to P-5, corresponding to PMDC-1 to PMDC-5, respectively. All the samples were packed in 200-liter drums with a wide lid which was tightly closed with a steel belt and an adhesive tape on it. From each lot of P-1 to P-5, about ten kilograms of raw coal was taken and sealed in a plastic bag to retain moisture. They were put in a drum containing the coal of the same origin.

The amount of coal samples received are shown on Table 9-1-2.

Table 9-1-2 Amount of Coal Sample

Sample	No. of drums	Net weight, kg (Invoiced)
P-1	16	2,000
P-2	16	2,000
P-3	16	2,000
P-4	8	1,000
P-5	8	1,000
Total	64	8,000

9-1-2 Condition of Biomass Sample

Three types of biomass: bagasse, wheat straw and cotton seed cake were sampled and sent to Japan. They were all products of Sind. The samples of bagasse, wheat straw and cotton seed cake were taken from a sugar mill, a wholesaler of wheat straw and an edible oil factory. The amounts of samples and kinds of packing are shown on Table 9-1-3.

Table 9-1-3 Amount and Packing of Biomass Sample

Sample	Container	Number	Weight,kg	Total weight,kg
Bagasse	PP	110	9.1	1,000
Wheat straw	JB	19	33.3	500
Cotton seed cake	PP	15	38.5	500

Note: PP and JB stand for polypropylene bag and jute bag, respectively.

9-1-3 Condition of Desulfurizer and Binder Sample

The project area is rich in limestone, slaked lime and also cement. Limestone and slaked lime were purchased from a lime kiln and cement from Zeal Pak, a cement work operating in Hyderabad. The amounts of samples and kinds of packing are shown on Table 9-1-4.

Table 9-1-4 Amount and Packing of Desulfurizer and Binder Sample

Sample	Container	Number	Weight,kg	Total weight,kg
Limestone	PP	20	50.0	1,000
Slaked lime	PP	13	50.0	500
Cement	PP	10	26.3	500

9-2 Analysis of Coal

9-2-1 Preliminary Analysis

First of all, the samples contained in plastic bags were analyzed, the result of which is given in Table 9-2-1. It may be noted from the table that the samples of P-1 and P-3 markedly deviate from other samples in ash content and heat of combustion; whereas as shown in Table 9-2-2 the heat of combustion of pure coal, or heat of combustion corrected for zero ash content and zero moisture content, is nearly the same for all lots except for P-3 which shows a slightly lower heat of combustion. This could be interpreted as indicating that the ranks, or degree of conversion into coal, are about the same for all lots. The heat of combustion of pure coal is calculated by the following equations:

$$HC(pc) = HC(rc) \times 100/(100 - CF(ash) \times A - M)$$

where
HC(pc): Heat of combustion of pure coal
HC(rc): Heat of combustion of raw coal
CF(ash): Correction factor for ash content, 1.08
A: Ash content, wt percent
M: Moisture content, wt percent.

Table 9-2-2 Heat of Combustion of Pure Coal

Sample	Heat of combustion, Kcal/kg
P-1	7,430
P-2	7,529
P-3	6,909
P-4	7,478
P-5	7,556

Table 9-2-1 Analysis of Samples Contained in Plastic Bag

	P-1		P-2		P-3		P-4		P-5	
	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry
Moisture	23.7	NA	20.8	NA	13.7	NA	20.4	NA	19.3	NA
Ash	5.6	7.34	11.6	14.65	52.7	61.07	8.2	10.30	14.8	18.34
Volatile matter	34.9	45.74	39.5	49.87	21.2	24.56	38.3	48.12	33.3	41.26
Fixed carbon	35.8	46.92	28.1	35.48	12.4	14.37	33.1	41.58	32.6	40.40
Heat of combustion	5220	6841	5020	6338	2030	2352	5290	6646	4890	6059
Total sulfur	1.6	2.1	2.7	3.4	3.0	3.5	2.1	2.6	3.4	4.2
Incombustible sulfur	-	0.7	-	1.0	-	0.4	-	1.0	-	0.9
Combustible sulfur	-	1.4	-	2.4	-	3.1	-	1.6	-	3.3
Total water	33.5	-	27.5	-	17.9	-	28.2	-	23.4	-
Surface water	9.7	-	6.7	-	4.2	-	7.8	-	4.1	-
Particle Distribution,%										
over 2.0 mm		-		-		-		-		-
1.0 /2.0		0.1		0.3		0.7		0.7		1.7
0.5 /1.0		44.2		33.6		34.9		39.7		42.8
0.25/0.5		29.2		28.0		23.7		28.5		25.8
under 0.25		26.5		38.1		40.7		31.1		29.7
total		100.0		100.0		100.0		100.0		100.0

Note:
Moisture, ash, volatile matter, fixed carbon, total sulfur, incombustible sulfur, combustible sulfur, total water and surface water are in weight percent.
Heat of combustion is gross heat of combustion in Kcal/kg.

To check further the validity of this argument, a sample of 500 grams of P-1 and P-2 each was taken from arbitrarily selected drums containing P-1 and P-3 and subjected to analysis again. The result is shown in Table 9-2-3.

Table 9-2-3 Analysis of P-1 and P-3 Samples from Drum

	P-1		P-2	
	wet	dry	wet	dry
Moisture	21.2	NA	18.6	NA
Ash	18.9	23.98	29.1	35.75
Volatile matter	31.2	39.59	28.0	34.40
Fixed carbon	28.7	36.43	24.3	29.85
Heat of combustion	4160	5279	3840	4416
Total sulfur	2.7	3.4	4.4	5.4
Incombustible sulfur	-	0.4	-	0.5
Combustible sulfur	-	0.4	-	0.5

Note:
Moisture, ash, volatile matter, fixed carbon, total sulfur, incombustible sulfur, and combustible sulfur are in weight percent.
Heat of combustion is gross heat of combustion in Kcal/kg.

The analytical data differ considerably between Tables 9-2-1 and 9-2-3.

