18-5-6 Effect of the Desulfurizing Agents on Moldability

Past experience indicates that the blend of desulfurizing agents has no adverse effect on moldability, but slightly increases the strength up to a blending ratio of 30 percent. In the case of this project, the blending ratio of the desulfurizing agents falls within this range, and therefore the tablet tests on the effect of blending desulfurizing agents were not conducted. Throughout the experimental production, no adverse effect that might stem from the desulfurizing agents was noticed.

18-6 Test by the Bench-scale Plant

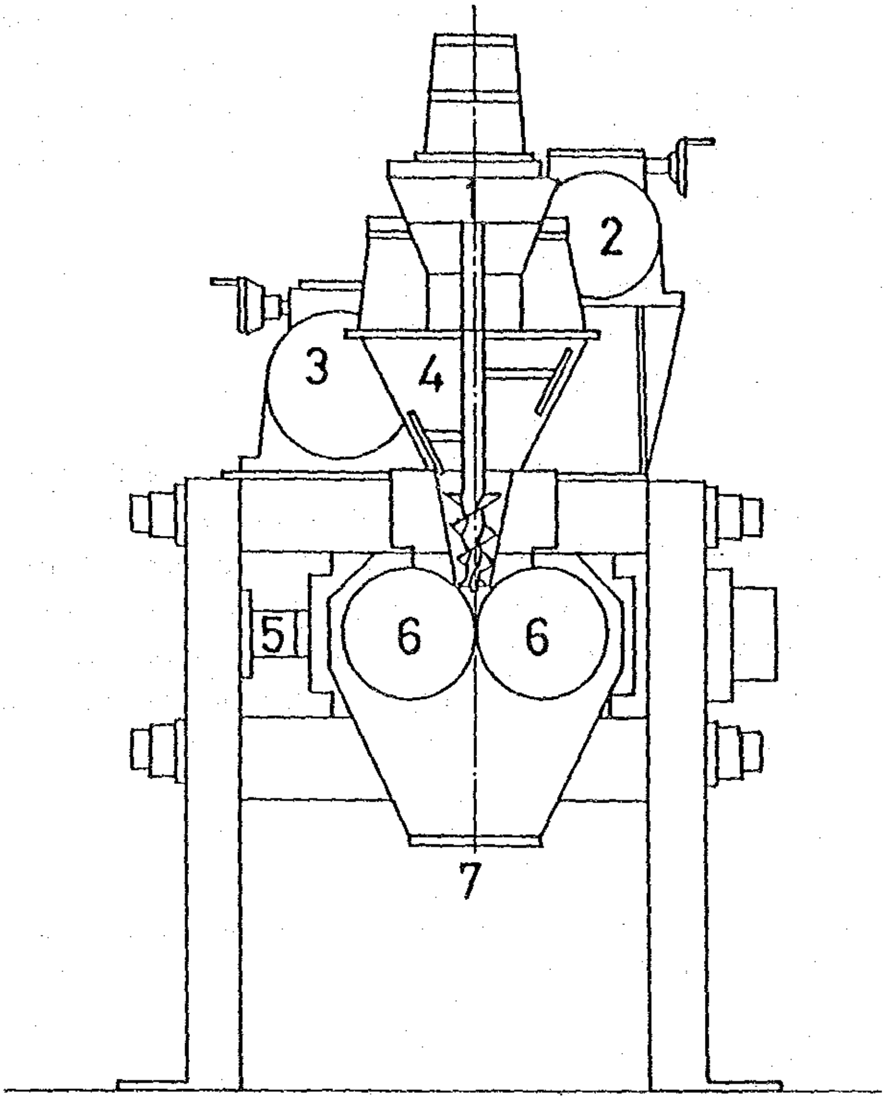
18-6-1 Bench-scale Plant

A bench-scale, high-pressure, roll-press briquetting machine was used; an outline sketch and the specifications are shown in Figure 18-17 and Table 18-12, respectively. The bench-scale plant is similar in specifications and capacity to that installed at the Fuel Test Center.

Table 18-12 Specifications of the Bench-scale Plant

Model number	K-123A
Roll diameter,mm	300
Roll thickness,mm	75
Roll pressure, kg/cm^2	165
Roll rotation, rpm	3.4 to 14
Feeder rotation, rpm	7.5 to 90
Motor, for the roll	5.5kw x 4P
Motor, for the feeder	3.7kw x 4P
Briquette dimensions,mm	37 x 21 x 12
Capacity, kg/hr	120 to 200

The samples of lignite and biomass both ground and crushed to predetermined sizes are blended in predetermined ratios. The blend is then mixed in a mixer equipped with a spiral ribbon at room temperature or while heated to a maximum of 80 C. A desulfurizing agent is added as necessary in the mixer; however, no other material like binder is added.



1 : Charging hopper
2 : Feeder drive motor
3 : Roll drive motor
4 : Screw
5 : Load cell
6 : Roll tyre
7 : Product outlet

Figure 18-17 Sketch of Pilot Briquetting Machine

The blended feed is fed into the hopper to the briquetting machine. Appropriate operating conditions are sought while producing the briquettes; once the operating conditions are set, the experimental production continues under these conditions. One operation cycle consumes 15 kilograms of the blended feed. One run of the experimental production consisted of one to three cycles, or produced 15 to 45 kilograms of briquettes.

18-6-2 Briquetting Condition

(1) Composition of the Raw Material

Based upon the results of the tests on the tablets, the standard blending ratio of the lignite to the biomass was determined to be at 80 to 20; the blending ratio was actually varied for the experimental production from 75 to 80 for the lignite and 20 to 25 for the biomass, in response to the moldability, strength and burning characteristics of the briquettes being produced. The desulfurizing agent was added at a ratio of 5 to 30 to each unit of 100 of the lignite/biomass blend.

(2) Particle Size

Based upon past experience, both lignite and biomass are ground or crushed to smaller than two millimeters.

(3) Moisture Content

The moisture content of the feed is known to have a significant influence upon the strength of the briquettes; therefore, the moisture content must be watched carefully. Dried biomass tends to absorb moisture and should be kept from doing so. Based upon previous experience, the biomass was dried to moisture contents of between four and seven percent, and lignite between four and 12 percent before the briquetting tests.

18-6-3 Results of the Briquetting Test

(1) High-quality Lignite

Table 18-13 lists the results of the experimental production for blends of the high-quality lignite and a single or mixed biomass. As may be expected from the lower Hardgrove Grindability Index, the moldability tends to be worse at room temperatures, 10 to 30 C, than the results on the feed with the low-quality lignite, as indicated in Table 18-14.

Table 18-13 Briquetting Test by Bench-scale Plant (High-quality Lignite)

No.	Raw Matl.	DSA	Moisture	Breaking Strength	Rotation Roll	Feeder	Remarks	Evaluation
6	H80,B20	0	-	129	7	57		A
45	H80,B20	T5	8.7	220	7	51	35C	A
50	H75,B25	T5	3.8	-	-	-	80C Not molded	C
35	H80,S20	T5	9.0	186	7	54-57	30C	B
4	H80,h20	0	-	68	7	51		B
21	H80,B10,h10	5	9.4	133	7	45		A
61	H80,B10,h10	10	9.4	119	7	42		A
62	H80,B10,h10	25	8.1	140	7	28		A
44	H80,B10,h10	T10	4.4	118	7	57	30C	A
39	H80,B10,h10	T10	4.4	131	7	45	50C	A
42	H80,B10,h10	T10	4.4	151	7	43	80C	A
24	H80,S10,h10	10	10.3	108	7	34		B
28	H80,S10,h10	T5	10.6	130	7	42		B

Note:

1. DSA, H, B, S, h, T stand for desulfurizing agent, high-quality lignite, bagasse, rice straws, rice husks and Thai lime. A, B, C in the column of evaluation represent good, fair and bad, respectively.
2. The biomass used are less than two millimeters in length except for Nos. 45 and 4 which used a biomass crushed to less than three millimeters in length.

The moldability improves with all the biomass when the feed is heated. Even with the biomass containing rice husks, higher temperatures improve the moldability as may be noted from the results of Sample Nos. 39, 42 and 44 which exhibit an increasingly greater breaking strength of 120, 130 and 150 Kgf at 30, 50 and 80 C, respectively. The temperatures to which the feeds were raised simulate the temperatures of the briquettes produced in a commercial plant; in a commercial plant the briquettes are raised to temperatures of 50 to 60 C by the friction heat generated when the feed is compressed under high pressures.

(2) Low-quality Lignite

Table 18-14 presents the results of the experimental production for blends of low-quality lignite and biomass in blending ratios similar to those for the high-quality lignite. The low-quality lignite is easier to mold than the high-quality lignite. The blends could be made into briquettes without heating with all three kinds of biomass.

Table 18-14 Briquetting Test by Bench-scale Plant (Low-quality Lignite)

No.	Raw Matl.	DSA	Moisture	Breaking Strength	Rotation Roll	Feeder	Remarks	Evaluation
12	L80,B20	0	-	130	7	45-56		B
32	L82.5,B17.5	0	7.9	112	7	67		B
29	L82.5,B17.5	T10	7.8	154	7	49		A
13	L80,S20	0	-	80	7	45-56		B
37	L80,S20	T10	7.8	180	7	45-85	30C	A
38	L80,S20	T10	7.1	204	4.5	45-85	80C	A
14	L80,B10,h10	0	-	64	7	51-57		B
15	L80,B10,h10	0	-	109	7	62-68		B
22	L80,B10,h10	10	7.8	98	7	57		B
22	L80,B10,h10	10	8.3	150	4.1	62		A
59	L80,B10,h10	10	6.4	127	7	49		A
60	L80,B10,h10	30	5.6	119	7	32		A
30	L80,B10,h10	T10	7.6	127	7	53		A
57	L80,B10,h10	T20	8.2	138	7	47		A
56	L80,B10,h10	T30	7.8	106	7	45		B
16	L80,S10,h10	0	-	73	7	62-68		B
31	L80,S10,h10	T10	7.9	123	7	56		A

Note:

1. DSA, L, B, S, h, T stand for desulfurizing agent, low-quality lignite, bagasse, rice straws, rice husks and Thai lime. A, B, C in the column of evaluation represent good, fair and bad, respectively.

From the foregoing discussions, the blending ratios which could make good briquettes are determined as shown in Table 18-15.

Table 18-15 Composition of the Raw Materials for the Briquettes

Lignite, less than 2 mm, wt%	80
Biomass, less than 2 mm, wt%	20
Desulfurizing agent, ratio to lignite plus biomass	0 to 30

18-7 Test by the Commercial Plant

18-7-1 Manufacturing Process of Coal Briquettes and Specifications

Table 18-16 gives the specifications of the commercial briquetting machine. This plant was built in 1985 in Hokkaido, Japan, to produce coal briquettes using coal and barks with a ratio of 75 to 25. The capacity of the plant is 1.25 tons per hour.

Table 18-16 Specifications of the Commercial Plant

Model number	K-209
Roll diameter,mm	520
Roll thickness,mm	236
Roll pressure, kg/cm^2	165
Roll rotation, rpm	10
Feeder rotation, rpm	9.9 to 39
Motor, for the roll	45kw x 6P
Motor, for the feeder	7.5kw x 4P
Briquette dimensions,mm	37 x 21 x 12
Capacity, kg/hr	1,250 to 1,200

The product briquettes are used as household fuel. The representative analyses of the products are shown in Table 18-17.

Table 18-17 Analysis of the Commercial Product

Sample	Product 1986		Product 1988	
Base	Wet	Dry	Wet	Dry
Moisture,%	6.6	-	1.9	-
Ash,%	9.6	10.3	12.1	12.3
Volatile matter,%	48.6	52.0	36.6	37.3
Fixed carbon,%	35.2	37.7	49.6	50.4
Gross heating value, kcal/kg	5,910	6,328	6,347	6,470
Sulfur,%				
Total		0.23		
Incombustible		0.10		
Combustible		0.13		
Carbon,%	59.9		66.9	
Hydrogen,%	4.7		4.5	
Nitrogen,%	1.1		1.0	
Oxygen,%	18.0		13.4	
Specifications				
Shape	Almond			
Gross heating value, kcal/kg	5,800 to 6,200			
Ash, wt%	10 to 15			

18-7-2 Test by the Commercial Plant

Table 18-18 shows the blending ratios of the feeds, briquetting conditions and breaking strength of the briquettes. It may be noted that briquettes of good quality may be produced in the blending ratios specified in Table 18-15, as was the case with the tests by the bench-scale plant. Thus, it has been confirmed that the intended briquettes may be produced on a commercial scale by maintaining the blending ratio of the raw materials in an appropriate range.

Table 18-18 Briquetting Test by the Commercial Plant

No.	Raw Matl.	DSA	Moisture	Breaking Strength	Rotation Roll	Rotation Feeder	Evaluation
1	H80,B20	0	10.8	92	10	39	B
6	H82.5,B17.5	0	13.1	72	10	39	B
14	H82.5,B17.5	T5	6.2	91	10	24	B
23	H80,B20	T5	8.7	104	10	26	B
27	H78,B22	T5	12.1	162	10	36.5	A
2	H80,S20	0	10.6	105	10	36.5	B

Table 18-18 Briquetting Test by the Commercial Plant (Continued)

No.	Raw Matl.	DSA	Moisture	Breaking Strength	Rotation Roll/Feeder		Evalua-tion
17	H80,S20	T5	6.8	120	10	21-22	A
3	H80,h20	0	11.4	44	10	36.5	B
8	H80,B12.5,h7.5	T5	11.8	108	10	32	B
15	H80,B12.5,h7.5	T5	5.9	101	10	29.5	B
5	H80,S10,h10	0	10.5	113	10	36.5	B
9	H80,B12.5,h7.5	T5	12.6	90	10	29.5	B
10	L82.5,B17.5	T10	8.4	128	10	29.5	A
18	L80,B20	T10	8.7	136	10	24	A
20	L80,h20	T10	7.6	143	10	23	A
22	L80,h20	T10	8.5	65	10	21.5	B
17	L80,B12.5,h7.5	T10	8.4	113	10	24.5	B
13	L80,B10,h10	T10	7.6	143	10	24	A
12	L82.5,S12.5, h7.5	T5	8.9	114	10	21	B
21	L82.5,S10,h10	T10	7.4	82	10	21.5	B

Note:

1. DSA, H, L, B, S, h, T stand for desulfurizing agent, high-quality lignite, low-quality lignite, bagasse, rice straws, rice husks and Thai lime. A, B, C in the column of evaluation represent good, fair and bad, respectively.

18-8 Analysis of the Briquettes

Table 18-19 shows the analyses of the briquettes produced with varying blending ratios. The samples may be viewed with the following groups: (6, 19), (25, 26), (9, 21, 20, 61, 62), (10, 24), (23, 22, 58, 59, 60) and (57, 56).

