CHAPTER 5

EXPERIMENT AND RESULT

5.1 Experimental Preparation

The first thing to be performed before doing combustion was fuel and bed material analysis.

5.1.1 Rice husk analysis.

The proximate analysis of rice husk done in the laboratory as shown in table 5.1

TABLE 5.1

Proximate analysis of rice husk

sample	moisture %	ash %	volatile matter %	fixed carbon %
1	8.1	18.2	54.1	19.6
2	9.9	16.3	55.3	18.5
average	9.0	17.25	54.9	19.05

The ultimate analysis of rice husk used in this work was done by the Scientific and Technological Research Equipment Center, Chulalongkorn University. It is shown in table 5.2

TABLE 5.2

Ultimate analysis of rice husk

sample	combustion[(1)] heat (cal/g)	%C[(2)]	%H[(2)]	%N[(2)]	%S[(3)]
1	3,670	38.23	4.98	-	0.08
2	3,647	37.92	4.89	-	
average	3,658	38.08	4.94	-	0.08

Note : Instruments used for analysis of (1),(2) and (3) were an Automatic Bomb Calorimeter (CA-3),an Element Analyzer (Perkin Elmer 240C) and an X-Ray Fluorescence Spectrometer (JEOL JSX-60 PA) respectively.

Table 5.3 shows the proximate analysis of rice husk for various sources (including those used in this work) and table 5.4 show the ultimate analysis of rice husk of vaious sources compared with other types of fuel.

TABLE 5.3
Fuel related characteristics of rice husk
(Proximate analysis)

	Source				
	Agnew#1	Basmati	Thai A863	A.I.T.	This study
Carolific value (cal/gm.)		2980	3619	3860	3658
% Moisture		3.6	9.1		9.0
%Ash	18.1	16.5	18.7	20.0	17.3
%Volatile Mat.	65.0	66.6	56.4	52.7	54.9
%Fixed carbon	16.9	16.9	15.8	17.4	19.1

TABLE 5.4
Fuel related characteristics of rice husk
(Ultiimate analysis)

	Rice Husk			Charcoal	Antracite
	Basmati	Thai A863	This study		
C %	38.68	40.0	38.08	48.0	90.0
H%	5.08	5.0	4.94	6.0	2.0
%S	0.10		0.08		

5.2 Initial Test Run

In order to observe the fluidization phenomena in the AFBC used in this work, a cold test was performed. This was done by manipulating the primary air valve to control the flow rate of fluidising air. The fluidized state was reached when the pressure drop across the bed remained constant with the increase of the air flow rate. Visual observation of bed behavior through the sight-glass was also done.

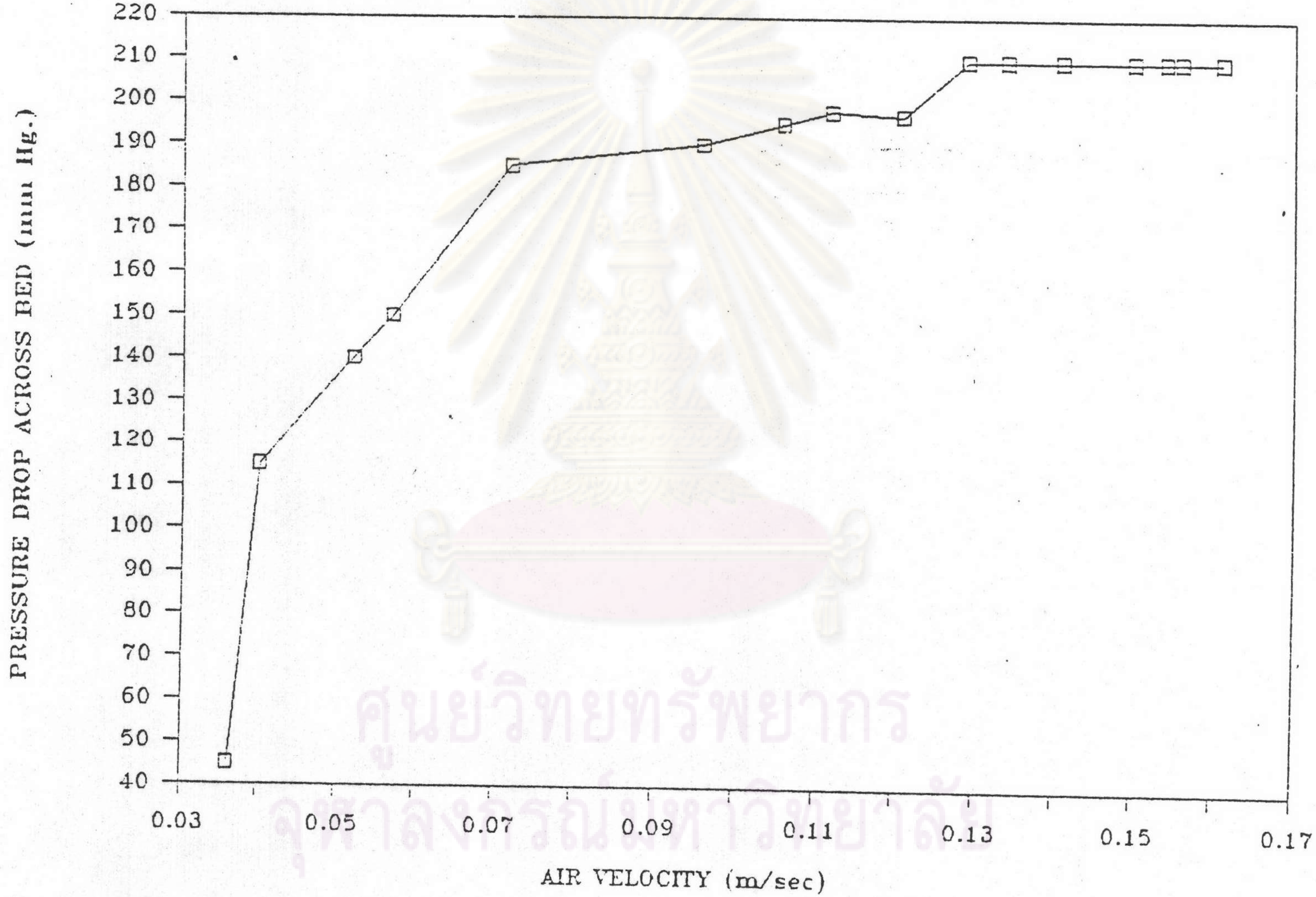
The following data were to be recorded at each step of air flow rate regulated :

1. Upstream pressure
2. Pressure drop across orifice
3. Pressure drop across bed
4. Inlet air temperature

The upstream pressure, the pressure drop across orifice and the inlet air temperature were measured data to be used as inputs into the "orifice" computer program. From this program, the volumetric flow rate and the superficial velocity of air were calculated. (Details and usage of the program are found in Appendix D.)

Bubbling bed behavior was observed throuhgout the fluidized state. Fig.5.1 shows the dependence of pressure drop across bed on superficial velocity of air in the fluidized bed.

FIG 5.1 PRESSURE DROP & AIR VELOCITY



5.3 Start Up Preheating Experiment

Start up of the bed was the most complicated technique in these experimental runs. The fluidized bed temperature was needed to be raised up to a temperature of 600-700 before feeding the fuel. After start up was achieved, all the preheating systems were shut off and rice husk was fed into the combustor. Combustion of rice husk would maintain the bed temperature throughout the experimental runs.

Firstly, it had to find out the way to heat the bed up to the desired temperature, or in other words, it had to set up the preheating method. A Diesel burner, placed over the bed,was used for preheating the fluidized bed and was found to be an inadequate heat source. LPG lines were then installed through the air distributor so as to assist the burner. This gave no better results; i.e., the fluidized bed temperature could be raised up only 30 c. above its initial temperature. the result agreed with the heat balance showing that most of the heat input was carried away from the combustor in the hot exit air stream.

The next step it tried to preheat a static bed since itknew that a great amount of heat had beenlost through convective heat transfer. As a result, the bed could reach a temperature around 100 c. which was stil unsatisfactory. From a heat balance it canbeshown that the target temperature could be reached by preheating the fixed bed with the LPG feed rate twice increased.

Finally, the most practical way of start up was found. It was achieved by introducing solid fuel (charcoal) into the bed, ignited by a diesel burner. Start up was accomplished by burning charcoal that was able to raise the temperature of the fluidized bed up to 600-700 c. as desired. A standard form and procedure for start-up using charcoal was then established after some experimental runs.

This section is divided into 4 parts, giving details on results, problems experienced, assumptions, etc. in each preheating method mentioned above which are :

1. Preheating the fluidized bed by a diesel burner alone
2. Preheating the fluidized bed by a Diesel burner with assistance of LPG lines
3. Preheating the static bed
4. Preheating the fluidized bed by burning charcoal

5.3.1 Preheating

This was done by using a diesel burner, installed over the bed, as a heat source. The problem experienced was that the fluidized bed temperature could be raised up only 40-50 c. The temperature at the other points (such as the overbed temperature) were much higher. This was due to the fact that the flame from the burner, blown up by the fluidising air, made a little direct contact with the sand bed. A little rise in the bed temperature was due to heat conduction from the surrounding walls.

The data recorded in this experimental run shown in table 5.5, fig. 5.2, is plots between T7 (bed temperature) vs. time and fig. 5.3 shows the four temperature plotted together.

TABLE 5.5

: DATA ON THE TEMPERATURE OF THE SYSTEM

TIME (MIN)	T2 c.	T4 c.	T6 c.	T7 c.
0	26.1	26.6	41.8	29.6
3	26.9	26.9	156.9	29.7
6	27.1	27.1	171.2	29.4
9	27.3	27.3	176.4	29.6
12	27.6	27.6	179.3	29.6
15	27.7	27.6	170.1	29.2
18	27.9	27.7	170.8	29.6
21	28.1	27.9	188.2	29.3
24	28.4	28.1	194.9	29.6
27	28.7	28.4	195.3	29.3
30	29	28.7	195.9	29.3
33	29.2	29	198.3	29.3
36	29.4	29.2	210.1	29.3
39	29.7	29.4	203.9	29.3
42	29.8	29.7	206.2	29.4
45	30	29.8	208.9	29.6
48	30.2	30	211.3	29.6
51	30.4	30.2	213.1	29.6
54	30.5	30.4	215.3	29.7
57	30.7	30.5	217.4	29.7
60	31	30.7	219.9	29.8
63	31.2	31	222.4	29.9
66	31.3	31.2	224.1	30.1
69	31.4	31.3	226.9	30.2
72	31.6	31.4	228.5	30.4
75	31.7	31.7	229.3	30.3
78	31.9	31.9	230.8	30.5
81	32.1	32.1	232.1	30.7
84	32.2	32.2	234.2	30.8
87	32.5	32.5	235.6	30.9
90	32.6	32.6	237.4	30.9
93	32.8	32.8	240.1	31
96	32.7	32.7	241.6	31.1
99	32.8	32.8	243.2	31.3
102	33.3	33.3	245.4	31.4
105	33.4	33.4	246.6	31.6
108	33.2	33.2	248.3	31.7
112	33.3	33.3	249.7	31.9
114	33.9	33.9	251.2	32.1
117	34.1	34.1	253.3	32.2
120	34.1	34.1	255.2	32.5
123	33.9	33.9	256.4	32.8
126	34.1	34.1	257.9	32.8
129	34.3	34.3	259.3	33.1
132	34.4	34.4	260.8	33.2

934	30.8	267.4	268.5	56.1
946	31.4	274.8	273.3	55.1
964	32.8	307.2	298.3	54.1
976	33.4	309.9	307.2	53.6
985	33.7	294.9	295.2	53.3
994	34.3	325.7	326.8	52.9
1000	34.2	326.7	324.3	53
1009	34.7	326.1	323.3	52.8
1018	34.8	333.6	325.7	52.7
1027	35.5	341.1	333.3	52.6
1036	35.6	344.8	345.2	52.6
1045	35.6	293	308.2	52.5
1054	35.8	330.6	315.6	52.6
1063	36.2	325.6	333.6	53
1072	36.8	328.9	430.4	54.4
1081	36.7	335.7	335.7	55.7
1090	37.2	320.4	336.2	57.1
1099	36.8	317.4	334.4	58.8
1108	37	312.3	327.9	59.8
1117	37.1	323.3	337.8	60.9
1126	37.3	325.1	342.1	62
1135	37.4	342.2	374.2	63.3
1144	37.5	325	347.3	64.9
1153	37.6	362.8	382.8	65.9
1162	37.5	344.8	372.5	66.9
1171	37.3	329.9	346.3	67.9
1180	37.7	328.3	343	69
1198	37.8	322.1	343.6	70.8
1210	37	323.9	341.7	72.1
1213	37.1	324.9	342	72.4
1222	38.2	336.9	344.6	73.2
1231	37.8	299.8	319.4	74
1240	36.7	289.2	306	74.8
1252	36.3	281.1	295.7	75.7
1261	36.2	276	289.6	76.5
1270	36.4	271.4	283.6	76.9
1288	36.4	263.2	273.4	78.5
1297	36.3	259.6	268.8	79.1
1306	36.5	256.3	264.1	79.2
1315	36.2	252.7	259.8	79.5
1324	36.5	249.7	255.8	79.9
1333	36.3	246.6	252	80.5
1342	36.2	243.8	248.6	80.8
1351	36.4	241.1	244.9	81.1
1360	36.2	238.6	241.7	81.3
1369	36.3	235.5	238.5	81.6
1378	36.3	233.4	235.6	81.7
1387	36.4	230.9	232.5	81.8
1396	35.7	228.9	229.7	82
1405	35.6	226.7	226.7	81.9
1414	35.7	224.2	224.1	82
1423	36.2	222.2	221.65	82.3
1432	36.4	220.3	219	82.1
1441	35.3	218.5	216.6	82.1

150	34.6	34.6	268.9	34.6
153	34.6	270.7	278.9	34.8
156	35.2	271.8	279.5	35.1
159	34.8	272.2	280.1	35.3
162	34.6	273.4	280.6	35.5
165	34.5	274.5	281.6	35.8
168	34.6	275.9	282.3	36
171	34.6	277.2	283.1	36.2
174	34.8	277.9	283.9	36.4
177	34.8	278.7	284.6	36.7
180	34.9	279.8	285.2	36.9
181	34.9	281	286	37.1
186	35.3	282.4	286.7	37.3
189	35.1	282.7	287.3	37.6
192	35.2	283.4	288.1	37.7
195	35.3	284.4	288.7	38
198	35.3	285.3	289.1	38.3
201	35.4	287.3	290.2	38.5
204	35.6	288.6	291.2	38.7
207	35.6	289.2	292.3	39.1
210	35.6	289.6	293	39.3
213	35.6	290.7	293.8	39.5
216	35.8	291.2	294.6	39.7
219	35.9	291.8	295.6	40.1
222	35.9	291.3	295.8	40.2
225	35.8	292.1	295.9	40.4
228	35.8	292.2	296.6	40.6
231	35.9	292.1	297.5	40.8
234	36.2	292.7	298.7	41.1
237	36	293.1	299.5	41.2
240	36.1	293.8	299.8	41.5
243	36.5	293.8	300.2	41.6
246	36.4	294.3	300.6	41.8
249	36.2	294.7	300.4	42
252	36.1	295.2	300	42.2
255	36.6	295.6	299.8	42.4
258	36.6	296.1	300	42.6
261	36.7	297.6	300.2	42.8
264	36.4	298.1	300.6	43.1
267	36.8	298.6	301	43.3
270	36.9	299	301.7	43.5
273	36.4	299.1	302.8	43.7
276	36.4	299.4	303.1	43.9
279	36.5	300.4	303.9	44.1
282	36.8	301.2	304.6	44.3
285	36.8	302.2	305.9	44.5
288	36.6	302.7	306.3	44.7
889	27.6	203.9	142.9	60.9
892	27.9	227.7	171.7	60.6
895	28.1	235.2	193.9	60.3
898	28.4	237.8	209.4	60.2
901	28.6	241	220.9	59.8
904	28.8	244.2	229.7	59.4
907	29	247.1	236.2	58.9