9-2-2 Analysis of representative samples

The above result implies that the samples contained in the plastic bags may not be the representative samples as is often the case with samples of solid materials and suggests that representative samples must be prepared and analyzed again if real qualities of the lots are to be investigated. Accordingly, representative samples were prepared and analyzed again. First, 500 kilograms of coal were taken from each lot and dried to a moisture content of about 12 percent and crushed into particles of

Table 9-2-4 Analyses of Representative Coal

	P-1		P-2		P-3		P-4		P-5		Average
	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	dry
Moisture	11.3	NA	12.0	NA	9.7	NA	10.8	NA	5.6	NA	NA
Ash	28.2	21.8	24.2	27.5	34.2	37.9	24.8	27.8	45.9	48.6	34.7
Volatile matter	32.0	36.1	34.2	38.9	29.9	33.1	33.1	37.1	29.0	30.7	35.2
Fixed carbon	28.5	32.1	29.6	33.6	26.2	29.0	31.3	35.1	19.5	20.7	30.1
Heat of combustion											
Sample	4140	4667	4410	5011	3800	4208	4380	4910	3090	3273	4414
Pure coal	7108		7129		7121		7017		6893		7054
Total sulfur	4.3	4.8	6.5	7.4	5.4	5.9	4.6	5.1	6.9	7.3	6.1
Incombustible sulfur		0.4		0.6		0.6		0.4		0.5	0.5
Combustible sulfur		4.4		6.8		5.3		4.7		6.8	5.6
Carbon		47.8		47.8		43.2		47.9		30.9	43.1
Hydrogen		3.7		3.8		3.4		3.9		3.0	3.6
Nitrogen		0.8		0.8		0.8		0.8		0.6	0.8
Oxygen		13.7		13.3		11.5		14.7		10.1	12.7

Note:
Moisture, ash, volatile matter, fixed carbon, total sulfur, incombustible sulfur, combustible sulfur, carbon, hydrogen, nitrogen and oxygen are in weight percent.
Heat of combustion is gross heat of combustion in Kcal/kg.

less than two millimeters in diameter. The particles were put in four drums; then about 35 cubic centimeters of samples were taken from each drum and mixed thoroughly. This procedure was repeatedly done to P-1 to P-5. The result of analysis done on the samples thus prepared in given on Table 9-2-4 which shows that Lakhra coal is of very high ash and sulfur contents.

The simple comparison between Table 9-2-1 and 9-2-4 indicates that as coal is in the form of lumps of various sizes, the quality can vary from one lump to another; it is therefore extremely difficult to prepare a mixture of uniform and homogeneous quality. This poses a serious problem to the process control and quality control of the product at the stage of manufacture. Sulfur, in particular, which ends up very irritating sulfur dioxide at the point of consumption, poses a problem to process control: the nearly impossible task of properly dealing with it varying almost unpredictably not from one lot to another but from one lump to another of the same lot of coal.

As an illustration of how much sulfur content can vary within the same lot, Table 9-2-5 shows analyses of two samples taken from the same lot, P-3.

Table 9-2-5 Variation of Sulfur within Lot

(weight percent)

	Sample A	Sample B
Ash	61.07	48.80
Volatile matter	24.56	27.40
Fixed carbon	14.37	23.80
Total sulfur	3.50	8.70
Incombustible sulfur	0.40	0.57
Combustible sulfur	3.10	8.13

9-3 Analysis of Biomass

9-3-1 Property of Biomass as Received

Table 9-3-1 and 9-3-2 indicate the results of analyses and particle distribution of biomass samples.

Table 9-3-1 Analysis of Biomass

	Bagasse		Wheat straw		Oil seed cake	
	wet	dry	wet	dry	wet	dry
Moisture	18.1		10.8		8.0	
Ash	2.5	3.1	10.6	11.9	3.9	4.2
Volatile matter	69.5	84.9	64.1	71.9	71.6	77.8
Fixed carbon	9.9	12.1	14.5	16.3	16.5	17.9
Heat of combustion	3,880	4,737	3,590	4,025	4,330	4,707
Total sulfur	0.1	0.1		0.8	0.3	0.3
Incombustible sulfur	0.0	0.0		0.3		0.1
Combustible sulfur	0.1	0.1		0.5		0.2
Carbon		49.7		41.4		48.1
Hydrogen		5.3		5.3		6.1
Nitrogen		0.2		0.7		2.9
Oxygen		41.6		40.2		38.5
Bulk density	0.0852		0.057		0.454	

Note:
Moisture, ash, volatile matter, fixed carbon, total sulfur, incombustible sulfur, combustible sulfur, carbon, hydrogen, nitorgen and oxygen are in weight percent.
Bulk density and real density are in grams per cubic centimeter.
Heat of combustion is gross heat of combustion in Kcal/kg.

Table 9-3-2 . Particle Distribution of Biomass

	Bagasse			Wheat straw		
second mm	30	60	120	30	60	120
7.92+	10.2	10.6	6.6	6.4	1.3	0.4
4.76-	20.0	13.6	13.0	31.0	17.1	9.2
2.80-	16.3	14.0	13.5	26.0	33.3	31.6
2.0-	12.9	12.2	11.6	14.1	17.4	20.2
1.0-	24.5	20.2	27.6	12.8	17.7	20.0
0.5-	11.7	13.7	19.6	5.7	9.2	10.6
0.25-	4.1	15.4	7.8	1.9	2.1	3.2
0.25-	0.3	0.3	0.3	2.1	1.9	4.8

9-3-2 Crushing Test

The samples of biomass as received were subjected to crushing tests after drying under a simulation of actual operating conditions using an actual crushing machine of a coal briquetting plant; the result is shown in Table 9-3-3.

Table 9-3-3 Result of Crushing Test

(weight percent)

	Bagasse	Bagasse	Bagasse	Bagasse	Bagasse	Straw	Straw	Oil Cake
Mesh of crusher, mm Sieve, mm	4.0	3.0	3.0	2.0	1.5	3.0	2.0	2.0
2.0+	4.9	1.4	3.3	0.3	0	3.8	0.1	55.8
1.0+	33.3	34.9	28.6	16.1	11.5	46.0	17.3	11.4
0.5+	36.2	35.7	34.9	32.0	44.4	28.7	37.4	11.4
0.25+	18.2	19.1	22.0	23.1	28.6	13.2	25.9	10.3
0.25-	7.4	8.9	11.2	28.5	15.5	8.3	19.3	11.1
	100	100	100	100	100	100	100	100
Water, wt%								
before crushing	27.5	27.5	-	-	-	12.9	12.9	-
after crushing	23.4	20.4	6.5	8.7	6.5	12.1	12.1	-
Forced dry			yes	yes	yes			

Table 9-3-3 gives the result of once-through crushing operation. The test result indicates that the bagasse is amenable to crushing by an actual cutting crusher used for the experiment. Although not indicated by the experimental results, the straw is found more difficult to crush than bagasse. The crushed bagasse produced by a cutting crusher equipped with 2 mm mesh proved to be the most satisfactory as a blending component.

It must be added that the samples analyzed gave a moisture content of 18.1 percent; however, the bagasse fresh from the sugar mill normally contains nearly 50 percent moisture. Since the project area is generally dry, the bagasse may be expected to lose some water while being stored outdoors.

9-4 Analysis of Desulfurizer

9-4-1 Analytical Result

Table 9-4-1 gives the results of analysis on the samples of limestone and slaked lime.

