	210	19.15	150	18.01	180	16.00
205	17.07	240	18.90	180	17.45	210	15.34
225	16.62	270	18.41	210	17.14	250	14.63
235	16.42	300	18.17	250	16.60	280	14.32
250	16.11	360	17.78	300	16.31	310	14.15
265	15.90			360	15.91	360	13.94
280	15.71						
295	15.46						

CODE : 543453504		CODE : 357452521		CODE : 356352522		CODE : 345252522	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	35.04	0	25.21	0	25.22	0	25.22
4	31.63	7	24.83	5	24.85	5	24.63
9	29.23	12	24.64	12	24.48	10	24.32
14	27.83	17	24.35	15	24.38	20	23.80
19	26.47	22	24.02	20	24.20	30	22.98
24	25.25	27	23.84	27	23.68	40	22.23
29	24.33	32	23.74	32	23.39	45	22.00
44	22.04	35	23.50	37	23.09	55	21.00
59	19.73	40	23.32	42	22.82	60	20.83
79	18.27	45	23.00	45	22.72	70	20.59
89	17.09	52	22.82	50	22.34	80	19.89
104	16.05	55	22.51	60	21.81	90	19.65
119	15.17	60	22.41	70	21.25	120	18.09
134	14.43	70	22.06	80	20.78	130	17.79
149	13.88	82	21.78	90	20.41	150	17.11
164	13.33	90	21.46	100	19.95	180	16.31
179	12.91	125	20.57	120	19.05	210	15.80
194	12.5	150	20.00	130	19.00	230	15.26
209	12.19	160	19.88	150	18.38	250	15.05
224	11.89	180	19.64	180	18.01	300	14.75
239	11.67	220	19.20	210	17.60	330	14.02
249	11.56	240	19.00	240	17.15	360	13.74
269	11.27	320	18.41	270	17.03		
284	11.12	365	18.37	300	16.94		
				360	16.21		

CODE : 443523638

T(MIN)	$\overline{M}$(%)
0	36.38
2	33.88
7	31.18
12	29.87
17	28.65
22	27.58
27	26.66
42	24.27
57	22.50
72	20.95
87	19.66
102	18.55
117	17.60
142	16.29
147	16.13
162	15.58
177	15.11
192	14.78
207	14.41
257	13.55
297	13.05
327	12.73
342	12.54
357	12.45
362	12.44

CODE : 433602240

T(MIN)	$\overline{M}$(%)
0	22.40
5	20.00
10	19.44
15	19.02
20	18.62
25	18.34
30	18.02
35	17.70
40	17.44
45	17.20
50	16.98
55	16.79
60	16.54
70	16.13
80	15.74
90	15.39
100	15.06
110	14.74
120	14.49
125	14.36
130	14.27
140	14.00
145	13.95
150	13.83
155	13.80
160	13.70
165	19.61
170	13.50
175	13.46
180	13.30
185	13.30
190	13.23
195	13.09
200	13.06
205	13.03
230	12.82
240	12.82

CODE : 356153038		CODE : 345203041		CODE : 417203246		CODE : 395953252	
T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)	T(MIN)	$\bar{M}$(%)
0	30.38	0	30.41	0	32.46	0	32.52
4	30.00	5	29.65	7	31.04	5	32.24
10	29.36	10	29.23	12	30.63	10	31.06
14	29.20	15	28.60	17	30.28	15	30.06
19	28.62	20	28.34	22	30.06	20	29.41
24	28.16	25	28.00	27	29.64	25	29.38
29	27.80	40	27.00	37	29.00	30	29.00
34	27.60	55	25.65	47	28.23	35	28.84
44	26.67	65	25.00	52	28.00	40	28.00
49	26.24	72	24.11	67	27.15	55	27.00
59	25.53	90	22.51	82	26.43	70	25.63
79	24.15	100	22.24	97	25.63	85	24.83
89	23.50	120	21.17	112	24.83	100	24.08
119	22.14	130	20.56	120	24.46	115	23.32
149	20.80	150	19.38	135	23.79	130	22.57
179	19.71	175	18.37	150	22.91	175	20.69
209	18.86	190	17.73	170	22.10	205	19.59
249	17.97	210	17.00	180	22.00	250	18.07
284	17.18	235	16.22	217	20.82	295	16.92
300	16.74	250	16.00	247	19.84	340	16.00
365	15.63	280	15.17	302	18.57	360	15.78
		300	14.95	367	18.35		
		340	14.27				
		360	14.17				

Appendix B

Experimental Uncertainty Estimation

The initial moisture content (M_i) determinations were made using the 16 hr.whole grain, 130°C standard oven method. It was calculated from the initial and dry weights for each sample (w_i and w_d respectively). The instantaneous average moisture content ($\bar{M}$) was then calculated from the initial and dry weights of sample (w_i and w_d), initial weights (W_i) and instantaneous weights of sample (W) in the brass-mesh tray.

The relation used were :

$$M_i \text{ (D.B., decimal)} = \frac{w_i}{w_d} - 1 \qquad \text{.....(B.1)}$$

$$\bar{M} \text{ (D.B., decimal)} = \frac{W\, w_i}{W_i w_d} - 1 \qquad \text{.....(B.2)}$$

If F is a function of the independent variables $V_1, V_2, V_3, \ldots, V_n$, and $U_1, U_2, U_3, \ldots, U_n$ are the uncertainties of $V_1, V_2, V_3, \ldots, V_n$ respectively then the uncertainty of F can be expressed as :

$$U_F = [(\frac{\partial F}{\partial V_1} U_1)^2 + (\frac{\partial F}{\partial V_2} U_2)^2 + (\frac{\partial F}{\partial V_3} U_3)^2 + \ldots\ldots + (\frac{\partial F}{\partial V_n} U_n)^2]^{1/2} \qquad \text{.....(B.3)}$$

Therefore the uncertainty of the average moisture content can be expressed as :

$$U_{\bar{M}} = [(\frac{w_i}{W_i w_d} U_W)^2 + (\frac{W}{W_i w_d} U_{w_i})^2 + (-\frac{W w_i}{w_d (W_i)^2} U_{W_i})^2 + (-\frac{W w_i}{W_i (w_d)^2} U_{w_d})^2]^{1/2} \qquad \text{(B.4)}$$

For the typical set of data as follows :

Measurement	Normal Value	Uncertainty
w_i	18.065 g	± 0.005 g
w_d	14.655 g	± 0.005 g
W_i	158.385 g	± 0.005 g
W	154.555 g	± 0.005 g
W_f	145.585 g	± 0.005 g

The uncertainty of an instantaneous average moisture content using the apparatus and procedure of this work was :

$$U_{\overline{M}} = \left[\left(\frac{18.065 \times 0.005}{158.385 \times 14.655}\right)^2 + \left(\frac{154.555 \times 0.005}{158.385 \times 14.655}\right)^2 + \left(\frac{154.555 \times 18.065}{14.655 \times (158.385)^2}\right)^2 + \left(\frac{154.555 \times 18.065 \times 0.005}{158.385 \times (14.655)^2}\right)^2 \right]^{1/2}$$

$$= \left[1.51\times10^{-9} + 1.10\times10^{-7} + 1.44\times10^{-9} + 1.68\times10^{-7}\right]^{1/2}$$

$$= \pm 5.30\times10^{-4} \text{ or } \pm 5.30\times10^{-2} \text{ \%}, \text{ so } \overline{M} = 20.28 \pm 5.30\times10^{-2} \text{ \%}$$

For $\overline{M} = M_i$. The uncertainty of the initial moisture content was estimated as :

$$U_{M_i} = \left[\left(\frac{1}{w_d} U_{w_i}\right)^2 + \left(\frac{w_i}{(w_d)^2} U_{w_d}\right)^2 \right]^{1/2} \quad \text{.....(B.5)}$$

$$= (1.10\times10^{-7} + 1.68\times10^{-7})^{1/2}$$

$$= \pm 5.27\times10^{-4} \text{ or } \pm 5.27\times10^{-2}\text{\%},$$

$$\text{so } M_i = 23.26 \pm 5.27\times10^{-2} \text{ \%}$$

For $\bar{M} = M_f$. The uncertainty of the final average moisture content was estimated as :

$$U_{M_f} = \left[\left(\frac{w_i}{W_i w_d} U_{W_f}\right)^2 + \left(\frac{W_f}{W_i w_d} U_{w_i}\right)^2 + \left(-\frac{W_f w_i}{w_d (W_i)^2} U_{W_i}\right)^2 + \left(-\frac{W_f w_i}{W_i (w_d)^2} U_{w_d}\right)^2 \right]^{1/2} \quad (B.6)$$

$$U_{M_f} = \left[\left(\frac{18.065 \times 0.005}{158.385 \times 14.655}\right)^2 + \left(\frac{145.585 \times 0.005}{158.385 \times 14.655}\right)^2 + \left(\frac{145.585 \times 18.065 \times 0.005}{14.655 \times (158.385)^2}\right)^2 + \left(\frac{145.585 \times 18.065 \times 0.005}{158.385 \times (14.655)^2}\right)^2 \right]^{1/2}$$

$$= \left[1.51 \times 10^{-9} + 9.83 \times 10^{-8} + 1.27 \times 10^{-9} + 1.49 \times 10^{-7} \right]^{1/2}$$

$$= \pm 5 \times 10^{-4} \text{ or } 5 \times 10^{-2} \%$$

so $M_f = 13.30 \pm 5 \times 10^{-2} \%$

Appendix C

The NLIN procedure

Computational Methods

For the nonlinear model,

$$Y = F(\beta_o, \beta_1, \beta_k, \ldots, X_1, X_2, \ldots, X_n) + \varepsilon = F(\beta) + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots (C.1)$$

the nonlinear "normal" equations are

$$X'F(\beta) = X'e \quad \ldots\ldots\ldots\ldots\ldots\ldots (C.2)$$

where $X = \partial F / \partial \beta$

In the nonlinear situation, both X and $F(\beta)$ are functions of β and a closed-form solution generally does not exist. Thus NLIN uses an iterative process : a starting value for β is chosen and continually improved until the error sum of squares $\varepsilon' \varepsilon$ (SSE) is minimized.

The iterative techniques NLIN uses are similar to a series of linear regressions involving the matrix X evaluated for the current values of β and $e = Y - \hat{Y}$, where

$$\hat{Y} = F(\beta) \quad \ldots\ldots\ldots\ldots\ldots\ldots (C.3)$$

are the predicted values evaluated for the current values of β.

The iterative process begins at some point β_o. Then X and Y are employed to compute a Δ such that

$$SSE(\beta_o + k\Delta) < SSE(\beta_o) \quad \ldots\ldots\ldots\ldots\ldots\ldots (C.4)$$

The three methods differ in how Δ is computed to change the vector of parameters.

Steepest descent $\Delta = X'e$ (direction)

Gauss-Newton $\Delta = (X'X)\ X'e$ (direction and distance)

Marquardt $\Delta = (X'X + \lambda 1)\ (X'e)$ (direction and distance)

Steepest descent (gradient) The steepest descent method is based on the gradient of $\varepsilon'\varepsilon$:

$$.5\ \partial\varepsilon'\varepsilon/\partial\beta = -X'Y + X'F(\beta) = -X'e \quad \text{.....(C.5)}$$

The quantity $-X'e$ is the gradient along which $\varepsilon'\varepsilon$ increases. Thus $\Delta = X'e$ is the direction of steepest descent.