FIG. 5.2

GRAPH FOR BED TEMP.(T7) vs. TIME

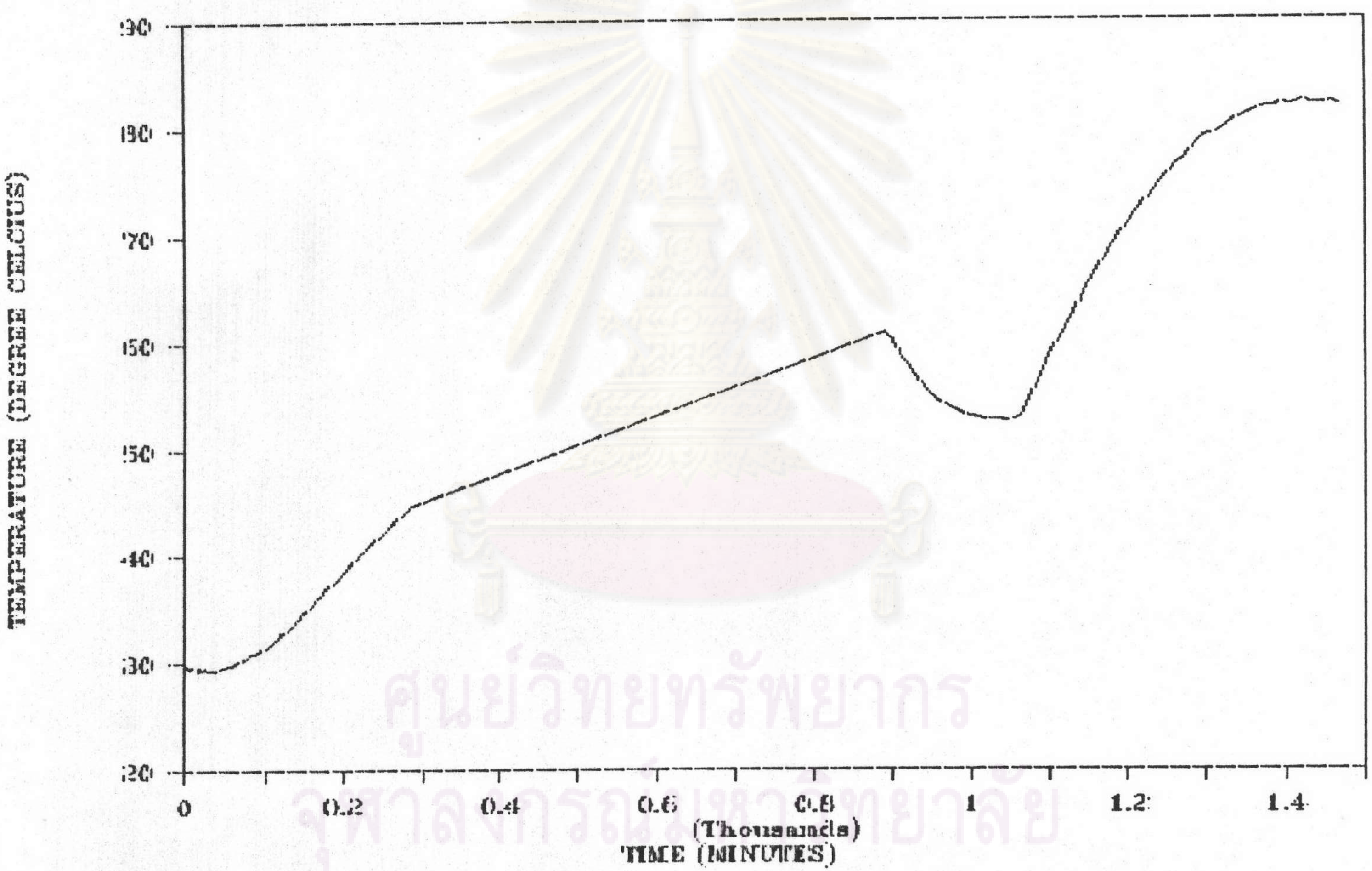
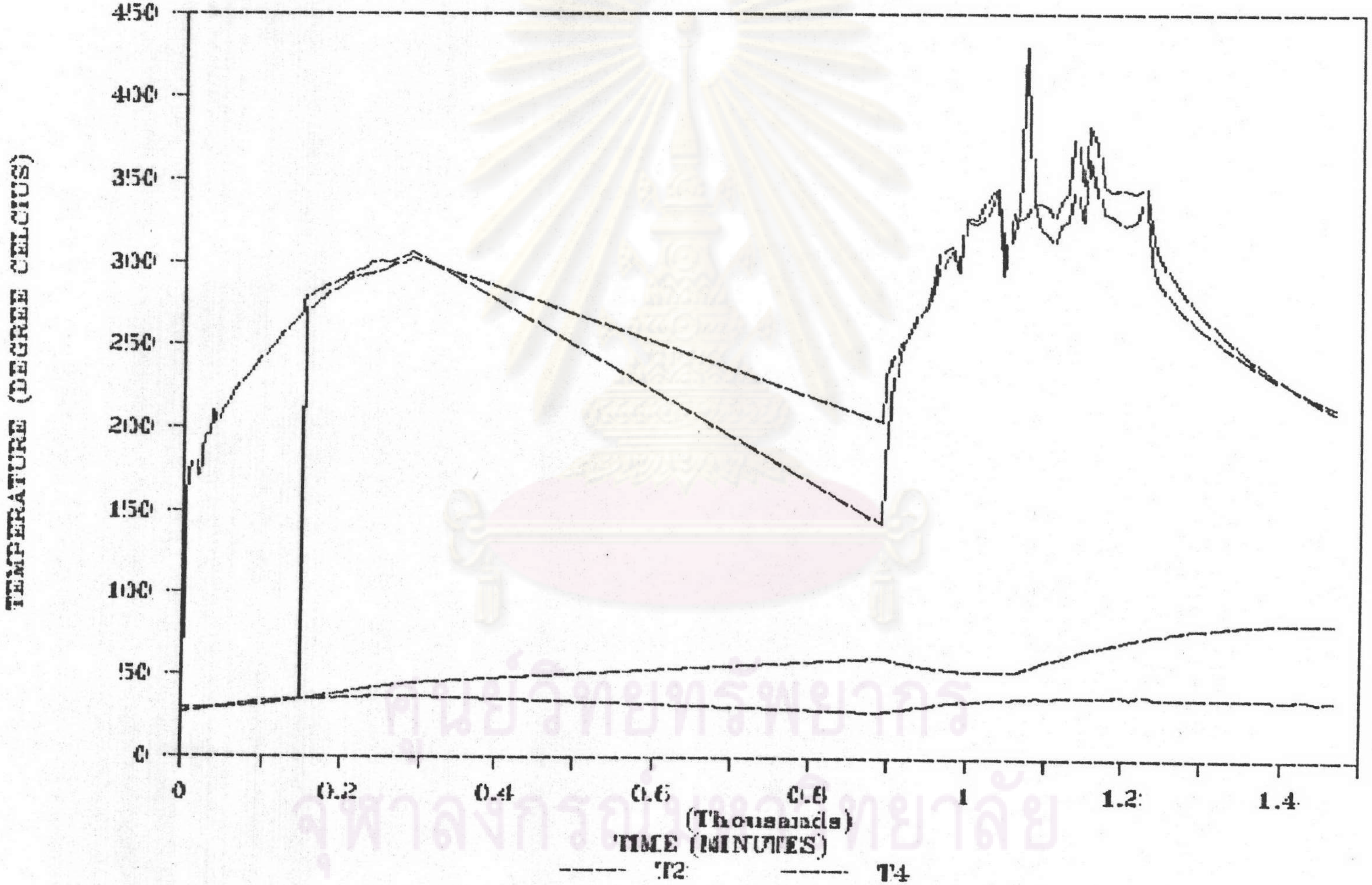


FIG. 5.3

GRAPH FOR T2 , T4 , T6 ,T7 vs. TIME



5.3.2 Preheating The Fluidized Bed By A Diesel Burner with Assistance of LPG Lines

LPG lines were installed through the air distributor in order to assist the diesel burner. The operating conditions and the experimental procedures were the same as the previous test run except that in this test run LPG was used with the burner.

The data on temperature of the system are shown in table 5.6 and fig. 5.4, shows the plots between T7 (bed temp.) vs. time. the four temperature are plotted together in fig. 5.5.

From the results shown, the bed temperature was slowly raised from 28.6 to 57.2 c. in approximately 8 hours and then declined. The following assumptions were possibly the causes of the problems experienced in this test :

- A large amount of heat input was carried away from the combustor in the exit air stream and only little amount was accumulated in the sand bed.

- LPG was burnt when it flew over the bed, not in the bed. This was due to the fact that there was an improper air to LPG ratio inside the bed.

A heat balance was then performed to determine whether the first assumption was true.

Consider the sand bed as a system

$$m_s c_{p,s}(T_s-T_{so})/Dt = Q_{in} - (P_{a}V_a)c_{p,a}(T_{a,out}-T_{a,in}) - k_w A_w(T_w-T_{wo})/d_w \quad ...(1)$$

Using a sand bed depth of 40 cm, void fraction = 0.41

$$m_s = (1-E)P_{s}V_s = (1-0.41)(2.55x10^3)(0.4x1.2x1.2)$$
$$= 870 \text{ kg}$$

All the heat capacities were considered constant with changing of temperature.

$c_{p,s}$ = 0.191 cal/g
= 802 J/kg
$c_{p,a}$ = 0.26 cal/g
= 1090 J/kg

To the target bed temperature of 700 temperature at other locations in the system were assumed :

the exit air ; $T_{a,out}$ = 700
the wall ; T_w = 700

The initial temperature of the sand bed, the inlet air, and the air outside the wall used in this calculation were 30

T_{so} = 30
$T_{a,in}$ = 30
T_{wo} = 30

The mass flow rate of the fluidising air was equal to $P_{a}V_a$, where

$$P_a = 1.293\ (273/T_{a,in})$$
$$= 1.293\ (273/303)$$
$$= 0.85 \quad kg/m^3$$
$$V_a = 7000 \quad m^3/hr$$

the wall thickness ; $d_w = 0.1$ m

the wall thermal conductivity ; $k_w = 304$ J/hr

the wall area ; $A_w = 4(1.2x3) + (1.2x1.2)$

$= 15.8$ m

Equation (1) was substituted by the above values :

$$(870)(802)(700-30)/Dt = Q_{in} - (0.85)(7000)(1090)(700-30) - (304)(15.8)(700-30)/(0.1)$$

$$246.7 \times 10^7 / Dt = Q_{in} - 4353 \times 10^7 - 3.2 \times 10^7 \quad \text{...(2)}$$

Using preheat time of 8 hr, it had

$$Q_{in} = 4600 \times 10^7 \quad J/hr$$

Heat input :

(i) from the Diesel burner

heating value = 8700 kcal/l , P = 0.85 kg/l

input rate = 6.01 kg/hr

$$Q_{in,D} = (6.01)(8700)(1/0.85)(4200)$$
$$= 25.8 \times 10^7 \quad J/hr$$

Assume 40% loss (such as incomplete combustion, etc.)

$$Q_{in,D} = 15.5 \times 10^{7} \quad J/hr$$

(ii) from LPG lines

heating value = 6369 kcal/l , P = 0.57 kg/l

input rate = 6.67 kg/hr

$$Q_{in,LPG} = (6.67)(6360)(1/0.57)(4200)$$
$$= 31.3 \times 10^{7} \quad J/hr$$

Again, assume 40% loss

$$Q_{in,LPG} = 18.8 \times 10^{7} \quad J/hr$$

Since the heat input by the Diesel burner was fixed,

$$Q_{in} - Q_{in,D} = (4600-15.5) \times 10^{7}$$
$$= 4584.5 \times 10^{7} \quad J/hr$$

In order to provide adequate heat, the LPG feed rate must be increased $= 4584.5 \times 10^{7} / 18.8 \times 10^{7}$

$= 240$ times

The calculated results agreed with the experimental results showing that the heat input was far inadequate since a large amount of heat had been lost through the convective heat transfer in the exit air stream.

TABLE 5.6

TIME MIN.	T2 c.	T4 c.	T6 c.	T7 c.
0	28.4	28.6	28.3	28.1
5	28.2	28.4	28.2	27.9
10	28.3	28.5	28.3	28
15	28.3	28.4	28.4	28.1
20	28.3	28.4	28.4	27.9
25	28.1	28.4	28.4	27.9
30	28.3	28.3	28.2	28
35	28.7	30.4	28.4	28
40	29.6	47.4	31.7	28.1
45	43.7	176.9	52.9	28.1
50	53.3	213.3	95.6	28.1
55	47.5	117.6	98.6	28.1
60	44.8	74.9	86.2	28.1
65	43.7	61.4	77.2	28.2
70	43.2	57.2	70.8	28.2
75	42.9	55	66.4	28.2
80	42.7	53.4	63	28.4
85	42.2	52.4	60.2	28.4
90	42.2	51.8	56.4	28.5
95	42.1	51	56.4	28.5
100	41.9	50.1	55.2	28.7
105	42.1	49.4	54.1	28.7
110	42	48.9	53.1	28.9
115	42.1	48.6	52.2	28.9
120	42.1	48.4	51.7	29.1
125	42.2	47.8	51.2	29.2
130	42.2	47.5	50.8	29.3
135	42.1	47	49.9	29.4
140	42.2	46.7	49.6	29.8
145	42.3	46.6	49.2	29.8
150	42.1	46.1	48.7	29.7
155	42.2	45.8	48.4	29.9
160	42.2	45.7	48	30
165	42.2	45.4	47.8	30.1
170	42.2	45.4	47.8	30.2
175	42.3	44.9	47.1	30.3
180	42.2	44.3	46.8	30.4
185	42.3	44.7	46.7	30.5
190	42.1	44.3	46.2	30.5
195	42.3	44	46.1	30.7
200	54.6	170.2	66.6	30.7
210	69	207.3	120.7	30.9
220	79.9	212.2	157.1	31.3
230	91.9	266.3	171.4	31.7
240	111.8	288.3	219.5	32
250	125.9	286.6	232.8	32.5
260	136.5	280.9	239.5	33.2

385	125.4	130.9	119.1	52.6
445	117.9	117.7	102.9	56.7
505	110.6	108.5	91.9	57.2
565	103.7	101.7	84.5	56.5
625	103.7	101.7	84.5	65.5
685	91.8	91.5	73.9	53.7
745	86.7	87.4	70.1	52.2
805	82.2	83.8	66.6	50.8
865	78.1	80.5	63.6	49.5
925	74.3	77.4	61.2	48.1
985	71	74.5	58.5	47.1
1045	67.9	71.7	56.2	46.2
1105	65.7	69.8	54.7	45.6
1165	62.9	69.9	52.4	44.7
1225	60.5	64.6	50.6	44.1
1285	58.6	63.2	50.3	43.5
1345	56.9	61.6	49.3	42.9
1405	55.1	59.7	47.9	41.9
1495	53.7	58.4	47.9	41.3
1525	52.3	57.2	47.2	40.7

FIG. 5.4

GRAPH FOR BED TEMP.(T7) vs. TIME

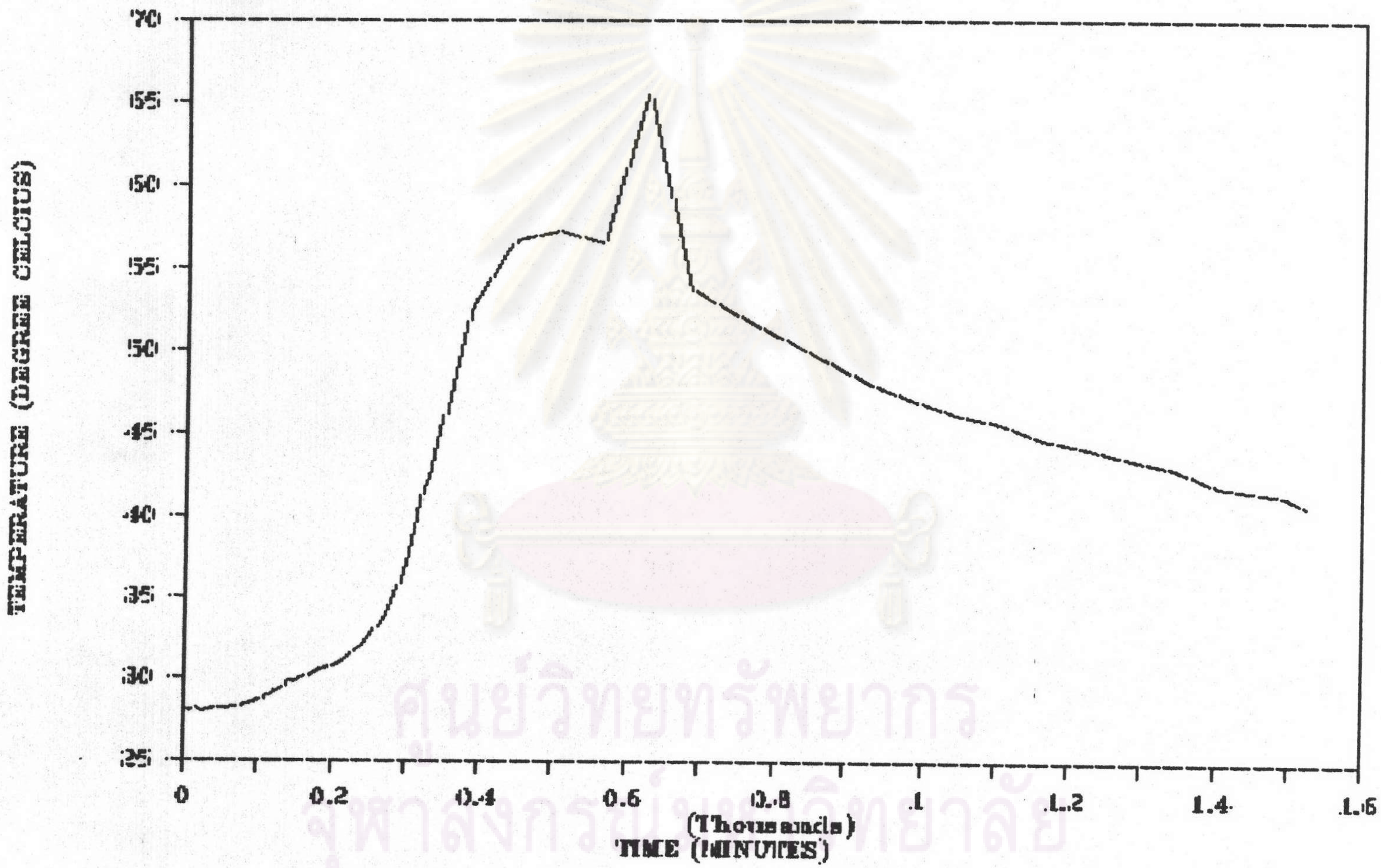
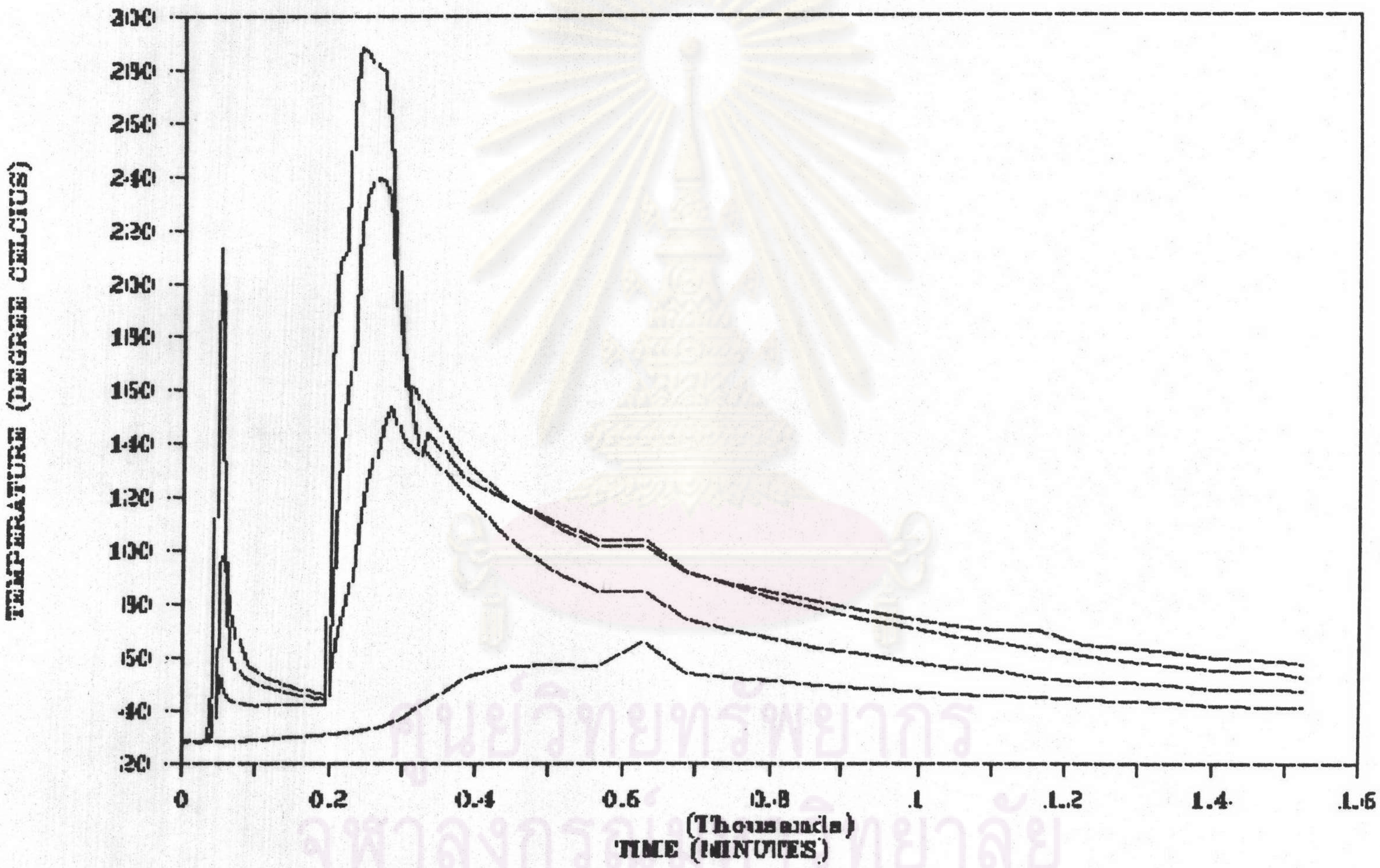


FIG. 5.5

GRAPH FOR T2 , T4 , T6 , T7 vs. TIME



5.3.3 Preheating The Static Bed

From the previous experimental run and heat balance, to realize that a large quantity of heat loss was due to convective heat transfer. Another test run was therefore performed which the static bed was heated.The air flow rate was kept the lowest possible.