Table 9-4-1 Analysis of Desulfurizer

(weight percent)

	Limestone	Slaked lime
Moisture	2.25	10.97
Ignition loss	37.37	19.56
SiO_2+insoluble	3.33	4.44
$SiO_2+Fe_2O_3$	1.50	1.47
CaO	51.01	63.14
MgO	0.66	0.66
K_2O	0.04	0.12
Na_2O	0.22	0.23
SO_3	0.35	0.76

To neutralize 1 kg of sulfur it is necessary to use either 3.1 kg of pure limestone or 2.3 kg of pure slaked lime if the chemical reactions proceed completely, or stoichiometrically. However, in real life situations, chemical reactions will never proceed completely; therefore, some extra desulfurizers must be added to help achieve complete neutralization of sulfur. Besides, more desulfurizers must be added if the purity of the active ingredients is low. The active ingredient of limestone is calcium carbonate and that of slaked lime is calcium hydroxide. The contents of these active ingredients are calculated from Table 9-4-1 to be 91.1 and 83.5 percent, respectively, which are not necessarily very satisfactory.

Taking sulfur contents given in Table 9-2-5, 3.50 and 8.70 percent, as an example of how much sulfur content can fluctuate, the amounts of limestone and slaked lime required to neutralize sulfur contained in one ton of dry coal are calculated as given in Table 9-4-2; in this calculation 20 percent more than theoretically required amounts of desulfurizers are used to achieve complete neutralization.

Table 9-4-2 Calculation of Amounts of Desulfurizers Required

(unit: kilograms/ton dry coal)

	Amount required	
Wt.% of Sulfur	Limestone	Slaked lime
3.50	143	106
8.70	355	262

It may be noted from Table 9-4-2 that a large amount of slaked lime, or an even greater amount of limestone, must be added to the blend in order to completely neutralize sulfur, the content of which can be unpredictably quite high. Actually, limestone is slower to react with sulfur; therefore, more limestone than calculated above is found necessary to arrest sulfur.

9-5 Test of Binder

The cement from Zeal Pak and a typical Japanese cement were blended with sand and aggregate in the same ratio and allowed to harden. The concretes prepared from the Zeal Pak cement showed a strength significantly lower than their Japanese counterparts. This will not cause any practical problem since cement is found not necessary for briquetting.

9-6 Pretreatment of Coal

The primary purpose of pretreatment is to increase the heat of combustion of coal by eliminating a significant portion of ash contained in the coal; reduction of ash content normally brings about the reduction of sulfur content. The method extensively employed uses either plain water or mud, the specific gravity of which is artificially increased by adding one or more components.

9-6-1 Dry Method of Pretreatment

As the first step, the dry method was tested. This method makes use of the difference in physical strength between lumps of coal and those of other mineral substances, the former being more fragile than the latter. The commercial facility usually consists of crushers, screens and belt conveyers. In actual practice, operators manually eliminate from the crushed coal lumps which are normally foreign substances. In case of Lakhra coal, however, there is almost no lump left after crushing because of the very fragile nature of this coal. In short, the dry method of pretreatment proved ineffective to Lakhra coal. Table 9-6-1 gives the results of experimental tests on the dry pretreatment which attests to this conclusion.

9-6-2 Washing Test

Given the result of the dry method being ineffective, a wet method, a process commonly known as coal washing, was experimentally tested on lot P-3. The test method consists in crushing the coal and separating the crushed coal by using a fluid of 1.6 specific gravity into those floating on the liquid and those sinking to the bottom. The experiment was done on two different particle sizes; one crushed to less than 10 mm and the other to less than 5 mm. This method proved to be very effective as shown on Table 9-6-2.

Table 9-6-2 indicates that a good separation can be achieved with a liquid of 1.6 specific gravity. Together with removal of ash which is the primary objective of coal washing, this method is

Table 9-6-1 Results of Dry Pretreatment Test

	P-1			P-2		
	Before	After		Before	After	
		No.1	No.2		No.1	No.2
Ash	31.8	30.1	29.9	37.9	34.4	43.6
Volatile matter	36.1	37.8	34.4	33.1	35.2	29.0
Fixed carbon	32.1	32.1	35.8	29.0	30.3	27.4
Heat of combustion	4667	4791	5025	4208	3895	3803
Total sulfur	4.8	6.4	5.0	5.9	6.4	6.1
Incombustible sulfur	0.4	0.8	0.6	0.6	0.8	0.8
Combustible sulfur	4.4	5.6	4.4	5.3	5.6	5.3

Note:
Ash, volatile matter, fixed carbon, total sulfur, incombustible sulfur, combustible sulfur are in weight percent.
Heat of combustion is gross heat of combustion in Kcal/kg.

Table 9-6-2 Result of Coal Wash Test

	Less than 10 mm				Less than 5 mm			
	Feed		Product		Feed		Rroduct	
	wet	dry	wet	dry	wet	dry	wet	dry
Moisture	13.7	NA	15.6	NA	21.4	NA	18.3	NA
Ash	30.8	35.7	9.3	11.0	26.1	33.2	5.8	7.1
Volatile matter	30.5	35.3	41.0	48.6	26.7	34.0	38.6	47.2
Fixed carbon	25.0	29.0	34.1	40.4			37.3	45.7
Heat of combustion	3690	4276	5310	6291		4570	5480	6707
Total sulfur	5.19	6.01	2.83	3.33		8.18	1.90	2.30
Incombustible sulfur	0.43	0.50	0.50	0.59		0.49		0.80
Combustible sulfur	4.76	5.51	2.33	2.76		7.69		1.50
Carbon		43.2		64.2				
Hydrogen		3.4		5.0				
Nitrogen		0.8		1.2				
Oxygen		11.5		15.8				

Note:
Moisture, ash, volatile matter, fixed carbon, total sulfur, incombustible sulfur, combustible sulfur, carbon, hydrogen, nitrogen and oxygen are in weight percent.
Heat of combustion is gross heat of combustion in Kcal/kg.

found to be quite effective for the removal of sulfur. This may be attributable to the fact that a greater portion of sulfur exists as pyrites, or a sulfide of iron, which has a far greater specific gravity of about 5 than that of coal, which is about 1.3, and tends to sink when mixed with a liquid of 1.6 specific gravity. As may be deduced from the data of Table 9-6-2, the smaller the particles of coal are, the more effective is the separation; however, crushing coal into too small particles would increase the cost of crushing, investment and operating costs of the washing facility and also increase the consumption of water. The consumption of water requires special consideration in the case of this project which plans to operate a plant where water is not easily available.

The overall material balance around washing is summarized in Table 9-6-3.