Table 18-19 Analysis of the Lignite Briquettes

No.	Raw Matl.	DSA %	MT %	Ash %	VM %	FC %	HV	TS %	IS %	CS %
6	H80,B20	0	8.5	11.5	46.6	33.4	5,160	0.78	0.27	0.51
19	H85,B15	0	9.0	8.8	45.8	36.4	5,440	0.94	0.23	0.71
25	H82.5,B17.5	0	8.9	8.4	46.6	36.1	5,380	0.85	0.34	0.51
26	H82.5,B17.5	T5	9.2	10.8	45.6	34.4	5,160	0.81	0.47	0.34
9	H80,B10,h10	0	8.5	14.5	43.8	33.2	4,980	0.81	0.27	0.54
21	H80,B10,h10	5	8.7	13.4	44.8	33.1	5,070	0.83	0.67	0.16
20	H80,B10,h10	10	8.0	16.0	43.8	32.2	4,890	0.80	0.67	0.13
61	H80,B10,h10	10	7.3	17.0	43.4	32.3	4,820	0.72	0.62	0.10

Table 18-19 Analysis of the Lignite Briquettes (Continued)

No.	Raw Matl.	DSA %	MT %	Ash %	VM %	FC %	HV	TS %	IS %	CS %
62	H80,B10,h10	25	6.1	24.1	41.7	28.1	4,290	0.58	0.56	0.02
27	H80,B12.5,h7.5	5	9.1	11.6	45.7	33.6	5,080	0.80	0.46	0.34
10	H80,S10,h10	0	8.0	17.0	42.5	32.5	4,860	0.80	0.31	0.49
24	H80,S10,h10	10	8.2	12.2	42.8	31.8	4,780	0.82	0.75	0.07
12	L80,B20	0	5.3	19.0	45.4	30.3	4,940	1.60	0.46	1.14
29	L82.5,B17.5	T10	7.4	24.7	43.0	24.9	4,370	1.36	0.80	0.56
15	L80,B10,h10	0	7.5	18.1	44.9	29.5	4,970	1.60	0.44	1.16
23	L80,B10,h10	5	7.0	24.3	43.0	25.7	4,540	1.33	0.92	0.41
22	L80,B10,h10	10	6.3	27.0	42.8	23.9	4,320	1.27	1.01	0.26
58	L80,B10,h10	15	5.7	30.1	41.3	22.9	4,110	1.16	0.92	0.24
59	L80,B10,h10	15	5.3	30.1	41.8	22.8	4,140	1.31	1.13	0.18
60	L80,B10,h10	30	4.9	35.4	40.7	19.0	3,680	1.15	1.01	0.14
57	L80,B10,h10	T20	5.9	29.7	44.1	20.3	3,950	1.09	0.79	0.30
56	L80,B10,h10	T30	5.9	29.7	42.0	22.4	4,140	1.09	0.96	0.13
30	L80,B12.5,h7.5	T10	7.0	25.5	40.0	27.5	4,300	1.28	0.74	0.54
31	L80,S12.5,h7.5	T10	7.4	26.3	42.3	24.0	4,240	1.29	0.90	0.39

Note:
DSA: Desulfurizing agent — H: High-quality lignite
L: Low-quality lignite — B: Bagasse
S: Rice straws — h: Rice husks
T: Thai slaked lime — MT: Moisture
VM: Volatile matter — FC: Fixed carbon
HV: Gross heating value, kcal/kg — TS: Total sulfur
CS: Combustible sulfur — IS: Incombustible sulfur

The comparisons of the analyses within the same groups lead to the following generalization:

(1) The addition of a desulfurizing agent decreases the levels of combustible sulfur.

(2) For these raw materials and blends, the addition of slaked lime at 25 percent would achieve maximum desulfurization as far as is practical.

(3) Slaked lime is more effective than calcium carbonate in desulfurization at a practical addition ratio of 10 percent.

The desulfurization rates are calculated to be 56.6, 78.9, 66.3, 76.7 and 80.4 for test numbers 20, 21, 29, 31 and 22, respectively. The rate of desulfurization ranges from 60 to as high as 85 percent.

18-9 Analysis of the Ash

Samples of ash from the lignites and briquettes were analyzed by emission spectrometry for heavy metals and by atomic absorption spectro photometry for chromium VI, hexa-valent chromium. Table 18-20 shows the analyses of the ash. Both lignites contained cadmium at less than five ppm which is the allowable limit for Japanese fertilizers. Cadmium was not detected in the ash from the briquettes. The calcium content was high in the ash from the briquettes, because the desulfurizing agent had been is added. Chromium VI was not detected. The ash showed pH values of about 12 when dissolved in water. As far as the analyses show, no hazard to the environment is anticipated from the ash.

Table 18-20 Analysis of the Ash

	High-quality lignite	Low-quality lignite	H-calorie lignite briquette	L-calorie lignite briquette
Cadmium, ppm	2.63	4.13	N.D	N.D
Total chromium, ppm	101.0	90.9	64.5	91.1
Calcium, %	3.0	2.3	23.6	20.5

18-10 Physical Properties of Lignite Briquettes

18-10-1 Resistance to Impact

To assess the ability of lignite briquettes to withstand rough handling, lignite briquettes placed in a bag were dropped on a steel plate from a height of 1.2 meters 10 times, and the percentage of broken briquettes was measured. This test was repeated three times; 12 to 15 percent were broken to pieces less than 14 millimeters. As a whole, the briquettes after this test could be burned like perfect ones for ordinal uses. The test method employed is a very severe one; it may therefore be judged that the lignite briquettes could well withstand normal transportation and storage.

18-10-2 Absorption of Moisture

Figure 18-18 shows the absorption of moisture over time by lignite briquettes placed in an environment maintained at 20 C and 95 percent relative humidity. The condition is more severe than normally expected over extended time.

The absorption rate of moisture, H, is given by the following equation:

$$H = (W - W_o)/W_o \times 100$$

where

- H: Absorption rate of moisture, %
- W: Weight of briquettes after absorption of moisture
- W_o: Weight of briquettes before absorption of moisture

18-10-3 Water Repellence

Lignite briquettes, if brought into direct contact with water, absorb water, swell and slake in a short time. An effective way to forestall this weakness is to coat the briquettes with wax. Lignite briquettes with a three percent wax coating and without a wax coating were exposed for 120 minutes to a simulated heavy precipitation of 50 millimeters per hour. The untreated briquettes collapsed in five minutes as water diffused into the inside, while the treated briquettes remained unchanged after 120 minutes of the test. The lignite briquettes, if coated with wax, could withstand becoming wet by rain during transportation and storage.

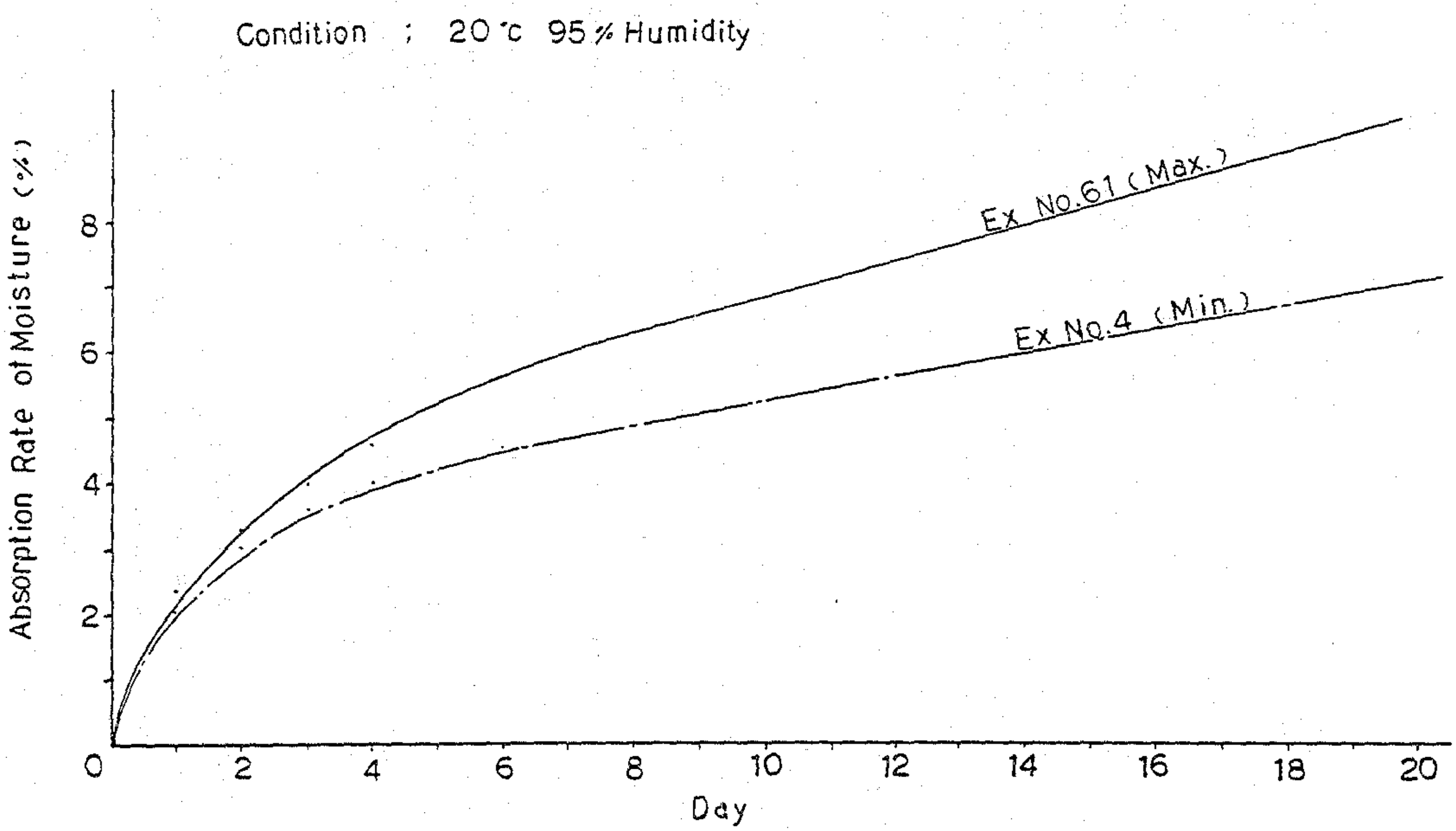


Figure 18-18 Moisture Absorption of Lignite Briquettes

18-11 Supplementary Experimental Production

As mentioned in Chapter 6, 6-2-3 (5) Safety, and also in Chapter 10, 10-5 Quality of Product, it was decided after the field survey of the second-stage study that the generation of smoke and soot should be reduced. Smoke and soot are normally generated during the initial stage of combustion from incomplete combustion of the volatile matter originally contained in the feed lignite and biomass. The potential users of lignite briquettes are accustomed to smoke and soot from biomass, or rice straws. The smoke and soot from lignite could be a problem. Therefore, it was decided that the manufacturing scheme will have a process to treat the feed lignite to remove a portion of the volatile matter. The process is partial carbonization, or partial destructive cracking, consisting in heating lignite in a closed vessel.

The operation conditions of this process were obtained by the supplementary experimental production done during the second-stage study. The experiment has three phases: (1) carbonization to obtain process conditions, (2) experimental production to confirm moldability of de-smoked lignite, and (3) burning tests to see the effect of the carbonization upon generation of smoke and soot. The experiment was difficult in that the optimum degree of carbonization suited to the Ban Pa Kha lignite must be identified. If carbonized excessively, the lignite would lose moldability and the burning quality would be impaired. On the other hand, if carbonized insufficiently, the lignite briquettes would generate too much smoke and soot. After a series of the experiments the following conditions were found best for the Ban Pa Kha lignite:

Temperature, degree Centigrade	250 to 300
Heating time, minutes	30
Blending ratio, weight	
Lignite	75
Rice straws	25
Slaked lime	10 to 30.

The lignite briquettes experimentally produced under the above conditions generate considerably lesser smoke and soot compared with those produced with untreated lignite. The burning tests were conducted in the common Thai clay cooking stoves.

Chapter 19 Burning Test

Chapter 19 Burning Test

19-1 Purposes of the Burning Test

The burning test was conducted for the following purposes:

(1) The burning test evaluated the quality of experimentally produced lignite briquettes with the tentative quality design as standard by actually burning them in stoves. When a sample of lignite briquettes failed to satisfy the tentative quality design, the conditions of the experimental production were adjusted to correct the deviation of the quality. The most important items of the tentative quality design which concerned the burning performance were as follows:

1) The lignite briquettes should burn well in the Thai clay cooking stoves commonly used by Thai people so that the lignite briquettes may be accepted by ordinary people.

2) The lignite briquettes must be easy to light in the Thai clay cooking stoves.

3) The lignite briquettes generate little smoke when burned in the Thai clay cooking stoves. However, during the initial five-minute period when the fire is still weak, the smoke can be tolerated in view of the open structure of the cooking places of common Thai houses.

That the lignite briquettes meet these three requirements is essential in terms of the feasibility of this project.

(2) A stove suited to the combustion of lignite briquettes was developed.

(3) In the light of the outcome of the above endeavor, recommendations should be presented for improvements to the Thai clay cooking stoves.

19-2 Achievements of the Burning Test

The burning test achieved the above objectives and produced the following results:

(1) The burning test confirmed that lignite briquettes nearly satisfying the tentative quality design could be obtained at the standard composition of the lignite at 80 percent, the biomass at 20 percent, and the desulfurizing agent at zero to 30 parts to 100 parts of the above blend.

(2) A cooking stove suited to burning lignite briquettes has been developed.

(3) Recommendations are made on making improvements to the Thai clay cooking stoves in the light of the outcome of the above endeavor.

19-3 Performance Test of Thai Clay Cooking Stoves

Thai clay cooking stoves should serve as the criteria to which the performance of the experimentally produced stoves are referred. The performance of Thai clay cooking stoves was evaluated by burning charcoal of Japanese origin and that of Thai origin, the analyses of which are shown in Table 19-1. The test measured the thermal efficiency of the stoves for boiling water and the concentration of carbon monoxide in the combustion gas. Three very common clay stoves of different sizes and one Japanese clay stove were used.

Table 19-1 Analysis of the Charcoal

	Thai charcoal	Japanese charcoal
Moisture, wt%	3.6	4.2
Ash, wt%	4.3	2.5
Volatile matter, wt%	11.0	17.3
Fixed carbon, wt%	81.1	76.0
Gross heating value, kcal/kg	7,340	7,340

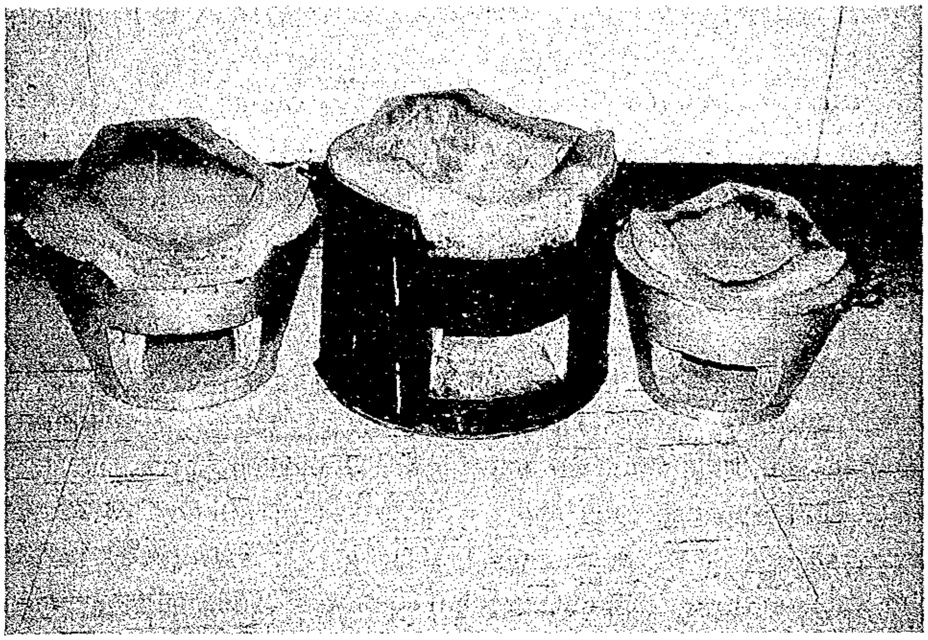


Photo 19-1 Thai Cooking Stoves

As kindlings, 90 grams of small wood sticks and 10 grams of paper were placed in the combustion chamber of the stoves. The kindlings were lit after a predetermined amount of charcoal was placed on them. A cooking pan containing 3.0 to 3.5 kilograms of water covered with a lid was placed on the stove ten minutes after the kindlings had been lit and the ignition of the charcoal had been confirmed. The cooking pan was 240 millimeters in diameter, and 109 millimeters deep, with a wall thickness of 0.65 millimeters. The cooking pan was made of aluminum alloy and conformed to JIS (Japan Industrial Standards)-2010s.

The test on thermal efficiency began when the pan was placed on the stove and ended when the water ceased to boil; this means that the heat generated during the initial ten minutes allowed for the fire to become strong was not absorbed by the water contained in the pan, and was not included in the calculation of the heat efficiency. The concentration of carbon monoxide was measured by gas detection tubes in the stream of the combustion gas which was flowing upwards along the side of the pan. The thermal efficiency is given by the following equation:

Thermal efficiency = $(A_o \times (100-T_o) + 539 \times V)/(F \times H) \times 100$

Where

A_o: Amount of water initially contained in the pan, kg

T_o: Initial temperature of the water, C

V : Vaporization loss of the water, kg

F : Amount of fuel consumed, kg

H : Net heating value, Kcal/kg

The burning test produced thermal efficiency rates as shown in Table 19-2. The Thai stoves yielded an average thermal efficiency of 30 percent with the Thai charcoal and 35 to 41 percent with the Japanese charcoal. The Japanese clay stoves exhibited efficiency rates as high as between 40 and 46 percent. Generally, higher efficiency rates were recorded when a larger amount of charcoal was used, because the heat required to heat the stove is nearly the same, irrespective of the amount of charcoal used. Although the heat contents of both types of charcoal were the same, the tests with the Japanese charcoal gave higher efficiency rates than those with the Thai charcoal. This is because the Thai charcoal burned so fast at the initial stage that a considerable amount of heat escaped without being absorbed by the cooking pan.