The results showed that the static bed could be heated up to the temperature of 100 c. which was still unsatisfactory

A heat balance was again performed as followes :

From equation (2), neglecting the convection term since the air flow rate was kept very low ;

$$246.7 \times 10^7 / Dt = Q_{in} - 3.2 \times 10^7 \qquad ...(3)$$

And from the previous calculations we had

$Q_{in,D} = 15.5 \times 10^7$ J/hr

$Q_{in,LPG} = 18.8 \times 10^7$ J/hr

Using Dt = 8 hr

$Q_{in} = 35 \times 10^7$ J/hr

The heat input by the burner was fixed,

$Q_{in} - Q_{in,D} = (35-15.5) \times 10^7$

$= 19.5 \times 10^7$ J/hr

So, the LPG feed rate was needed to be increased

$= 19.5 \times 10^7 / 18.8 \times 10^7$

$= 1.1$ times

It could be concluded that the existing fuel (Diesel and LPG) feed rate provided inadequate heat to the system, either for fluidized bed or static bed. To use this preheating system, a lot more modifications had to be done.

5.3.4 Preheating The Fluidized Bed Combustor By Burning Charcoal

Experimental runs were carried out using charcoal as heat source which directly contacted the sand bed. In fluidized state, conductive heat transfer from the burning charcoal to the sand bed occurred and the bed temperature would be raised up to the desired temperature.

From the results of the first test run in which the bed temperature reached 700 c.in 20 minutes.It can be abled to examine and interpreted all the phenomena that took place in the test run. Hence it set another run in order to acquire more understanding about this preheating method. Finally, from the results of the two test runs, standard forms and procedures of start up by burning charcoal were established.

a) The first test run

Operating condition:

In this test run sand bed depth was 40 cm. The fluidized state was observed by reading the manometer (the pressure drop across bed was approximately 1.8-2.0 (cmHg) from the sight glass.

20 kg of charcoal was introduced into the bed. After a while, the bed temperature rose sharply to 700 c. in 20 minutes and then dropped. After observing in the sight glass that it was dark inside the combustor; that meant no burningcharcoalremained,then the fluidising air was shut off. The bed temperature then remained constant. This temperature

possibly showed the real sand temperature.

Table 5.7 the shows data recorded in the data-locker inthis experimental run. fig.5.6 plots between T-7 (bed temp) vs.time .In fig. 5.7 the four temperature are plotted together.

From close examination on the temperature profile of the sand bed (fig. 5.7), every change occurring the profile in each interval: can be described

1-2: The bed temperature rose sharply to 700 in 20 minutes due to the fact that 20 kg of charcoal had been added to the combustor.

2-3: The temperature fell down with constant rate before the fluidizing air was shut off.

3-4: The temperature dropped slowly because the air had been shut off. No heat loss through convective heat transfer occurred in this interval.

4-5: The temperature declined with the same rate as in 2-3 after the fluidizing air had been introduced into the system again.

5-6: After the air had been shut off again, the bed could keep its temperature around 190-230 c. for 11 hours. It could be concluded that this temperature was the real bed temperature.

TABLE 5.7

: DATA ON THE TEMPERATURE OF THE SYSTEM

TIME MIN	T2 C	T4 C	T6 C	T7 C
0	292	366.9	438.2	69.7
8	287.5	354.5	421	87.9
16	283.9	34.44	407.7	108.2
24	281.3	256.4	395.2	128.7
36	280.6	334.1	392.2	133.5
44	278.3	326.9	382.4	152.7
50	279.5	330.8	387.2	143.3
60	276.9	322.4	375.9	166.2
70	275.1	315.1	365.6	186.7
80	303.2	465.3	370.4	197.4
90	342.6	470.6	570.9	143.7
100	359.7	484.8	576.2	91
110	389.7	559.3	621.3	62.5
120	430.1	574.4	704.7	296.2
130	444.8	568.9	661.3	690.9
140	432.6	612.8	565.1	578.1
150	416.2	471.3	489.8	456.7
160	401.6	435.5	445.7	338.4
170	389.4	431.8	427.6	287.1
180	381.7	398.2	413.1	263.9
190	357.4	336.9	327.3	187.6
200	352.4	334.3	336.6	161.6
210	345.1	358.8	327.4	170.3
220	338.1	321.2	317.5	176.6
230	332.2	341.8	322.6	181.1
240	326.8	334.4	318	184.8
250	321.6	327.6	311	188.3
260	293.2	293.9	273.4	206.4
270	265.1	265.9	242.7	223.3
280	254.5	255.9	222.3	232.2
290	204.4	210.9	184.1	236.2
300	180.2	189	162.2	228.6
310	169.9	179.7	153.1	222.9
320	160.6	171	145.1	216.6
350	174.9	184.3	157.3	225.8
380	169.9	179.7	153.1	222.9
410	164.9	175.2	148.8	219.7
440	160.6	171	145.1	216.6
470	156.3	166.9	141.3	213.3
530	147.1	158.2	133.4	205.7
590	140.1	151.2	127.6	199
650	133.4	144.7	212.8	192.3
710	127.3	138.5	116.1	185.7
770	121.6	132.8	110.2	179.3
830	116.1	127.3	105.3	173.2

1190	92	101.6	86.9	140.7
1250	88.9	92.6	84.3	136.1
1310	86	94.9	81.9	131.7
1370	83.3	91.8	79.5	127.4
1430	80.6	88.9	77.3	123.2
1490	78.2	86.1	75.2	119.2
1550	75.9	83.5	73.3	115.4
1610	71.9	78.8	69.7	108.6
1670	69.9	76.6	68.1	105.2
1730	68.1	74.4	66.4	102.1
1790	66.4	72.4	64.7	99.1
1850	64.6	70.5	63.1	69.1
1910	63.1	68.7	61.6	93.3
1970	61.7	67.1	60.4	90.7
2030	60.3	65.3	59.2	88.2
2090	58.8	63.8	57.5	85.7
2150	57.7	62.3	55.7	83.4
2210	56.4	60.9	54.3	81.1
2270	55.4	59.7	53.2	79.1
2330	54.2	58.4	52.3	76.8
2390	53.2	57.2	51.7	74.8
2450	52.4	56.3	51.5	73.2
2510	51.4	55.2	50.8	71.3
2570	50.6	54.2	50.2	69.6
2630	49.7	53.2	49.4	67.9
2690	48.8	52.2	48.6	66.3
2750	48.3	51.4	48.1	65
2810	47.6	50.6	47.5	63.6
2870	46.8	49.7	46.8	62.2
2930	46.1	48.9	46.2	60.9
2990	45.5	48.2	45.7	59.7
3050	44.8	47.4	45	58.5
3110	44.2	46.2	44.3	57.4
3170	43.7	46.1	43.8	56.3
3230	43	45.4	43.1	55.2
3290	42.5	44.3	42.6	54.3
3350	42	44.2	42	53.3

FIG. 5.6

GRAPH FOR BED TEMP. (T7) vs. TIME

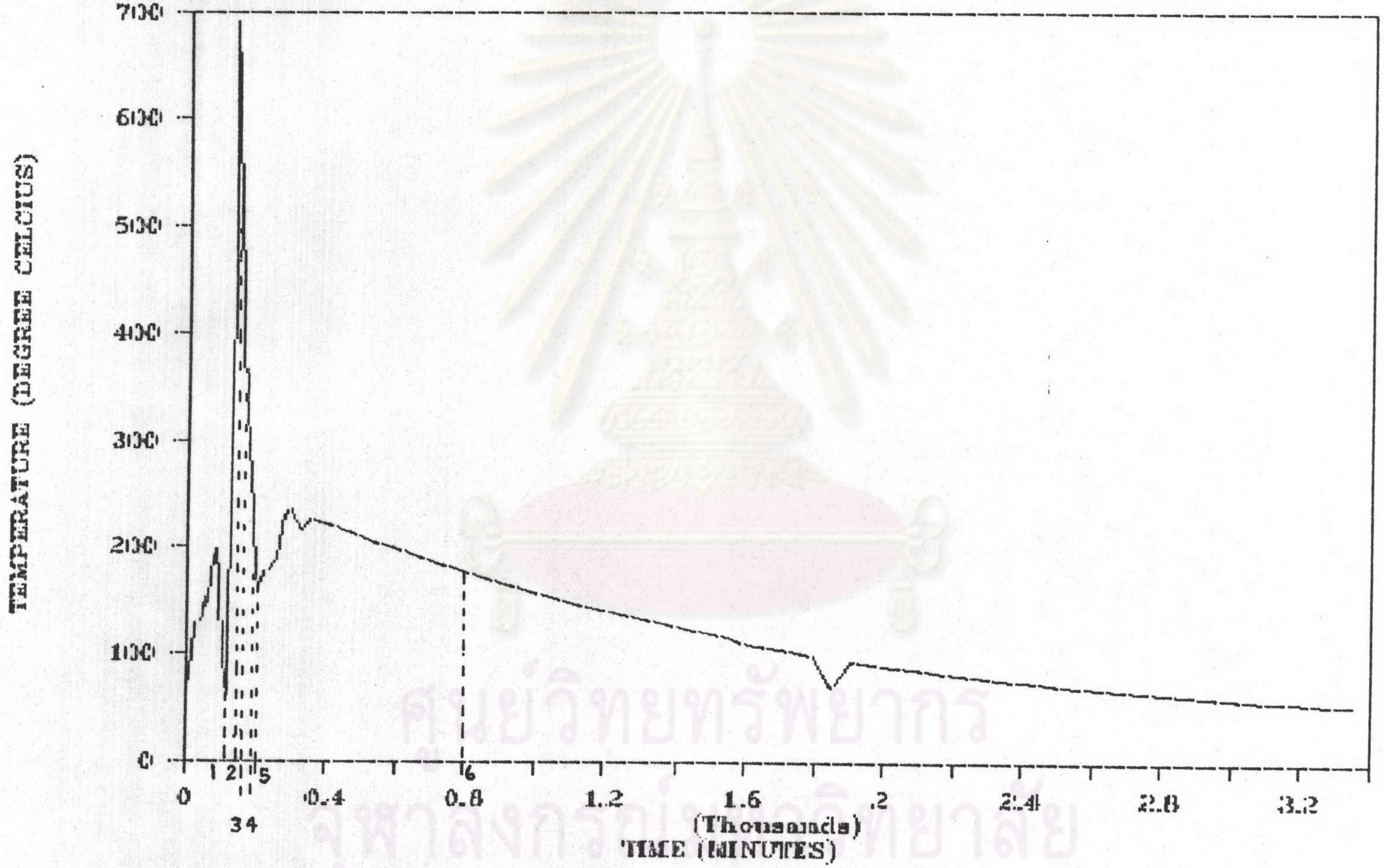


FIG. 5.7

GRAPH FOR T2 , T4 , T6 , T7 vs. TIME

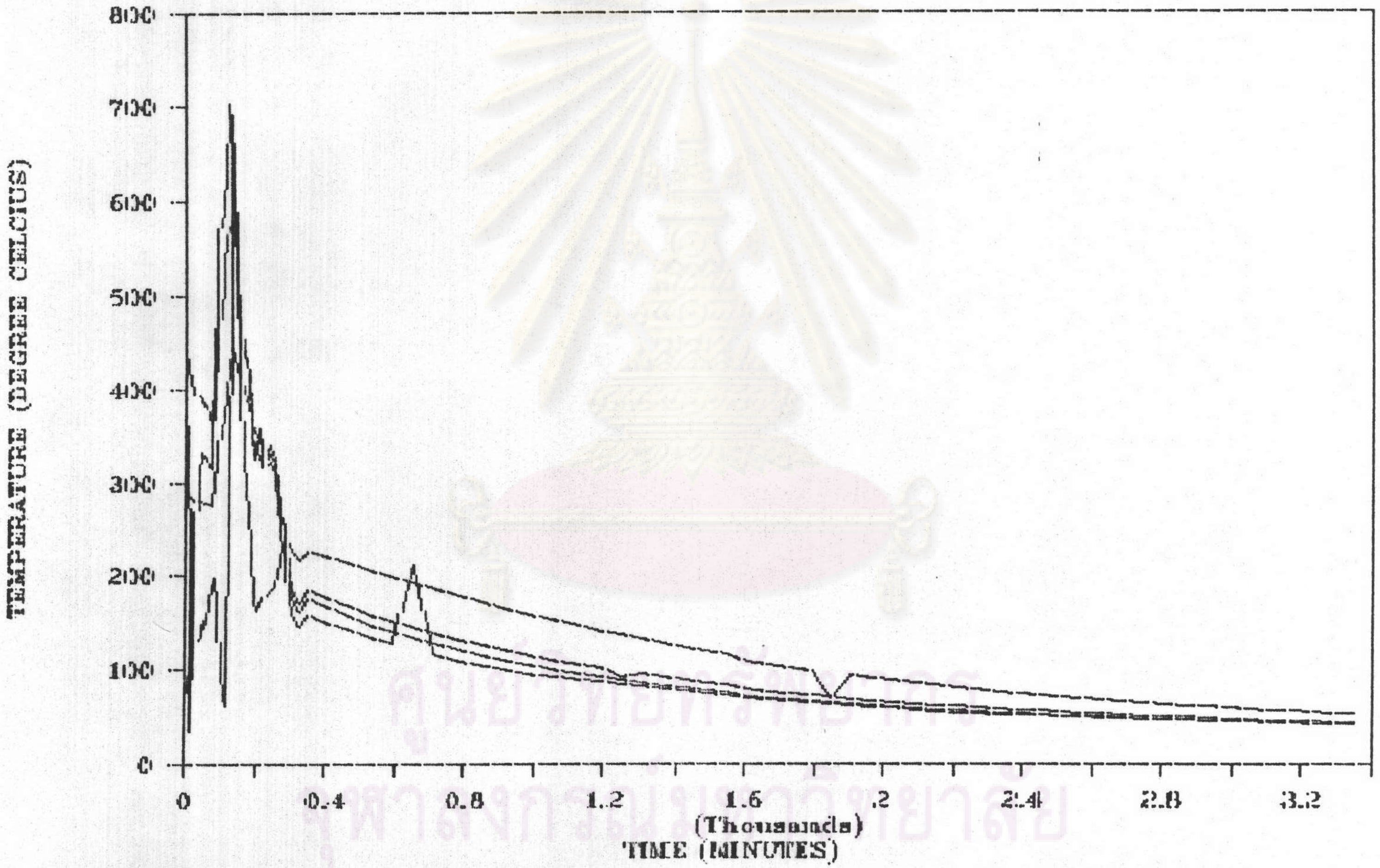


TABLE 5.8

TIME MIN	T2 C.	T4 C.	T6 C.	T7 C.
0	30.3	30.6	29.9	30.6
30	30.4	30.7	29.9	30.7
40	49.3	159.2	116.3	30.6
50	67	228.9	205.3	30.6
60	78.2	202.6	209.6	30.7
70	96	280.4	275.9	30.8
80	119.9	275.6	316	30.6
90	145.7	334.7	401.2	32.8
100	182.7	364.9	478.4	41.4
110	189.9	297.6	404.7	62.3
120	257.2	477.3	611	92.4
130	257.5	410.2	494.2	503.2
140	262.7	391.6	463.3	463.4
150	255.7	359.3	347.9	346.8
160	282.1	428.4	524.3	526.7
170	289.9	401.6	506.3	509.1
180	281.4	375.4	441	445.1
190	315.7	460.9	575.8	578.6
200	336.1	472.6	573.8	582.4
210	358.3	512.5	628.6	631.3
220	382.6	521.2	644.1	646.9
230	382.8	485.7	565.6	568.2
240	366.8	430.2	468.1	470.3
250	344.1	378.8	379.5	381.4
260	336.8	377.4	385.9	387.7
270	331.1	367.4	385.4	388.6
280	324.9	355.3	365.7	388.6
290	319.6	345.4	351.1	386.7
300	312.9	333.7	331.5	373
310	306.6	316.3	321.6	368.2
320	302.3	310.4	312.3	361.8
330	294.7	303.5	288.8	331.1
340	286.5	294.9	293	330.2
360	275.9	281.5	279.8	328.1
390	266.9	270.6	268.3	324.8
420	257.6	260.5	257.1	321
450	248.7	251.4	246.9	317.1
480	240.4	243.3	238.3	313.1
510	233.1	236.3	230.5	308.8
540	225.8	229.6	224.2	304.2
570	218.8	223.2	217.2	299.4
600	212.3	217.3	210.6	294.3
630	206.3	211.8	204.5	289.3
690	200.4	206.4	198.5	283.9
750	189.4	196.6	187.7	273.4
910	179.9	187.6	178.2	263.1
970	171.1	179.3	169.6	252.6
1030	163.1	171.7	161.5	242.7

1440	120.7	130.1	119.7	183.5
1500	116.2	125.4	115.9	176.7
1560	112	121.1	111.9	170.3
1620	108.1	116.8	108.1	164
1680	104.3	112.9	104.8	158.3
1740	100.8	109.2	101.2	152.6
1780	97.6	105.8	98.2	147.5
1840	94.4	102.4	95.2	142.5
1900	91.4	99.2	92.2	137.7
1960	88.7	96.1	89.3	133.2
2020	85.9	93.1	86.6	128.8
2080	83.3	90.4	84.1	124.6
2140	80.9	87.7	81.8	120.6
2200	78.6	85.3	79.6	116.8
2260	76.3	82.8	77.1	113.1

b) The second test run

Operating conditions:

This test run was performed after the results from the first test run had been analysed. The major objective of this experiment was to acquire more understanding about the preheating characteristics of the combustor and to determine the standard start up procedures of the combustor.