Table 9-6-3 Material Balance of Washing

(basis: 1,000kg)

	Input	Output	
	ROM coal	Spent	Washed coal
Moisture	200.0	75.0	125.0
Ash	250.0	200.0	50.0
Sulfur	50.0	35.0	15.0
Net coal	500.0	65.0	435.0
Subtotal	1,000	375.0	625.0
Water	200.0	75.0	125.0

CHAPTER 10 EXPERIMENTAL PRODUCTION OF COAL BRIQUETTES

The purpose of experimental production of coal briquettes is to establish the technical feasibility of manufacturing the coal briquettes of the desired quality using the raw material available in the project area. For this purpose various samples of sufficient quantities were collected and sent to the Japanese test site. There were five different lots of coal, three kinds of biomass -- bagasse, wheat straw, and cottonseed oil cake --, two desulfurizers -- limestone and slaked lime -- , cement as binder; furthermore, washed coal and ROM coal were to be tested.

The experimental production covered a wide range of possible variations to find the optimum condition: different lots, different biomass, different blending ratios, different particle distributions, etc.

The experimental production of coal briquettes was conducted in two stages; first on a bench-scale to screen the promising conditions from a large number of possible combinations of conditions and then by an actual industrial briquetting machine simulating the actual manufacturing circumstances. Experimentation by the actual use of machines is preferable from the standpoint of confirming manufacturing feasibility; however, the drawback is that this consumes a large amount of sample. One experiment consumes about 50 kg. Before the samples were used for experimental production, they were analyzed; the results of analysis are presented in Chapter 9. The briquettes experimentally produced were subjected to performance tests: collapse strength tests and burning tests. The burning test is described in CHAPTER 11, BURNING TEST.

10-1 Bench-scale Test (Tablet Test)

10-1-1 Method of Bench-scale Test

The purpose of the bench-scale test is to find a promising range of conditions with small amounts of samples. The tests covered a very wide ranges of conditions. The samples were tabletized for the experimental production test. The mold used for tabletting is schematically shown in Figure 10-1-1. Three grams of the sample was placed in the mold and a pressure of 2.4 tons/cm^2 was applied for ten seconds. The molded tablets were tested for collapse strength, spring back, and density. Collapse strength was measured by pressing a steel ball on the tablets by means of a universal testing machine with a jig schematically shown in Figure 10-1-2. An increasing pressure is exerted on the tablet by a steel ball descending at a speed of 2 mm per minute and the force when the tablet collapses is read. The spring back is defined by the following equation:

Spring back $=(T_1 - T_2)/T_2$

Where

T_1: Thickness of tablet released after briquetting

T_2: Thickness of tablet under being briquetted

10-1-2 Result of Bench-scale Test

Two lots of coal, P-2 and P-3, were used for bench-scale tests, the former representing the ROM coal and the latter representing the washed coal. All three kinds of biomass, -- bagasse, wheat straw and cottonseed oil cake -- were used. Limestone, slaked lime and cement were also blended in some samples.

The results are shown in Tables 10-1-1 through 10-1-6 and graphically in Figures 10-1-3 through 10-1-6.

(1) Spring back

For combinations of coal and bagasse, whether coal is washed or not (i.e.,ROM) makes no difference in the value of spring

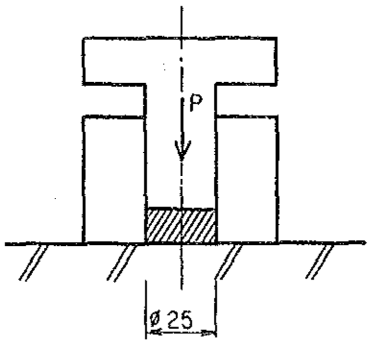


Figure 10-1-1 Schematic Mold Used for Tabletting

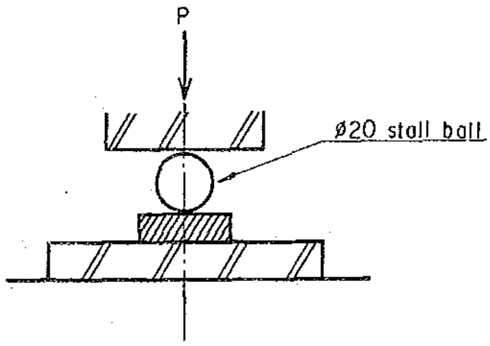


Figure 10-1-2 Schematic Universal Testing Machine with Jig

back. With slaked lime more consistent results were obtained than with limestone over the range tested. Bagasse gives smaller spring backs than wheat straw and hence gives a better molding performance.

(2) Collapse strength

Bagasse and wheat straw give tablets similarly high collapse strength with washed and ROM coal. Cottonseed oil cake gives much lower collapse strength. In a comparison between limestone and slaked lime, slaked lime is found to furnish a more uniform blend with various amounts of bagasse used; when wheat straw is used, however, blending limestone or slaked lime really does not make a difference.

(3) Density

Limestone compared to slaked lime provides lower densities of tablets. Bagasse compared to wheat straw and cottonseed oil cake provides the highest densities. Coal with a high ash content, Lot P-5 for example, provides higher densities of tablets.

(4) Blending ratio of biomass

As seen from Figures 10-1-3 through 10-1-5, the collapse strength increases with increasing blending ratio of biomass in the case of bagasse and wheat straw with washed and ROM coal; however, in the case of cottonseed oil cake, the tablets exhibit lower collapse strength which remains almost unchanged in varying blending ratios.

The blends without biomass provide insufficient collapse strength even with cement used, as shown in Table 10-1-6. Without biomass it is difficult to produce coal briquettes for practical use.

(5) Origin of coal

Lot P-5, gave a much lower collapse strength; this resulted presumably more from the high ash content than from the nature of coal itself.

Table 10-1-1 Tablet Test, Washed Coal and Bagasse

Ex.No.	Bagasse %	Coal %	Desulf. %	Spring Back %	Collapse Strength kg	Density g/cm^3
1	10	90	S.L10	24.2	271	1.12
2	15	85	"	23.8	320	1.13
3	20	80	"	23.8	310	1.12
4	25	75	"	24.7	333	1.11
5	30	70	"	24.8	397	1.16
6	10	90	L.S10	24.9	175	1.05
7	15	85	"	23.5	240	1.06
8	20	80	"	26.1	277	1.02
9	25	75	"	26.4	367	1.06
10	30	70	"	28.2	387	1.04

Note: S.L and L.S represent slaked lime and limestone, respectively.