Table 19-2 Thermal Efficiency with Charcoal

Stove	Charcoal,grams	Thermal Efficiency, %
Japanese stove	200	40.6
	296	46.6
Thai stove, small	202(1)	32.5
Thai stove, medium	298	34.9
	302(1)	29.3
Thai stove, large	401(1)	30.3
	401	40.6

Note: (1) Thai charcoal is used.

The concentration of carbon monoxide in the combustion gas reached as high as 300 to 1,200 ppm, a level which could be dangerous. In Thailand, these kinds of clay stove are usually used where there is sufficient natural ventilation. In the case where these stoves are used in a closed space, frequent ventilation will be necessary.

19-4 Burning Test of Lignite Briquettes in Test Stove

To evaluate lignite briquettes as cooking fuel, the burning characteristics were observed.

19-4-1 Test Stove

Figure 19-1 shows the structure of the test stove. The stove is made of steel and measures 200 millimeters in diameter and 420 millimeters high. The stove is partitioned in the middle by a grate; the upper side is the combustion chamber and the lower side is the ash pit. A primary air inlet is provided on the side of the ash pit. The inner cylinder is 180 millimeters in diameter; the space between the outer and inner cylinders is filled with an appropriate insulator. A total of 102 holes are provided in three rows on the inner cylinder near the bottom. The upper two rows consist of nine millimeter holes, the lowest rows six millimeter holes. A perpendicular air pipe 45 millimeters in diameter and 55 millimeters long is provided at the center of the grate to draw air directly into the combustion chamber to assist combustion and thereby reduce the amount of smoke.

19-4-2 Testing Unit and Test Method

The testing unit, or the arrangement of instruments and the stove, is shown in Figure 19-2. The test measured the consumption of fuel, analyzed the exhaust gas, and measured the density of the smoke, the temperature of the exhaust gas and the length of the flame. The measurement methods were as follows:

(1) Length of the Flame

A measuring rule was posted by the stove. The length of the flames was measured by making observations against the rule.

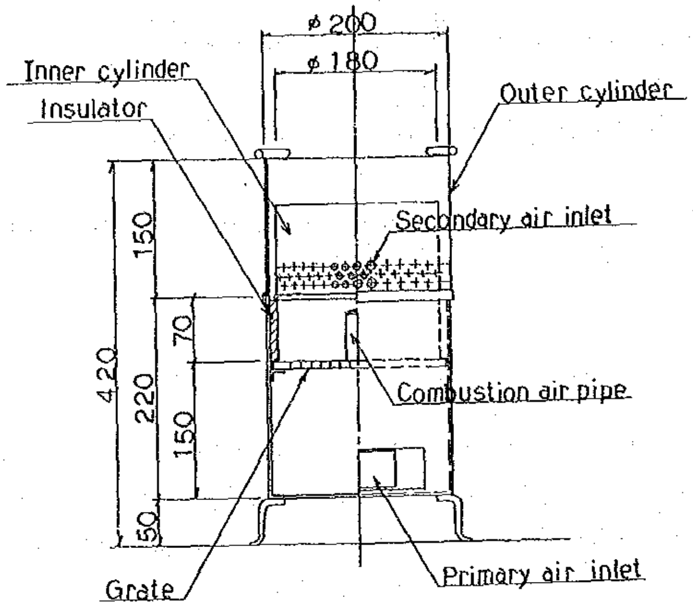


Figure 19-1 Test Stove

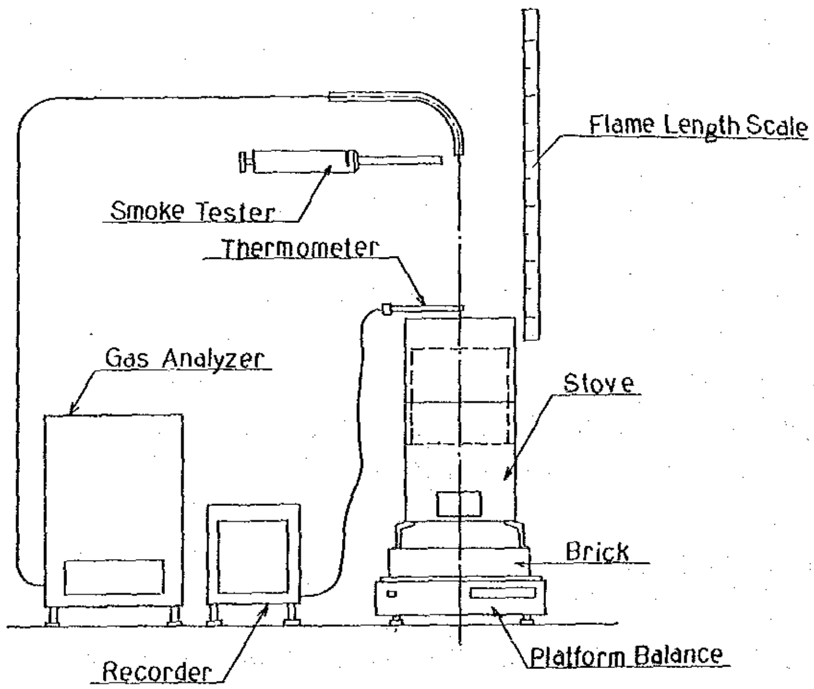


Figure 19-2 Arrangement of Instrument for Burning Test

(2) Density of the Smoke

A Bacharach true-spot smoke tester was used. Normally, this method is used for the exhaust from the combustion of petroleum products, and in such cases the sample is sucked in ten times. For this test, the sample was sucked in once. The density of the smoke is expressed as a smoke number which increases as the density of the smoke rises, as shown in Table 19-3. Samples were taken 30 centimeters above the upper side of the stove.

Table 19-3 Smoke Generation versus Smoke Number

Smoke Number	Smoke Generation
0	Not generated
1	Generated, but not discernible
2 to 3	Discernible
4 to 5	Disagreeable
6 to 9	Not tolerable

(3) Analysis of the Exhaust Gas

A gas analyzer and detection tubes were used to continuously monitor the concentrations of sulfur oxides, carbon monoxide and carbon dioxide. Samples were taken 30 centimeters above the upper side of the stove.

Each test burned 1,500 grams of lignite briquettes and 100 grams of kindlings -- 90 grams of small wood sticks and 10 grams of paper. They were placed in three layers; 1,300 grams of lignite briquettes at the bottom, 200 grams of lignite briquettes at the top, and the kindlings in between. The primary air inlet was wide open when the kindlings were lit. The samples of the lignite briquettes used for the burning test are shown in Table 19-4 in terms of composition and breaking strength.

19-4-3 Results of the Test

The evaluations of the selected samples are shown in Table 19-5. Figures 19-3 to 19-8 show the changes in the flame length, smoke number, combustion rate and the concentration of sulfur dioxide over time.

Table 19-4 Lignite Briquettes Used for the Burning Test

Sample No.	Composition		Breaking strength,kg
5	HC:B	80:20	91
10-1	LC:B:Ca	82.5:17.5:10	128
15	LC:B:RH	80:10:10	109
21	HC:B:RH:Ca	80:10:10:5	133
24	HC:RS:RH:Ca	80:10:10:10	108
27	HC:B:RH:Ca	80:12.5:7.5:5	117
29	LC:B:Ca	82.5:17.5:10	15
42	HC:B:RH:Ca	80:10:10:10	151
46	HC:B:Ca	80:20:5	170
56	LC:B:RH:Ca	80:10:10:30	106
57	LC:B:RH:Ca	80:10:10:20	138
58	LC:B:RH:Ca	80:10:10:15	121
59	LC:B:RH:Ca	80:10:10:15	127
61	LC:B:RH:Ca	80:10:10:10	119

Note:
HC, LC, B, RS, RH and Ca stand for high-quality lignite, low-quality lignite, bagasse, rice straws, rice husks and desulfurizing agent.

(1) Length of the Flame

At first, the lignite briquettes burned with a flame when the volatile matter was released. The length of the flame varied with the amount of the volatile matter released and the degree of mixing with air. Immediately after the kindlings were lit, the length of the flame extended for as long as 40 to 50 centimeters; it was actually the flame generated by the kindlings. When the lignite briquettes started to burn, the length of the flame was reduced to 5 to 30 centimeters. The flame was longer with the lignite briquettes made from high-quality lignites than with the lignite briquettes made from low-quality lignites. The addition of the desulfurizing agent reduced the length of the flame.

Generally, the lignite briquettes burned with a flame for an initial 20 to 30 minutes.

(2) Density of the Smoke

The density of the smoke was very high when the kindlings burned, but became low as the kindlings burned out. The smoke number ranged from one to three for the initial five to 15 minutes.

(3) Analysis of the Exhaust Gas

Of toxic gases, sulfur dioxide and carbon monoxide were measured. The concentration of sulfur dioxide averaged at 40 and peaked at 80 ppm with the lignite briquettes made from the high-quality lignite; whereas it averaged at 80 and peaked at 130 ppm with the lignite briquettes made from the low-quality lignite. The concentration was reduced to less than 30 ppm with the lignite briquettes containing the desulfurizing agent, attesting to the effect of the desulfurizing agent. The concentration of carbon monoxide ranged from 10 to 200 ppm when the lignite briquettes burned without a flame. This was lower than the concentration of carbon monoxide when charcoal was burned which recorded from 300 to 1,200 ppm.

Table 19-5 Evaluation of Burning Test

Sample	Flame	Smoke	SO_x	Overall
5	C	B	C	C
21	D	B	A	B
24	B	A	A	A
27	D	C	C	D
42	D	D	A	D
46	D	B	B	C
61	B	B	A	A
10-1	D	C	D	D
15	D	D	D	D
29	B	D	D	D
56	A	A	A	A
57	A	A	A	A
58	B	A	A	A
59	B	B	B	B

Note: A: Excellent; B: Good; C: Fair; D: Bad

It was observed that, by closing the air holes in the inner cylinder and admitting more secondary air from the bottom of the inner cylinder, the amount of smoke, as well as the duration of the flame generation, could be reduced. This is attributable to better mixing between the volatile matter and air.

The results of the tests indicate that the lignite briquettes made from Thai raw materials, except for Thai rice straws and rice husks which could not be imported, meet the quality standards and can serve as household fuel.

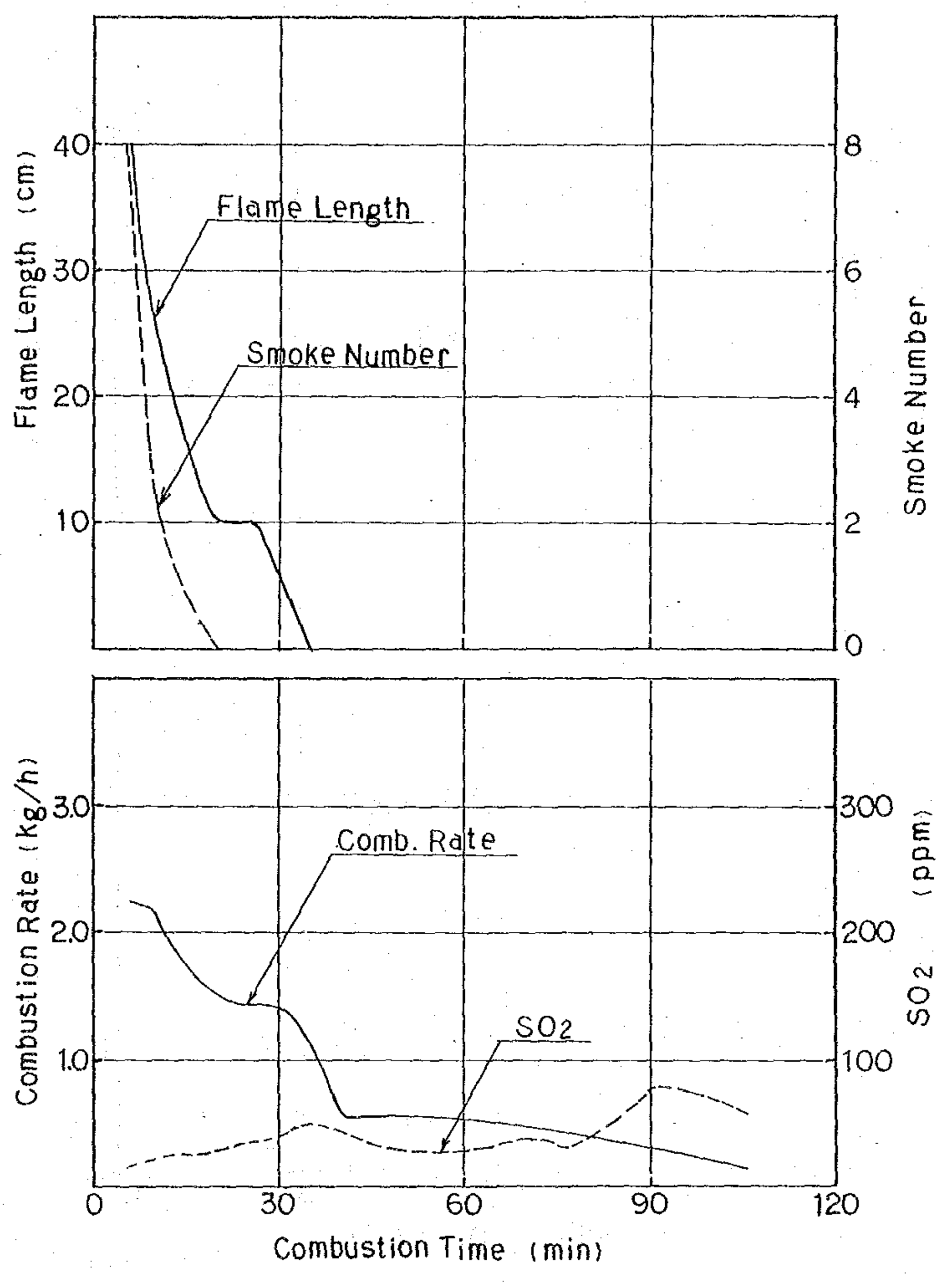


Figure 19-3 Flame Length, Smoke Number, SO_2, Combustion Rate
High-quality Coal:Bagasse = 80:20