40 kg of charcoal was first introduced into the combustor and the diesel burner was used for ignition of charcoal in the initial state. From an observation from the sight glass, seeing that the charcoal was widespreadly burnt, when increasing the air flow rate until the fluidized state was achieved. The bed temperature rose up to 500 c. in 100 minutes and then started to decline. So 20 kg of charcoal was added into the combustor and the bed temperature was again raised up. In 20 minutes the bed temperature of 530 c. was reached and when it started to descend, another 20 kg of charcoal was added again. The procedures were done repeatedly until the target bed temperature was reached.

Table 5.8 shows the data from this experimental runs. fig. 5.8, .5.9, 5.10, 5.11 show the plots between T-2, T-4, T-6 and T-7 vs. time respectively.The four temp are plotted together in fig. 5.12.

From the two test runs . It is possible establish standard procedure of start up by burning charcoal as shown below.

<u>Standard start up procedure</u> (sand bed 40 cm)

1. Introduce 40 kg of charcoal into the combustor. Ignite it by the Diesel burner. At this state the overbed temperature (T-6) is approximately 300-400 c.

2. Increase the air flow rate until fluidized state is reached. Bed temperature (T-7) will be raised up relatively fast. When T-7 starts to decline, shut off the blower and add 20 kg of charcoal.

3. Introduce the fluidising air into the combustor. T-7, in the fluidized state, will increased again. When bed temperature begins to drop, observed from T-7, add another 20 kg of charcoal.

4. Repeat (2), (3) again until the desired bed temperature is reached.

This is the most appropriate method of start up in this study since charcoal is easy-to-find, easily ignited and a cheap fuel. In this method, where approximately 100 kg of charcoal is used, the cost of the preheating fuel is only 200-300 Baht (US$ 8-12). The Diesel burner is used only at the very first start.

FIG. 5.8

GRAPH FOR WALL TEMP.(T2) vs. TIME

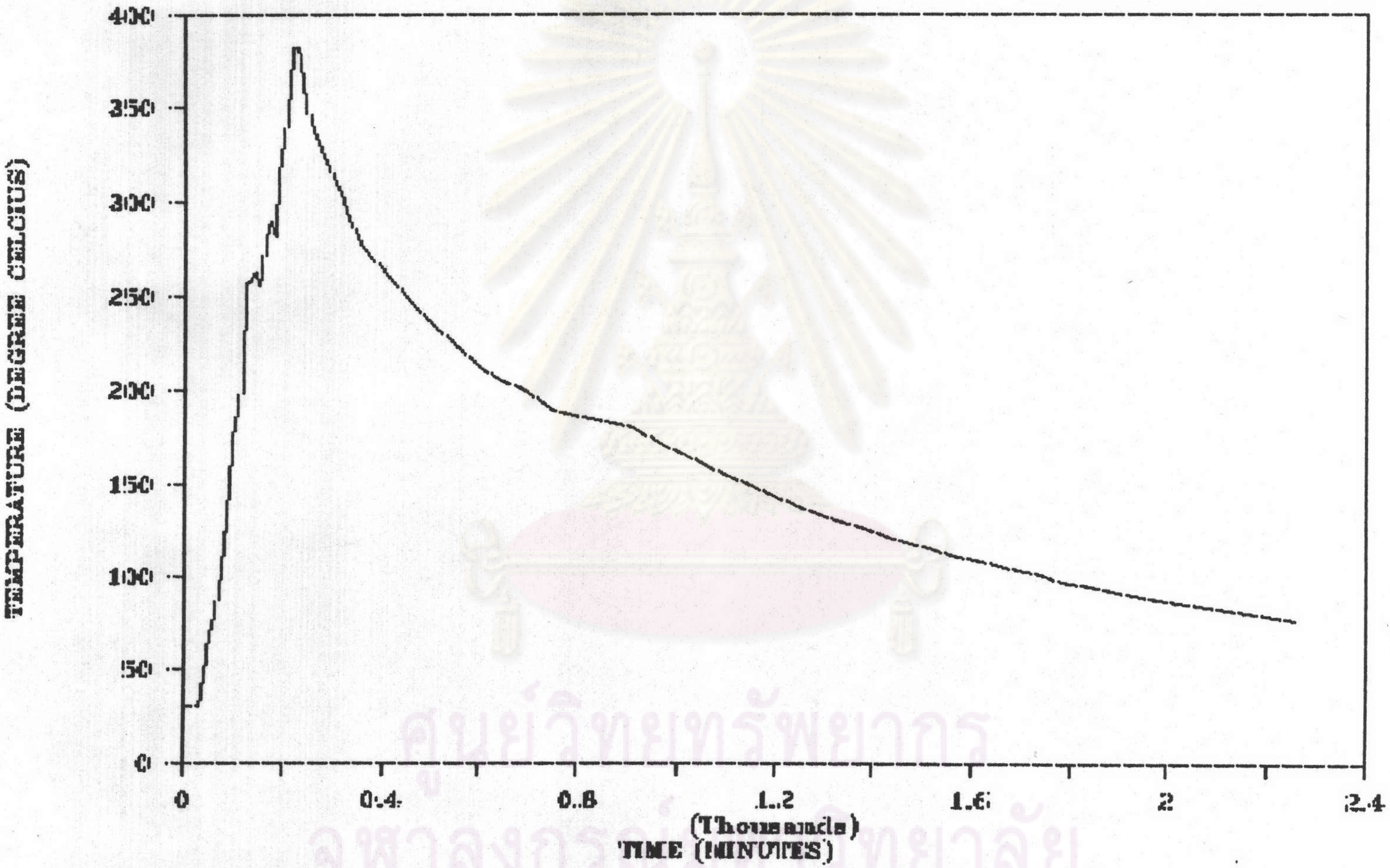


FIG. 5.9

GRAPH FOR EXIT AIR TEMP.(T4) vs. TIME

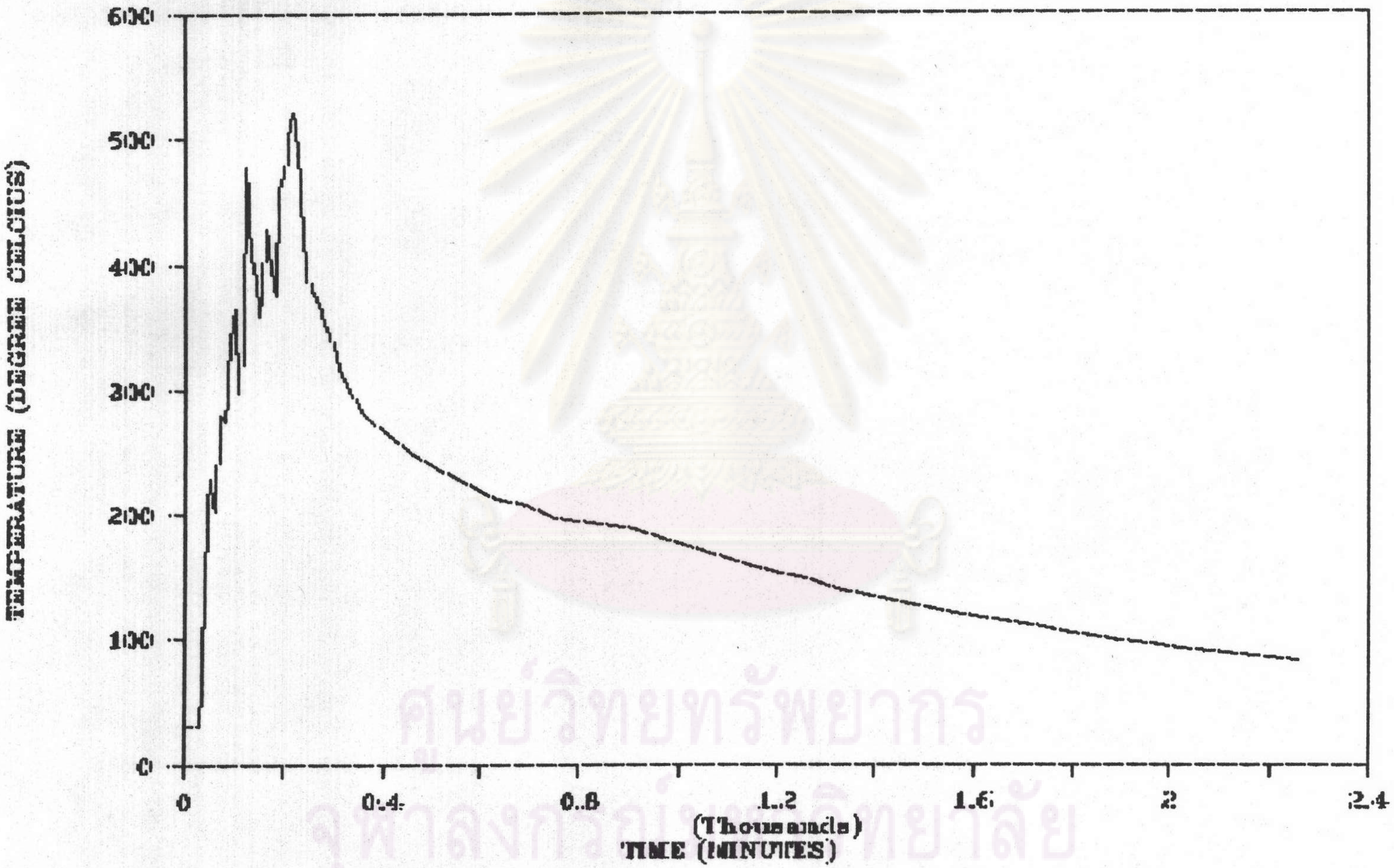


FIG. 5.10

GRAPH FOR OVER BED TEMP.(T6) vs. TIME

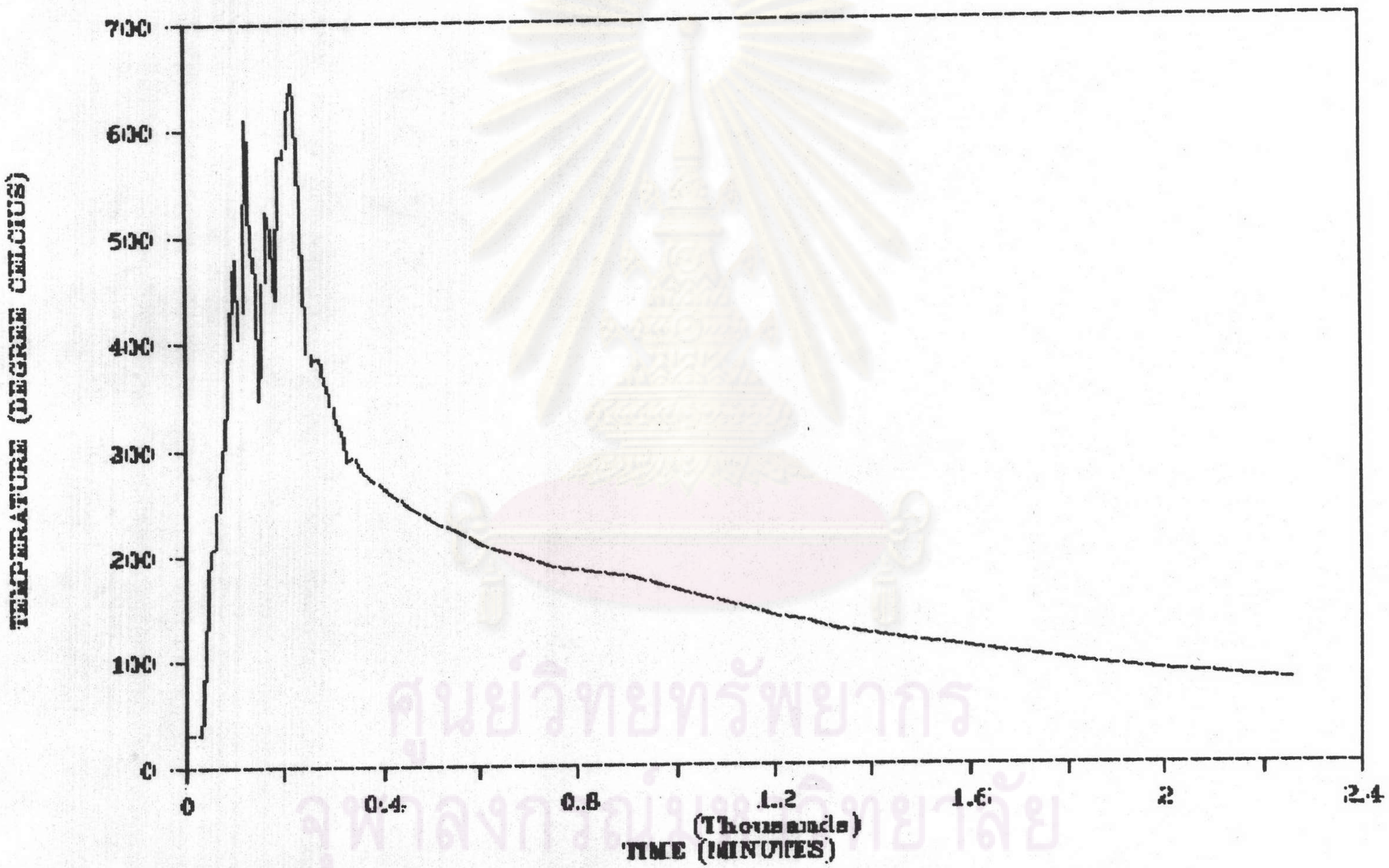


FIG. 5.11

GRAPH FOR BED TEMP.(T7) vs. TIME

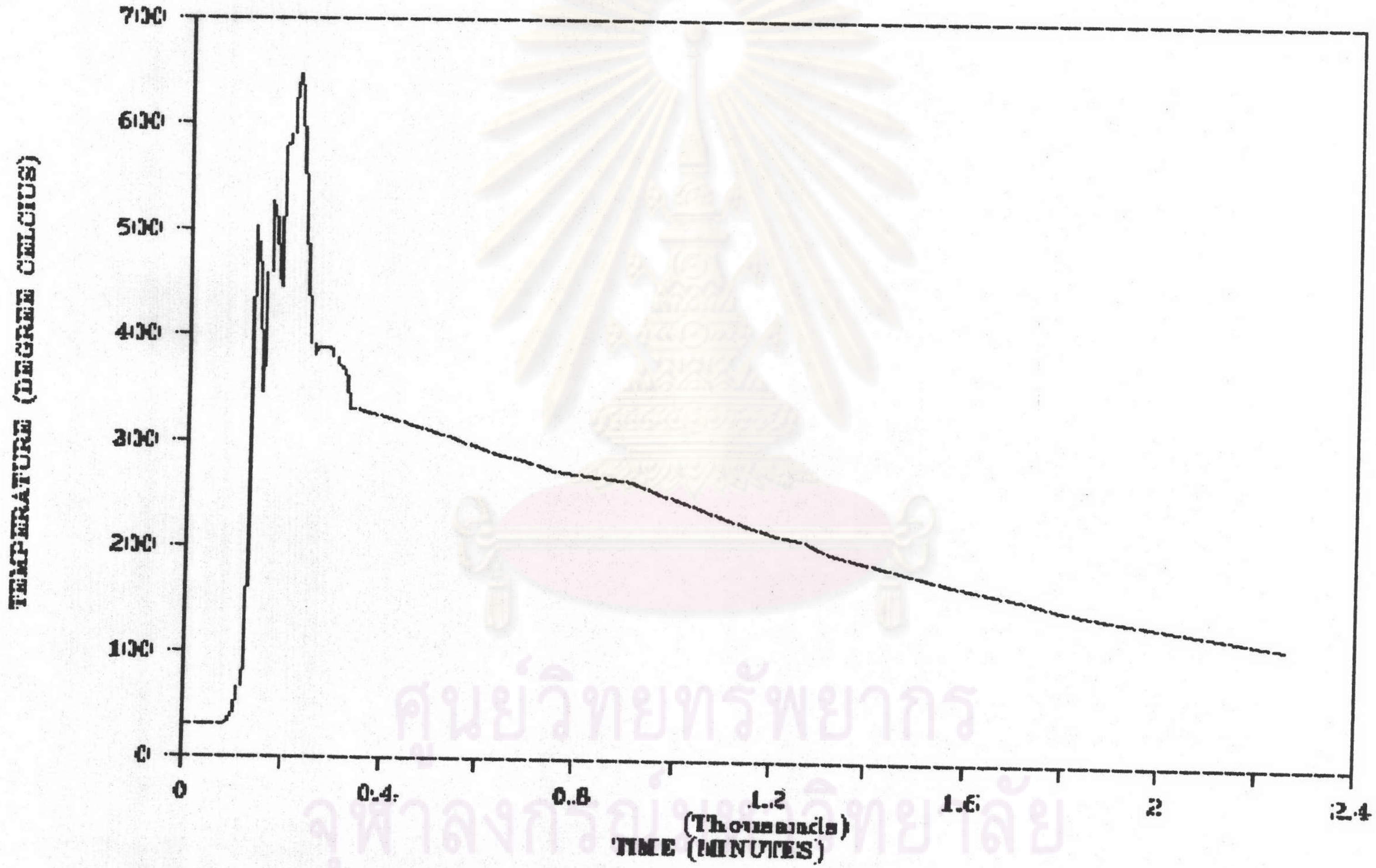
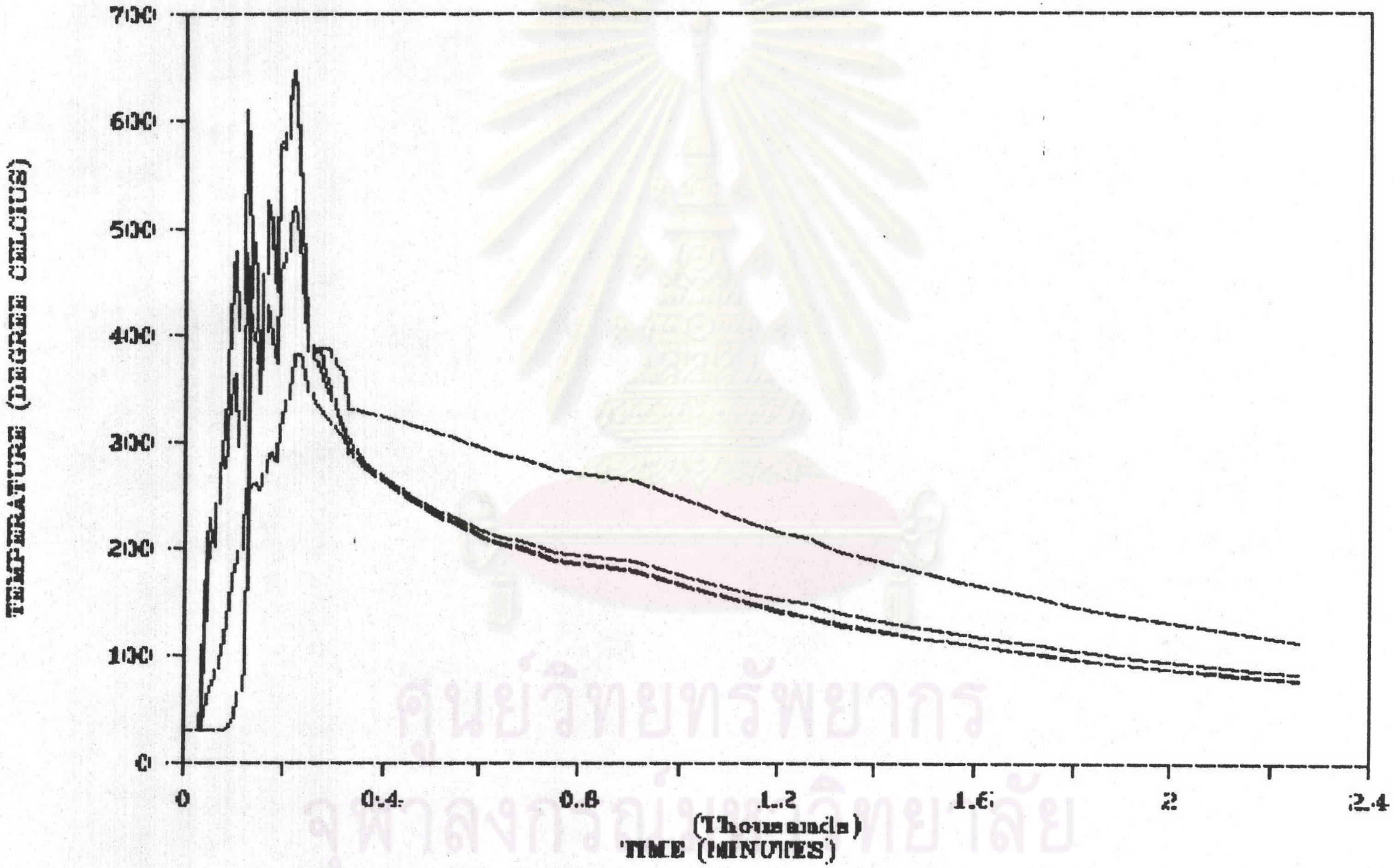