Using the method of steepest descent, let

$$\beta_{i+1} = \beta_i + k\Delta \quad \text{.....(C.6)}$$

where the scalar k is chosen such that

$$SSE(\beta_i + k\Delta) < SSE(\beta_i) \quad \text{.....(C.7)}$$

Gauss-Newton The Gauss-Newton method uses the Taylor series

$$F(\beta) = F(\beta_o) + X(\beta - \beta_o) + \ldots \quad \text{.....(C.8)}$$

where $X = \partial F/\partial\beta$ is evaluated at $\beta = \beta_o$

Substituting the first two terms of this series into the "normal" equations :

$$X'F(\beta) = X'Y \quad \text{.....(C.9)}$$

$$X'(F(\beta_o)+X(\beta-\beta_o)) = X'Y \quad \text{.....(C.10)}$$

$$X'F(\beta_o)+X'X(\beta-\beta_o) = X'Y \quad \text{.....(C.11)}$$

$$(X'X)(\beta-\beta_o) = X'Y-X'F(\beta_o) \quad \text{.....(C.12)}$$

$$(X'X)\ \Delta = X'e \quad \text{.....(C.13)}$$

and therefore

$$\Delta = (X'X)^{-1}X'e$$

Marquardt The Marquardt updating formula is as follows :

$$\Delta = (X'X + \lambda \text{diag}(X'X))^{-1} X'e \quad \ldots\ldots\ldots (C.14)$$

The Marquardt method is a compromise between Gauss-Newton and steepest descent. As $\lambda \to 0$, the direction approaches Gauss-Newton. As $\lambda \to \infty$, the direction approaches steepest descent.

Secant method The multivariate secant method is like Gauss-Newton, except that the derivatives are estimated from the history of iterations rather than being supplied analytically. The method is also called the method of false position. If only one parameter is being estimated, the derivative for iteration i + 1 can be estimated from the previous two iterations :

$$\text{der}_{i+1} = (\hat{Y}_i - \hat{Y}_{i-1})/(b_i - b_{i-1}) \ldots (C.15)$$

When k parameters are to be estimated, the method uses the last k + 1 iterations to estimate the derivatives.

Appendix D

Sample SAS program for NLIN procedure and its output for Model 1

```
1          SASRUN LOG   OS SAS 5.18              OS/VS1 JOB ZJAEA838 STEP SAS

NOTE: COPYRIGHT (C) 1984,1988 SAS INSTITUTE INC., CARY, N.C.  27512, U.S.A.
NOTE: THE JOB ZJAEA838 HAS BEEN RUN UNDER RELEASE 5.18 OF SAS AT CHULALONGKORN UNIVERSITY

NOTE: CPUID    VERSION = FF  SERIAL = 970222  MODEL = 3031 .

NOTE: SAS OPTIONS SPECIFIED ARE:
      SCRI=4

1          DATA EXAMPLE;
2               INFILE SMALLZZZ;
3               INPUT T  H MO ME TI M MR N;
4          IF N= 38;


NOTE: INFILE SMALLZZZ IS:
      DSNAME=SYS89057.T183330.RF101.ZJAEA838.R0000005,
      UNIT=TAPE,VOL=SER=9044,LABEL=2,DISP=OLD,
      DCB=(BLKSIZE=800,LRECL=80,RECFM=FB)

NOTE: 1925 LINES WERE READ FROM INFILE SMALLZZZ.
NOTE: DATA SET WORK.EXAMPLE HAS 24 OBSERVATIONS AND 9 VARIABLES. 123 OBS/TRK.
NOTE: THE DATA STATEMENT USED 4.15 SECONDS AND 450K.

5          PROC NLIN BEST =10  PLOT METHOD=MARQUARDT;
6          PARMS  A=0 TO 2 BY 0.1 K=0  TO 2  BY  0.1;
7          MODEL  MR=A*EXP(-K*TI);
8          DER.A= EXP(-K*TI);
9          DER.K= -(A*TI)*EXP(-K*TI);
10         OUTPUT OUT =B     P=YHAT  R=YRESID;
NOTE: THE DATA SET WORK.B HAS 24 OBSERVATIONS AND 10 VARIABLES. 99 OBS/TRK.
NOTE: THE PROCEDURE NLIN USED 34.61 SECONDS AND 844K AND PRINTED PAGES 1 TO 4.

11         PROC PLOT  DATA=B;
12         PLOT   MR*TI='A'  YHAT*TI='P'  /OVERLAY  VPOS=25;
13         PLOT   YRESID*TI / VREF=0  VPOS=25;
NOTE: THE PROCEDURE PLOT USED 1.05 SECONDS AND 542K AND PRINTED PAGES 5 TO 6.
NOTE: SAS USED 844K MEMORY.

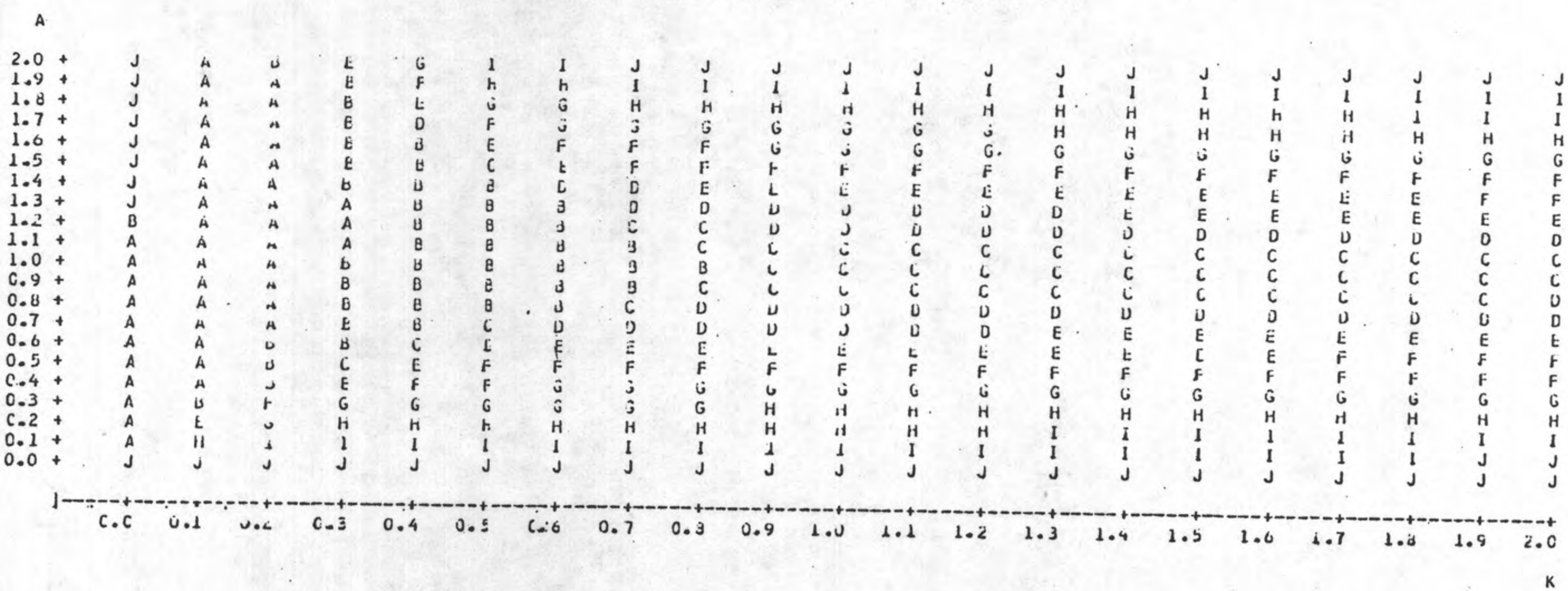
NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BOX 8000
      CARY, N.C. 27512-8000
```

SAS 18:33 MONDAY, FEBRUARY 6, 1989

NON-LINEAR LEAST SQUARES GRID SEARCH DEPENDENT VARIABLE MR

A	K	RESIDUAL SS
0.6	0.0	1.6110293608510
0.7	0.0	1.7453515608510
0.5	0.0	1.9574071508510
0.8	0.0	2.3600737608510
0.4	0.0	2.7831349608510
0.9	0.0	3.4554295908510
0.3	0.0	4.0689527608510
1.0	0.0	5.0285116608510
0.2	0.0	5.8774705608510
1.1	0.0	7.0327403608510

RESIDUAL SS CONTOUR PLOT DEPENDENT VARIABLE MR



SYMBOL	MINIMUM SS	MAXIMUM SS	SYMBOL	MINIMUM SS	MAXIMUM SS
A	1.6112293808510000	9.3614295094413500	F	10.0450575655006000	10.1904269052610000
B	9.3785330069132700	9.8519126455606000	G	10.2058336019978000	10.3680591427438000
C	9.8546631806256300	9.8961985699339200	H	10.3657226905012000	10.5255804642224000
D	9.8962163133660100	9.9729001465378500	I	10.5257077894676000	10.6962720421858000
E	9.9735789493323900	10.0459585272564000	J	10.6962815328116000	47.1707401608509000

NON-LINEAR LEAST SQUARES ITERATIVE PHASE

DEPENDENT VARIABLE: MR METHOD: MARQUARDT

ITERATION	A	K	RESIDUAL SS
0	0.600000000	0	1.5116293606[illegible]
1	0.830338163	0.0042969436	0.1066839889[illegible]
2	0.994231110	0.0059663661	0.0049329779958
3	1.004178200	0.0061115846	0.0043154750770
4	1.004371519	0.0061154186	0.0043151376640
5	1.004375368	0.0061155050	0.0043151374958
6	1.004375454	0.0061155069	0.0043151374957

NOTE: CONVERGENCE CRITERION MET.