Table 10-1-2 Tablet Test, Washed Coal and Wheat Straw

Ex.No.	Wheat Straw %	Coal %	Desulf. %	Spring Back %	Collapse Strength kg	Density g/cm^3
11	10	90	S.L10	25.8	133	1.04
12	15	85	"	31.2	207	1.04
13	20	80	"	31.1	220	1.01
14	25	75	"	31.8	300	1.03
15	30	30	"	34.4	380	1.01
16	10	90	L.S10	27.4	140	1.02
17	15	85	"	29.8	177	1.03
18	20	80	"	37.1	273	0.96
19	25	75	"	42.0	297	0.91
20	30	70	"	41.7	340	0.93

Note: S.L and L.S represent slaked lime and limestone, respectively.

Table 10-1-3 Tablet Test, ROM Coal and Biomass (3 Kinds)

Ex.No.	Biomass %	P-2 %	Slaked Lime %	Spring Back %	Collapse Strength kg	Density g/cm^3
21	B10	90	10	22.9	163	1.32
22	15	85	"	21.2	227	1.32
23	20	80	"	23.5	227	1.25
24	25	75	"	24.7	250	1.28
25	30	70	"	24.4	240	1.28
26	W10	90	"	24.5	160	1.30
27	15	85	"	24.8	183	1.31
28	20	80	"	25.7	210	1.25
29	25	75	"	27.8	257	1.25
30	30	70	"	28.2	307	1.26
31	C10	90	"	25.7	72	1.29
32	15	85	"	26.0	75	1.28
33	20	80	"	25.4	74	1.25
34	25	75	"	25.7	75	1.28
35	30	70	"	29.0	80	1.24

Table 10-1-4 Tablet Test, Washed Coal and Cottonseed Oil Cake

Ex.No.	Cottonseed Oil Cake %	Coal %	Slaked Lime %	Spring Back %	Collapse Strength kg	Density g/cm^3
36	10	90	10	24.9	63	1.10
37	15	85	10	24.8	73	1.09
38	20	80	10	26.0	76	1.10
39	25	75	10	26.9	83	1.08
40	30	70	10	26.8	78	1.10

Table 10-1-5 Tablet Test, ROM Coal and Bagasse

Ex.No.	Bagasse %	Coal %	Slaked Lime %	Spring Back %	Collapse Strength kg	Density g/cm^3
41	20	P-1 80	10	22.5	220	1.31
42	20	P-2 80	"	23.5	227	1.25
43	20	P-3 80	"	23.4	200	1.39
44	20	P-4 75	"	25.8	178	1.30
45	20	P-5 70	"	23.1	145	1.45
46	20	P-1~P-2 90	"	25.1	195	1.35

Table 10-1-6 Tablet Test, ROM Coal and Cement Without Biomass

Ex.No.	Coal %	Cement %	Slaked Lime %	Spring Back %	Collapse Strength kg	Density g/cm^3
47	P-1 100	10	10	23.0	60	1.42
48	P-2 100	10	10	22.6	65	1.41
49	P-3 100	10	10	22.1	58	1.51
50	P-4 100	10	10	22.6	57	1.43
51	P-5 100	10	10	21.1	33	1.62
52	P-1~P-5 100	10	10	21.8	58	1.52
53	P-1~P-5 100	15	10	20.1	58	1.51
54	P-1~P-5 100	15	15	19.0	55	1.53