FIG. 5.12

GRAPH FOR T2 , T4 , T6 , T7 vs. TIME



5.4 Experimental Test Run

The experimental conditions are summarized in table 5.9 the fixed variable are bed height, bed size ; the mainpulated variable is the rice husk feed rate , the controlled variables is the fuel-air ratio and the independent variable are bed temperature.

Experimental Test Run Procedure

1. Preheat the combustor by using charcoal until the bed temperture is about 500 c (steady temperature about 10 minute)
2. Feed rice husk in the bed and adjust the operating condition by air feed and rice husk feed
3. Detect the result of
   - 3.1 Rice Husk Feed Rate
   - 3.2 Air Feed Rate
   - 3.3 Bed Temperature and the profile temperature

5.5 Experimental Test Run Result

The result of the test are presented in tables 5.10 - 5.13. By mean of analysis with graphs ,it can be summarized in graphs 5.13 - 5.31.

TABLE 5.10

% EXCESS AIR	R/H FEED RATE (KG/HR.)	HEAT GENERATE FORM R/H (K CAL/HR.)	ROOM TEMP. DEGREE CELCIUS	AIR OUTLET TEMP. DEGREE CELCIUS	AIR FEED RATE (M^3/HR.)	AIR FEED RATE (KG./HR.)	HEAT SUPPLIED TO AIR (K CAL/HR.)	FUEL/AIR RATIO	THERMAL EFFICIENCY (%)	HEAT ACCUMULATE (%)
7	117	4.28E+05	30	548	620	715	1.04E+05	0.1636	24.23	75.77
	138	5.05E+05	30	550	731	843	1.23E+05	0.1637	24.31	75.69
	160	5.85E+05	30	554	849	979	1.44E+05	0.1634	24.54	75.46
	181	6.62E+05	30	554	958	1105	1.62E+05	0.1638	24.48	75.52
	203	7.43E+05	30	562	1077	1242	1.85E+05	0.1634	24.91	75.09
7	117	4.28E+05	30	589	620	715	1.12E+05	0.1636	26.15	73.85
	138	5.05E+05	30	600	731	843	1.35E+05	0.1637	26.65	73.35
	160	5.85E+05	30	605	849	979	1.58E+05	0.1634	26.93	73.07
	181	6.62E+05	30	609	958	1105	1.79E+05	0.1638	27.05	72.95
	203	7.43E+05	30	619	1077	1242	2.05E+05	0.1634	27.58	72.42
7	117	4.28E+05	30	643	620	715	1.23E+05	0.1636	28.67	71.33
	138	5.05E+05	30	649	731	843	1.46E+05	0.1637	28.94	71.06
	160	5.85E+05	30	651	849	979	1.70E+05	0.1634	29.09	70.91
	181	6.62E+05	30	650	958	1105	1.92E+05	0.1638	28.97	71.03
	203	7.43E+05	30	662	1077	1242	2.20E+05	0.1634	29.60	70.40
7	117	4.28E+05	30	694	620	715	1.33E+05	0.1636	31.06	68.94
	138	5.05E+05	30	699	731	843	1.58E+05	0.1637	31.28	68.72
	160	5.85E+05	30	702	849	979	1.84E+05	0.1634	31.48	68.52
	181	6.62E+05	30	711	958	1105	2.11E+05	0.1638	31.82	68.18
	203	7.43E+05	30	715	1077	1242	2.38E+05	0.1634	32.08	67.92
7	117	4.28E+05	30	744	620	715	1.43E+05	0.1636	33.40	66.60
	138	5.05E+05	30	745	731	843	1.69E+05	0.1637	33.43	66.57
	160	5.85E+05	30	751	849	979	1.98E+05	0.1634	33.77	66.23
	181	6.62E+05	30	755	958	1105	2.24E+05	0.1638	33.87	66.13
	203	7.43E+05	30	758	1077	1242	2.53E+05	0.1634	34.09	65.91

TABLE 5.11

% EXCESS AIR	R/H FEED RATE (KG/HR.)	HEAT GENERATE FORM R/H (K CAL/HR.)	ROOM TEMP. DEGREE CELCIUS	AIR OUTLET TEMP. DEGREE CELCIUS	AIR FEED RATE (M^3/HR.)	AIR FEED RATE (KG./HR.)	HEAT SUPPLIED TO AIR (K CAL/HR.)	FUEL/AIR RATIO	THERMAL EFFICIENCY (%)	HEAT ACCUMULATE (%)
10	117	4.28E+05	30	548	638	736	1.07E+05	0.1590	24.93	75.07
	138	5.05E+05	30	551	769	887	1.29E+05	0.1556	25.63	74.37
	160	5.85E+05	30	556	872	1006	1.48E+05	0.1591	25.30	74.70
	181	6.62E+05	30	554	985	1136	1.67E+05	0.1593	25.17	74.83
	203	7.43E+05	30	559	1107	1277	1.89E+05	0.1590	25.46	74.54
10	117	4.28E+05	30	589	638	736	1.15E+05	0.1590	26.91	73.09
	138	5.05E+05	30	594	769	887	1.40E+05	0.1556	27.74	72.26
	160	5.85E+05	30	599	872	1006	1.60E+05	0.1591	27.37	72.63
	181	6.62E+05	30	606	985	1136	1.83E+05	0.1593	27.67	72.33
	203	7.43E+05	30	607	1107	1277	2.06E+05	0.1590	27.77	72.23
10	117	4.28E+05	30	648	638	736	1.27E+05	0.1590	29.75	70.25
	138	5.05E+05	30	653	769	887	1.55E+05	0.1556	30.64	69.36
	160	5.85E+05	30	653	872	1006	1.75E+05	0.1591	29.97	70.03
	181	6.62E+05	30	661	985	1136	2.01E+05	0.1593	30.31	69.69
	203	7.43E+05	30	665	1107	1277	2.27E+05	0.1590	30.57	69.43
10	117	4.28E+05	30	700	638	736	1.38E+05	0.1590	32.25	67.75
	138	5.05E+05	30	700	769	887	1.66E+05	0.1556	32.96	67.04
	160	5.85E+05	30	706	872	1006	1.90E+05	0.1591	32.52	67.48
	181	6.62E+05	30	702	985	1136	2.14E+05	0.1593	32.28	67.72
	203	7.43E+05	30	704	1107	1277	2.41E+05	0.1590	32.44	67.56
10	117	4.28E+05	30	748	638	736	1.48E+05	0.1590	34.56	65.44
	138	5.05E+05	30	753	769	887	1.80E+05	0.1556	35.56	64.44
	160	5.85E+05	30	759	872	1006	2.05E+05	0.1591	35.07	64.93
	181	6.62E+05	30	759	985	1136	2.32E+05	0.1593	35.02	64.98
	203	7.43E+05	30	761	1107	1277	2.61E+05	0.1590	35.19	64.81

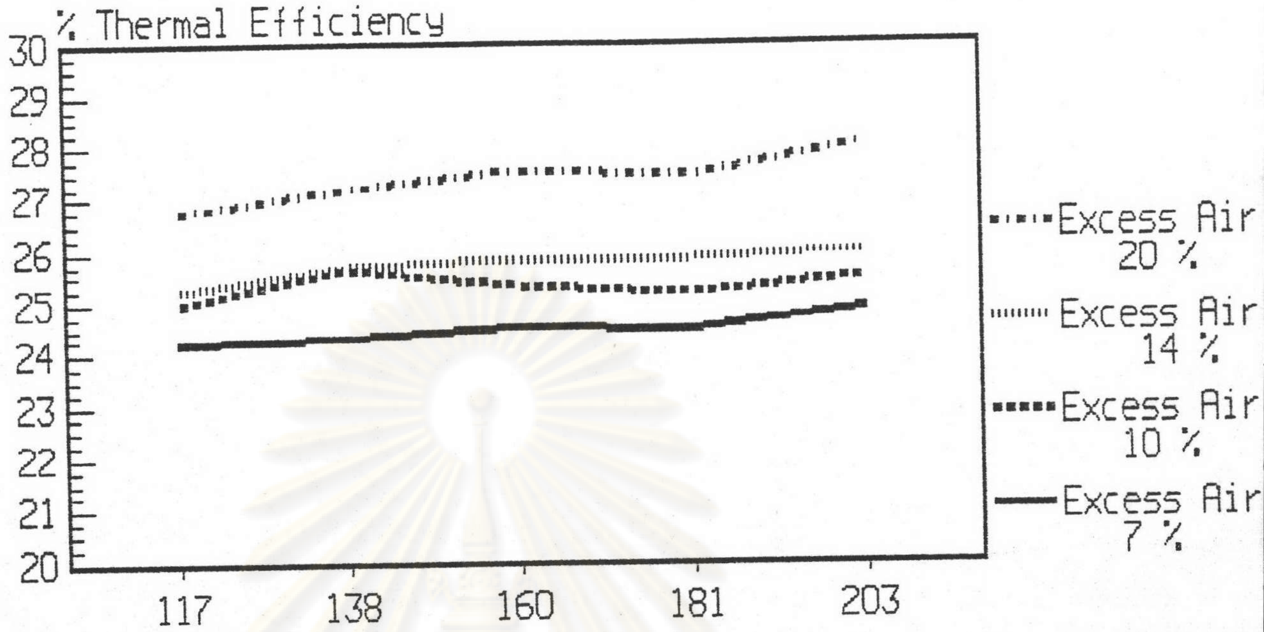
TABLE 5.12

% EXCESS AIR	R/H FEED RATE (KG/HR.)	HEAT GENERATE FORM R/H (K CAL/HR.)	ROOM TEMP. DEGREE CELCIUS	AIR OUTLET TEMP. DEGREE CELCIUS	AIR FEED RATE (M^3/HR.)	AIR FEED RATE (KG./HR.)	HEAT SUPPLIED TO AIR (K CAL/HR.)	FUEL/AIR RATIO	THERMAL EFFICIENCY (%)	HEAT ACCUMULATE (%)
14	117	4.28E+05	30	536	661	762	1.08E+05	0.1535	25.23	74.77
	138	5.05E+05	30	545	779	898	1.30E+05	0.1536	25.66	74.34
	160	5.85E+05	30	548	904	1042	1.51E+05	0.1535	25.83	74.17
	181	6.62E+05	30	549	1020	1176	1.71E+05	0.1539	25.82	74.18
	203	7.43E+05	30	550	1148	1324	1.93E+05	0.1533	25.96	74.04
14	117	4.28E+05	30	586	661	762	1.19E+05	0.1535	27.73	72.27
	138	5.05E+05	30	589	779	898	1.41E+05	0.1536	27.85	72.15
	160	5.85E+05	30	589	904	1042	1.63E+05	0.1535	27.88	72.12
	181	6.62E+05	30	591	1020	1176	1.85E+05	0.1539	27.91	72.09
	203	7.43E+05	30	596	1148	1324	2.10E+05	0.1533	28.25	71.75
14	117	4.28E+05	30	634	661	762	1.29E+05	0.1535	30.12	69.88
	138	5.05E+05	30	636	779	898	1.52E+05	0.1536	30.20	69.80
	160	5.85E+05	30	639	904	1042	1.78E+05	0.1535	30.37	69.63
	181	6.62E+05	30	641	1020	1176	2.01E+05	0.1539	30.39	69.61
	203	7.43E+05	30	642	1148	1324	2.27E+05	0.1533	30.55	69.45
14	117	4.28E+05	30	689	661	762	1.41E+05	0.1535	32.86	67.14
	138	5.05E+05	30	699	779	898	1.68E+05	0.1536	33.34	66.66
	160	5.85E+05	30	699	904	1042	1.95E+05	0.1535	33.37	66.63
	181	6.62E+05	30	700	1020	1176	2.21E+05	0.1539	33.33	66.67
	203	7.43E+05	30	700	1148	1324	2.48E+05	0.1533	33.45	66.55
14	117	4.28E+05	30	726	661	762	1.49E+05	0.1535	34.71	65.29
	138	5.05E+05	30	728	779	898	1.76E+05	0.1536	34.78	65.22
	160	5.85E+05	30	727	904	1042	2.03E+05	0.1535	34.76	65.24
	181	6.62E+05	30	739	1020	1176	2.34E+05	0.1539	35.27	64.73
	203	7.43E+05	30	741	1148	1324	2.64E+05	0.1533	35.49	64.51

TABLE 5.13

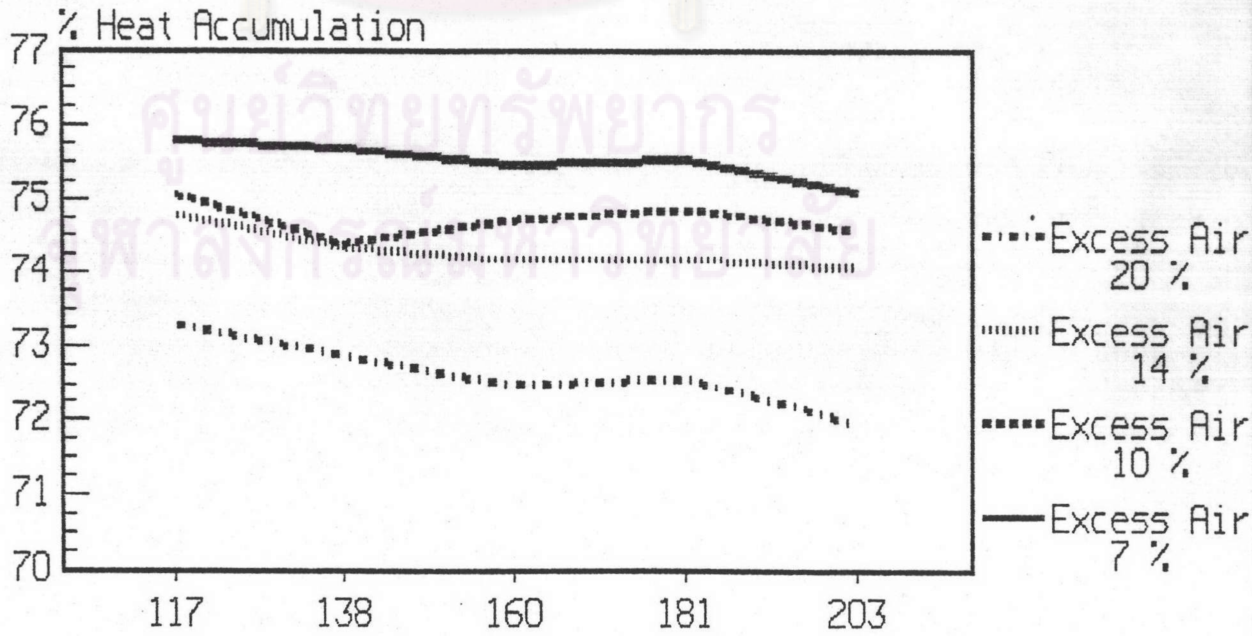
% EXCESS AIR	R/H FEED RATE (KG/HR.)	HEAT GENERATE FORM R/H (K CAL/HR.)	ROOM TEMP. DEGREE CELCIUS	AIR OUTLET TEMP. DEGREE CELCIUS	AIR FEED RATE (M^3/HR.)	AIR FEED RATE (KG./HR.)	HEAT SUPPLIED TO AIR (K CAL/HR.)	FUEL/AIR RATIO	THERMAL EFFICIENCY (%)	HEAT ACCUMULATE (%)
20	117	4.28E+05	30	539	696	803	1.14E+05	0.1458	26.73	73.27
	138	5.05E+05	30	548	820	945	1.37E+05	0.1460	27.16	72.84
	160	5.85E+05	30	555	952	1097	1.61E+05	0.1458	27.56	72.44
	181	6.62E+05	30	554	1074	1239	1.82E+05	0.1461	27.45	72.55
	203	7.43E+05	30	564	1208	1394	2.08E+05	0.1457	28.06	71.94
20	117	4.28E+05	30	587	696	803	1.25E+05	0.1458	29.25	70.75
	138	5.05E+05	30	598	820	945	1.50E+05	0.1460	29.78	70.22
	160	5.85E+05	30	602	952	1097	1.76E+05	0.1458	30.03	69.97
	181	6.62E+05	30	610	1074	1239	2.01E+05	0.1461	30.38	69.62
	203	7.43E+05	30	616	1208	1394	2.29E+05	0.1457	30.79	69.21
20	117	4.28E+05	30	643	696	803	1.38E+05	0.1458	32.19	67.81
	138	5.05E+05	30	646	820	945	1.63E+05	0.1460	32.29	67.71
	160	5.85E+05	30	655	952	1097	1.92E+05	0.1458	32.81	67.19
	181	6.62E+05	30	654	1074	1239	2.16E+05	0.1461	32.68	67.32
	203	7.43E+05	30	665	1208	1394	2.48E+05	0.1457	33.37	66.63
20	117	4.28E+05	30	701	696	803	1.51E+05	0.1458	35.23	64.77
	138	5.05E+05	30	699	820	945	1.77E+05	0.1460	35.07	64.93
	160	5.85E+05	30	702	952	1097	2.06E+05	0.1458	35.28	64.72
	181	6.62E+05	30	715	1074	1239	2.38E+05	0.1461	35.88	64.12
	203	7.43E+05	30	715	1208	1394	2.67E+05	0.1457	35.99	64.01
20	117	4.28E+05	30	741	696	803	1.60E+05	0.1458	37.33	62.67
	138	5.05E+05	30	745	820	945	1.89E+05	0.1460	37.48	62.52
	160	5.85E+05	30	749	952	1097	2.21E+05	0.1458	37.75	62.25
	181	6.62E+05	30	752	1074	1239	2.50E+05	0.1461	37.82	62.18
	203	7.43E+05	30	755	1208	1394	2.83E+05	0.1457	38.10	61.90

Graph of R/H Feed Rate vs. Ther. Eff.
At 550 c.