NON-LINEAR LEAST SQUARES SUMMARY STATISTICS DEPENDENT VARIABLE MR

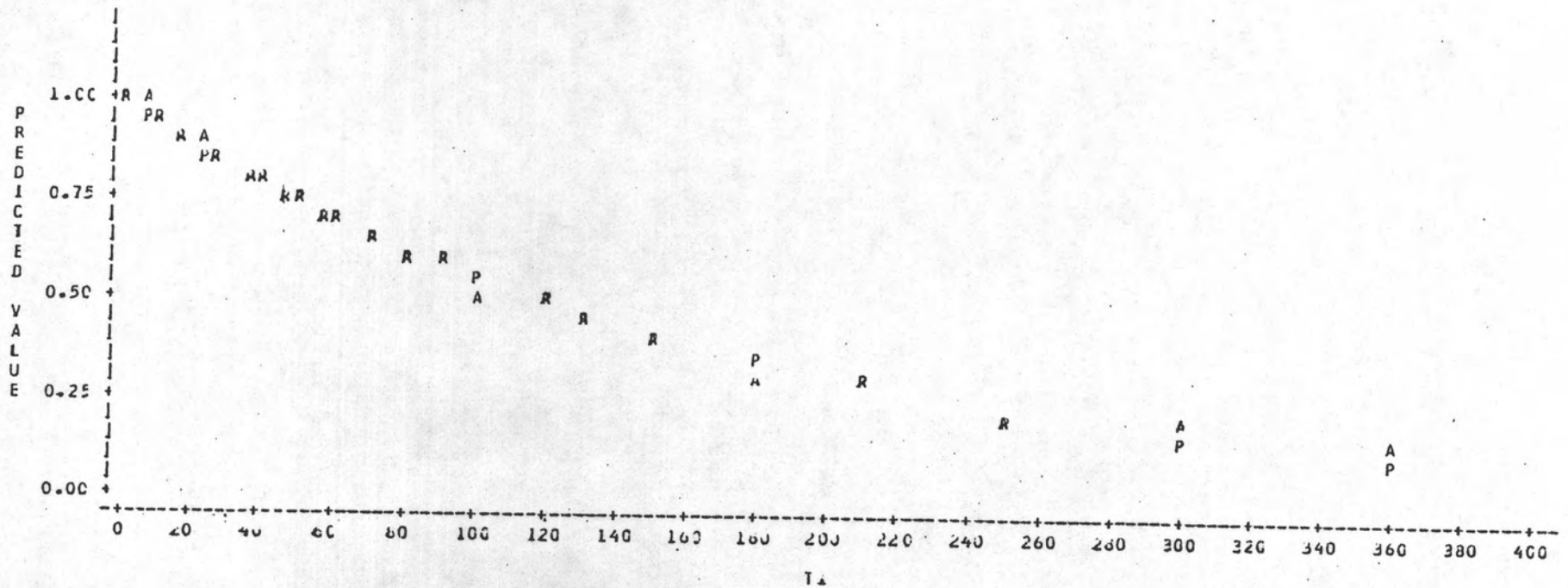
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	2	10.881981023	5.440990512
RESIDUAL	22	0.004315137	0.000196143
UNCORRECTED TOTAL	24	10.886296161	
(CORRECTED TOTAL)	23	1.599974212	

PARAMETER	ESTIMATE	ASYMPTOTIC STD. ERROR	ASYMPTOTIC 95 % CONFIDENCE INTERVAL LOWER	UPPER
A	1.004375454	0.005983118[illegible]	0.991967323[illegible]	1.0167835840
K	0.006115507	0.000594275[illegible]	0.005919993[illegible]	0.0063110201

ASYMPTOTIC CORRELATION MATRIX OF THE PARAMETERS

CORR	A	K
A	1.0000	0.7015
K	0.7015	1.0000

PLOT OF MR*T1 SYMBOL USED IS A
PLOT OF YHAT*T1 SYMBOL USED IS P



Appendix E

List of results of NLIN procedure for Model 1

T	H	M_i	M_e	A	K
35	73.5	37.40	17.40	0.937646	0.006813
33	60.0	37.36	14.94	0.921471	0.005930
35	63.5	37.00	15.50	0.934399	0.007878
34	52.5	36.80	13.67	0.943740	0.009330
39	49.5	36.25	13.10	0.913871	0.008710
39	58.5	36.26	14.57	0.925145	0.007867
42	73.5	36.10	17.25	0.924135	0.007326
47	72.5	35.50	16.92	0.923300	0.006193
44	48.5	35.89	12.85	0.877856	0.006858
45	65.0	35.70	15.56	0.909193	0.006983
44	35.0	36.38	10.73	0.862171	0.009541
44	42.5	35.56	11.91	0.868102	0.007940
50	38.5	36.00	11.19	0.919859	0.011890
44	36.0	35.44	10.88	0.840520	0.007388
50	47.5	36.08	12.60	0.930968	0.015839
50	58.0	36.11	14.27	0.953995	0.010538
51	29.0	36.02	9.65	0.838616	0.011539
50	29.0	35.87	9.67	0.847935	0.011194
55	50.0	34.75	12.91	0.933685	0.013220
55	29.5	34.77	9.73	0.875461	0.017220
61	38.0	21.78	10.98	0.880166	0.007194
60	29.5	33.82	9.63	0.938836	0.011798
35	74.5	25.21	17.61	1.000221	0.007408
34	52.5	25.22	13.67	1.014223	0.008119
35	63.4	25.22	15.50	1.019351	0.007640
41	72.5	23.41	17.08	1.002037	0.005408
38	51.5	23.42	13.44	1.013138	0.007541

T	H	M_i	M_e	A	K
41	59.5	23.41	14.69	1.004375	0.006115
46	71.5	23.87	16.75	1.017660	0.008217
44	43.0	24.08	11.99	1.012857	0.009194
43	47.5	24.00	12.71	1.002622	0.006869
43	36.0	22.40	10.90	0.816202	0.007883
45	61.5	24.13	14.95	0.988749	0.007277
51	57.5	24.10	14.17	1.023313	0.006513
45	36.0	28.82	10.87	0.856637	0.004650
50	48.5	24.00	12.75	1.027190	0.007096
51	28.5	24.20	9.57	1.013205	0.008986
50	39.5	24.08	11.35	1.042624	0.007995
55	29.5	21.40	9.69	0.968714	0.013531
44	36.0	26.61	10.88	0.810862	0.000462
54	38.5	21.45	11.14	0.992150	0.012631
54	49.5	21.50	12.85	1.015384	0.012118
61	38.0	21.78	10.96	0.880166	0.007194
60	28.5	21.95	9.46	0.846190	0.007753
41	72.0	32.46	16.96	0.973524	0.006149
35	61.5	30.38	15.15	1.011952	0.006883
34	52.0	30.41	13.67	1.025454	0.007395
37	72.5	30.40	17.15	1.025758	0.006914
39	59.5	32.52	14.73	0.982550	0.006536
38	48.5	32.47	12.96	0.972112	0.006798
45	64.5	28.45	15.47	1.035431	0.006778
46	73.5	28.48	17.15	1.021286	0.006443
44	48.0	28.46	12.78	1.012155	0.006393

T	H	M_i	M_e	A	K
51	47.5	31.23	12.58	1.004488	0.006326
54	34.5	35.04	10.51	0.891460	0.013670
45	36.0	28.82	10.87	0.856637	0.004650
51	57.5	31.21	14.17	1.035103	0.005972
43	42.5	28.50	11.93	1.020915	0.007931
51	38.0	31.22	11.10	1.023996	0.007284
50	30.5	31.23	9.91	1.003633	0.008829
55	49.0	30.20	12.75	1.004486	0.007504
54	38.5	30.22	11.14	1.010355	0.008100
55	29.5	34.77	9.73	0.875461	0.017220
55	38.0	34.69	11.05	0.925351	0.014900
59	29.5	31.43	9.47	0.983225	0.009850
60	37.5	31.40	10.90	0.991064	0.008073

Appendix F

List of results of NLIN procedure for Model 2

T	H	M_i	M_e	K	N
35	73.5	37.40	17.40	0.016510	0.834588
33	60.0	37.36	14.94	0.019179	0.78764
35	63.5	37.00	15.50	0.019202	0.827542
34	52.5	36.80	13.67	0.018927	0.859836
39	49.5	36.25	13.10	0.027966	0.768203
39	58.5	36.26	14.57	0.027071	0.756502
42	73.5	36.10	17.25	0.025497	0.757938
47	72.5	35.50	16.92	0.022418	0.757957
44	48.5	35.89	12.85	0.036831	0.683186
45	65.0	35.70	15.56	0.027134	0.741812
44	35.0	36.38	10.73	0.054490	0.666818
44	42.5	35.56	11.91	0.041449	0.684114
50	38.5	36.00	11.19	0.032830	0.788119
44	36.0	35.44	10.88	9.954234	0.635170
50	47.5	36.08	12.60	0.026260	0.817015
50	58.0	36.11	14.27	0.020605	0.862283
51	29.0	36.02	9.65	0.059414	0.674409
50	29.0	35.87	9.67	0.060380	0.669760
55	50.0	34.75	12.91	0.030730	0.821851
55	29.5	34.77	9.73	0.063146	0.711607
61	38.5	34.00	11.04	0.013726	0.938411
60	29.5	33.82	9.63	0.023998	0.856432
35	74.5	25.21	17.61	0.007972	0.983914
34	52.5	25.22	13.67	0.005535	1.076908
35	63.5	25.22	15.50	0.006217	1.037661
41	72.5	23.41	17.08	0.004851	1.021323
38	51.5	23.42	13.44	0.005277	1.071869

T	H	M_i	M_e	K	N
41	59.5	23.41	14.69	0.006380	0.989348
46	71.5	23.87	16.75	0.006270	1.052832
44	43.0	24.08	11.99	0.007405	1.043467
43	47.5	24.00	12.71	0.007425	0.982636
45	61.5	24.13	14.95	0.008404	0.973002
43	36.0	22.40	10.90	0.057434	0.628215
51	57.5	24.10	14.17	0.004413	1.072956
50	48.5	24.00	12.75	0.003385	1.147806
45	36.0	28.82	10.87	0.042460	0.605820
51	28.5	24.20	9.57	0.007070	1.048897
50	39.5	24.08	11.35	0.003031	1.196715
55	29.5	21.40	9.69	0.025332	0.860781
44	36.0	26.61	10.88	0.076979	0.506463
54	38.5	21.45	11.14	0.016082	0.944861
54	49.5	21.50	12.85	0.010044	1.038021
61	38.0	21.78	10.96	0.040148	0.666548
60	28.5	21.95	9.46	0.054143	0.627584
41	72.0	32.46	16.96	0.007337	0.972277
35	61.5	30.38	15.15	0.005078	1.059092
34	52.0	30.41	13.67	0.003349	1.155061
37	72.5	30.40	17.15	0.003363	1.143044
39	59.5	32.52	14.73	0.007831	0.969583
38	48.5	32.47	12.96	0.008111	0.972430
45	64.5	28.45	15.47	0.004413	1.072956
46	73.5	28.48	17.15	0.004026	1.090328
44	48.0	28.46	12.78	0.005474	1.027966

T	H	M_i	M_e	K	N
51	47.5	31.23	12.58	0.005213	1.038775
54	34.5	35.04	10.51	0.046507	0.750232
51	57.5	31.21	14.17	0.002651	1.152616
43	42.5	28.50	11.93	0.005299	1.079061
51	38.0	31.22	11.10	0.010044	1.038021
50	30.5	31.23	9.91	0.007410	1.036986
55	49.0	30.20	12.75	0.006004	1.045650
54	38.5	30.22	11.14	0.006693	1.037889
55	29.5	30.22	9.69	0.003731	1.178979
55	38.0	34.69	11.05	0.036257	0.810541
59	28.5	31.43	9.47	0.012390	0.954682
60	37.5	31.40	10.90	0.008621	0.98869