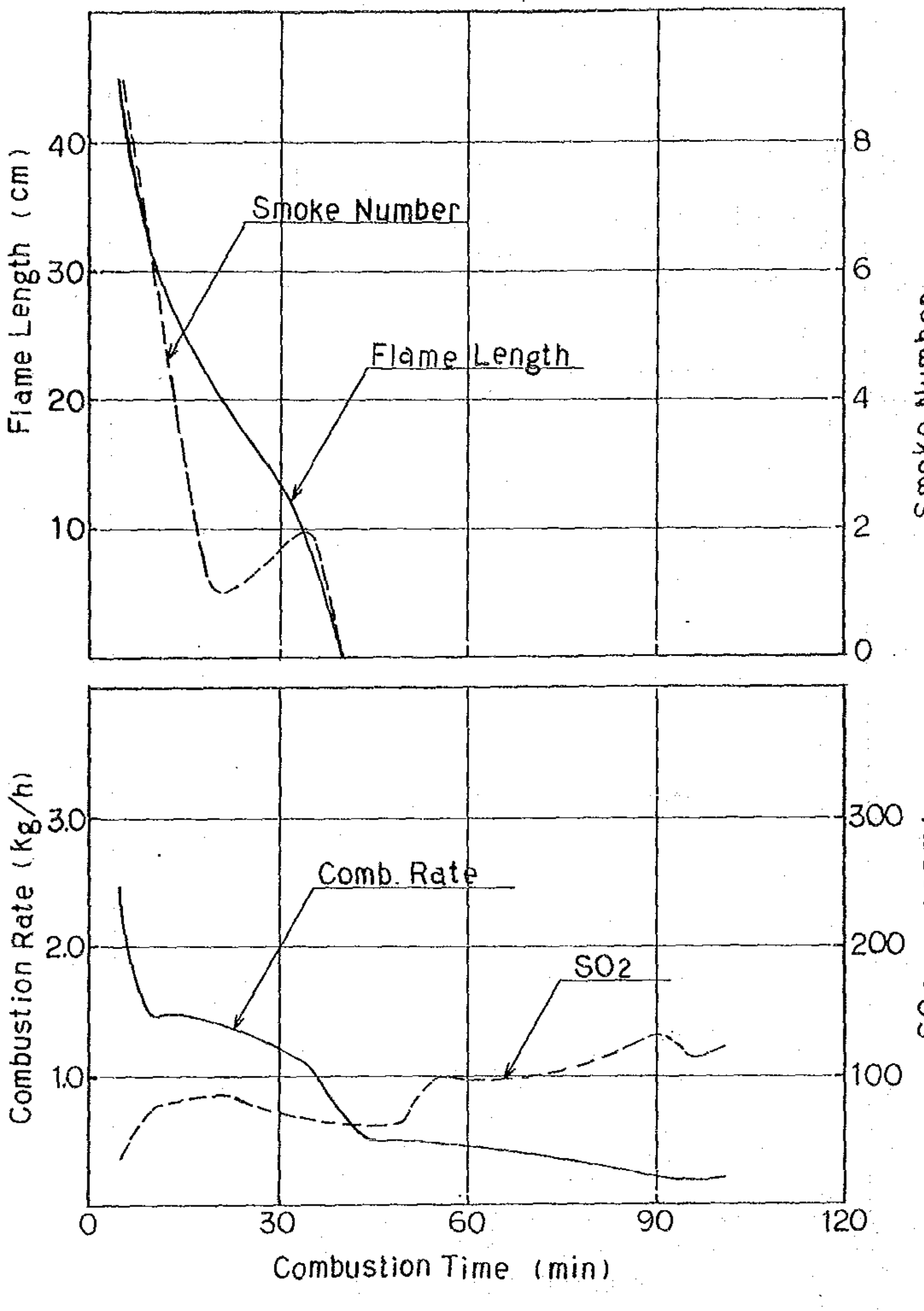


Figure 19-4 Flame Length, Smoke Number, SO_2, Combustion Rate
Low-quality Coal:Bagasse = 82.5:17.5

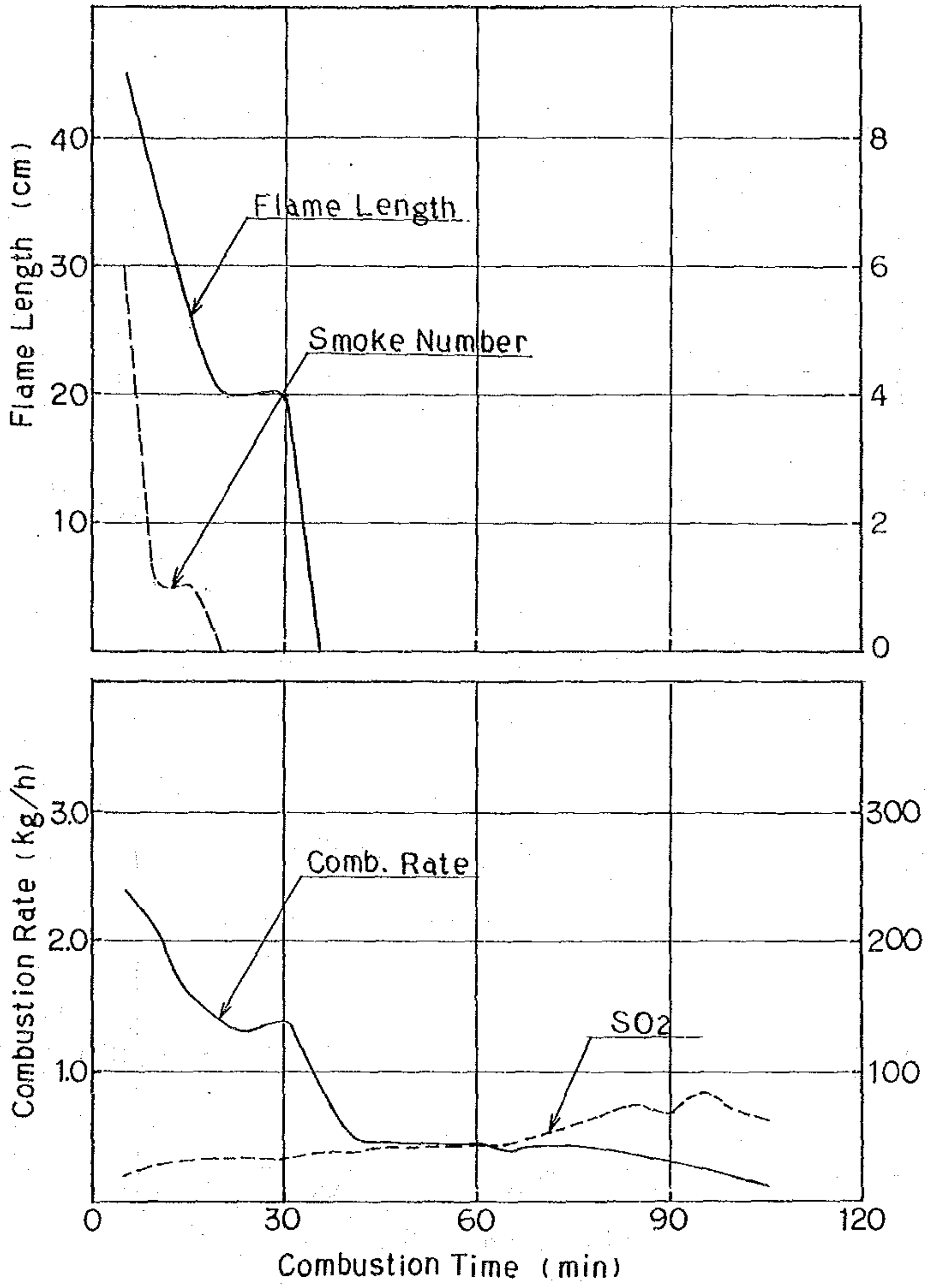


Figure 19-5 Flame Length, Smoke Number, SO_2, Combustion Rate
High-quality Coal:Bagasse:Rice husks = 80:10:10

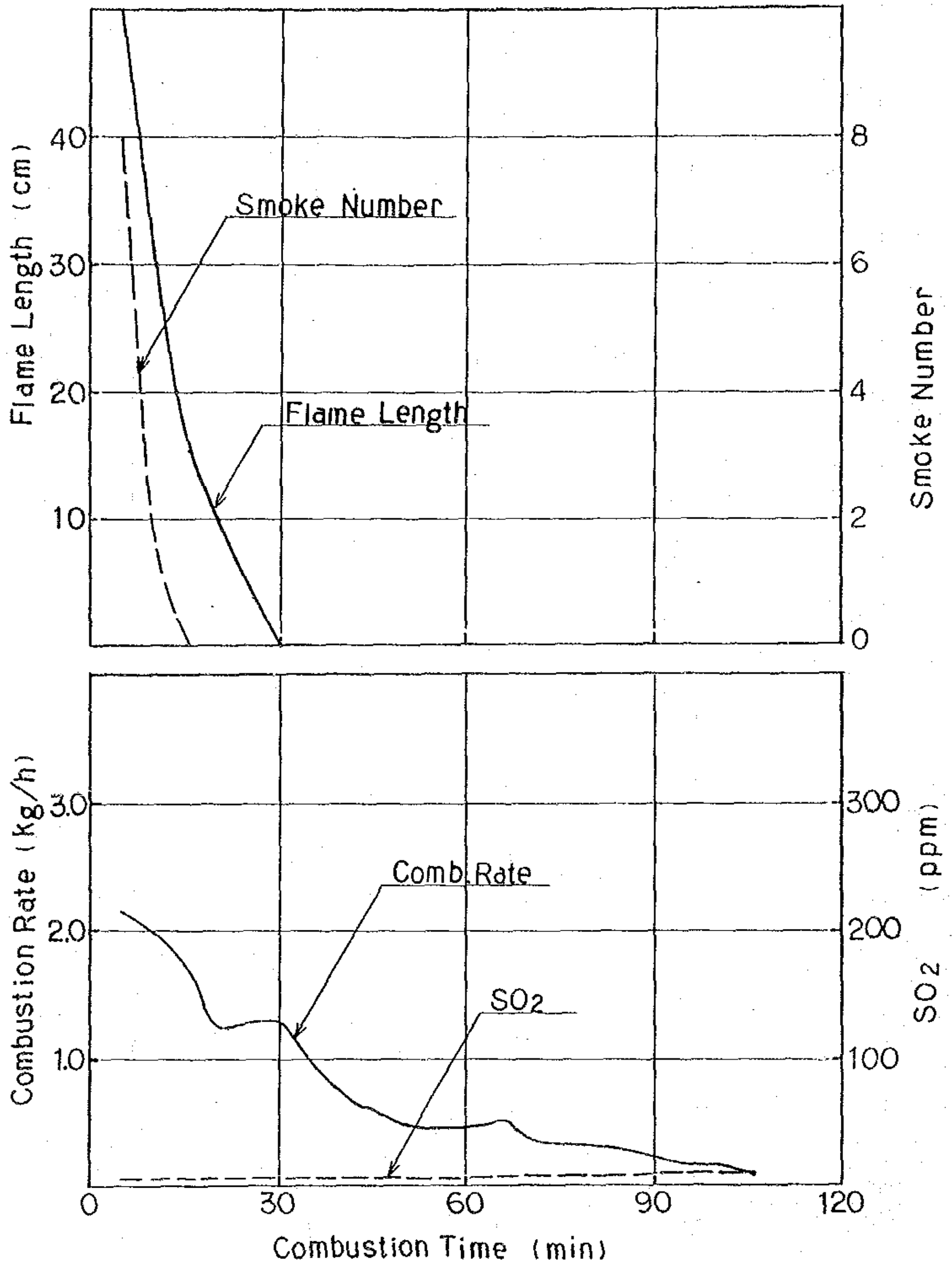


Figure 19-6 Flame Length, Smoke Number, SO_2, Combustion Rate
High-quality Coal:Rice straw:Rice husks:Slaked lime = 80:10:10:10

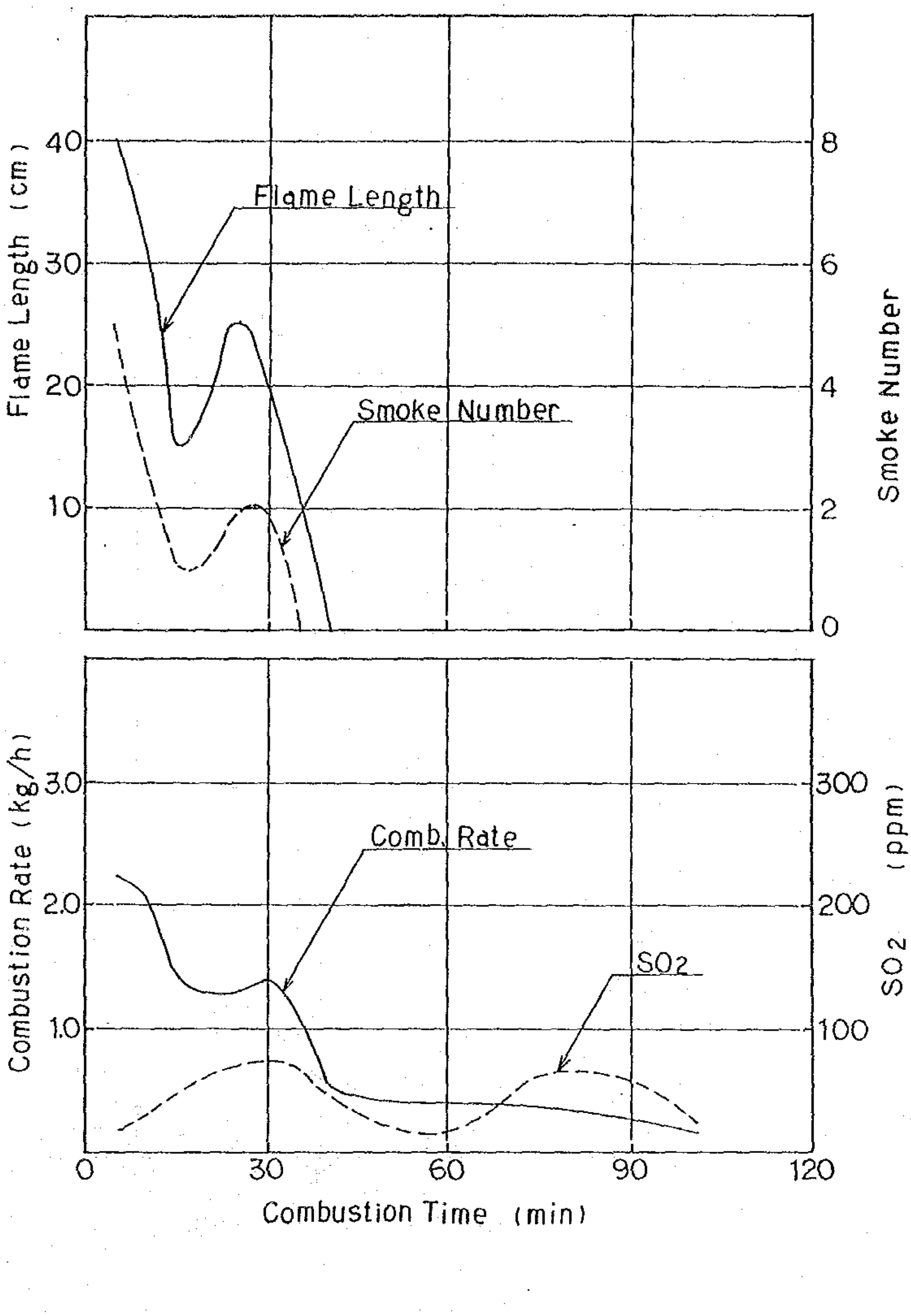


Figure 19-7 Flame Length, Smoke Number, SO_2, Combustion Rate
Low-quality Coal:Bagasse:Rice husks = 80:10:10

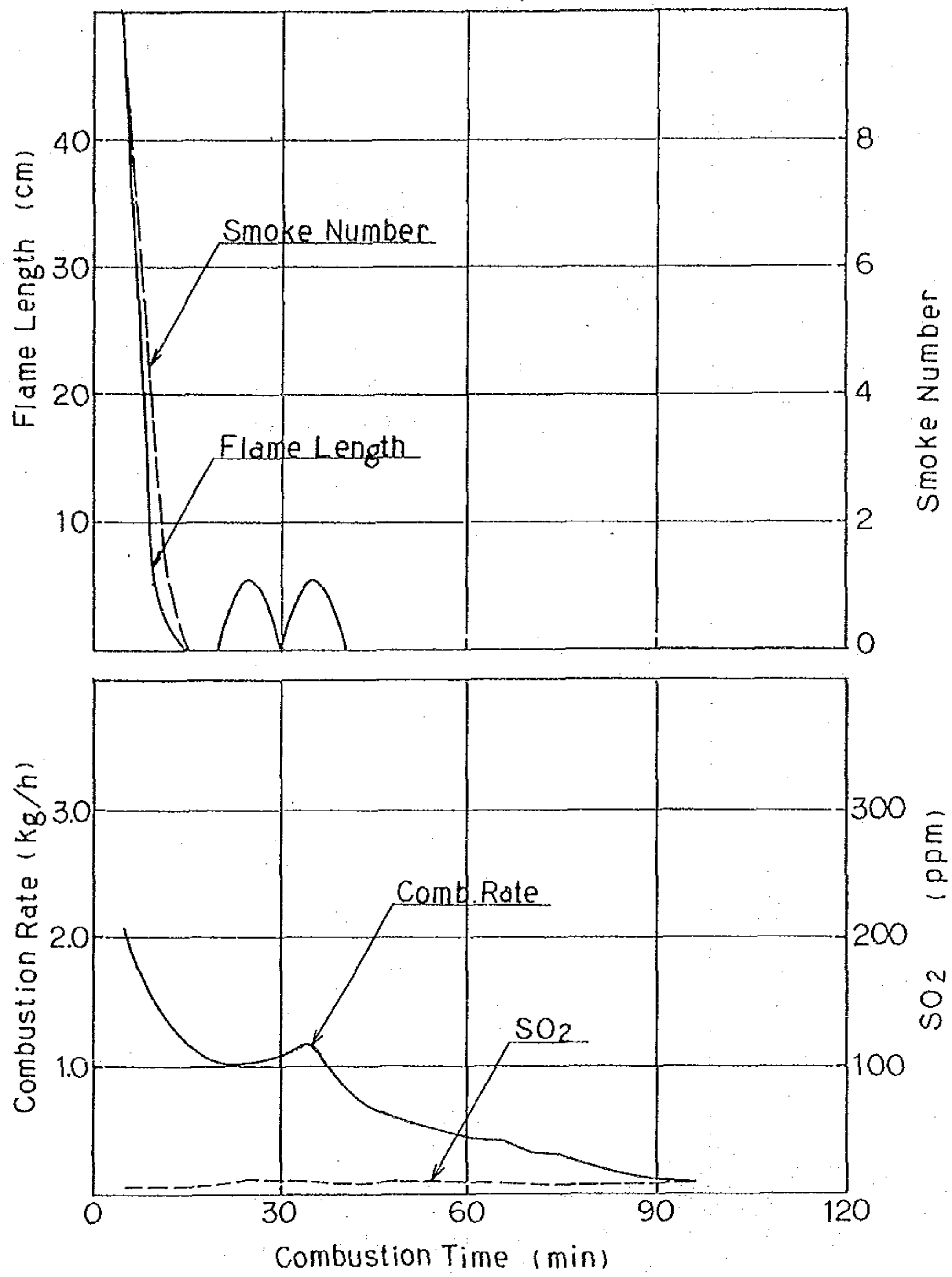


Figure 19-8 Flame Length, Smoke Number, SO_2, Combustion Rate
Low-quality Coal:Bagasse:Rice husks:Slaked lime = 80:10:10:20

19-5 Burning Test in Thai Stoves

The purpose of this test was to establish the evaluations of lignite briquettes in terms of compatibility with Thai stoves.