Rice Husk Feed Rate(kg./hr)
Fig. 5.13

Graph of R/H Feed Rate vs. Heat Accum.
At 550 c.



Rice Husk Feed Rate(kg./hr)
Fig. 5.14

Graph of R/H Feed Rate vs. Ther. Eff.
At 600 c.

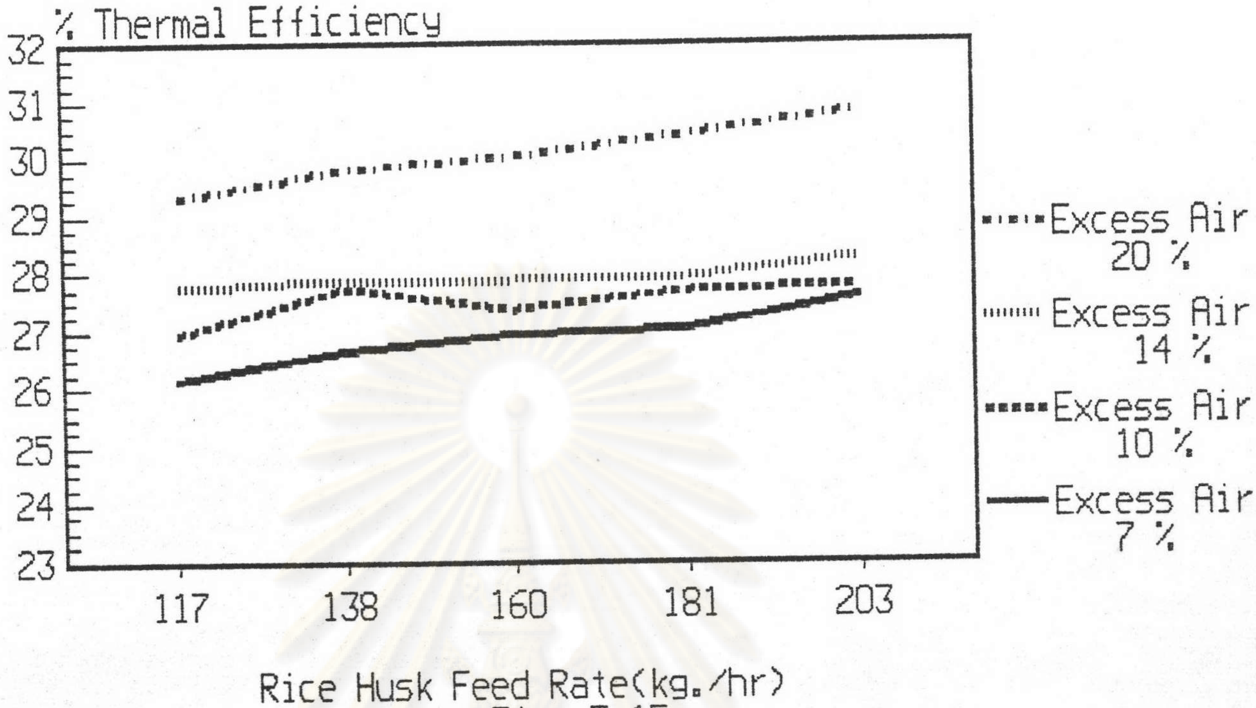


Fig. 5.15

Graph of R/H Feed Rate vs. Heat Accum.
At 600 c.

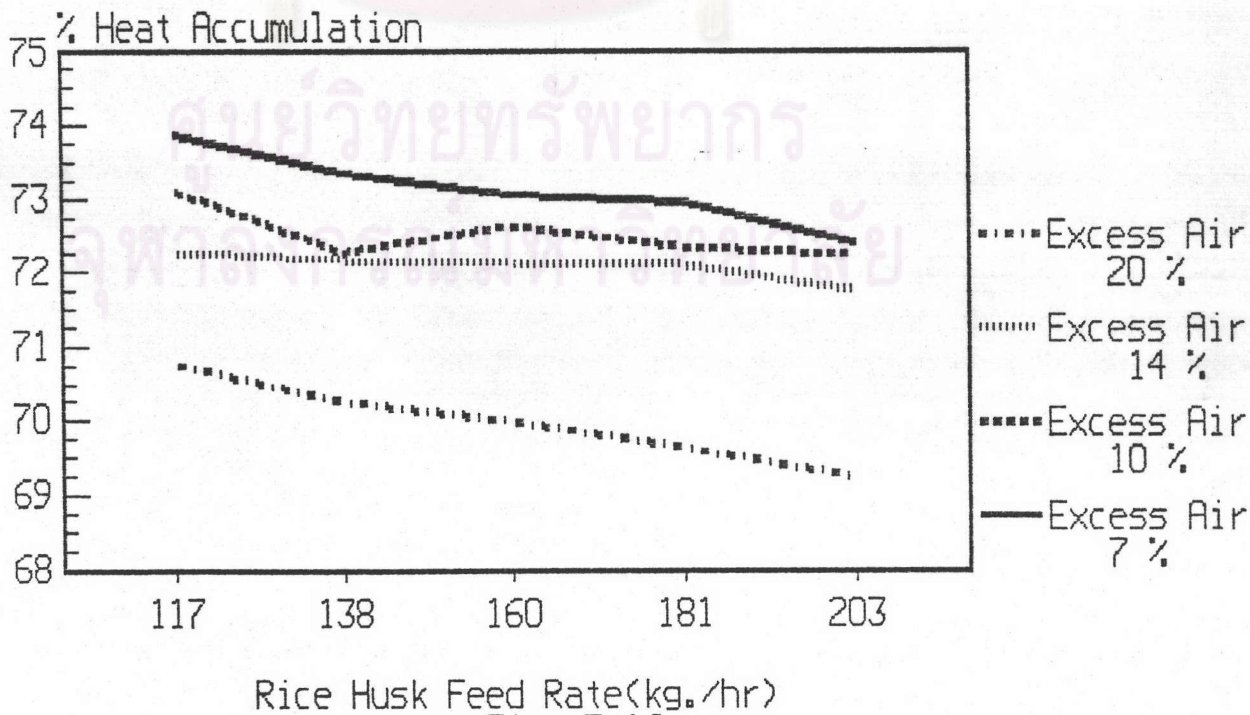


Fig. 5.16

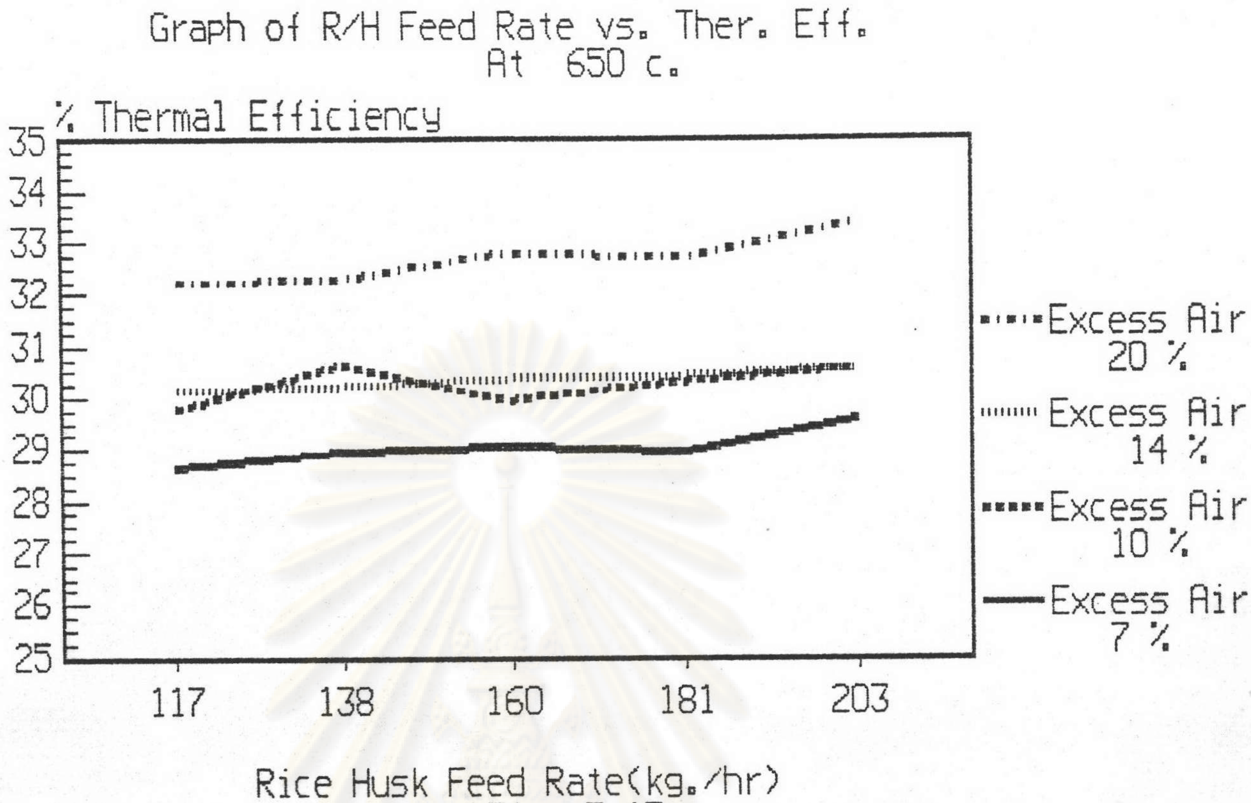


Fig. 5.17

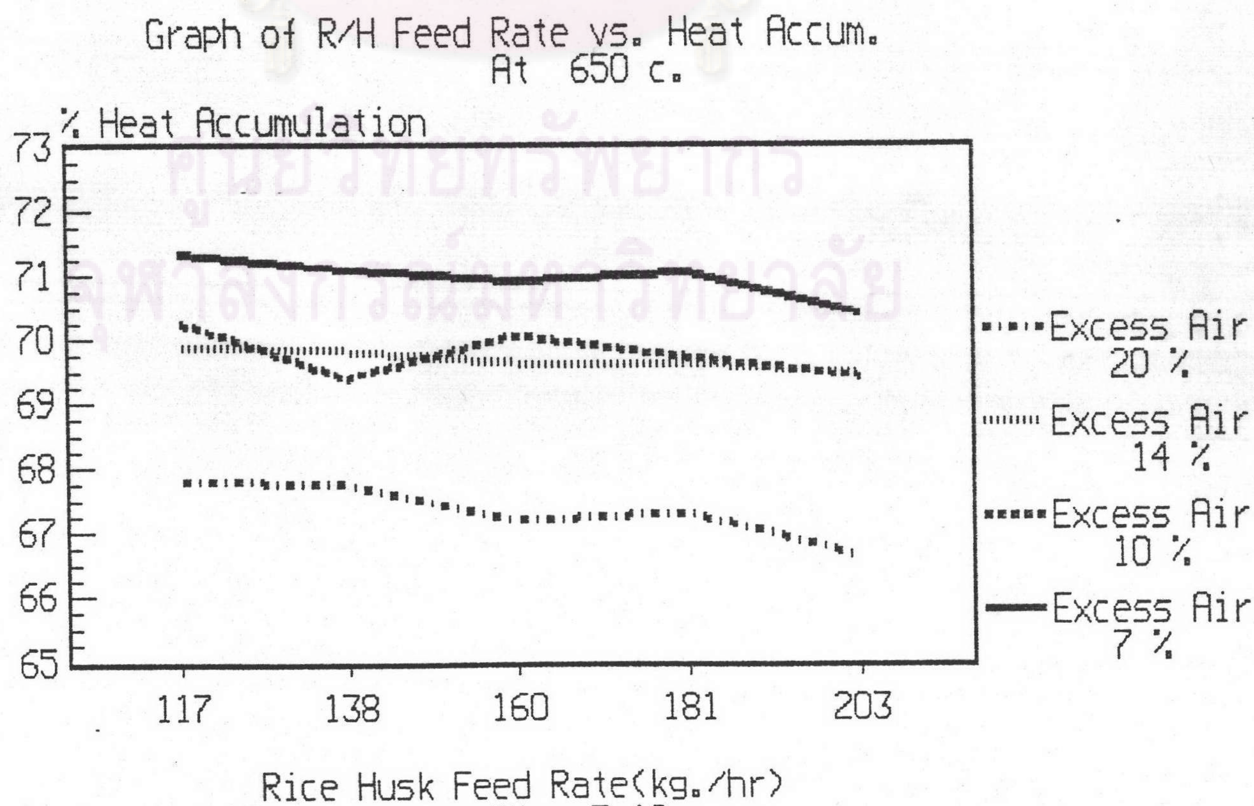
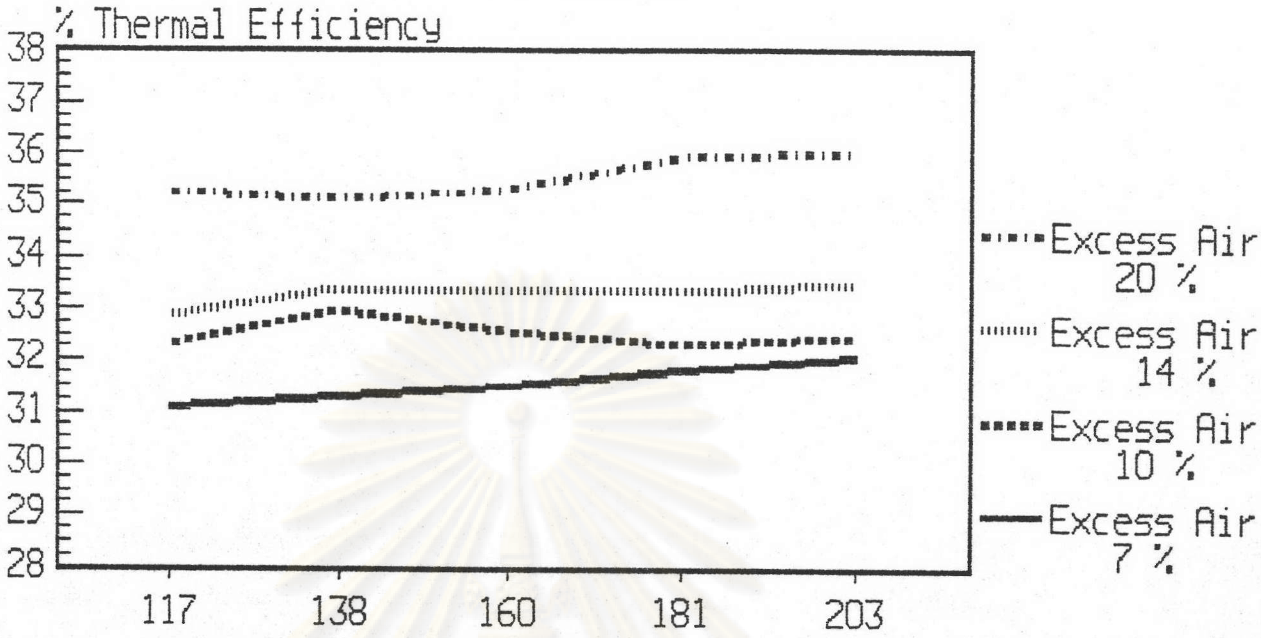


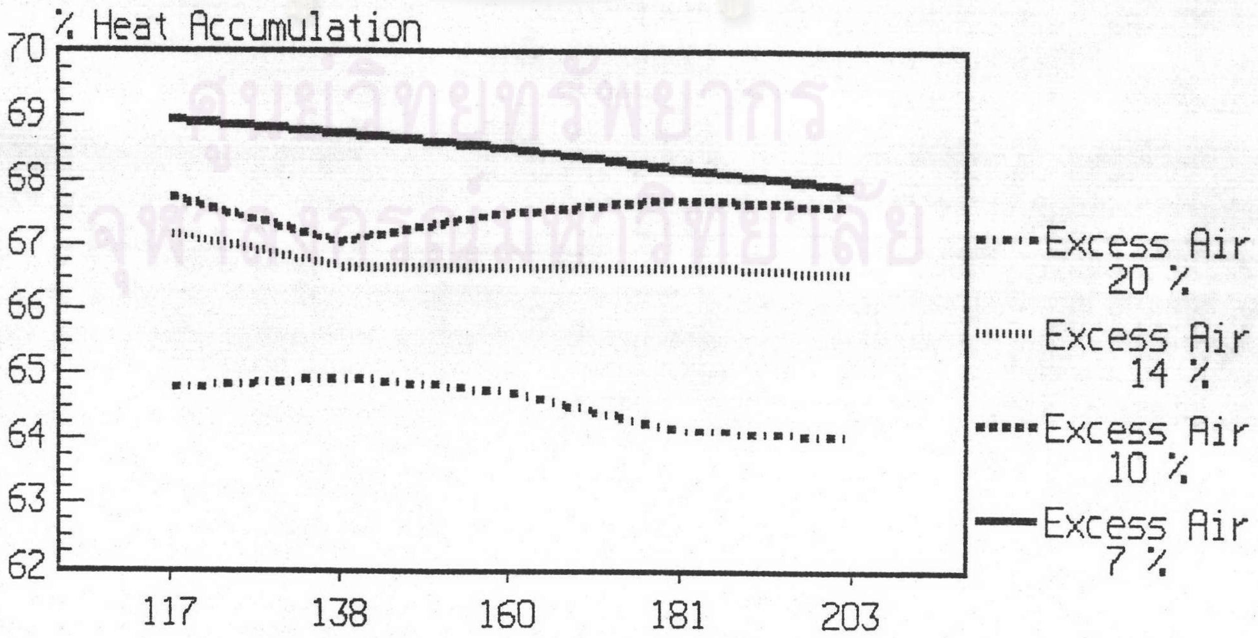
Fig. 5.18

Graph of R/H Feed Rate vs. Ther. Eff.
At 700 c.