Appendix G

List of results of NLIN procedure for Model 3

T	H	M_i	M_e	A	$Bx10^6$
35	73.5	37.40	17.40	-0.006235	10.8889
33	60.0	37.36	14.94	-0.005498	8.834
35	63.5	37.00	15.50	-0.006921	12.6434
34	52.5	36.80	13.67	-0.007632	14.6050
39	49.5	36.25	13.10	-0.007643	15.1056
39	58.5	36.26	14.57	-0.007040	13.7207
42	73.5	36.10	17.25	-0.006767	12.8436
47	72.5	35.50	16.92	-0.006385	12.1773
44	48.5	35.89	12.85	-0.007157	14.1064
45	65.0	35.70	15.56	-0.006838	13.3490
44	35.0	36.38	10.73	-0.007553	14.6130
44	42.5	35.56	11.91	-0.007562	15.1681
50	38.5	36.00	11.19	-0.008657	17.5649
44	36.0	35.44	10.88	-0.007056	13.6525
50	47.5	36.08	12.60	-0.008260	16.8486
50	58.0	36.11	14.27	-0.008050	16.3639
51	29.0	36.02	9.65	-0.008586	17.8026
50	29.0	35.87	9.67	-0.008300	17.0148
55	50.0	34.75	12.91	-0.009002	18.6464
55	29.5	34.77	9.73	-0.010597	23.2036
61	38.5	34.00	11.04	-0.007686	14.6902
60	29.5	33.82	9.63	-0.008399	16.9400
35	74.5	25.21	17.61	-0.006162	10.5048
34	52.5	25.22	13.67	-0.006180	9.9805
35	63.5	25.22	15.50	-0.006188	10.6712
41	72.5	23.41	17.08	-0.004607	6.1676
38	51.5	23.42	13.44	-0.005982	9.5583

T	H	M_i	M_e	A	$Bx10^6$
41	59.5	23.41	14.69	-0.005360	8.5463
46	71.5	23.87	16.75	-0.006325	10.3707
44	43.0	24.08	11.99	-0.006886	11.9568
43	47.5	24.00	12.71	-0.005832	9.7870
45	61.5	24.13	14.95	-0.006157	10.3355
43	36.0	22.40	10.90	-0.009056	24.9457
51	57.5	24.10	14.17	-0.005378	8.2407
50	48.5	24.00	12.75	-0.005589	8.3700
45	36.0	28.82	10.87	-0.006244	13.5591
51	28.5	24.20	9.57	-0.006902	12.3081
50	39.5	24.08	11.35	-0.006060	9.5365
55	29.5	21.40	9.69	-0.008891	18.3658
44	36.0	26.61	10.88	-0.006387	13.1588
54	38.5	21.45	11.14	-0.008631	17.4653
54	49.5	21.50	12.85	-0.008022	15.3831
61	38.0	12.78	10.96	-0.007392	15.2427
60	28.5	21.95	9.46	-0.007567	15.4425
41	72.0	32.46	16.96	-0.005320	7.9006
35	61.5	30.38	15.15	-0.005419	7.9696
34	52.0	30.41	13.67	-0.005573	8.1625
37	72.5	30.40	17.15	-0.005357	7.5206
39	59.5	32.52	14.73	-0.005485	8.2713
38	48.5	32.47	12.96	-0.005839	9.2676
45	64.5	28.45	15.47	-0.005235	7.3562
46	73.5	28.48	17.15	-0.005140	7.2172
44	48.0	28.46	12.78	-0.005324	8.1082

T	H	M_i	M_e	A	$Bx10^6$
51	47.5	31.23	12.58	-0.005206	7.4990
54	34.5	35.04	10.51	-0.009895	24.3694
51	57.5	31.21	14.17	-0.004633	5.8022
43	42.5	28.50	11.93	-0.006090	9.7899
51	38.0	31.22	11.10	-0.005687	8.6513
50	30.5	31.23	9.91	-0.006664	11.2187
55	49.0	30.20	12.75	-0.006027	9.7829
54	38.5	30.22	11.14	-0.006300	10.4402
55	29.5	30.22	9.69	-0.006618	11.0743
55	38.0	34.69	11.05	-0.010331	25.4469
59	28.5	31.43	9.47	-0.007329	13.4820
60	37.5	31.40	10.90	-0.006510	11.1141

Appendix H

Sample SAS program for STEPWISE MULTIPLE REGRESSION procedure and its output

```
1          SAS(R) 6.06   OS SAS 5.18          OS/VSE JOB ZJAEAZZZ STEP SAS                    22:
NOTE: COPYRIGHT (C) 1985,1988 SAS INSTITUTE INC., CARY, N.C.  27512, U.S.A.
NOTE: THE JOB ZJAEAZZZ HAS BEEN RUN UNDER RELEASE 5.18 OF SAS AT CHUCAE:JNGKUKN UNIVERSITY (136200041).

NOTE: CPUID   VERSION = FF  SERIAL = 970322  MODEL = 3031 .

NOTE: SAS OPTIONS SPECIFIED ARE:
      SCRT=4

1          DATA EXAMPLE;
2              INPUT TIPFUZZZ;
3              INPUT T H MU PE TI M MR;
4              LNLNMR = LOG(-(LOG(MR)));
5          T2 = T**2;
6          LNT = LOG(T);
7          H2 = H**2;
8          LNH = LOG(H);
9          MU2 = MU**2;
10         LNMU = LOG(MU);
11         LNTI = LOG(TI);
12         TLNTI = T*LOG(TI);
13         T2LNTI = (T**2)* LOG(TI);
14         LNTLNTI = (LOG(T))*(LOG(TI));
15         HLNTI = H*LOG(TI);
16         H2LNTI = (H**2)*(LOG(TI));
17         LNHLNTI = (LOG(H))*(LOG(TI));
18         MULNTI = MU*LOG(TI);
19         MU2LNTI = (MU**2)*(LOG(TI));
20         LNMULNTI = (LOG(MU))*(LOG(TI));
21         TO5 = (T**(0.5));
22         TM1 = (T**(-1));
23         HO5 = (H**(0.5));
24         HM1 = (H**(-1));
25         MUO5 = (MU**(0.5));
26         MUM1 = (MU**(-1));
27         TO5LNTI = (T**(0.5))*(LOG(TI));
28         TM1LNTI = (T**(-1))*(LOG(TI));
29         HO5LNTI = (H**(0.5))*(LOG(TI));
30         HM1LNTI = (H**(-1))*(LOG(TI));
31         MO5LNTI = (MU**(0.5))*(LOG(TI));
32         MM1LNTI = (MU**(-1))*(LOG(TI));
33         THM1 = T*(H**(-1));
34         TMUM1 = T*(MU**(-1));
35         HTM1 = H*(T**(-1));
36         MUTM1 = MU*(T**(-1));
37         TH =T*H;
38         TMU=T*MU;
39         THMU=T*H*MU;
40         TM2=T**(-2);
41         TH5=T*(H**0.5);
```

```
1C          SAS(R) 6.06   OS SAS 5.18            OS/VS1 JOB ZJA3ALL2 STEP SAS

NOTE: MATHEMATICAL OPERATIONS COULD NOT BE PERFORMED AT THE
      FOLLOWING PLACES. THE RESULT OF THESE OPERATIONS HAVE
      BEEN SET TO MISSING VALUES.
      EACH PLACE IS GIVEN BY: (NUMBER OF TIMES) AT (LINE):(COLUMN).

      81 AT 4:15   82 AT 11:8   82 AT 12:9   82 AT 13:10   82 AT 14:11   82 AT 15:9   82 AT 16:10   82 AT 17:11
      82 AT 18:10   82 AT 19:11   82 AT 20:12   82 AT 27:11   82 AT 28:11   82 AT 29:11   82 AT 30:11   82 AT 31:12
      82 AT 32:13

NOTE: 1923 LINES WERE READ FROM INFILE TIPF0ZZZ.
NOTE: DATA SET WORK.EXAMPLE HAS 1923 OBSERVATIONS AND 45 VARIABLES. 22 OBS/TRK.
NOTE: THE DATA STATEMENT USED 19.50 SECONDS AND 450K.

42          PROC STEPWISE;
43          MODEL LNLNMA = LNMOLNTI THM1 MOLNTI MO MO05;
44          MODEL LNLNMA =LNMOLNTI THM1 MOLNTI T TMO TMOM1;
45          MODEL LNLNMA =LNMOLNTI H H2LNTI MOLNTI TMO T TMOM1;
46          MODEL LNLNMA =LNTI H TMO  H2LNTI T TMOM1 MOLNTI LNMOLNTI ;
47          MODEL LNLNMA =LNTI H TMO  H2LNTI LNT TMOM1 T2 MOLNTI LNMOLNTI;
48          MODEL LNLNMA =MO05LNTI MOLNTI THM1 MO MO05;
49          MODEL LNLNMA =MO05LNTI MOLNTI HM1 TMO T TMOM1;
50          MODEL LNLNMA =MO05LNTI MOLNTI HM1 HM1LNTI TMO T TMOM1;
51          MODEL LNLNMA =LNTI MO5 TMO H2LNTI T TMOM1 MOLNTI MO05LNTI;
52          MODEL LNLNMA =LNTI MO5 TMO H2LNTI LNT TMOM1 T2 MOLNTI MO05LNTI;
NOTE: THE PROCEDURE STEPWISE USED 22.73 SECONDS AND 524K AND PRINTED PAGES 1 TO 36.

53          PROC PRINT;
54          RUN;
NOTE: THE PROCEDURE PRINT USED 145.82 SECONDS AND 500K AND PRINTED PAGES 37 TO 157.

NOTE: SAS USED 524K MEMORY.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BOX 8000
      CARY, N.C. 27512-8000
```

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE LNLNRR

WARNING: 62 OBSERVATIONS DELETED DUE TO MISSING VALUES.

NOTE: SLENTRY AND SLSTAY HAVE BEEN SET TO .15 FOR THE STEPWISE TECHNIQUE.

STEP 1 VARIABLE LNTI ENTERED R SQUARE = 0.88174054 C(P) = 2792.04743565

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	2046.82217810	2046.82217810	13711.55	0.0001
ERROR	1639	274.51977247	0.14927720		
TOTAL	1640	2321.34295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-4.99557772				
LNTI	0.92075630	0.00786325	2046.82217810	13711.55	0.0001

BOUNDS ON CONDITION NUMBER: 1, 1

STEP 2 VARIABLE HOS ENTERED R SQUARE = 0.90033458 C(P) = 2040.77511178

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	2091.49419323	1045.74709912	8362.33	0.0001
ERROR	1638	229.84875214	0.12903373		
TOTAL	1640	2321.34295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-5.30462075				
LNTI	0.91435578	0.00720596	2013.67772501	16104.10	0.0001
HOS	-0.[illegible]17690	0.00769232	44.67202013	357.22	0.0001

BOUNDS ON CONDITION NUMBER: 1.002229, 4.008917

STEP 3 VARIABLE TMO ENTERED R SQUARE = 0.90325512 C(P) = 1758.18532846

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	2098.37161337	702.79053786	6051.67	0.0001
ERROR	1637	212.97133720	0.11659432		
TOTAL	1640	2321.34295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-5.08024232				
LNTI	0.91557174	0.00693813	2015.03573091	17284.05	0.0001
HOS	-0.[illegible]44[illegible]	0.00771600	34.34294290	297.95	0.0001
TMO	0.00037742	0.00002283	16.87741534	145.36	0.0001