19-5-1 Test Method

The test is carried out in a manner basically similar to that for the test stove.

19-5-2 Results of the Test

It took five to ten minutes for the fire to become strong; in other words, the lignite briquettes failed to satisfy the tentative quality design of five minutes. Immediately after the ignition, smoke was generated due to incomplete combustion of the volatile matter and the kindlings. The amount of smoke, however, may be regarded as tolerable in view of the open structure of common Thai cooking places. When the volatile matter started to burn steadily, the amount of smoke subsided. After the volatile matter had been exhausted and the lignite briquettes burned like charcoal, no smoke was generated. From this, it may be concluded that, although not without problems, the lignite briquettes can be burned in Thai clay stoves.

However, with the following modifications, Thai clay cooking stoves would be better suited to burning lignite briquettes.

(1) The flows of the primary air and secondary air through the stove are improved, and a provision is made so that they can be controlled.

(2) The openings of the grate are enlarged.

(3) A cylinder is provided separately from the stoves to be placed upon the stove during the initial period of combustion in order to help the fire become strong quickly, thereby reducing the duration of the generated smoke.

To burn lignite briquettes better in Thai clay stoves, the use of a cylinder like those shown in Figures 19-9 and 19-10 is effective. These cylinders would help achieve the better combustion of fuels like lignite briquettes which contain a large amount of volatile matter. The cylinders shown in Figures 19-9 and 19-10 are of porcelain 215 and 180 millimeters in diameter, both equipped with secondary air inlets. These cylinders were actually tested and proved effective in reducing the generation of smoke.

19-6 Development of Stoves for Lignite Briquettes

The basic design concepts for the development of the stoves are as follows:

(1) A steel plate is used instead of clay to facilitate the production. However, the structure must be simple enough to enable small-scale Thai stove manufacturers to produce similar stoves from clay.

(2) The time required for one cooking cycle is assumed to be one to 1.5 hours; the combustion chamber should accommodate one to 1.5 kilograms of lignite briquettes to last for the same period.

(3) The stove should be well insulated to keep the temperature of the combustion chamber high so that the generation of smoke may be reduced and the thermal efficiency may be kept high.

(4) The upper half of the combustion chamber may be detached in order to realize the better transmission of heat to the pan when the briquettes begin burning without a flame.

The particulars of the five stoves developed on the basis of these design concepts are shown on Figures 19-11 to 19-16. These stoves have the following features.

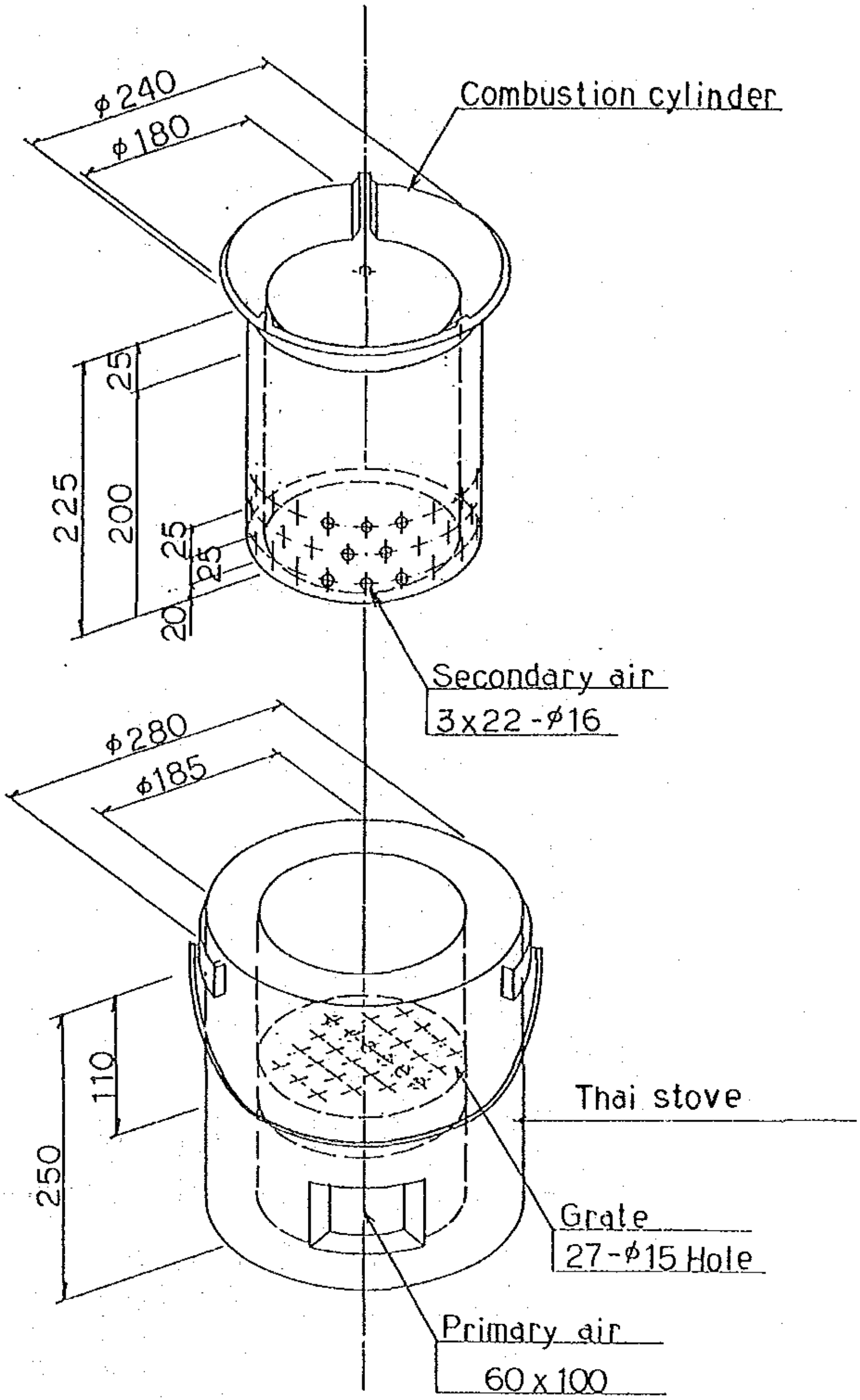


Figure 19-9 Type A Combustion Cylinder

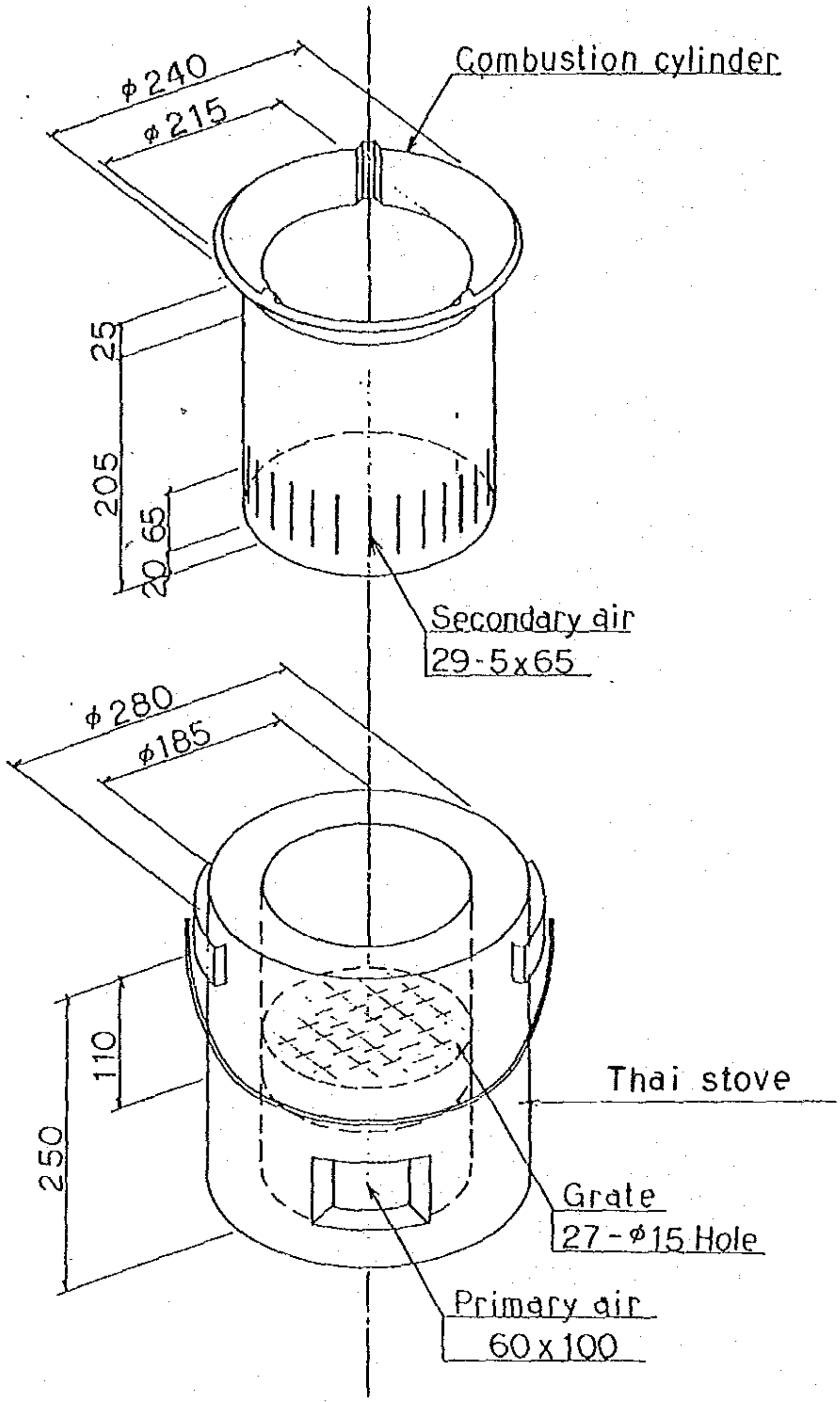


Figure 19-10 Type B Combustion Cylinder

19-6-1 Characteristic Features

(1) Casing

Insulation is provided between the casing and the combustion chamber to reduce the dissipation of heat to the atmosphere. Secondary air enters the combustion chamber from the side in the case of Stove A. In the case of Stoves B, C and D, secondary air enters from the skirt of the casing and ascends along the wall of the combustion chamber before entering the slits. As the air flows upwards along the wall, the air is preheated by the heat lost by the combustion chamber. Stove E admits air from the round holes in the wall of the cylinder. This design would help realize the better combustion of the volatile matter, and thus reduce the generation of smoke by not cooling the volatile matter.

(2) Secondary Air

Stoves A, B, C and D have perpendicular elongated rectangular secondary air inlets designed to promote the diffusion of air into the combustion chamber and thereby reduce the generation of smoke. Stove E has round inlets.

(3) Grate

The ratios of the openings range from 60 to 70 percent so as to draw sufficient air into the combustion chamber.

(4) Primary Air

In order to control the strength of the fire, the flow of the primary air is made controllable.

19-6-2 Major Differences among the Stoves

Figures 19-12 to 19-16 show the designs of the stoves developed for burning lignite briquettes. Stove A was first developed; Stoves B, C, D and E were subsequently produced to correct the drawbacks of the preceding designs, finally to arrive at the design of Stove E. Stoves A and B are single-pieces; Stoves C, D and E are separable. The separable stoves are designed to achieve higher rates of efficiency both during the combustion of both volatile matter and fixed carbon. The inlets of air are elongated rectangles from Stoves A to D but round for Stove E in order for it to be easy to make similar stoves from clay.

19-6-3 Performance of the Stoves

The performance of these stoves was tested by burning 1.0 to 1.5 kilograms of Sample Nos. 24, 56, 57, 58, 59, 60, 61, and 62 using the method described in 19-3, Performance Test of Thai Clay Cooking Stoves. Carbon monoxide and sulfur dioxide were measured using detection tubes. The rates of desulfurization were calculated from the sulfur in the fuel and that remaining in the ash.

(1) Density of the Smoke

Stove A generated a considerable amount of smoke at smoke number 3. This is presumably because the fire became so intense during the initial period, and this caused gasification of too much volatile matter at one time for it to burn well. Other stoves generated smoke at a smoke number from one to three at the most during the 10 to 15 minutes after the pan had been placed on the stoves. Afterwards, the smoke number dropped to nearly zero. It was found that if the clearance between the stove and pan is smaller than one centimeter, the smoke number can become as high as eight.

(2) Carbon Monoxide

The concentration of carbon monoxide in the combustion gas was less than 50 ppm when the volatile matter burned; it became as high as 300 ppm when the fixed carbon was burning.

(3) Rate of Desulfurization

Table 19-6 shows the rates of desulfurization. All tests showed rates of desulfurization higher than 70 percent except in one test. The smell of sulfur dioxide was not detected by the human sense. In the case where the rate of desulfurization was low at 47.1 percent, the temperature in the combustion chamber was too high for the sulfur dioxide to be caught. In actual cooking use, the level of the sulfur dioxide would not irritate the eyes or throat, and would not present practical problems.

Table 19-6 Rate of Desulfurization

Stove	Sample No.	Rate of Desulfurization
A	56	74.8
A	57	74.8
A	58	73.5
B	58	73.5
B	56	74.8
B	61	86.2
B	62	47.1
C	59	71.5
C	60	82.0
C	60	86.0

(4) Thermal Efficiency

Table 19-7 shows the rates of thermal efficiency of these stoves obtained by the burning tests. Stoves C, D and E yielded high rates of efficiency.

Table 19-7 Thermal Efficiency, %

No.	Stove	Sample No.	Sample kg.	Net heating value kcal/kg	Efficiency
1	A	56	1.35	3,880	28.2
2	A	56	1.5	3,950	28.3
3	A	58	1.5	3,840	33.1
4	B	58	1.5	3,840	27.2
5	B	56	1.5	3,880	23.4

Table 19-7 Thermal Efficiency, % (Continued)

No.	Stove	Sample No.	Sample kg.	Net heating value kcal/kg	Efficiency
6	B	61	1.0	4,540	24.2
7	B	62	1.483	4,020	21.8
8	C	60	1.0	3,430	30.4
9	C	60	1.0	3,430	33.5
10	C	59	1.0	3,880	35.8
11	D	61	1.5	4,540	31.0
12	D	61	1.5	4,540	34.2
13	D	59	1.5	3,880	31.8
14	D	41	1.5		33.3
15	E	57	1.265	3,950	29.0
16	E	41	1.0		34.1

Based on these results and the ease of making similar stoves in particular, the design of Stove E is recommended.