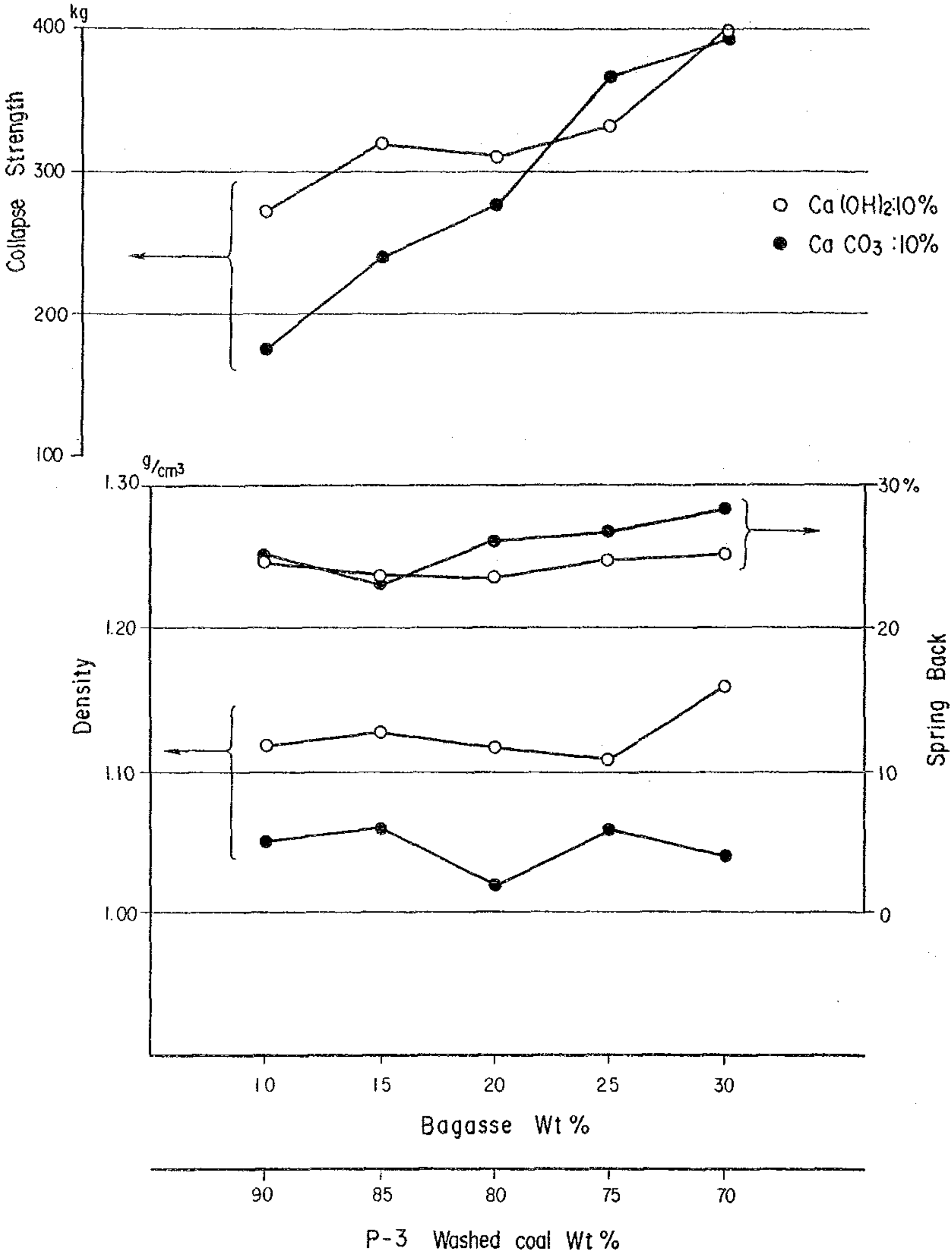


Figure 10-1-3 Tablet test, Washed Coal and Bagasse

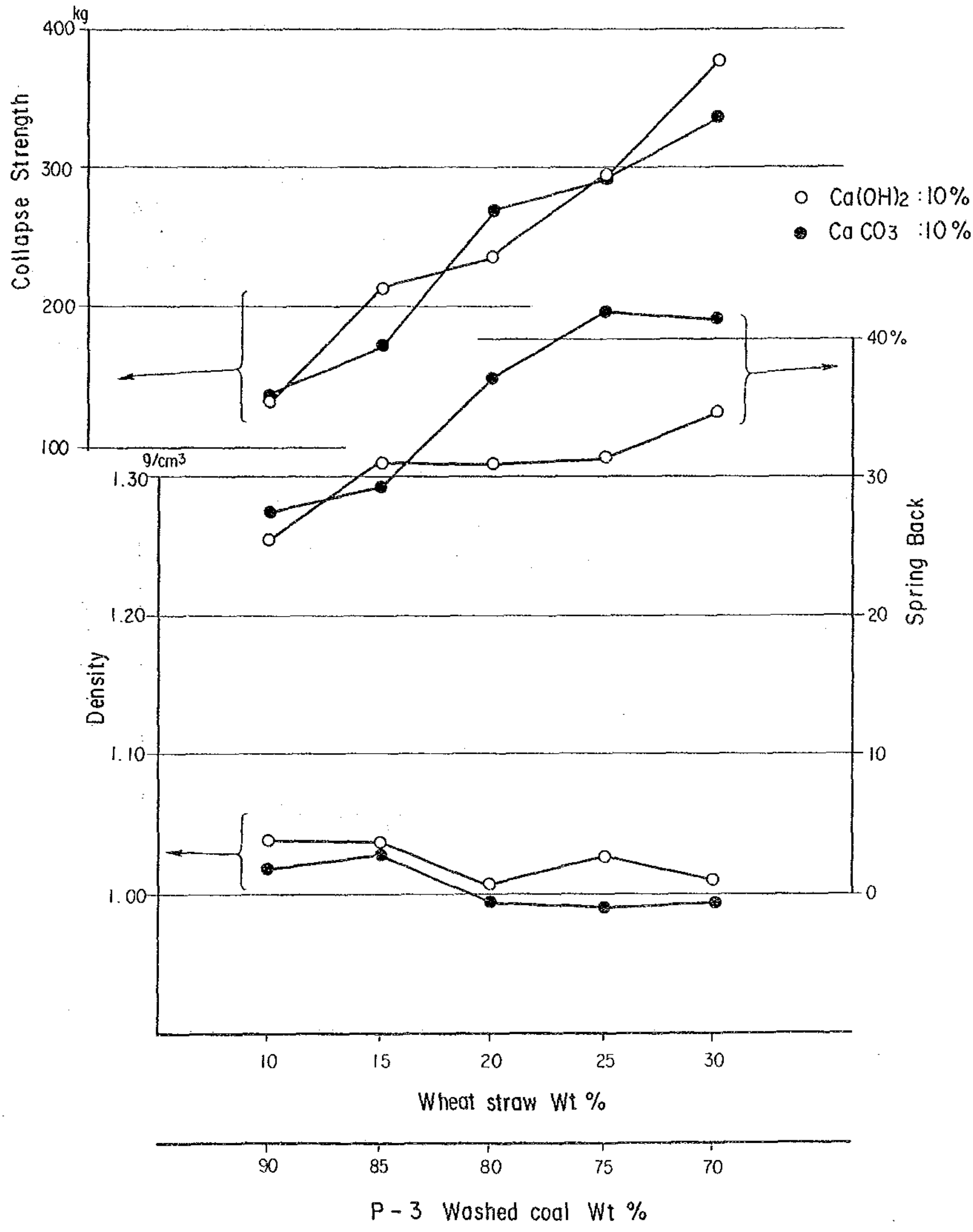


Figure 10-1-4 Tablet Test, Washed Coal and Wheat Straw

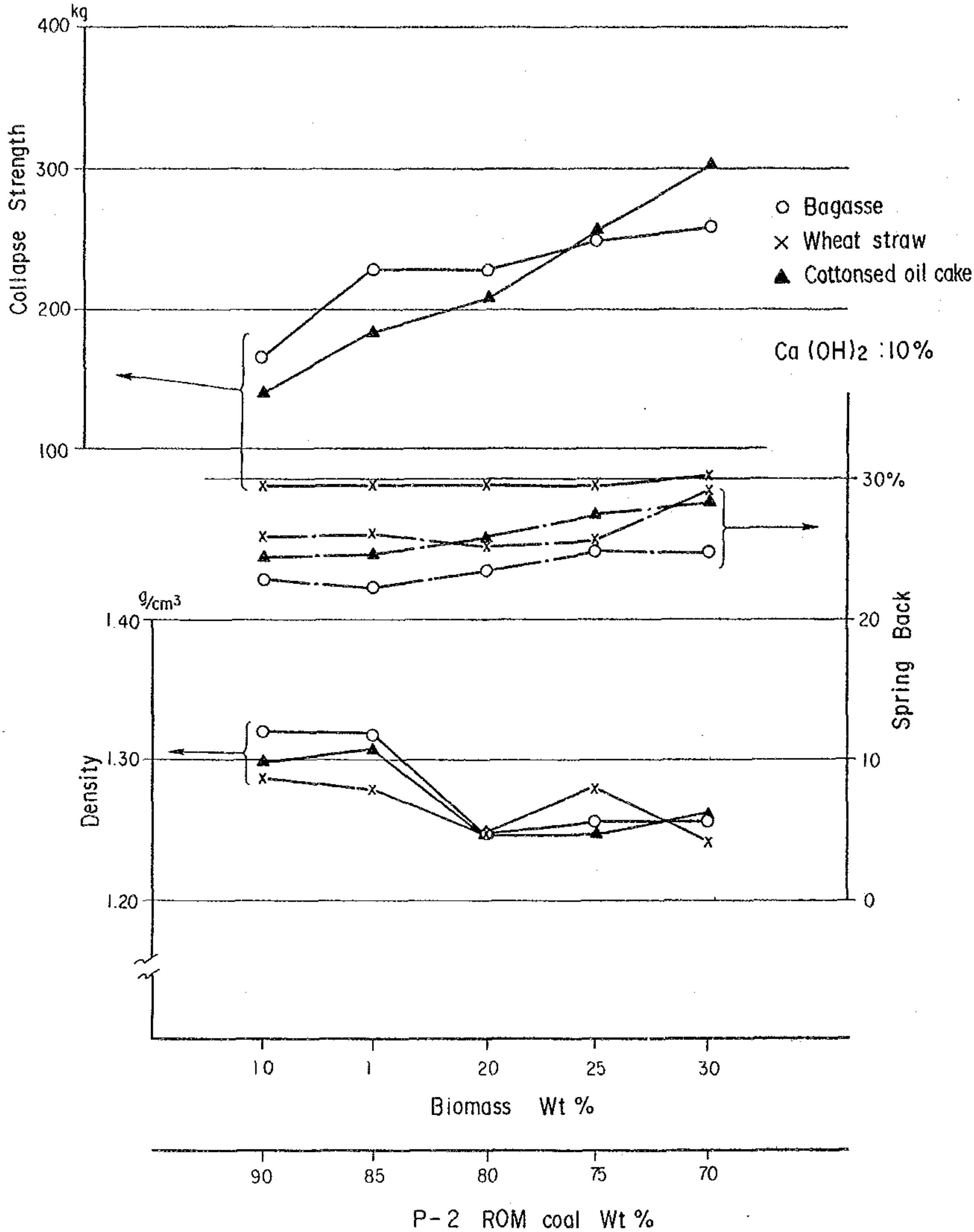


Figure 10-1-5 Tablet Test, Lot P-2 Coal and Biomass (3 Kinds)

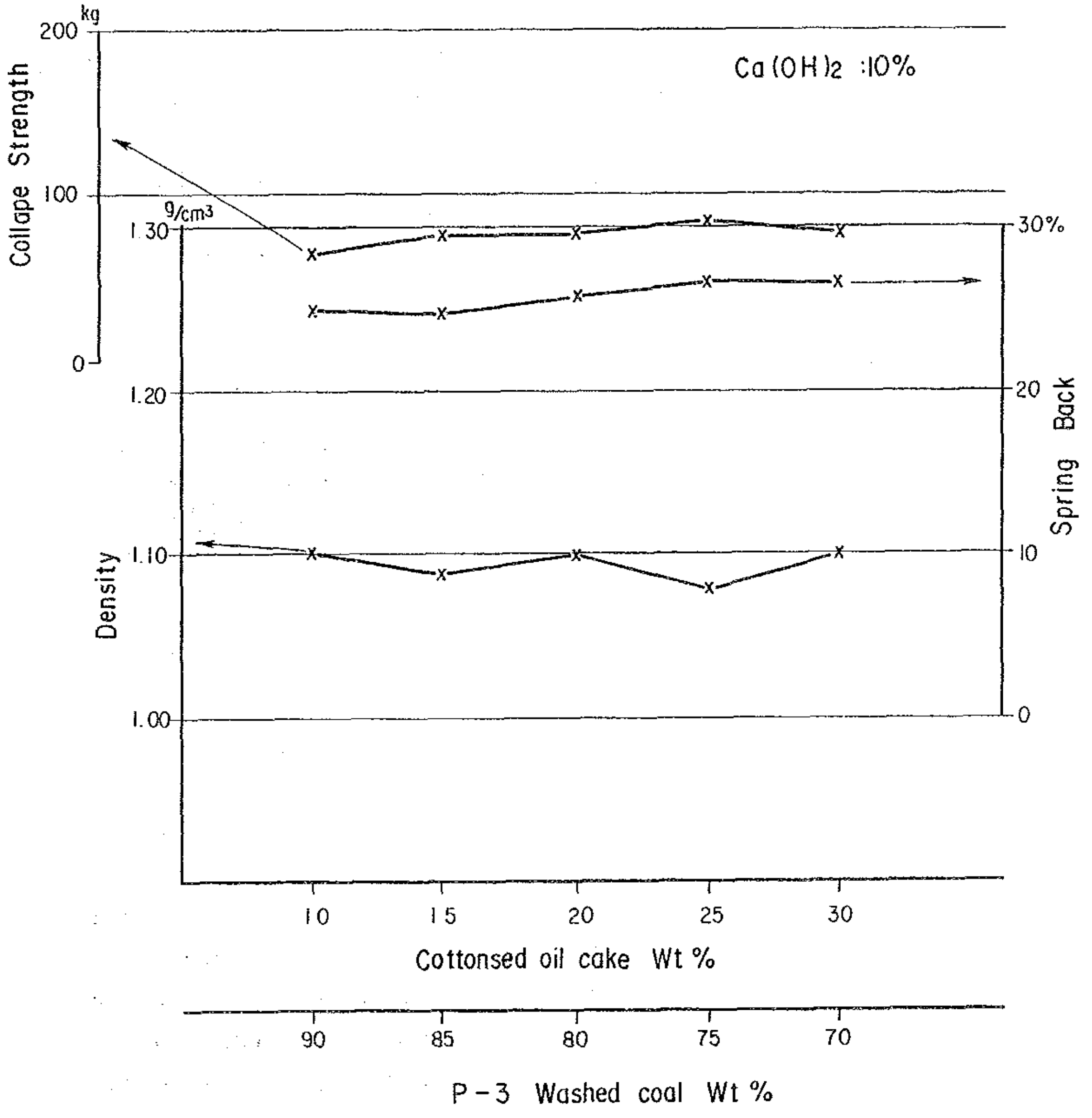


Figure 10-1-6 Tablet Test, Washed Coal and Cottonseed Oil Cake

10-2 Briquetting Test by Industrial Machine

10-2-1 Method of Briquetting Test

The briquetting test by industrial machine of coal briquettes was conducted in two stages; first on a pilot briquetting machine and second on a commercial machine used for commercial production. Two test groups of blends were molded under pressure; the first group comprising coal, biomass and desulfurizing agent, the second group, the same except that biomass was replaced with cement. The former is further divided into two sub-groups; almond-shaped and pillow-shaped. Overall, the grouping of samples of blends for briquetting test is summarized as shown in Table 10-2-1. When the coal briquette samples were produced experimentally, the results of bench-scale test were reflected in the composition of the blends.

Table 10-2-1 Classification of Coal Briquette Samples

Type of Test Machine	With Biomass		Without Biomass (With Cement)
	Almond-shaped	Pillow-shaped	Almond-shaped
Pilot	1-1 to 1-19	3-1 to 3-6	-
Commercial	2-1 to 2-31	-	4-1 to 4-4

Almond-shaped coal briquettes were experimentally manufactured using first a pilot briquetting machine and second an actual commercial production machine. After having established the experimental conditions for this "almond-shaped" briquettes, additional tests were conducted to produce "pillow-shaped" briquettes using a pilot machine. Blends with biomass and without biomass were tested to confirm the results of bench-scale tests. Blends with limestone and slaked lime were also tested. Cement was added to the blends without biomass to see if cement helps them form into briquettes.