BOUNDS ON CONDITION NUMBER: 1.032753, 9.197349

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE LNLNMR

STEP 4 VARIABLE H2LNTI ENTERED R SQUARE = 0.91304375 C(P) = 1572.74121729

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	2119.43767014	529.85941754	4819.52	0.0001
ERROR	1636	201.95528043	0.10994296		
TOTAL	1640	2321.39295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-2.17737567				
LNTI	0.80077171	0.01258821	453.82806320	4127.85	0.0001
H0S	-0.55257072	0.02401977	25.03044289	227.69	0.0001
TMO	0.00026209	0.00002244	14.99322014	136.37	0.0001
H2LNTI	0.00005734	0.00000571	11.11005697	101.11	0.0001

BOUNDS ON CONDITION NUMBER: 12.47415, 113.1879

STEP 5 VARIABLE T ENTERED R SQUARE = 0.91470679 C(P) = 1509.64472932

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	2123.34314365	424.66862873	3965.80	0.0001
ERROR	1635	197.99480192	0.12109907		
TOTAL	1640	2321.39295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.80241327				
LNTI	0.80445852	0.01249148	447.50421780	4147.45	0.0001
H0S	-0.57842566	0.02394283	25.53473049	249.81	0.0001
TMO	0.00037642	0.00002934	17.73774292	164.11	0.0001
H2LNTI	0.00005840	0.00000583	11.72550559	108.67	0.0001
T	-0.00755680	0.00126359	3.35047851	33.78	0.0001

BOUNDS ON CONDITION NUMBER: 12.5023, 152.1153

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE LNLAMR

STEP 6 VARIABLE TMJ41 ENTERED R SQUARE = 0.93934819 C(P) = 547.10249198

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	2180.54930802	363.42488467	4754.03	0.0001
ERROR	1834	140.79364255	0.07676662		
TOTAL	1840	2321.34295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.90057299				
LNTI	0.80368720	0.01053855	445.84327991	5818.05	0.0001
H05	-0.38606510	0.02019907	25.49001393	332.04	0.0001
TMO	0.00062414	0.00019378	64.58452406	842.33	0.0001
H2LNTI	0.00010801	0.00000311	11.48897211	149.65	0.0001
T	-0.30945834	0.01111098	59.34027833	775.69	0.0001
TMOM1	4.17562711	0.15297172	57.20115930	745.11	0.0001

BOUNDS ON CONDITION NUMBER: 207.8213, 2757.469

STEP 7 VARIABLE MOLNTI ENTERED R SQUARE = 0.94699081 C(P) = 255.86085478

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	2198.05850170	314.00835881	4088.69	0.0001
ERROR	1833	123.28464887	0.06725640		
TOTAL	1840	2321.34295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.85135417				
LNTI	1.25674870	0.02359517	125.51200765	1670.59	0.0001
H05	-0.37198342	0.01990036	26.01757597	366.83	0.0001
TMO	0.00770215	0.00022240	80.62043325	1198.76	0.0001
H2LNTI	-0.00005872	0.00000261	11.91767447	177.20	0.0001
T	-0.39051023	0.01171638	77.35151240	1145.31	0.0001
TMOM1	4.86832946	0.14944539	71.51511352	1060.32	0.0001
MOLNTI	-0.01425419	0.00083846	17.50899305	260.32	0.0001

BOUNDS ON CONDITION NUMBER: 263.7603, 4517.635

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE LNLNMR

STEP 8 VARIABLE MOOSLNTI ENTERED R SQUARE = 0.95319745 C(P) = 9.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	2212.69812715	276.58726589	4663.89	0.0001
ERROR	1832	108.63682643	0.05930394		
TOTAL	1840	2321.34295057			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.79003208				
LNTI	-9.12108018	0.05978518	11.33368169	191.11	0.0001
H05	-0.37116500	0.01773494	25.94706169	437.02	0.0001
TMO	0.02531497	0.00052754	49.95229923	842.48	0.0001
H2LNTI	0.00005855	0.00000273	11.82507624	199.23	0.0001
T	-0.03996483	0.03029273	45.59624395	768.86	0.0001
TMOM1	11.05815636	0.41832603	41.45980573	698.77	0.0001
MOLNTI	-0.57352455	0.02288195	15.30371953	266.49	0.0001
MOOSLNTI	3.87402196	0.24660576	14.63962244	246.66	0.0001

BOUNDS ON CONDITION NUMBER: 84382.54, 1081352

NO OTHER VARIABLES MET THE 0.1500 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL.

SUMMARY OF STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE LNLNMR

STEP	VARIABLE ENTERED	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	MODEL R**2	C(P)	F	PROB>F
1	LNTI		1	0.6317	0.6317	2792.05	9999.9999	0.0001
2	H05		2	0.0192	0.9010	2040.78	357.2226	0.0001
3	TMO		3	0.0075	0.9085	1758.18	145.5774	0.0001
4	H2LNTI		4	0.0046	0.9130	1572.74	101.1075	0.0001
5	T		5	0.0017	0.9147	1509.64	35.7786	0.0001
6	TMOM1		6	0.0246	0.9393	547.10	745.1112	0.0001
7	MOLNTI		7	0.0073	0.9466	253.86	260.3245	0.0001
8	MOOSLNTI		8	0.0066	0.9532	9.00	246.8669	0.0001

Appendix I

List of deep bed drying simulation program

MUSIC ID: ZJAE000 FILE NAME: TEST2BAC

```
//ZJAEZZZZ JOB CLASS=Y,MSGCLASS=Z,MSGLEVEL=(1,1)
//       EXEC FORTVCLG
//FORT.SYSPRINT DD  SYSOUT=Z
//FORT.SYSIN  DD *
C*************************************************************************
C**                                                                     **
C**  COMPUTER PROGRAM FOR DEEP BED ROUGH RICE DRYING SIMULATION,        **
C**        A THIN-LAYER DRYING EQUATION DEVELOPED BY:                   **
C**              SOMCHAI WONGWISES                                      **
C**              MECHANICAL ENGINEERING DEPARTMENT                      **
C**              CHULALONGKORN UNIVERSITY                               **
C**              BANGKOK,THAILAND                                       **
C**                                                                     **
C*************************************************************************
C
C  DEFINITION OF TERMS:
C
C      BD          = BULK DENSITY OF GRAIN,KG/CU.M
C      C           = SPECIFIC HEAT OF ROUGH RICE MULTIPLIED BY GRAIN TO
C                    AIR RATIO, BTU/LB/DEG.F
C      C1          = SPECIFIC HEAT OF ROUGH RICE MULTIPLIED BY GRAIN TO
C                    AIR RATIO, KJ/KG/DEG.C
C      C2          = CONSTANT IN EQUILIBRIUM MOISTURE CONTENT EQUATION
C      CK          = CONSTANT IN THIN LAYER DRYING EQUATION
C      CN          = CONSTANT IN THIN LAYER DRYING EQUATION
C      DELH        = DIFFERENCE BETWEEN INLET AND OUTLET ABSOLUTE
C                    HUMIDITY OF DRYING AIR AT EACH LAYER,
C                    LB WATER/LB DRY AIR
C      DELL        = LATENT HEAT OF VAPORIZATION OF WATER IN ROUGH RICE,
C                    BTU/LB WATER
C      DEPTH       = DEPTH OF EACH LAYER,M
C      DMW         = DRY MATTER WEIGHT OF GRAIN IN EACH LAYER,LB
C      DMW1        = DRY MATTER WEIGHT OF GRAIN IN EACH LAYER,KG
C      DTIME       = EQUIVALENT DRYING TIME,MIN
C      G(I,J)      = GRAIN TEMPERATURE IN LAYER J AND TIME INTERVAL I,
C                    DEG.F
C      GC(I,J)     = GRAIN TEMPERATURE IN LAYER J AND TIME INTERVAL I,
C                    DEG.C
C      GTEMP1      = INITIAL GRAIN TEMPERATURE,DEG.C
C      GE          = EQUILIBRIUM GRAIN TEMPERATURE,DEG.F
C      GW(I,J)     = GRAIN WEIGHT IN LAYER J AND TIME INTERVAL I,LB
C      GW1         = GRAIN WEIGHT IN LAYER J AND TIME INTERVAL I,KG
C      H(I,J)      = ABSOLUTE HUMIDITY OF THE INCOMING DRYING AIR TO
C                    LAYER J IN TIME INTERVAL I,LB WATER/LB DRY AIR
C      HF          = ABSOLUTE HUMIDITY OF THE EXHAUST DRYING AIR FROM
C                    LAYER J IN TIME INTERVAL I,LB WATER/LB DRY AIR
C      HUMI1       = ABSOLUTE HUMIDITY OF THE INCOMING DRYING TO
C                    FIRST LAYER,KG WATER/KG DRY AIR
C      I           = TIME INTERVAL INDEX
C      OIMC        = INITIAL MOISTURE CONTENT OF ROUGH RICE,
C                    PERCENT D.B.
C      J           = LAYER INDEX
C      LAYNUM      = TOTAL NUMBER OF THIN LAYERS
C      M(I,J)      = AVERAGE MOISTURE CONTENT OF GRAIN AFTER DRYING FOR
C                    TIME INTERVAL I AT LAYER J,PERCENT D.B.
C      ME          = EQUILIBRIUM MOISTURE CONTENT,PERCENT D.B.
C      MR          = AVERAGE MOISTURE RATIO,DIMENSIONLESS
```