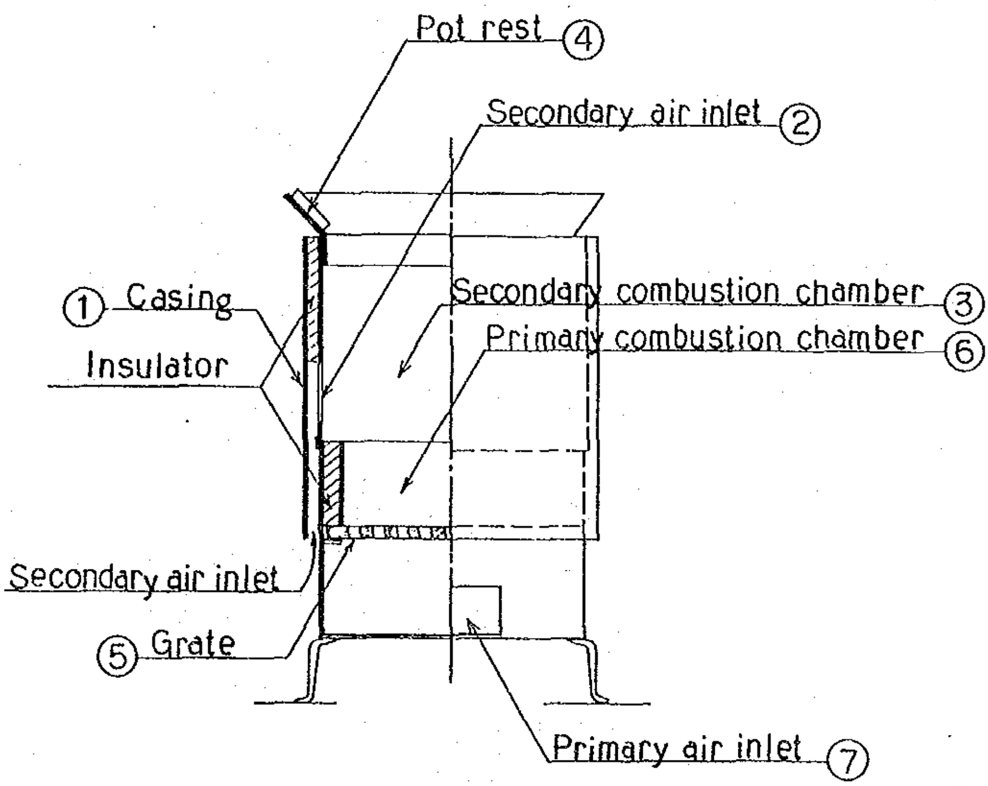


Figure 19-11 Trial Stove

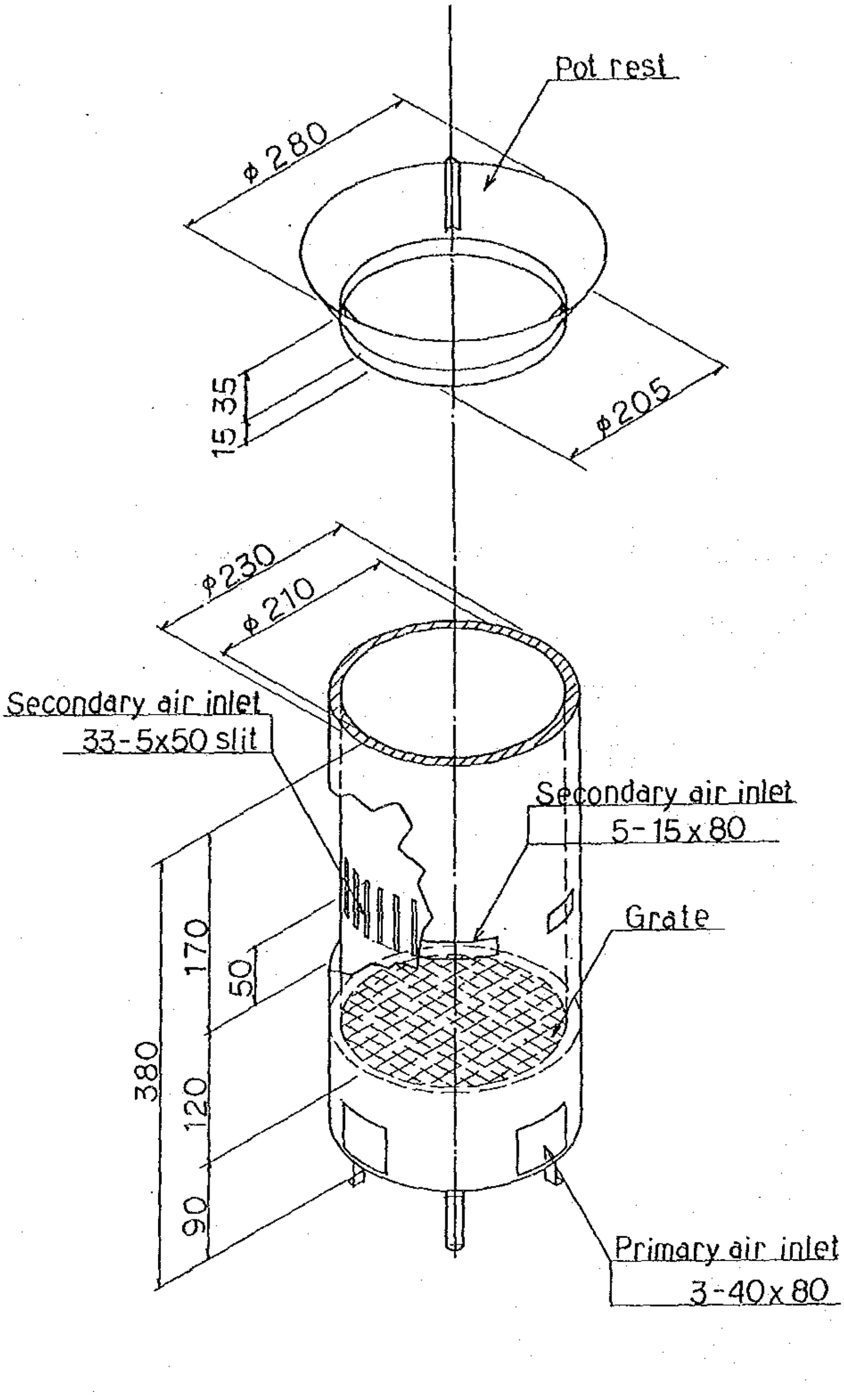


Figure 19-12 Type A Stove

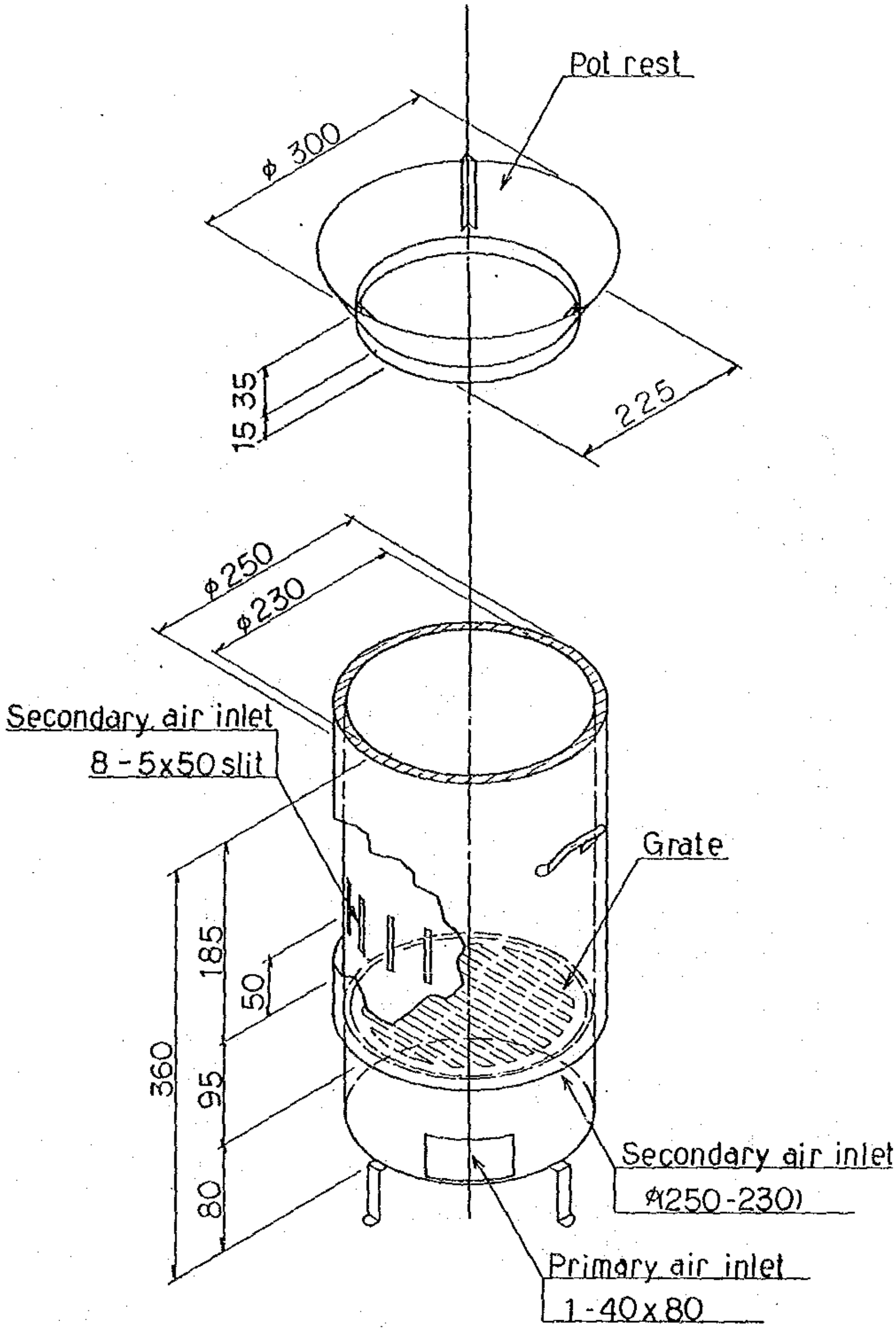


Figure 19-13 Type B Stove

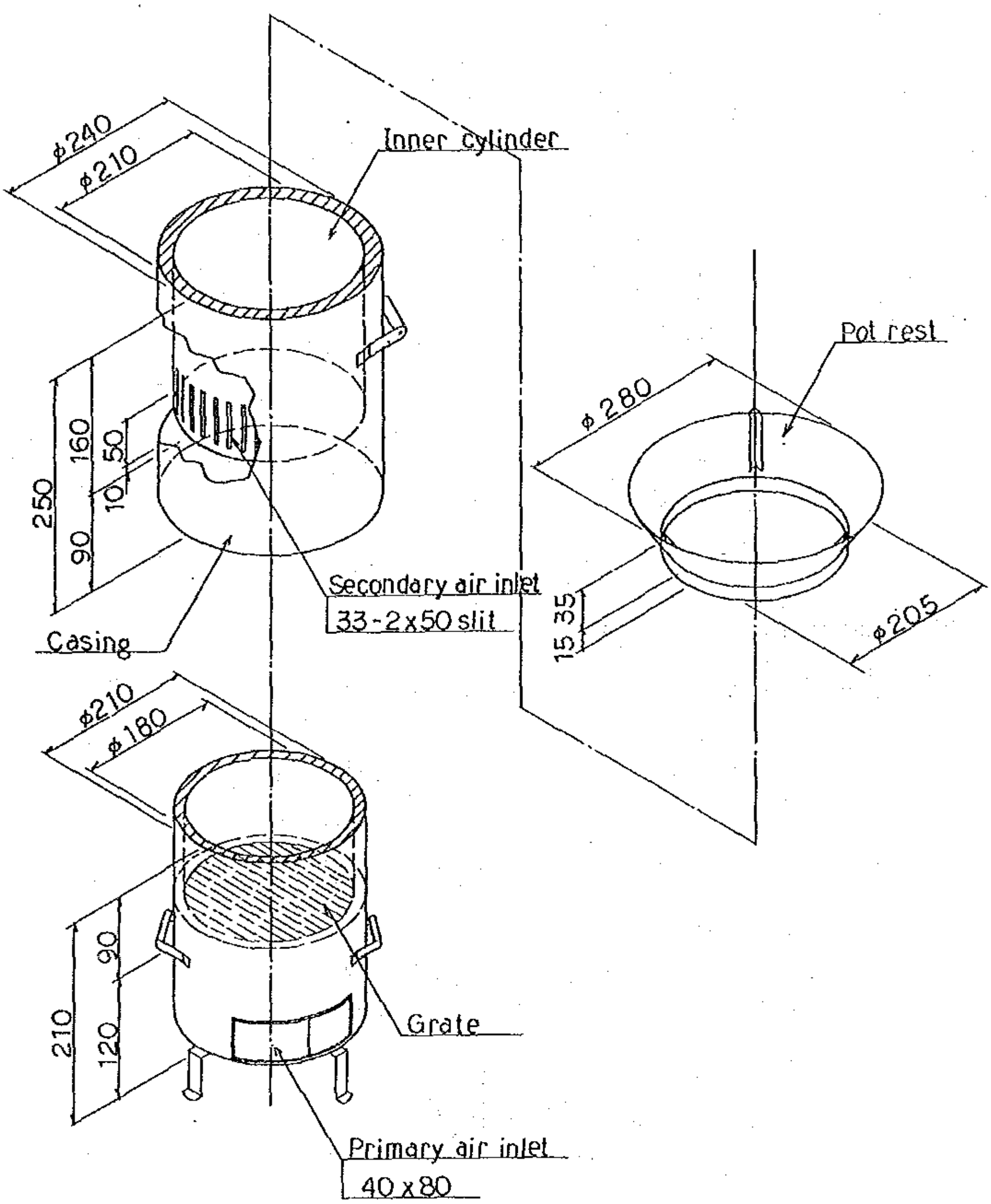


Figure 19-14 Type C Stove

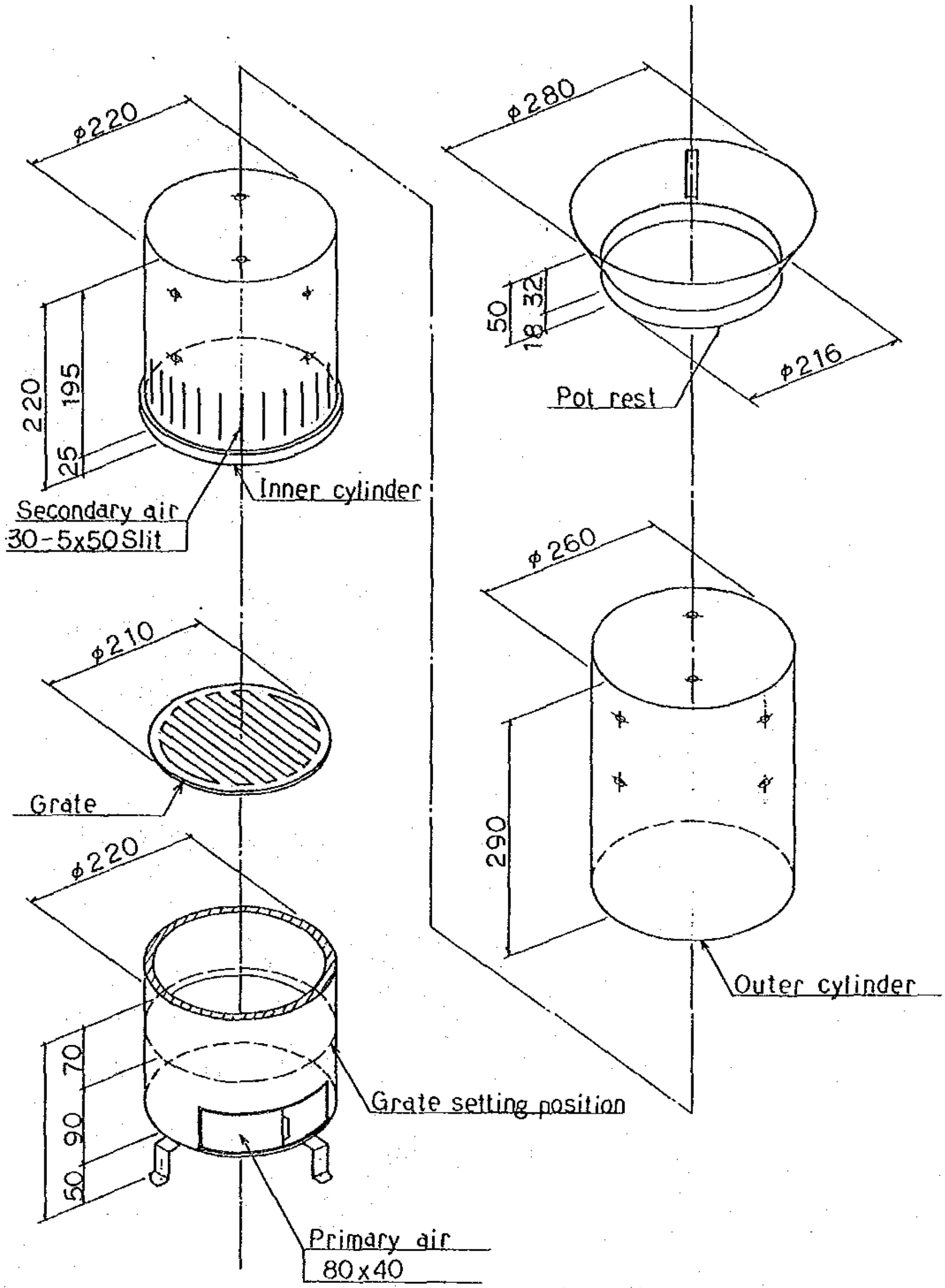


Figure 19-15 Type D Stove

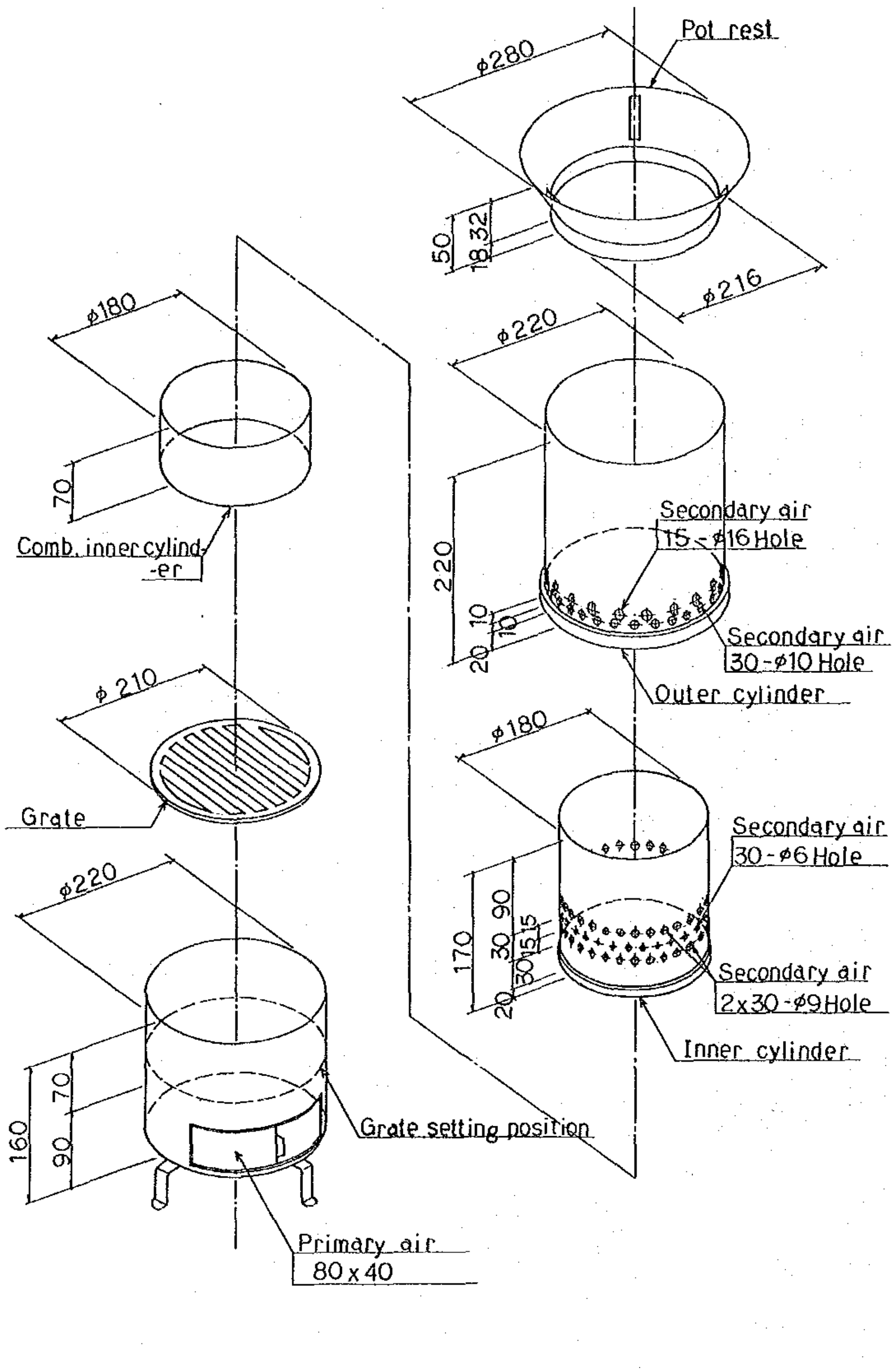


Figure 19-16 Type E Stove

Chapter 20 Bench-scale Plant

Chapter 20 Bench-scale Plant

20-1 Purpose of the Bench-scale Plant

The bench-scale plant was installed at the Fuel Test Center of NEA near Bangkok for the following purposes.

(1) To confirm that lignite briquettes of good quality can be produced from Thai domestic raw materials;

(2) To familiarize the staff of NEA with the operation of the bench-scale plant so that they may use the plant for research and development work;

(3) To produce a sufficient amount of lignite briquettes to be used for the monitoring survey.

20-2 Installation of the Bench-scale Plant

20-2-1 Inspection of the Delivered Cargo

The staff of NEA and the study team together confirmed while the cargo was being opened that:

(1) There were no undelivered goods by referring to the packing list.

(2) There were no damaged goods.

Table 20-1 lists the machines delivered.

Table 20-1 Machine List

Item	Machine Name	Specifications
Coal Crusher	Roll Jaw Crusher	Coal: 200 to 300 kg/h Particles: 100 to 5 mm
Coal Pulverizer	Hammer Crusher	Coal: 100 to 150 kg/h Particles: 5 to 2 mm
Biomass Pulverizer	Pin Mill Machine	Biomass: 50 kg Particles: 10 to 2 mm
Vibrating Screen	Vibrating Screen	3 Decks, Closed Screen Area: 0.31 m^2/deck
Mixer	Mixer	Coal, Biomass: 100 to 150kg/h Ribbon spiral, barrel type, batch mixer with heater
Briquetting Machine	Briquetting Machine	Briquettes: 150 to 200 kg/h Single-shaft drive, double-roll type with cantilever
Vibrating Sifter	Vibrating Sifter	Screen mesh: 14 mm Total screen area: 0.524 m^2
Belt Conveyer	Belt Conveyer	Belt: width 50 mm x Length 5 m
Platform Scale	Platform Scale	Max. capacity: 100 kg Reading: 10 gr.
Tablet Tester	Tablet Tester	Max. Pressure: 4 tons/cm^2 Tablet size: 25 mm dia.
Unconformity Compression Tester	Compression Tester	Max. Capacity: 200 Kgf
Vernier Caliper	Vernier Caliper	L 200 mm x 0.05 mm
Dust Collector	Dust Collector	Static pressure: 110 mmAq Capacity: 28 m^3/min.
Air Compressor	Air Compressor	Max. pressure: 7 Kg/cm^2g Air tank: 38 liters Filling up time: 5 min.
Oil Burner Combustion Test Kit	Combustion Test Kit	1. MFZ draft, 2. Thermometer, 3. Smoke tester, 4. CO_2 Detector
Gas Detector	Gas Detector	Tube: CO, CO_2, NO_2, SO_2

Note: One each item was provided.

20-2-2 Condition of the Plant Site

Prior to the arrival of the machines, all the preparatory works necessary for the installation and operation of the bench-scale plant had been completed in accordance with the requests made by the study team, which included some modifications to the existing structure and the installation of electric wiring, a water supply and drainage pipings.

20-2-3 Installation of the Machines

All machines were installed at the designated places and the electric wires were connected by the staff of NEA with the assistance of the study team and an engineer dispatched by JICA.

20-3 Preparation for the Start-up

20-3-1 Delivery of Raw Materials and Lubricants

The following raw materials were used for the production of lignite briquettes.

(1) Lignite
(2) Biomass
(3) Slaked lime or calcium carbonate as the desulfurizing agent

Sufficient amounts of raw materials listed below were collected at the plant site to ensure uninterrupted operation necessary for the monitoring survey.

(1) High-quality and low-quality lignites from the Ban Pa Kha Coal Mine
(2) Rice straws, rice husks and bagasse
(3) Slaked lime