Rice Husk Feed Rate(kg./hr)
Fig. 5.19

Graph of R/H Feed Rate vs. Heat Accum.
At 700 c.



Rice Husk Feed Rate(kg./hr)
Fig. 5.20

Graph of R/H Feed Rate vs. Ther. Eff.
At 750 c.

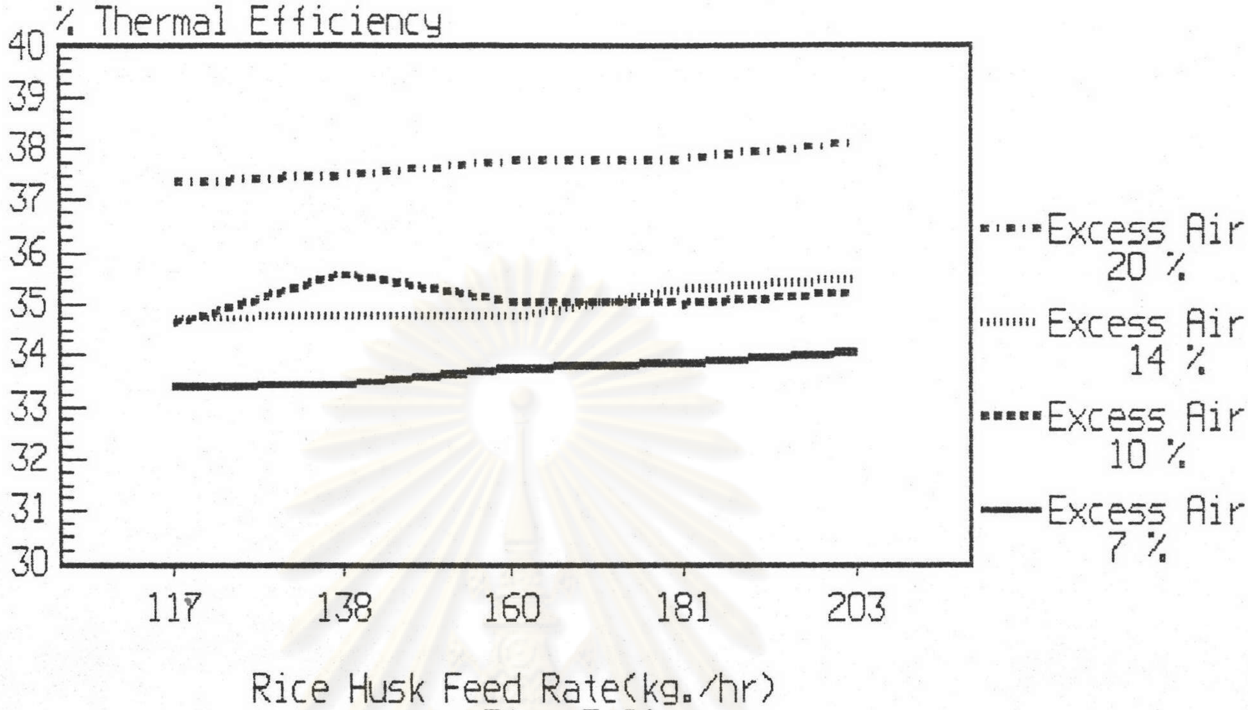


Fig. 5.21

Graph of R/H Feed Rate vs. Heat Accum.
At 750 c.