D: ZJAE000 FILE NAME: TEST2BAC

```
C     N          = CONSTANT IN EQUILIBRIUM MOISTURE CONTENT EQUATION
C     NC         = TOTAL NUMBER OF TIME INTERVAL
C     PAT        = ATMOSPHERIC PRESSURE,PSI
C     PV         = PARTIAL VAPOR PRESSURE OF WATER VAPOR,PSI
C     PVS        = SATURATED VAPOR PRESSURE OF PURE WATER,PSI
C     Q          = AIR FLOW RATE,CU.FT/MIN./SQ.FT
C     Q1         = AIR FLOW RATE,CU.M/SEC./SQ.M
C     R(I,J)     = WEIGHT OF AIR TO GRAIN RATIO
C     RH(I,J)    = RELATIVE HUMIDITY OF THE INCOMING DRYING AIR TO
C                    LAYER J AT TIME INTERVAL I,DECIMAL
C     RH1        = RELATIVE HUMIDITY OF THE INCOMING DRYING AIR TO
C                    LAYER J AT TIME INTERVAL I,PERCENT
C     RHP        = RELATIVE HUMIDITY OF THE INCOMING DRYING AIR TO
C                    LAYER J AT TIME INTERVAL I,PERCENT
C     T(I,J)     = TEMPERATURE OF THE INCOMING DRYING AIR TO
C                    LAYER J AT TIME INTERVAL I,DEG.F
C     TC(I,J)    = TEMPERATURE OF THE INCOMING DRYING AIR TO
C                    LAYER J AT TIME INTERVAL I,DEG.C
C     TEMP1      = TEMPERATURE OF THE INCOMING DRYING AIR TO
C                    FIRST LAYER,DEG.C
C     TIME       = DRYING TIME INTERVAL,MIN
C     TE(I,J)    = EQUILIBRIUM DRYING AIR TEMPERATURE AT TIME INTERVAL
C                    I AND LAYER J,DEG.F
C     TE1(I,J)   = EQUILIBRIUM DRYING AIR TEMPERATURE AT TIME INTERVAL
C                    I AND LAYER J,DEG.C
C     TT         = TOTAL DRYING TIME,MIN.
C     TF         = TEMPERATURE OF THE EXHAUST AIR FROM EACH LAYER,DEG.F
C     WAIR(I,J)  = WEIGHT OF AIR PASSING THROUGH LAYER J AT TIME
C                    INTERVAL I,LB
C     WAIR1      = WEIGHT OF AIR PASSING THROUGH EACH LAYER FOR
C                    A GIVEN TIME INTERVAL,KG
C     WMC        = AVERAGE MOISTURE CONTENT OF GRAIN,PERCENT W.B.
C     XAREA      = CROSS-SECTIONAL AREA OF DRYING BIN,SQ.M.
C
C     MAIN PROGRAM
C
C
      DIMENSION M(220,60),G(220,60),T(220,60),H(220,60),GC(220,60),
     * GW(220,60),WAIR(220,60),TE(220,60),RH(220,60),TC(220,60),
     * MR(220,60),DTIME(220,60),R(220,60),CK(220,60),EN(220,60),
     * TE1(220,60)
      REAL  N,M,ML,MF,MR1,MRE,MR
C
C     SET INITIAL CONDITIONS
C
C
C     READ INPUT DATA
C
      READ  (5,*) TEMP1,HUMI1,GTEMP1,GIMC,DEPTH,XAREA,TIME,
     *  LAYNUM,NC,Q1
C
C
C     PRINT INITIAL CONDITIONS
C
      WRITE (6,500)    GIMC,GTEMP1,TEMP1,HUMI1,DEPTH,XAREA,TIME,
     *  LAYNUM,NC,Q1
C
```

```
MUSIC ID= ZJAE000          FILE NAME= TEST2BAC

      C     RESULTS FROM CALCULATION USING INITIAL CONDITIONS
      C
      C     CALCULATE WEIGHT OF AIR THROUGH FIRST LAYER IN FIRST INTERVAL
      C
            Q          =  .1/5.C8D-3
            WAIR(1,1)  =  Q*TIME*0.075*1.0
            WAIR1      =  WAIR(1,1)*0.4536
      C
            T(1,1)     =  ((TEMP1*9.0/5.0)+32.0)
            H(1,1)     =  HUMI1
            G(1,1)     =  ((GTEMP1*9.0/5.0)+32.0)
            M(1,1)     =  GIMC
      C     CALCULATE GRAIN WEIGHT
      C
            BD         =  552.10+(2.82)*(M(1,1))
            GW1        =  DEPTH * XAREA * BD
            GW(1,1)    =  GW1*2.2045
      C
      C     CALCULATE DRY MATTER WEIGHT
      C
      C
            DMW        =  GW(1,1)-GW(1,1)*M(1,1)/(100+M(1,1))
      C
            DMW1       =  DMW*0.4536
      C
      C     CALCULATE RELATIVE HUMIDITY OF INCOMING DRYING AIR TO FIRST LAYER
      C
            PAT        =  14.7
            PV         =  PAT*H(1,1)/(H(1,1)+0.622)
            PVS        =  EXP(54.6326-(12301.683/(T(1,1)+459.69))-5.1928*
           *   ALOG(T(1,1)+459.69))
            RH(1,1)    =  PV/PVS
            RHP        =  RH(1,1)*100.00
      C
      C     CALCULATE EQUILIBRIUM MOISTURE CONTENT OF GRAIN
      C
      C     C2 AND N ARE CONSTANTS IN EQUILIBRIUM MOISTURE CONTENT  EQUATION
      C
            C2         =  4.7230-05
            N          =  2.386
            ME         =  ((-ALOG(1.0-RH(1,1)))/(C2*(TEMP1+273.15)))**(1/N)
      C
      C     PRINT RESULTS FROM CALCULATION USING INITIAL CONDITIONS
      C
            WRITE (6,501) RHP,ME,WAIR1,GW1,DMW1,BD
      C
      C     CALCULATIONS FOR FIRST INTERVAL AND FIRST LAYER
      C
            I          =  1
            DO 10 J    =  1,LAYNUM
            M(I,J)     =  M(1,1)
            G(I,J)     =  G(1,1)
            GW(I,J)    =  GW(1,1)
      C
            CALL   KN(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,C,ME,I,J)
            CALL MASS(K,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,TIME,ME,I,J)
            CALL HEAT(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,ME,CMA,I,J)
```

```
MUSIC ID: ZJAE000          FILE NAME: TEST28AC

      10 CONTINUE
C
C     CALCULATIONS FOR FIRST LAYER AND EVERY INTERVAL
C
      J          =  1
      DO 20 I    =  2,NC
      T(I,J)     =    T(1,1)
      H(I,J)     =    H(1,1)
      RH(I,J)    =   RH(1,1)
      WAIR(I,J) = WAIR(1,1)
      CALL   KN(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,C,ME,I,J)
      CALL MASS(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,TIME,ME,I,J)
      CALL HEAT(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,ME,DM,I,J)
   20 CONTINUE
C
C     CALCULATIONS FOR THE REMAINING LAYERS AND INTERVALS
C
      DO 30 I = 2,NC
      DO 40 J = 2,LAYNUM
      CALL   KN(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,C,ME,I,J)
      CALL MASS(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,TIME,ME,I,J)
      CALL HEAT(M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,ME,DM,I,J)
   40 CONTINUE
   30 CONTINUE
C
C     PRINT RESULTS FROM SIMULATION
C
      WRITE (6,510)
      WRITE (6,511)
      TIM    = TIME
      NNC    = 1
      DO 51 I = 1,NC,NNC
      TIM1   = TIM/60.0
      WRITE (6,512) TIM1,I
      DO 59 J = 1,LAYNUM
      TC(I,J)   = (T(I,J)-32.0)*5./9.
      GC(I,J)   = (G(I,J)-32.0)*5./9.
      WRITE (6,513) J,M(I,J),GC(I,J),TC(I,J),H(I,J),
     *  GW(I,J),WAIR(I,J),RH(I,J),CK(I,J),CN(I,J)
   59 CONTINUE
      TIM    = TIM+TIME*NNC
   51 CONTINUE
      STOP
  500 FORMAT (1H1,/////12X,'SIMULATION OF DEEP BED ROUGH RICE DRYING'/
     * 12X,'**********************************************'/
     *//23X,'BY'//19X,'SOMCHAI WONGWISES'/
     *19X,'MECHANICAL ENGINEERING DEPT.'/
     *19X,'CHULALONGKORN UNIVERSITY'/
     *19X,'BANGKOK,THAILAND'///
     *12X,'INITIAL GRAIN AND AIR CONDITIONS' /
     *12X,'**************************'//
     *12X,'MOISTURE CONTENT OF GRAIN (% D.B.)    =',F10.2/
     *12X,'GRAIN TEMPERATURE (DEG.C)             =',F10.2/
     *12X,'AIR TEMPERATURE (DEG.C)               =',F10.2/
     *12X,'ABSOLUTE HUMIDITY OF AIR (DECIMAL)    =',F10.4/
     *12X,'DEPTH OF EACH LAYER (M)               =',F10.2/
     *12X,'CROSS-SECTIONAL AREA OF BIN (SQ.M)    =',F10.4/
```

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MUSIC ID: ZJAE000          FILE NAME: TEST2BAC

      *12X,'DRYING TIME INTERVAL (MIN)                    =',F10.2/
      *12X,'NUMBER OF LAYERS                              =',I10/
      *12X,'NUMBER OF INTERVALS                           =',I10/
      *12X,'AIR FLOW RATE  (CU.M/SEC/SQ.M)                =',F10.4 )
  501 FORMAT (12X,'RELATIVE HUMIDITY OF AIR (%)                =',F10.2/
      *12X,'EQUILIBRIUM MOISTURE CONTENT (% D.B.) =',F10.2/
      *12X,'WEIGHT OF AIR (KG)                            =',F10.3/
      *12X,'WEIGHT OF GRAIN IN EACH LAYER (KG)            =',F10.3/
      *12X,'DRY MATTER WEIGHT OF GRAIN (KG)               =',F10.3/
      *12X,'BULK DENSITY OF GRAIN (KG/CU.M)               =',F10.3//)
  510 FORMAT (1H1,//////25X,'RESULTS FROM THE SIMULATION'/25X,
      * '************************'//)
  512 FORMAT (/10X,'DRYING TIME HRS  =',F8.2,10X,'INTERVAL NO. =',I5/)
  511 FORMAT (1X,'LAY',1X,'MOISTURE',1X,'GRAIN',3X,'AIR',4X,'ADJ.',
      * 5X,'GRAIN',3X,'WEIGHT',5X,
      * 'RH',7X,'K',7X,'N'/
      * 1X,'NO.',1X,'CONTENT',2X,'TEMP.',2X,'TEMP.',2X,'HUMIDITY',2X,
      * 'WEIGHT',2X,'OF AIR',4X,'DECI.'/
      * 5X,'%(DB)',6X,'C',6X,'C',6X,
      * 'DECI.',4X,' G. ',4X,' G. ')
  513 FORMAT (I3,2F8.3,F8.3,F8.4, F8.4,F10.4,F8.4,
      * 2F8.4)
      STOP
      END
C
C     SUBPROGRAM TO CALCULATE COEFFICIENT IN THIN LAYER DRYING EQUATION
C
      SUBROUTINE KN(M,G,T,H,GW,AIR,TE,TE1,RH,MR,DTIME,R,CK,CN,C,N,I,J)
      DIMENSION M(220,60),G(220,60),T(220,60),H(220,60),GW(220,60),
     * AIR(220,60),TE(220,60),RH(220,60),TE1(220,60),
     * MR(220,60),DTIME(220,60),R(220,60),CK(220,60),CN(220,60)
      REAL N,M,ME,MF,MR1,MRE,MR
      CK1   =  -1.79003208
      CK2   =  -0.37116580
      CK3   =   0.01581497
      CK4   =  -0.85590483
      CK5   =  11.05813036
      CN1   =  -9.12108018
      CN2   =   0.00003855
      CN3   =  -0.37355455
      CN4   =   3.87462196
      C2    =   4.7230E-06
      N     =   2.380
C
C     CALCULATE AIR TO GRAIN RATIO
C
      R(I,J)=   AIR(I,J)/GW(I,J)
      WMC   =   H(I,J)*100/(M(I,J)+100)
      C1    =   (1.292+(0.042*M(I,J)))/R(I,J)
      C     =   C1*0.2388
C
C     CALCULATE EQUILIBRIUM TEMPERATURE
C
      TE(I,J)  =  (0.24*T(I,J)+H(I,J)*(1060.8+0.45*T(I,J))+
     * C*G(I,J)-1060.8*H(I,J))/(0.24+0.45*H(I,J)+C)
      TE1(I,J) =  (TE(I,J)-32.0)*5.0/9.0
C
```