The above materials were examined for important properties prior to feeding them so that the operating conditions of the plant could be adjusted according to the quality of the feeds. The lubricants with specifications meeting the requirements of the machines were procured and charged to the machines.

20-3-2 Adjustment of the Machines and No-load Operation

Upon completion of the installation, the conditions of all the machines were checked and adjusted ready for operation. All machines were run without load to see that they would move smoothly.

20-4 Test Production of Lignite Briquettes

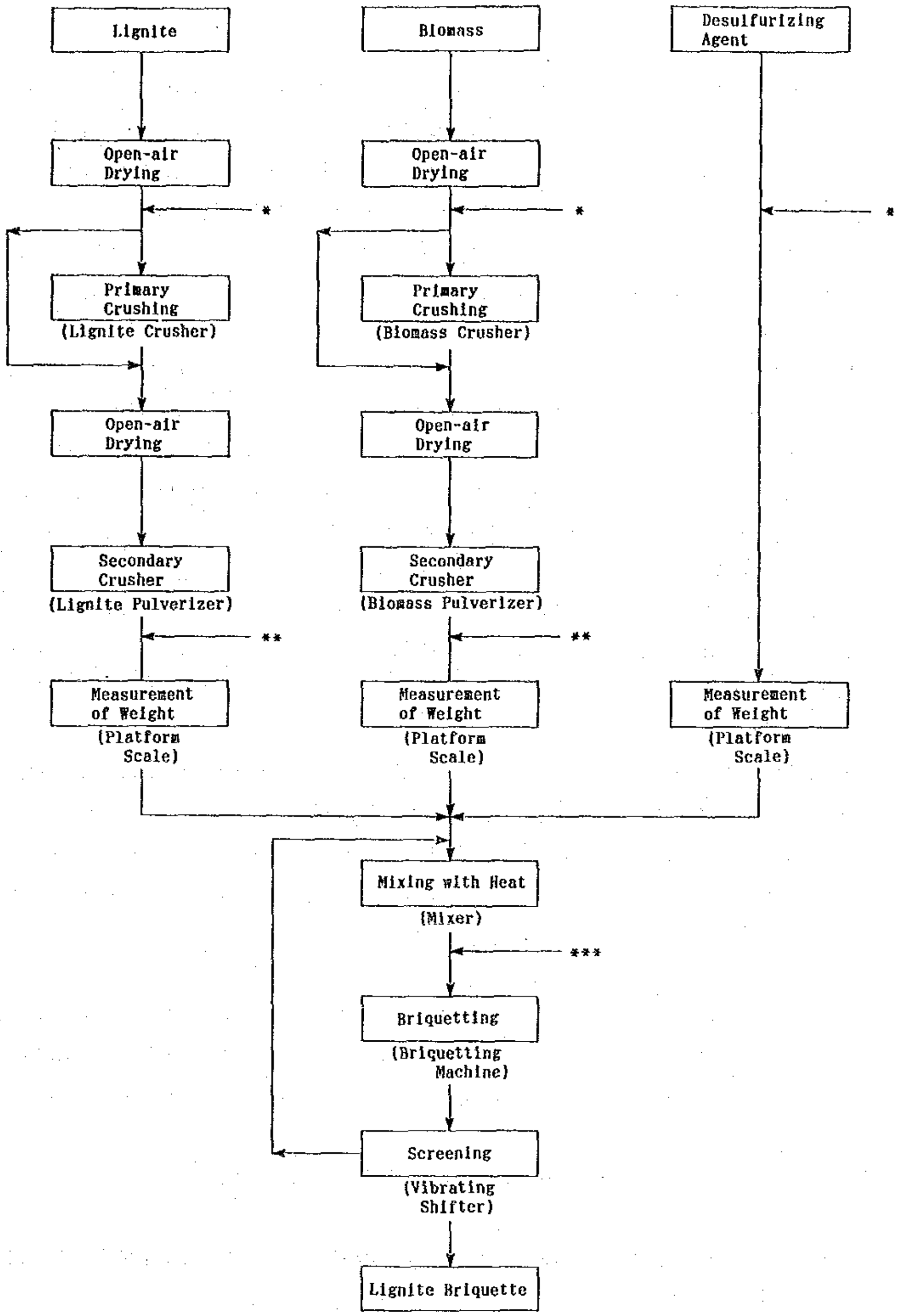
20-4-1 Production Schedule

During the two months from the commencement of operation, the operation of the bench-scale plant was concentrated on the production of the lignite briquettes to be used for the monitoring survey. For this purpose, a considerable amount of lignite briquettes with the desired, uniform quality had to be prepared in a short period of time. For this operation, proven operating conditions established through a series of experimental productions conducted in Japan were applied. Approximately four tons of lignite briquettes were produced during this period and used for the monitoring survey.

After the bench-scale plant was released from the production for the monitoring survey, various kinds of test on the production and combustion of lignite briquettes were conducted to study the effect of the operating conditions on the quality of the lignite briquettes. The tests were carried out while varying the raw materials and such major operating parameters as the mixing ratios of the raw materials and the moisture contents.

20-4-2 Process Description

A simplified flow diagram for lignite briquette production using the bench-scale plant is shown in Figure 20-1.



(Note) * : Test of composition, particle size distribution and moisture content

** : Test of moisture content and particle size distribution

*** : Test of moisture content and tablet test

Figure 20-1 Block Flow Diagram of Lignite Briquette Test Production

The lignite briquette is produced by compressing a mixture of pulverized lignite, biomass and a desulfurizing agent. The optimum mixing ratio of lignite and biomass varies with the characteristics of these two components. The quantity of the desulfurizing agent to be added is determined depending upon the sulfur content of the raw lignite, as well as the type of desulfurizing agent.

Lignite, the main raw material, is crushed to a specified particle size by the primary and secondary lignite crushers after the moisture content of the lignite has been controlled by drying. If the particle size of the raw lignite is less than 25 mm, use of the primary crusher could be skipped. The biomass is also crushed into a specified particle size by using the primary and secondary biomass crushers. To make a uniform mixture as well as to control the moisture content, the pulverized lignite, biomass and desulfurizing agent are heated while being mixed in the mixer.

The mixture from the mixer is fed to the briquetting machine which produces briquettes by compressing the mixture under high pressures at approximately 170 Kg/cm^2g. The briquettes are screened on the vibrating sifter to finish the briquettes in good shapes by removing the fringes. The refuse from screening is recycled back to the mixer.

As shown in Figure 20-1, several tests are involved in the lignite briquette production to examine the properties of the raw materials and to check the performance of the important operations.

All these steps are conducted in batch operations.

20-4-3 Operating Conditions for Producing the Samples for the Monitoring Survey

The samples of lignite briquettes for the monitoring survey were produced basically under the following operating conditions.