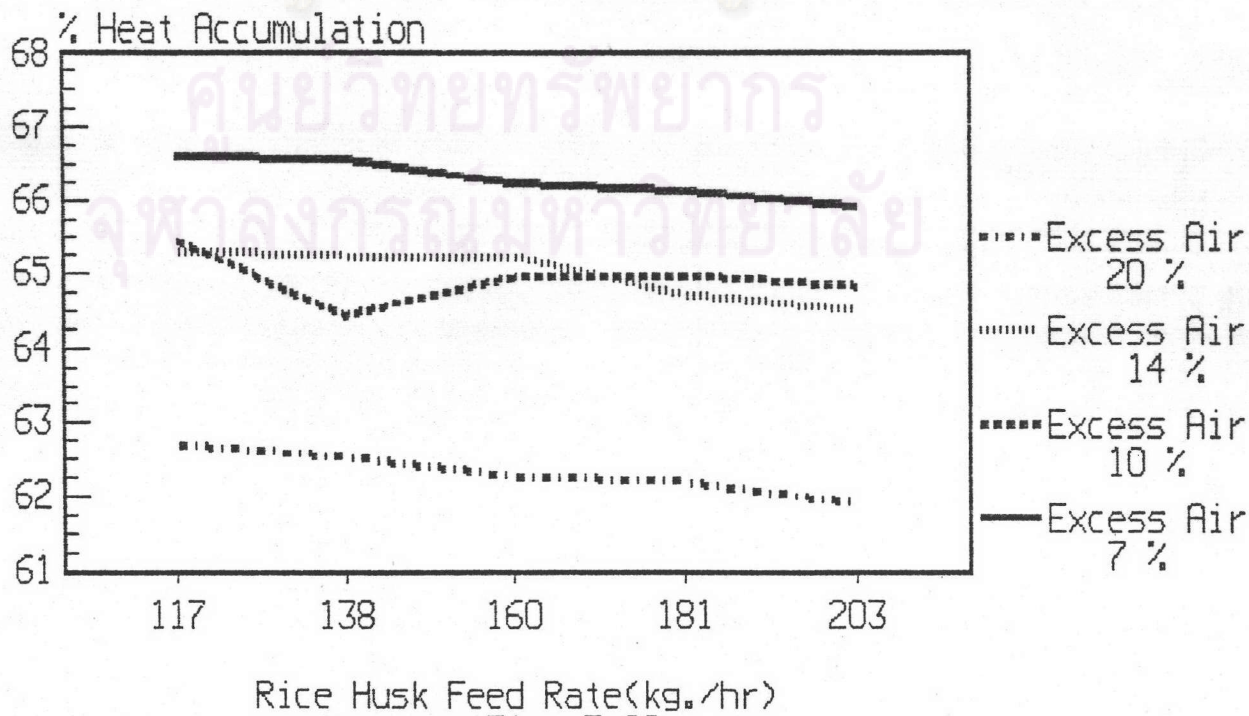


Fig. 5.22

Graph of Bed Temp. vs. Ther. Eff.
At 7 % Excess Air

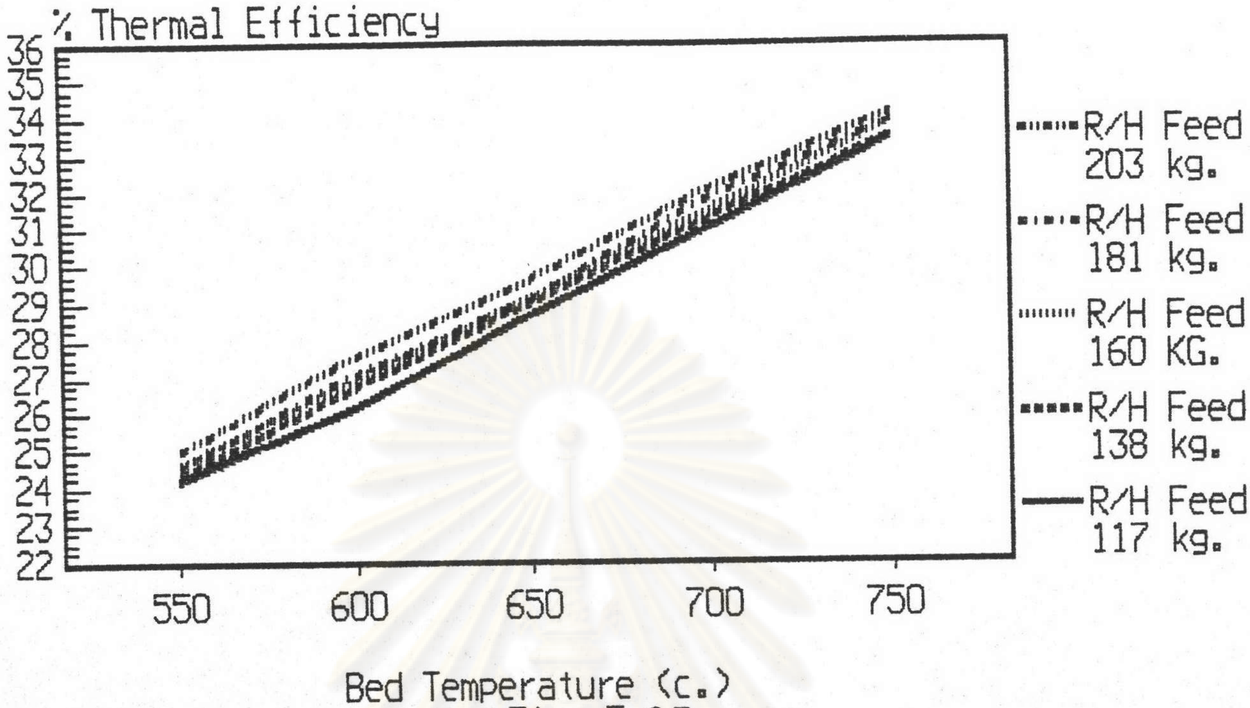


Fig. 5.23

Graph of Bed Temp. vs. Heat Accumulation
At 7 % Excess Air

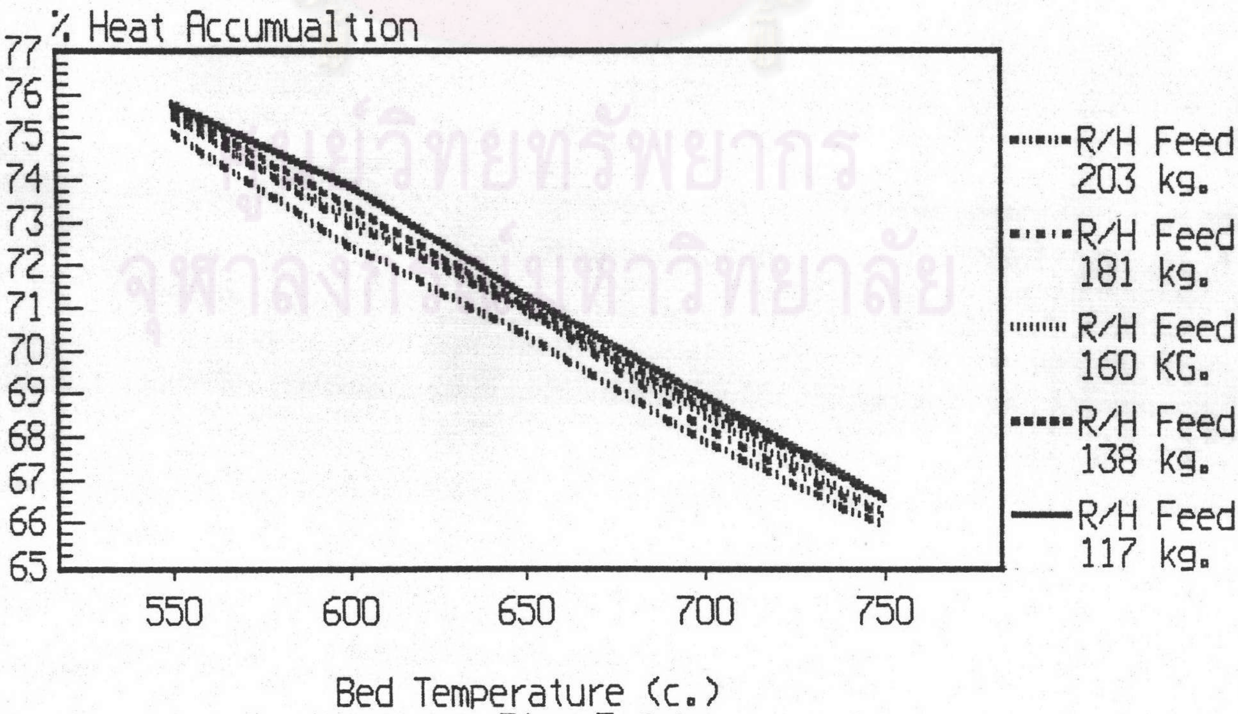


Fig. 5.24

Graph of Bed Temp. vs. Ther. Eff.
At 10 % Excess Air

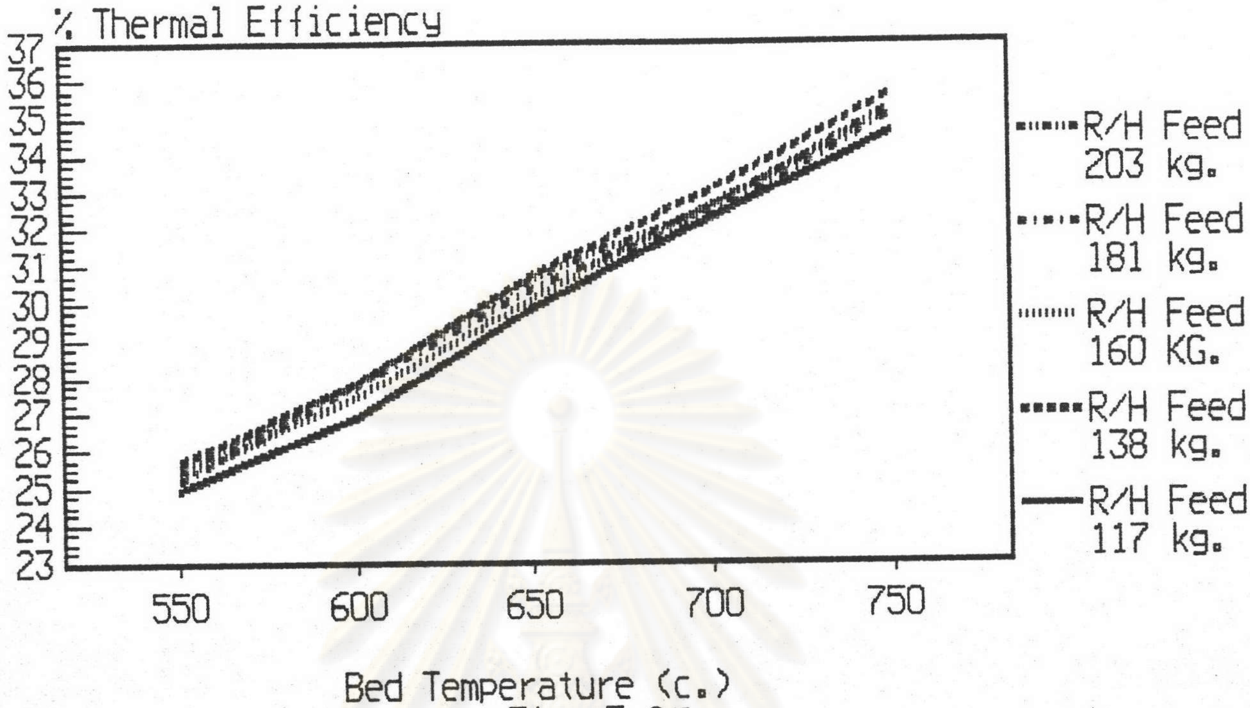


Fig. 5.25

Graph of Bed Temp. vs. Heat Accumulation
At 10 % Excess Air

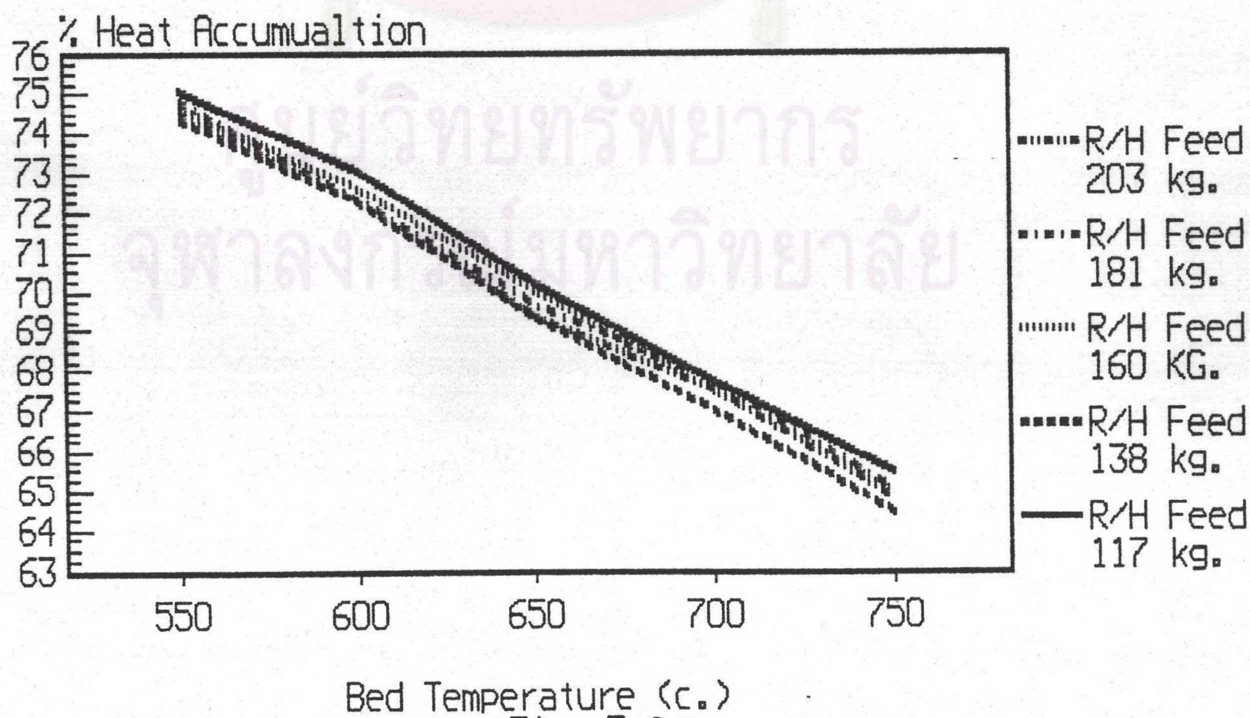


Fig. 5.26

Graph of Bed Temp. vs. Ther. Eff.
At 14 % Excess Air

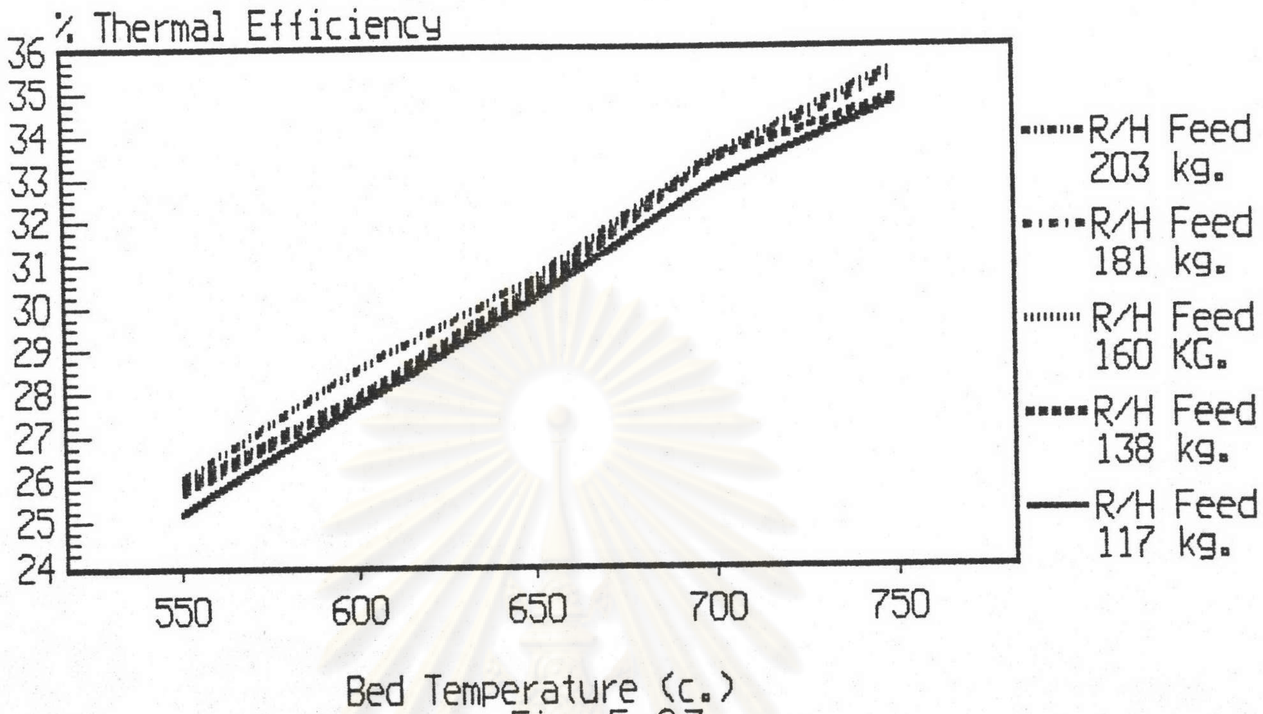


Fig. 5.27

Graph of Bed Temp. vs. Heat Accumulation
At 14 % Excess Air

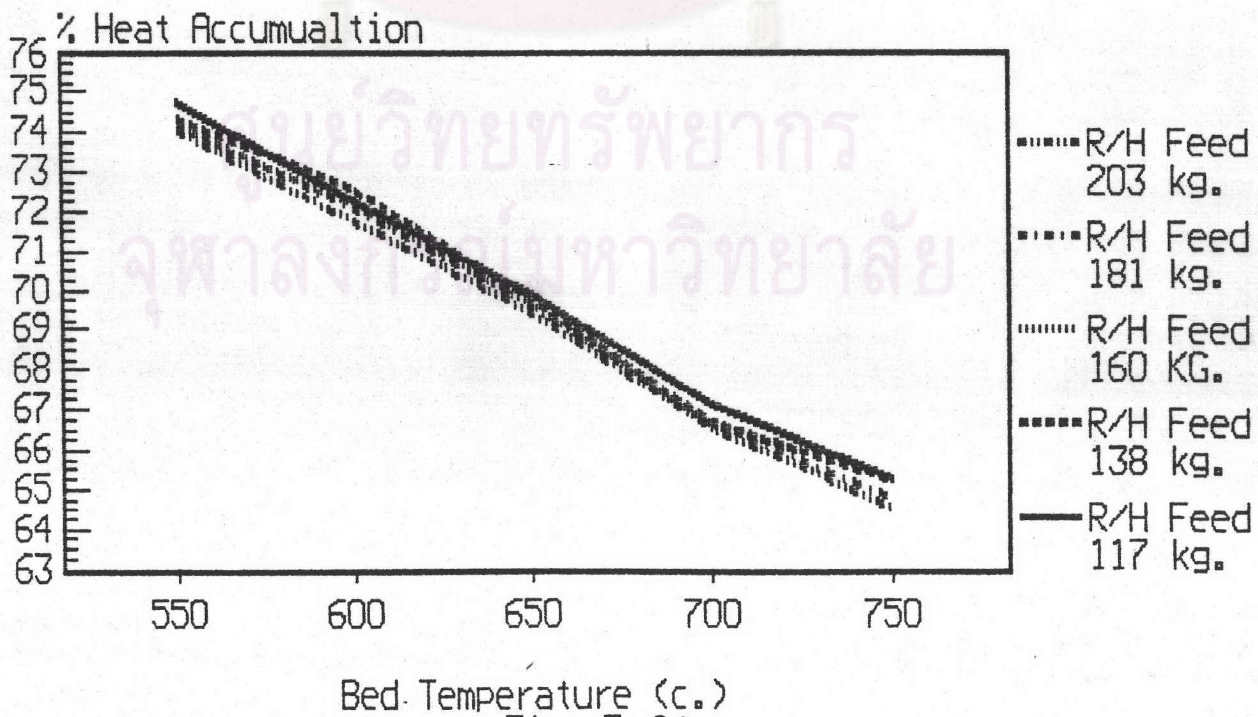


Fig. 5.28

Graph of Bed Temp. vs. Ther. Eff.
At 20 % Excess Air

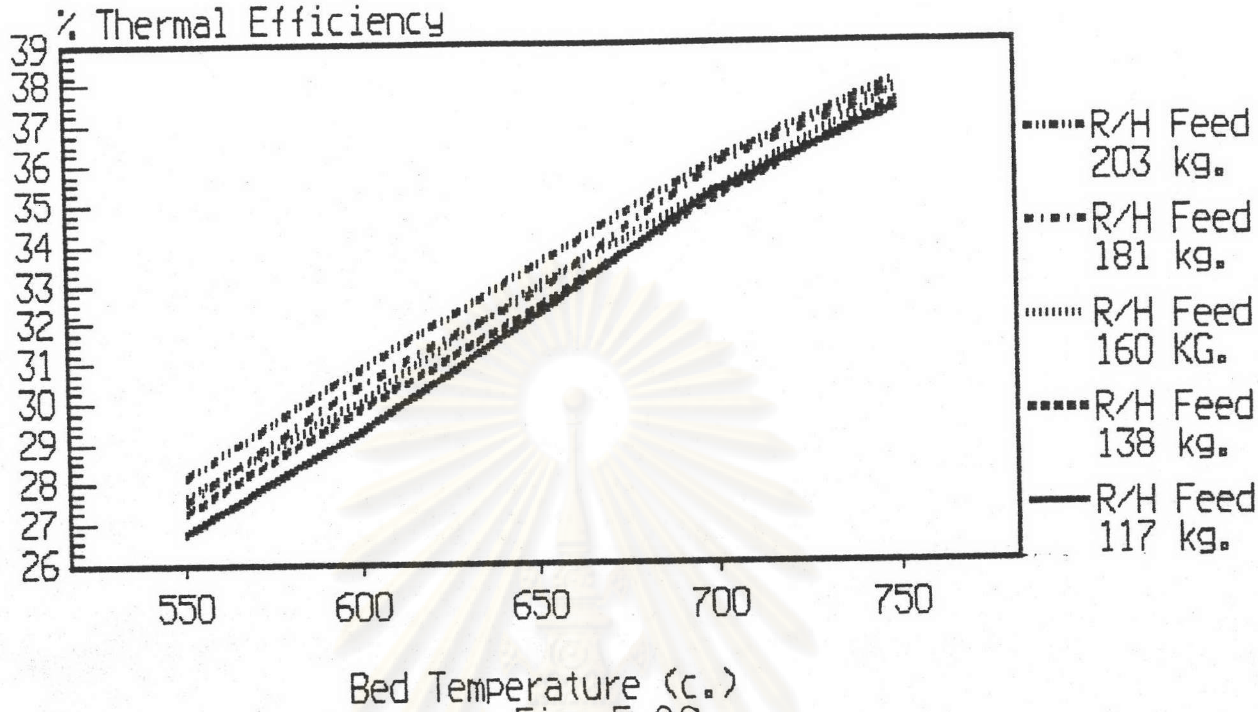


Fig. 5.29

Graph of Bed Temp. vs. Heat Accumulation
At 20 % Excess Air

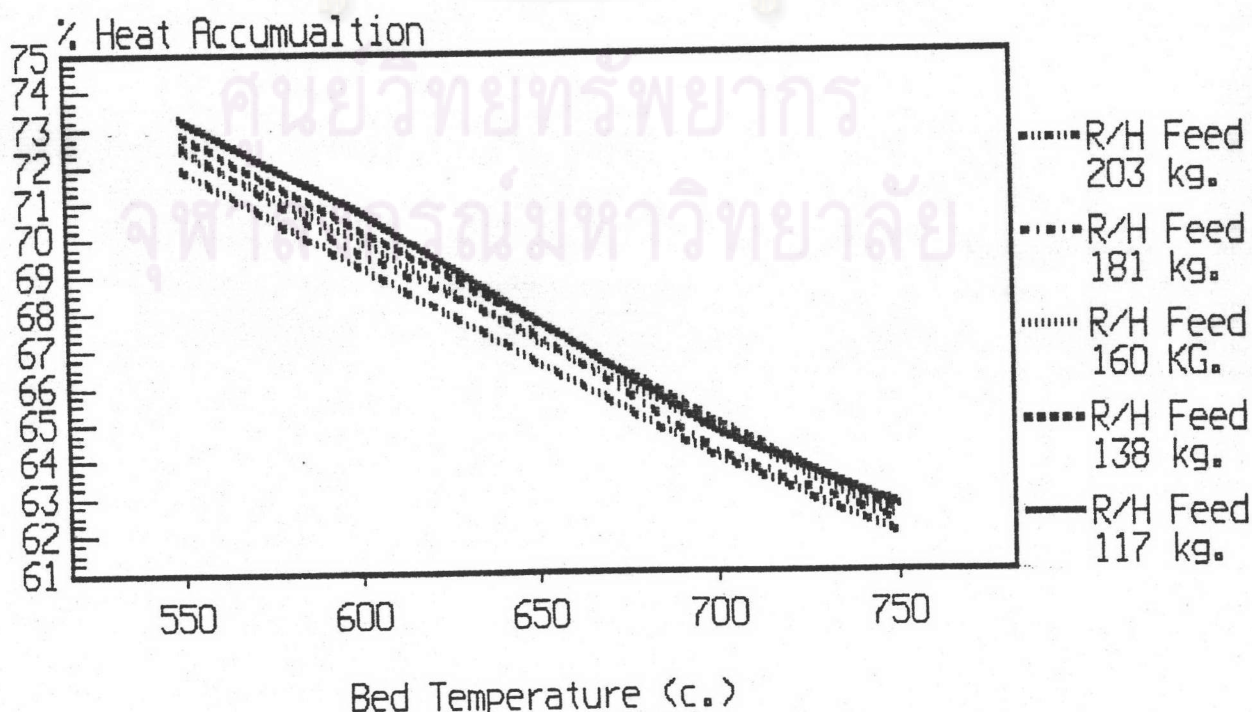


Fig. 5.30

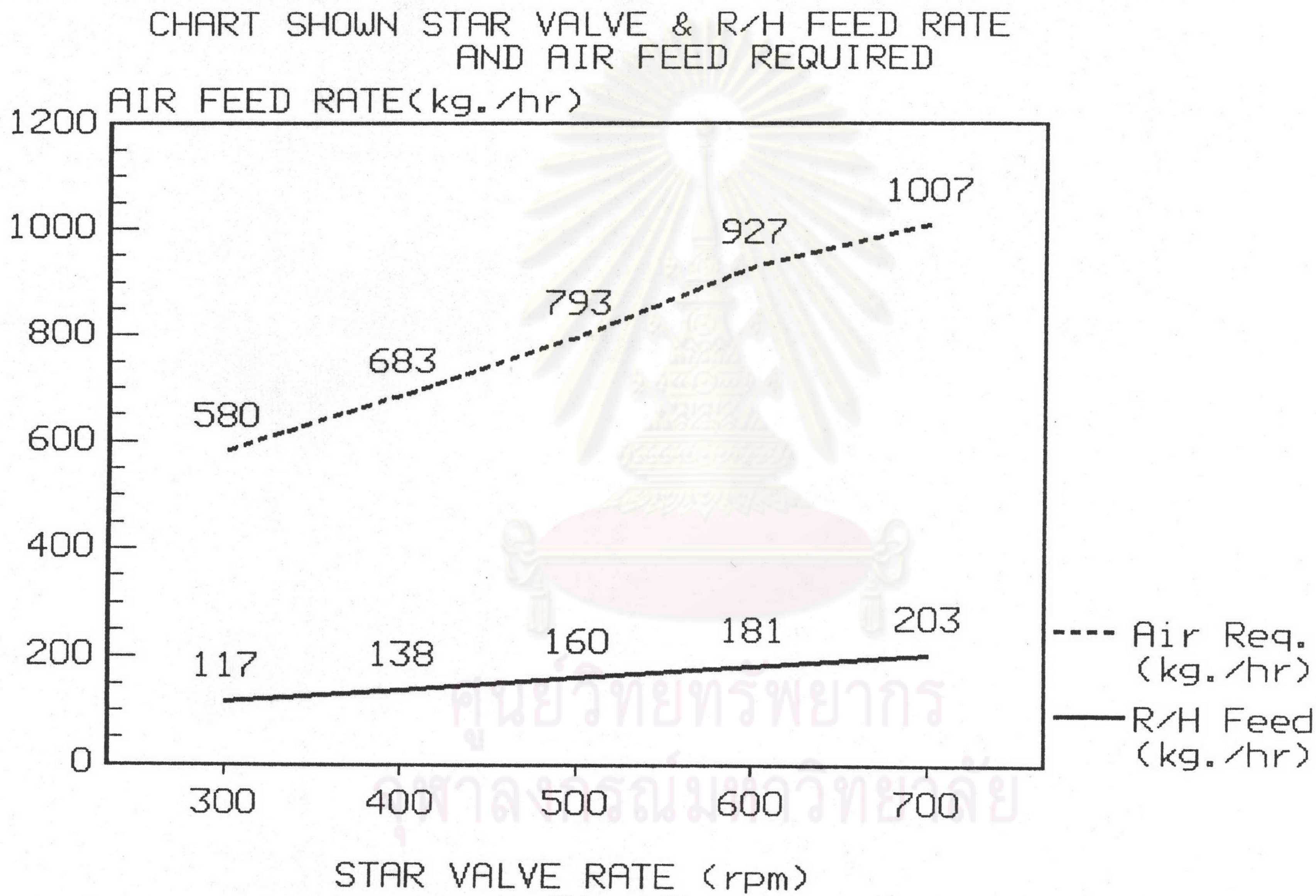


CHART SHOWN STAR VALVE & R/H FEED RATE
AND AIR FEED REQUIRED
AIR FEED RATE(kg./hr)
1200
1000
800
600
400
200
0
1007
927
793
683
580
203
181
160
138
117
Air Req.
(kg./hr)
R/H Feed
(kg./hr)
300
400
500
600
700
STAR VALVE RATE (rpm)

Fig. 5.31

5.5 Discussion of experiment result (not included heat start up)

From experiment the data are

- rice husk feed rate
- air feed rate
- temp of exit air (above bed)
- pressure in combustor

The pressure in combustor is atsmopheric by heat balance

Heat output + Heat accumulation = Heat input

Quit + Qacc = Q in

In this study, heat input is generated by a rice husk combustion so:

Q in = m_r (h.v.r)

m_r = mass of rice husk

h.v.r = heating (calorific) value of rice husk

From data table 5.10 at rice husk feed rate 117 kg/hr

Q in = 177*3658

= 427,986

Find Qout

Qout is heat carried over with exit gas (obove bed)

Q out = MC_p t.

at 7% excess air for 117 kg rice husk

t = 548-30 = 518

Q out = 715. * 0.28 * 518

= 104,000 k cal

So: Q accumulation = 323,986 k cal

Find % Thermal Efficieney of exit air

$$\% \text{ Ther. Eff} = \frac{\text{Qout}}{\text{Qin}} \times 100$$

$$= \frac{104,000}{427,986} \times 100$$

= 24.29

Find % Heat Accumulaltion

% Heat Acc = $\frac{Qacc}{Qin}$ x 100

= $\frac{323,986}{427,986}$ x 100

= 75.70

So that:

For 7% excess air

Rice Husk Feed rate	117	kg/hr
Exit Air Temperature	548	
% Thermal Effieiency	24.29	
% Heat Accmmulation	75.70	

For the other data, the calculations are too.

For data analysing , it provides graph of

- Rice husk feed rate vs% Thermal eff
- Rice husk feed rate vs% Heat acc

(for each % excess air)

- Temp (Over bed temp) vs% Thermal eff
- Temp (over bed temp) vs% Heat acc

(for each rice husk feed rate,)

By graph fig 5.11-5.20, while rice husk feed rate increased,% thermal eff. also increased slightly . By adjusting % excess air, it effected to % thermal eff. , while increasing % excess air, also it increased % thermal eff. and it is the same tendency for every combustion temperature.

It is explained that % thermal eff. is varied by air flowrate and temperature, so when air flow rate is increased (by changing % excess air), heat carried over with air is increaed also.

By graph fig 5.21-5.28 which bed temperature was increased, % thermal eff. also increared more.

% Accumalation as defined were the heat increasing the bed temperature slightly as followed calculation:

	Heat Accumulation	=	323,986	k.cal/hr.
	volume of sand bed	=	980	kg.
	specific heat of sand	=	0.191	kcal/kg.
so	sand will had temperature			
	rising up	=	29.03	°c./min

but ,truely there was slightly increasing of temperature because this heat accumulation occured due to heat carried with ash (fly ash and bed ash),so, the heat increasing exactly in bed was hardly detected. And the condition which done the experiment was the semi - steady state temperature.