```
MUSIC ID: ZJAE000          FILE NAME: TEST2BAC

      C     CALCULATE EQUILIBRIUM MOISTURE CONTENT
      C
            ME        =  ((-ALOG(1.0-RH(I,J)))/(C2*(TE1(I,J)+279.15)))**(1/N)
            RH1       =  RH(I,J)*100
            T1        =  TE1(I,J)
      C
      C     CALCULATE CONSTANTS FOR THIN LAYER DRYING EQUATION
      C
            CK(I,J)   =  EXP(CK1+(CK2*(RH1**0.5))+(CK3*T1*M(1,1))
           * +(CK4*T1)+(CK5*T1/M(1,1)))
            CN(I,J)   =  CN1+(CN2*(RH1**2))+(CN3*M(1,1))
           * +(CN4*(M(1,1)**0.5))
            RETURN
            END
            END
      C
      C     SUBPROGRAM TO CALCULATE AVERAGE MOISTURE CONTENT AFTER
      C        SPECIFIC DRYING TIME INTERVAL
      C
            SUBROUTINE MASS (M,G,T,H,GW,WAIR,TE,TE1,RH,MR,DTIME,R,CK,CN,
           *  TIME,ME,I,J)
            DIMENSION M(220,60),G(220,60),T(220,60),H(220,60),GW(220,60),
           * WAIR(220,60),TE(220,60),RH(220,60),TE1(220,60),
           * MR(220,60),DTIME(220,60),R(220,60),CK(220,60),CN(220,60)
            REAL N,M,ME,MF,MR1,MRE,MR
            MR(I,J)   =  (M(I,J)-ME)/(M(1,1)-ME)
            IF   (MR(I,J).EQ.1)  GO TO 111
            DTIME(I,J) = EXP(1.0/CN(I,J)*(ALOG(-ALOG(MR(I,J)))-ALOG(CK(I,J))))
            GO TO 112
        111 DTIME(I,J) = 0.
        112 TT         = TIME + DTIME(I,J)
            MR1        = EXP(-CK(I,J)*(TT**CN(I,J)))
            M((I+1),J) = MR1*(M(1,1)-ME)+ME
            RETURN
            END
      C
      C
      C     SUBPROGRAM TO CALCULATE FINAL TEMPERATURE AND HUMIDITY OF DRYING
      C       AIR AFTER PASSING EACH LAYER
      C
            SUBROUTINE HEAT (M,G,T,H,GW,WAIR,TE,TE1, RH,MR,DTIME,R,CK,CN,
           *  ME,DM,I,J)
            DIMENSION M(220,60),G(220,60),T(220,60),H(220,60),GW(220,60),
           *  WAIR(220,60),TE(220,60),RH(220,60),TE1(220,60),
           *  MR(220,60),DTIME(220,60),R(220,60),CK(220,60),CN(220,60)
            REAL   N,M,ME,MF,MR1,MRE,MR
            PAT  =  14.7
            C2   =  4.7250E-6
            N    =  2.380
            DELH =  (M(I,J)-M((I+1),J))/(R(I,J)*100.0)
            H(I,(J+1)) =  H(I,J)+DELH
            PV         =  PAT*H(I,(J+1))/(H(I,(J+1))+0.622)
            TEABS      =  TE(I,J)+459.69
      C
      C     CALCULATE RELATIVE HUMIDITY OF DRYING AIR
      C
            PVS        =  EXP(54.0329-12301.683/TEABS-5.18925*ALOG(TEABS))
```

```
MJS.C ID: ZJAE000          FILE NAME: TEST2BAC

      RH(I,(J+1))=  PV/PVS
C
C     CHECK CONDENSATION
C
      IF(RH(I,(J+1)).LE.RH(I,J))  RH(I,(J+1)) =  RH(I,J)
      IF(RH(I,(J+1)).LT.1.0) GO TO 27
      HA    =  H(I,(J+1))
      CALL ZERO (G,T,HA,C,I,J,TF,HF)
      RH(I,(J+1))  =  0.9999
      H(I,(J+1))   =  HF
      T(I,(J+1))   =  TF
      IF(T(I,(J+1)).GE.T(I,J))  T(I,(J+1))=T(I,J)
      GO TO 29
   27 DELH    =  H(I,(J+1))-H(I,J)
C
C
C
C
      DELL    =  (676.81-0.3487*TE(I,J))*(M(I,J))**(-0.340)
      GE      =  TL(I,J)
C
C     CALCULATE FINAL DRYING AIR TEMPERATURE FROM EACH LAYER
C
      T(I,(J+1)) =  ((0.24+0.45*H(I,J))*TE(I,J)-DELH*(1060.8+DELL+
     *  32.-GE)+C*GE)/(0.24+0.45*H(I,(J+1))+C)
      IF (T(I,(J+1)).GE.T(I,J))  T(I,(J+1)) = T(I,J)
C
C     CALCULATE GRAIN TEMPERATURE
C
   29 G((I+1),JJ)  =  T(I,J)
      GW((I+1),J) =  (DMW*M((I+1),J)/100)+DMW
      MRE         =  GW(I,J)-GW((I+1),J)
C
C     CALCULATE MASS FLOW RATE OF AIR AFTER PASSING AT SPECIFIC LAYER
C
      WAIR(I,(J+1))  =  WAIR(I,J)+MRE
      RETURN
      END
C
C
C     SUBPROGRAM TO ESTIMATE THE FINAL AIR CONDITIONS BY FINDING THE
C       ZERO OF AN UNKNOWN FUNCTION
C
      SUBROUTINE ZERO (G,T,HA,C,II,JJ,TF,HF)
      DIMENSION XX(50),G(220,60),T(220,60),X(220,50),P(50),PP(60),
     *  PVS(60),Y(60)
      XX(1)  =  G(II,JJ)
      XX(2)  =  T(II,JJ)
      X(1,1) =  XX(1)
      X(2,1) =  XX(2)
      N      =  3
      PQ     =  0.24*T(II,JJ)+HA*(1060.8+0.45*T(II,JJ))+
     *  C*G(II,JJ)-HA*(G(II,JJ)-32)
      DO 10 J = 2,N
      P(J-1)  = PQ-XX(J-1)*(0.24+C)
      PP(J-1) = 1060.8+0.45*XX(J-1)-G(II,JJ)+32
      TABS    = XX(J-1)+459.69
```

```
MUSIC ID: ZJAE000          FILE NAME: TEST23AC

400         PVS(J-1)= EXP(54.6329-12301.683/TABS-5.16923*ALOG(TABS))
401         Y(J-1)  = 0.9999*PVS(J-1)*(0.622*PP(J-1)+P(J-1))-14.7*P(J-1)
402      10 CONTINUE
403      18 NN      = N-1
404         DO 11 I = 2,NN
405         DO 12 J = 2,I
406         X(I,J)  = (X(I-1,J-1))*Y(I)-X(I,J-1))*Y(J-1))/
407        *  (Y(I)-Y(J-1))
408      12 CONTINUE
409      11 CONTINUE
410         I       = N-1
411         P(N)    = P(I)-X(I,1)*(0.24+C)
412         PP(N)   = 1000.0+0.45*X(1,I)-G(II,JJ)+32
413         TABS    = X(1,1)+459.69
414         PVS(N)  = EXP(54.6329-12301.688/TABS-5.16923*ALOG(TABS))
415         Y(N)    = 0.9999*PVS(N)*(0.622*PP(N)+P(N))-14.7*P(N)
416         IF (Y(N).GE.-0.01.AND.Y(N).LE.0.01)  GO TO 51
417         XX(N)   = X(I,1)
418   C
419         CALL SORT(N,XX,Y)
420   C
421         J       = 1
422         DO 17 I = 1,N
423         X(I,J)  = XX(I)
424      17 CONTINUE
425         N       = N+1
426         IF (N.GT.98) GO TO 98
427         GO TO 18
428      51 TF    = X(1N-1),(N-1))
429         P1    = P(I)-TF*(0.24+C)
430         PP1   = 1000.0+0.45*TF-G(II,JJ)+32
431         HF    = P1/PP1
432         TABS  = TF+459.69
433         PVS1  = EXP(54.6329-12301.688/TABS-5.16923*ALOG(TABS))
434         ERR   = 14.7*P1/(PVS1*(0.622*PP1+P1))
435         RETURN
436      98 WRITE  (6,100)
437     100 FORMAT (5X,'ONE HUNDRED TRIALS ARE NOT ENOUGH')
438         RETURN
439         END
440         SUBROUTINE SORT (N,P,X)
441         DIMENSION  X(16),P(N)
442         M     =  N
443      20 M     =  M/2
444         IF (M.EQ.0) RETURN
445         K     =  N-M
446         J     =  1
447      30 I     =  J
448      40 L     =  I+M
449         IF (X(I).LE.X(L)) GO TO 50
450         XX    =  X(I)
451         PA    =  P(I)
452         X(I)  =  X(L)
453         P(I)  =  P(L)
454         X(L)  =  XX
455         P(L)  =  PA
456         I     =  I-M
```