(1) Mixing ratio by weight

Lignite : Rice straws : Slaked lime = 80 : 20 : 20

(2) Moisture content, wt%

Lignite: 10 or less

Rice straws: 7 or less

Slaked lime: 1 or less

(3) Particle size, mm

Lignite: 2 or less

Rice straws: 3 or less in length

Slaked lime: 0.5 or less

20-4-4 Quality of Products

Table 20-2 shows the results of the analysis of the raw materials and the lignite briquettes.

Although the lignite briquettes have some drawbacks, as pointed out by the monitoring survey, the results of the monitoring survey generally indicate that the lignite briquettes of the quality used for the same survey will be accepted by potential users under certain conditions.

Table 20-2 Results of Proximate Analysis of Raw Materials and Product

	Moisture wt%	Ash wt%	Volatile Matter wt%	Fixed Carbon wt%	Heating Value* (Gross) kcal/kg	Total Sulfur* wt%
Raw Materials						
Low-quality Lignite	13.2	29.3	30.8	26.8	3,951	1.55
High-quality Lignite	16.1	5.3	37.8	40.8	6,337	0.53
Rice Straws	6.2	14.1	62.6	17.1	3,940	0.18
Rice Husks	7.7	15.2	59.0	18.1	4,119	0.12
Bagasse	7.8	15.1	66.4	10.8	4,363	0.12
Product						
Lignite Briquettes	9.0	21.9	39.1	30.1	4,305	0.20

Note: * dry base

20-5 Technology Transfer

20-5-1 Assistance for Operation

Until NEA's operational personnel became familiar with the operation of the bench-scale plant, the study team assisted the operation to help NEA produce both safely and effectively lignite briquettes of good quality, as well as maintain the plant in good condition.

20-5-2 Standard Operation Practices

To ensure that the technology for the operation and maintenance of the bench-scale plant is duly transferred to NEA, the study team prepared a booklet entitled, "Standard Operation Practice" describing the basic principles for the operation and maintenance of the plant and presented it to NEA. Each step of the "Standard Operation Practice" was confirmed with NEA and the study team by the plant. Furthermore, the "Standard Operation Practice" was translated into Thai by NEA in order to assure effective utilization.

20-6 Troubleshooting

After two weeks from the commencement of the production, an unduly metal-to-metal contact was found in the briquetting machine. However, the trouble was eliminated by an engineer promptly dispatched by the machine manufacturer. Thus, any major inconvenience to the monitoring survey was avoided.

20-7 Future Plan

According to NEA, NEA is planning the following with regard to the utilization of the bench-scale plant in the future.

20-7-1 Relocation of the Bench-scale Plant

To improve the operational environment, the bench-scale plant will be moved to a new building to be constructed next to the present site.

20-7-2 Test Production of Lignite Briquettes

NEA will further intensify its research activities into the utilization of various kinds of raw material, improvements to the quality of the lignite briquettes and a reduction of the production cost.

20-8 Evaluation and Recommendations

Based on the results of the observations made by the study team from July to October 1990 when the study team was in Thailand, the significance of the bench-scale plant was evaluated as follows:

(1) As indicated in the results of the monitoring survey, it was confirmed that lignite briquettes of the quality acceptable to potential users could be produced by using Thai domestic raw materials.

(2) The bench-scale plant produced a sufficient amount of samples of lignite briquettes to enable the monitoring survey.

(3) Through the operating experience for four months from July to October 1990, the operational personnel of NEA became familiar with the operation of the bench-scale plant, so that the plant could be operated without any assistance from outside. It was expected that the plant would be utilized efficiently for the research and development work of NEA.

The following items are important for the effective utilization of the plant for the research and development work of NEA.

(1) Care must be taken to forestall accidents by observing each item in the "Standard Operation Practice."

(2) A budget must be secured for not only procuring raw materials, but also for supplying lubricants and spare parts to maintain the plant in good conditions.

Chapter 21 Past Studies on Briquettes

Chapter 21 Past Studies on Briquettes

21-1 Problem with Coal Utilization in Thailand

As explained in Chapter 4, Thailand has more coal resources than any other energy resource; however, more than 95 percent of the coal is low-quality lignite. The use of coal has been limited almost exclusively to mine-mouth power generation. The basic policy of the government for energy is to decrease the degree of dependence on imported energy; therefore, the development and effective utilization of these coal resources will be ever more important. Recently, there has been an increasing awareness of the need to effectively utilize lignite as industrial fuel for small- and medium-scale industries and as household fuel as a substitute for charcoal and firewood to protect the diminishing forests as well as to increase energy self-sufficiency.

21-2 History of Coal Utilization in Thailand

Lignite had been used since long before the energy crisis of the 1970's. In 1957, about 100,000 tons of lignite were used for power generation. Under the very tight circumstances prevailing during the energy crisis of the 1970's, the government accelerated the program for coal development in line with the objective of reducing the dependence on imported oil from 75 to 43 percent under the Fifth National Economic and Social Development Plan (1982-1986). By 1985, Thailand had become the biggest user of indigenous coal in Southeast Asia.

There is no viable alternative but to use the bulk of the country's low-quality lignite for mine-mouth power generation, because the high contents of ash and moisture and the low heating value make transportation over long distances not viable. Coals of higher ranks, subbituminous coal or high-quality lignite, are produced in small quantities; the former is used for cement production and the latter for tobacco curing. No coal of any kind has ever been used for household purpose.

The government declared for the first time in the Sixth Five-year Plan

(1987 to 1992) a policy of promoting the use of domestic lignite for small industries and rural households as a measure for improving self-sufficiency in energy supply as well as for protecting the diminishing forests. For this purpose, the government plans to support the related research and development work in this area.

21-3 Research Work on Briquette Production using Thai Coal

21-3-1 Historical Background

Briquetting is considered one of the best ways to effectively utilize low-quality lignite and coal fines for small-scale industries and households. Over the last 20 years, a considerable amount of research has been undertaken on briquetting Thai coal in universities, research institutes and private companies. This research work may be classified and summarized as follows.

(1) Research on the Production of Metallurgical Briquettes

A study was undertaken on the possibility of producing metallurgical briquettes and coke from Thai coal with cooperation from German companies. Coal tar was used as the binder for the production of metallurgical briquettes.

(2) Briquetting of Carbonized Coal

There were several research projects on briquetting carbonized coal to produce smokeless fuels conducted at universities and research organizations of the government. This research work involved the use as binders coal tar, asphalt, starch and black liquor, a waste stream from pulp production. The results indicate that briquettes of good quality could be produced with the carbonization of coal; however, this route would be more expensive in terms of investment and operating costs compared with other methods. The process of carbonization produces a large volume of gas as a by-product. This route is considered uneconomical unless carbonization is undertaken in a large scale with the facilities for the recovery and utilization of gas integrated into the carbonization facility.

(3) Briquetting of Non-carbonized Coal

There was some research work carried out by a Thai university into the production of non-carbonized fuels for both household and industrial uses from low-quality lignite and coal fines, for which there were only limited uses. Locally available clay was used as the binder. The performance of the fuel was evaluated as nearly equal to that of firewood. The generation of a great deal of smoke is the drawback to this fuel as a household fuel.

(4) Briquetting of the Biomass

Research work was carried out on briquetting the biomass to be used as a substitute for wood fuel in rural areas. It was found that, for briquetting the biomass, sticky materials such as clay, molasses, tar, sludge and slops from distilleries could be used as the binder. In addition, it was found that other materials including lignite could be mixed and briquetted with the biomass. The main advantages of this technology are the low investment and operation costs. However, this technology is not used widely because of the low quality of the product, smoke as well as odors in particular, generated when the briquettes burn.

21-3-2 Objectives of the Research

To expand the consumption of coal so as to increase energy self-sufficiency and to protect the forests, one of the surest ways is the utilization of the large resources of lignite in place of the wood fuel, currently used by households and small-scale industries. However, the use of lignite for the above purpose is quite limited for the following reasons:

(1) Low-quality lignite, to be briquetted or not, should be beneficiated so as to improve its heating value, in order to lower transportation costs, as well as to improve its accept-

ability to potential users.

(2) The research activities carried out so far have not identified good binders for briquetting non-carbonized lignite.

(3) For the production of a smokeless fuel from lignite, a large-scale plant must be constructed, including facilities for the recovery and utilization of the large volume of by-product gas generated during the carbonization process.

Considering the above, research work should be targeted at achieving the following objectives to expand the use of lignite in Thailand.

(1) The technical problems identified by the research activities should be solved. This includes the identification of an appropriate binder.

(2) The installation of a coal beneficiation plant will be very effective in improving the quality of Thai coal in terms of the heating value and consistency. This will need a techno-economic study including detailed washability tests and impacts on the environment.

21-3-3 Features of the Adopted Process

The process of manufacturing lignite briquettes adopted in this feasibility study has the following features compared with the processes used in the research work conducted in Thailand.

(1) Biomass, one of the raw materials, works as a binder in addition to helping the briquettes burn better. Therefore, no binder other than the biomass is needed.

(2) By the addition of a desulfurizing agent such as slaked lime, the generation of a bad odor, as well as the air pollution caused by the combustion of the sulfur compounds contained in the lignite, could be diminished.

(3) Because of the simplicity of the process of producing briquettes by just compressing pulverized raw materials, the investment and operation costs are moderate. Thus, briquettes can be produced at lower costs.

(4) Although the process is simple, the selection of the operating conditions is difficult. It is therefore necessary before commercialization to conduct experimental production with the raw materials under consideration so as to assure the the quality of the products and optimize the operating conditions. The heating value, critical of all the properties, is determined primarily by the heating value of the lignite, the main raw material.

(5) The manufacturing process adopted by this study incorporates a process to decrease generation of smoke, in consideration of the convenience in the use and health of the persons exposed to the environment in which lignite briquettes are burned.

Chapter 22 Conclusion and Recommendations

Chapter 22 Conclusion and Recommendations

In concluding this study, the following conclusion and recommendations are presented.

22-1 Conclusion

Although the pilot plant, per se, is not financially feasible, the pilot plant is worth realizing for the following reasons:

(1) There exists in Thailand an environment ideally favorable to the realization of lignite briquette projects: the policy of the government committed to protecting the forests from further destruction, diversification of the sources of energy supply, and effective utilization of the lignite resources; lifestyle and cooking habits of most Thai people that could accommodate lignite briquettes; availability of raw materials -- lignite, biomass and limestone; serious deforestation that cannot afford to supply wood fuel as demanded.

(2) Charcoal and firewood are the most important cooking fuels in Thailand, collectively accounting for about 80 percent of the cooking fuel consumption. Use of charcoal and firewood as cooking fuel is a major cause of deforestation. The simulation conducted by the study indicates that the Thai forest cannot supply charcoal and firewood as much as to meet their forecast demands without being exhausted in a matter of two decades. This means that restriction of cutting down of trees must be intensified in order to preserve the forest. This will result in shortfalls of the supply of cooking fuels. If the volume of trees cut down is decreased by six percent per year as a reasonable compromise between the supply of wood fuel and preservation of the forest, the nation' forest will be saved from extinction. In this case, the supply of charcoal will fall short of the demand by 0.4 to 1.3 million TOE from 1995 to 2010. Such shortfalls in the supply of cooking fuel must be filled by appropriate substitutes, of which lignite briquettes will be a

promising candidate.

(3) Charcoal for cooking purpose was identified as the most promising candidate for substitution by lignite briquettes. It was found difficult to burn lignite briquettes as a substitute for firewood either for cooking purpose or industrial purpose. The estimated price of lignite briquettes is not competitive with that of firewood for both household and industrial uses.

Many industrial furnaces have to be modified before they can burn lignite briquettes. If such modifications are made, they will become able to burn lignite rather than lignite briquettes. Lignite is much cheaper than lignite briquettes; therefore, consumers will naturally choose lignite. One advantage of lignite briquettes over lignite is the ability to reduce emission of sulfur oxides generated from the combustion of sulfur originally contained in lignite. However, this ability is suppressed at high temperatures prevailing in most industrial furnaces. There is not a great merit in the use of lignite briquettes in place of lignite for industrial applications, if desulfurization is not expected.

(4) On the bases of the foregoing conclusion, the quality of lignite briquettes are designed to be a substitute for charcoal for cooking purpose. Lignite briquettes meeting such a quality requirement were experimentally produced from Thai lignite, rice straws and slaked lime, all abundantly available in Thailand. The experiments were done initially on a tablet scale, then on a bench-scale plant, and finally by a commercial plant. The technical feasibility of producing lignite briquettes meeting the quality target and the best blending ratio were confirmed.

(5) A bench-scale plant was installed at the Fuel Test Center in Rangsit. A large amount of lignite briquettes was produced by this plant and used for opinion surveys on the potential consumers; namely, the present charcoal consumers, in and

around major local cities and Bangkok. The result of the opinion survey indicates that 60 percent of the potential consumers will accept lignite briquettes, provided that the price of lignite briquettes is 60 percent of that of charcoal and that charcoal becomes difficult to obtain.

(6) Assuming that lignite briquettes will fill 60 percent of the forecast shortfalls in the supply of charcoal, the demand for lignite briquettes is forecast as below.

(Unit: KTOE)

Year	1995	2000	2005	2010
Forecast demand	229	518	711	831

(7) The capacity and other details of the pilot plant, and the commercial plant that would recover the investment in the pilot plant, were developed as a result of this study as indicated in Chapter 10.

(8) The investment in and the loss incurred by the pilot plant is recoverable by one or two of the commercial plants.

(9) Lignite briquettes are a new commodity unknown to most Thai people; therefore, it would be too adventurous to attempt to manufacture and sell lignite briquettes on a commercial scale, without first developing the market on a pilot plant scale.

(10) The knowledge to be learned about the market and technology at the pilot plant stage will prove to be valuable and worth laboring for at the commercial stage.

(11) The socio-economic benefits that could be brought about by large-scale commercialization of lignite briquettes are very versatile and great, although many of the benefits are not

quantifiable in monetary terms. The pilot plant project is the first step forward to large-scale commercialization and should therefore be evaluated in terms of the socio-economic benefits of the large-scale commercialization of lignite briquettes.

1) Contribution to conservation of environment
Lignite briquettes will help conserve the ever-diminishing forests. The forests of Thailand are destined to become extinct unless appropriate substitute fuels for charcoal and firewood are made available to most Thai people. Lignite briquettes are certainly one of very promising candidate substitute fuels. Deforestation causes, directly and indirectly as well, floods, droughts, salt attacks, land slides, abnormal climates and is endangering the very foundation on which agriculture is based. On a global scale, deforestation is now acknowledged as an important cause of atmospheric warming. Lignite briquettes will also save the nation the cost of replantation.

2) Desulfurization
A good portion of sulfur originally contained in lignite could be caught in ash when lignite briquettes burn, that would otherwise escape into atmosphere and cause a series of health hazards like asthma and environmental disruptions: acid rains, destruction of ecosystems of rivers and lakes, and would damage the sound conditions on which livelihood of people the world over depends. The cost associated with affording lignite briquettes the ability to catch sulfur is very low in comparison with other methods of desulfurization.

3) Saving of foreign currency
The only conceivable substitute fuel along with lignite briquettes is LPG. Should there not be lignite briquettes, more LPG would have to be imported at the expense of foreign currency that could otherwise be spent for importation of capital goods effectively usable to the betterment

of the living standard of the people and for further development of economy.

4) Creation of employment opportunities
Installation of lignite briquettes plants in rural areas will generate employment opportunities in the job-scarce rural areas. Lignite briquettes will also give some compensation to charcoal dealers throughout the countries for diminishing sales of charcoal.

5) Transfer of technology and stimulation of industries
Realization of lignite briquettes industries will promote transfer of technology to Thailand not only of that related to the manufacture of lignite briquettes but also of that related to design and fabrication of machines and equipment used by lignite briquette plants.

22-2 Recommendations

Based upon the preceding conclusions of this study, the following recommendations are made.

(1) The construction of the pilot plant is worth realizing in order to facilitate the commercialization of lignite briquettes, thereby bringing about all the benefits mentioned above to the nation and people.

(2) All the procedures for the construction of the plant should conform to the recommended schemes for the construction so as to ensure smooth implementation of the project.

(3) In parallel with such implementation, the recommendations for the strategy for the dissemination of lignite briquettes given in Chapter 17 should be adopted to develop the market for lignite briquettes, from the standpoint of preserving the endangered Thai forest.