```
MODIC ID: ZJAE000          FILE NAME: TEST28AC

457           IF (I.GE.1) GO TO 40
458        50 J    =  J+1
459           IF (J.GT.K) GO TO 20
460           GO TO 30
461           END
462     /*
463     //GO.FT05F001   DD *
464     /*
465     //GO.FT06F001  DD  SYSOUT=M
466     //
```

Appendix J

Sample computer output of fixed-bed grain dryer

SIMULATION OF DEEP BED ROUGH RICE DRYING
****

BY

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INITIAL GRAIN AND AIR CONDITIONS
****

MOISTURE CONTENT OF GRAIN (% D.B.)	=	30.36
GRAIN TEMPERATURE (DEG.C)	=	31.00
AIR TEMPERATURE (DEG.C)	=	33.00
ABSOLUTE HUMIDITY OF AIR (DECIMAL)	=	0.0190
DEPTH OF EACH LAYER (M)	=	0.03
CROSS-SECTIONAL AREA OF BIN (SQ.M)	=	0.0729
DRYING TIME INTERVAL (MIN)	=	30.00
NUMBER OF LAYERS	=	6
NUMBER OF INTERVALS	=	15
AIR FLOW RATE (CU.M/SEC/SQ.M)	=	0.6240
RELATIVE HUMIDITY OF AIR (%)	=	59.34
EQUILIBRIUM MOISTURE CONTENT (% D.B.)	=	14.01
WEIGHT OF AIR (KG)	=	125.365
WEIGHT OF GRAIN IN EACH LAYER (KG)	=	2.962
DRY MATTER WEIGHT OF GRAIN (KG)	=	2.272
BULK DENSITY OF GRAIN (KG/CU.M)	=	637.715

RESULTS FROM THE SIMULATION
****

LAY NO.	MOISTURE CONTENT %(DB)	GRAIN TEMP. C	AIR TEMP. C	ABS. HUMIDITY DECI.	GRAIN WEIGHT KG.	WEIGHT OF AIR KG.	RH DECI.	K	T
DRYING TIME HRS = 0.50						INTERVAL NO. = 1			
1	30.360	31.000	33.000	0.0190	2.9621	125.3649	0.5984	0.0066	1.0256
2	30.360	31.000	30.917	0.0197	2.9621	125.4333	0.6240	0.0064	1.0376
3	30.360	31.000	29.008	0.0204	2.9621	125.4998	0.7210	0.0052	1.0880
4	30.360	31.000	27.484	0.0210	2.9621	125.5564	0.8219	0.0043	1.1479
5	30.360	31.000	26.331	0.0215	2.9621	125.6030	0.9135	0.0036	1.2092
6	30.360	31.000	25.600	0.0218	2.9621	125.6372	0.9893	0.0031	1.2648
DRYING TIME HRS = 1.00						INTERVAL NO. = 2			
1	27.345	33.000	33.000	0.0190	2.8936	125.3649	0.5984	0.0066	1.0256
2	27.435	30.917	31.391	0.0196	2.8956	125.4217	0.6160	0.0065	1.0338
3	27.865	29.008	29.768	0.0202	2.9054	125.4791	0.6946	0.0055	1.0735
4	28.308	27.484	28.232	0.0207	2.9153	125.5308	0.7823	0.0046	1.1235
5	28.853	26.331	26.821	0.0212	2.9278	125.5790	0.8746	0.0039	1.1824
6	30.179	25.600	25.623	0.0216	2.9579	125.6199	0.9672	0.0033	1.2482
DRYING TIME HRS = 1.50						INTERVAL NO. = 3			
1	24.843	33.000	33.000	0.0190	2.8367	125.3649	0.5984	0.0066	1.0256
2	24.951	31.391	31.718	0.0195	2.8392	125.4103	0.6124	0.0063	1.0321
3	25.545	29.768	30.422	0.0199	2.8527	125.4565	0.6738	0.0057	1.0625
4	26.162	28.232	29.144	0.0204	2.8671	125.5009	0.7416	0.0050	1.0996
5	27.047	26.821	27.964	0.0208	2.8863	125.5436	0.8151	0.0043	1.1436
6	29.255	25.623	26.685	0.0212	2.9370	125.5844	0.8937	0.0038	1.1954
DRYING TIME HRS = 2.00						INTERVAL NO. = 4			
1	22.321	33.000	33.000	0.0190	2.7908	125.3649	0.5984	0.0066	1.0256
2	22.435	31.718	31.982	0.0194	2.7933	125.4019	0.6094	0.0063	1.0317
3	23.068	30.422	30.592	0.0197	2.8032	125.4396	0.6674	0.0059	1.0642
4	24.297	29.144	29.909	0.0201	2.8243	125.4752	0.7399	0.0053	1.0813
5	25.250	27.894	28.855	0.0204	2.8460	125.5117	0.8171	0.0047	1.1144
6	27.524	26.685	27.776	0.0208	2.8976	125.5486	0.8999	0.0042	1.1553
DRYING TIME HRS = 2.50						INTERVAL NO. = 5			
1	21.197	33.000	33.000	0.0190	2.7539	125.3649	0.5984	0.0066	1.0256
2	21.312	31.982	32.195	0.0193	2.7565	125.3944	0.6071	0.0065	1.0296
3	21.971	30.952	31.375	0.0196	2.7715	125.4239	0.6447	0.0060	1.0473
4	22.668	29.909	30.529	0.0199	2.7877	125.4538	0.6854	0.0056	1.0686
5	23.627	28.855	29.655	0.0202	2.8091	125.4845	0.7301	0.0051	1.0930
6	25.704	27.776	28.727	0.0205	2.8563	125.5165	0.7797	0.0046	1.1213

DRYING TIME HRS = 3.00 INTERVAL NO. = 6

1	19.900	33.000	33.000	0.0190	2.7244	125.3649	0.5984	0.0066	1.0256
2	20.012	32.193	32.261	0.0192	2.7269	125.3824	0.6052	0.0066	1.0268
3	20.647	31.375	31.712	0.0195	2.7414	125.4120	0.6343	0.0062	1.0429
4	21.335	30.529	31.027	0.0197	2.7570	125.4364	0.6665	0.0059	1.0588
5	22.217	29.659	30.305	0.0199	2.7770	125.4620	0.7016	0.0054	1.0775
6	24.034	28.727	29.521	0.0202	2.8183	125.4894	0.7410	0.0050	1.0992

DRYING TIME HRS = 3.50 INTERVAL NO. = 7

1	18.866	33.000	33.000	0.0190	2.7009	125.3649	0.5984	0.0066	1.0256
2	18.973	32.361	32.494	0.0192	2.7038	125.3835	0.6038	0.0066	1.0261
3	19.569	31.712	31.979	0.0194	2.7168	125.4023	0.6270	0.0063	1.0391
4	20.207	31.027	31.425	0.0195	2.7314	125.4223	0.6519	0.0059	1.0515
5	21.012	30.303	30.828	0.0198	2.7497	125.4435	0.6796	0.0056	1.0656
6	22.575	29.521	30.172	0.0200	2.7852	125.4667	0.7110	0.0053	1.0824

DRYING TIME HRS = 4.00 INTERVAL NO. = 8

1	18.042	33.000	33.000	0.0190	2.6822	125.3649	0.5984	0.0066	1.0256
2	18.143	32.494	32.600	0.0191	2.6845	125.3797	0.6027	0.0066	1.0273
3	18.635	31.979	32.191	0.0193	2.6968	125.3947	0.6209	0.0063	1.0362
4	19.270	31.425	31.742	0.0194	2.7101	125.4100	0.6405	0.0061	1.0457
5	19.993	30.828	31.251	0.0196	2.7265	125.4285	0.6625	0.0058	1.0568
6	21.325	30.172	30.703	0.0198	2.7563	125.4490	0.6877	0.0055	1.0699

DRYING TIME HRS = 4.50 INTERVAL NO. = 9

1	17.389	33.000	33.000	0.0190	2.6673	125.3649	0.5984	0.0066	1.0256
2	17.481	32.600	32.683	0.0191	2.6694	125.3765	0.6018	0.0066	1.0271
3	17.969	32.191	32.356	0.0192	2.6805	125.3886	0.6161	0.0064	1.0339
4	18.494	31.742	31.996	0.0193	2.6924	125.4018	0.6316	0.0062	1.0415
5	19.135	31.251	31.592	0.0195	2.7070	125.4163	0.6492	0.0060	1.0500
6	20.266	30.703	31.135	0.0196	2.7327	125.4326	0.6695	0.0057	1.0603

DRYING TIME HRS = 5.00 INTERVAL NO. = 10

1	16.870	33.000	33.000	0.0190	2.6555	125.3649	0.5984	0.0066	1.0256
2	16.954	32.683	32.750	0.0191	2.6575	125.3742	0.6010	0.0066	1.0268
3	17.337	32.358	32.492	0.0192	2.6673	125.3837	0.6124	0.0064	1.0321
4	17.852	31.996	32.198	0.0193	2.6779	125.3944	0.6246	0.0063	1.0379
5	18.416	31.592	31.866	0.0194	2.6907	125.4063	0.6387	0.0061	1.0448
6	19.372	31.135	31.486	0.0195	2.7124	125.4200	0.6551	0.0059	1.0530

DRYING TIME HRS = 5.50 INTERVAL NO. = 11

1	16.458	33.000	33.000	0.0190	2.6462	125.3649	0.5984	0.0066	1.0256
2	16.534	32.750	32.802	0.0191	2.6479	125.3732	0.6005	0.0066	1.0265
3	16.914	32.492	32.597	0.0191	2.6566	125.3797	0.6094	0.0065	1.0307
4	17.322	32.198	32.360	0.0192	2.6658	125.3884	0.6191	0.0064	1.0353
5	17.814	31.866	32.087	0.0193	2.6770	125.3982	0.6304	0.0062	1.0408
6	18.622	31.486	31.772	0.0194	2.6954	125.4095	0.6437	0.0060	1.0473

DRYING TIME HRS = 6.00 INTERVAL NO. = 12

1	16.133	33.000	33.000	0.0190	2.6388	125.3649	0.5984	0.0066	1.0256
2	16.200	32.802	32.844	0.0191	2.6403	125.3707	0.6000	0.0066	1.0263
3	16.531	32.597	32.681	0.0191	2.6478	125.3766	0.6071	0.0065	1.0296
4	16.886	32.260	32.489	0.0192	2.6559	125.3836	0.6148	0.0064	1.0332
5	17.312	32.087	32.265	0.0193	2.6656	125.3917	0.6239	0.0063	1.0376
6	17.994	31.772	32.005	0.0195	2.6811	125.4011	0.6347	0.0061	1.0428

DRYING TIME HRS = 6.50 INTERVAL NO. = 13

1	16.375	33.000	33.000	0.0190	2.6329	125.3647	0.5984	0.0066	1.0253
2	16.434	32.944	32.977	0.0190	2.6343	125.3694	0.5997	0.0066	1.0260
3	16.720	32.691	32.747	0.0191	2.6409	125.3748	0.6063	0.0065	1.0288
4	16.527	32.489	32.592	0.0191	2.6477	125.3799	0.6114	0.0063	1.0319
5	16.894	32.265	32.408	0.0192	2.6561	125.3865	0.6197	0.0064	1.0351
6	17.468	32.003	32.191	0.0193	2.6691	125.3944	0.6275	0.0062	1.0393

DRYING TIME HRS = 7.00 INTERVAL NO. = 14

1	16.671	33.000	33.000	0.0190	2.6283	125.3647	0.5984	0.0066	1.0255
2	16.723	32.877	32.903	0.0190	2.6295	125.3686	0.5994	0.0066	1.0260
3	16.968	32.747	32.800	0.0191	2.6351	125.3723	0.6038	0.0066	1.0281
4	16.231	32.592	32.674	0.0191	2.6410	125.3769	0.6087	0.0065	1.0303
5	16.547	32.408	32.524	0.0192	2.6482	125.3823	0.6146	0.0064	1.0332
6	17.030	32.191	32.344	0.0192	2.6592	125.3898	0.6218	0.0063	1.0366

DRYING TIME HRS = 7.50 INTERVAL NO. = 15

1	16.510	33.000	33.000	0.0190	2.6247	125.3647	0.5984	0.0066	1.0256
2	16.555	32.903	32.923	0.0190	2.6257	125.3673	0.5992	0.0066	1.0259
3	16.764	32.800	32.841	0.0191	2.6304	125.3709	0.6027	0.0066	1.0278
4	16.989	32.674	32.740	0.0191	2.6355	125.3744	0.6065	0.0065	1.0299
5	16.259	32.524	32.617	0.0191	2.6417	125.3790	0.6113	0.0065	1.0326
6	16.664	32.344	32.468	0.0192	2.6509	125.3843	0.6172	0.0064	1.0364

VITAE

Mr.Somchai Wongwises was born October 3, 1959, in Bangkok, Thailand, the son of Col.Sombun Wongwises and Mrs.Buppha Wongwises. From 1977 to 1982 he attended King Mongkut's Institute of Technology Thonburi, Thailand, from which he received a Bachelor of Mechanical Engineering (second class honours).

In January 1983, he continued his education by attending Asian Institute of Technology. He received a Master of Engineering degree in Energy Technology in August of 1984. Upon receipt of his Master degree Mr.Wongwises was offered the position of consulting engineer at Jalaprathan Cement Company to conduct research with energy conservation of the manufacture of cement.

In June 1985,he joined for the Doctor of Engineering degree at the graduate school of Mechanical Engineering Department, Chulalongkorn University, Thailand. In June 1987, he served as a staff member of the Mechanical Engineering Department of King Mongkut's Institute of Technology Thonburi, Thailand.