The samples of coal and biomass received were dried in a hot stream of air and crushed by the actual machines used in a coal-briquetting plant, the coal by an impact crusher and the biomass by a cutting crusher, each attached with a 2 mm screen. Table 10-2-2 (A), (B), (C) and (D) show particle distributions of the coal and biomass samples prepared for briquetting.

Figure 10-2-1 gives a sketch of the pilot machine used in the experiment for manufacturing almond-type briquettes. The machine is a unit fully provided with motors, reduction gears and briquetting rolls.

Table 10-2-3 shows the specifications of the briquetting machines used for the briquetting experiments.

The pilot machine consumes about five kilograms of samples per run which takes five to ten minutes; the commercial machine consumes 50 to 60 kilograms per run which takes only two to three minutes. It is no doubt better to use the commercial machine to obtain data which are reproducible in commercial operation; however, the large amounts of sample required did not permit every experiment to be conducted by the commercial machine. Regarding the pillow-type briquettes, the only machine available was the pilot machine employed.

Table 10-2-2(A) Particle Distribution of Coal

(Unit: percent)

Screen,mm	P-1	P-2	P-3	P-4	P-5	P-1 (DP)	P-3 (DP)	P-3 (Washed)
over 2.0	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
1.0/2.0	4.9	4.7	3.7	7.5	3.3	4.4	5.7	6.1
0.5/1.0	23.2	25.8	15.4	34.3	19.2	21.9	26.2	31.5
0.25/0.5	27.1	27.2	22.4	25.0	26.3	22.9	26.1	27.1
under 0.25	44.6	42.1	58.2	33.0	51.0	50.6	41.8	35.1
Moisture	13.7	12.9	12.2	12.2	7.0	11.9	12.9	8.6

Note: DP stands for dry pretreatment.

Table 10-2-2(B) Particle Distribution of Bagasse

(Unit: percent)

Screen,mm	1.0	1.5	2.0	3.0
over 2.0	0	0	0.3	3.3
1.0/2.0	0	11.5	16.1	28.6
0.5/1.0	50.2	44.4	32.0	34.9
0.25/0.5	32.3	28.6	23.1	22.0
under 0.25	17.5	15.5	28.5	11.2
Moisture	8.7	8.7	8.7	8.7

Note: Bagasse dried by hot air

Table 10-2-2(C) Particle Distribution of Wheat Straw and Cottonseed Oil Cake

(Unit: percent)

	Wheat Straw		Cottonseed Oil Cake
Screen,mm	2.0	3.0	2.0
over 2.0	0.1	3.8	55.8
1.0/2.0	17.3	46.0	11.4
0.5/1.0	37.4	28.7	11.4
0.25/0.5	25.9	13.2	10.3
under 0.25	19.3	8.3	11.1
Moisture	Naturally dried		

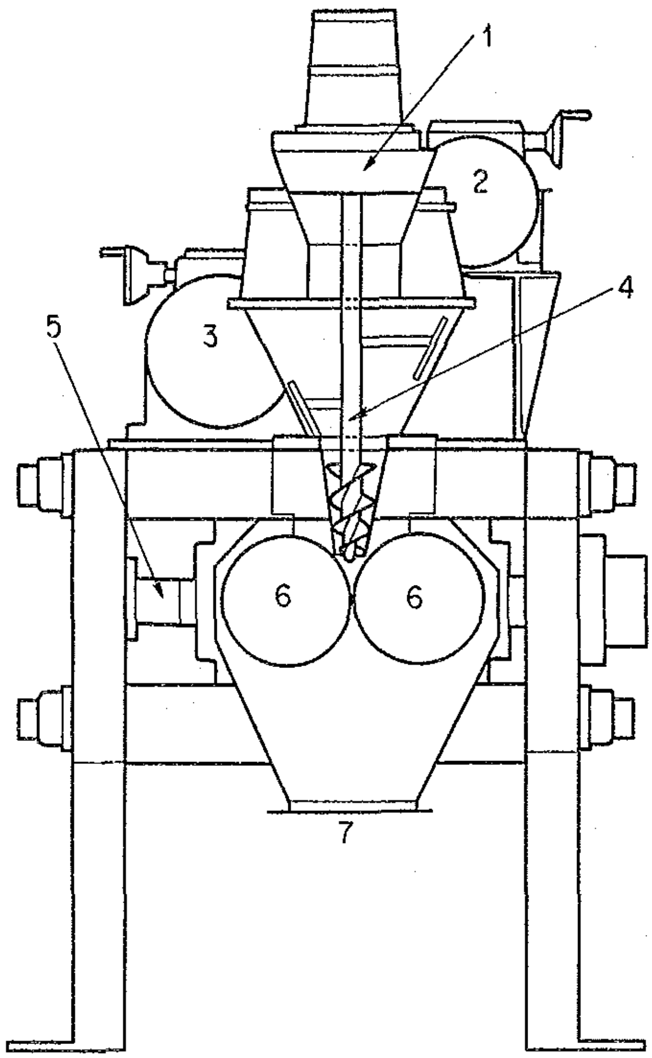
Table 10-2-2(D) Particle Distribution of Feed to Pillow-type Briquette

(Unit: percent)

Screen,mm	P-1	P-2	P-3	P-4	P-5	Bagasse
over 2.38				0.1		
1.19 -2.38		1.4		1.2	0.9	3.7
0.59 -1.19	1.5	20.2	1.0	19.8	18.3	25.5
0.297-0.59	24.0	21.9	23.4	25.6	25.6	28.1
0.149-0.297	30.4	17.2	28.0	22.4	22.7	17.4
0.074-0.149	24.7	10.5	21.7	14.3	14.7	8.7
under 0.074	19.4	28.8	25.9	16.6	17.8	16.6
Moisture	12.4	10.0	11.1	9.2	5.7	9.2

Table 10-2-3 Specifications of Briquetting Machines Used for Briquetting Test

Type of Machine	Pilot	Pilot	Commercial
Shape of Coal Briquette	Almond	Pillow	Almond
Manufacturer	- - Otsuka Iron Works - -		
Model No.	K-123A	K-205	K-209
Roll			
diameter, mm	300	520	520
weight,ton	75		
pressure,kg/cm^2	165	170	165
rotation,rpm	3.4 to 14		10
Feeder			
rotation,rpm	7.5 to 90		9.8 to 39
Electric motor			
for roll	5.5kw x 4p	37kw x 4p	45kw x 6p
for feeder	3.7kw x 4p	5.5kw x 4p	7.5kw x 4p
Mold,mm			
width	37	38	37
length	21	38	21
height	12	12	12
Capacity,kg/h	120 to 200	600 to 800	
Capacity,ton/h			1.25 to 5



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

Figure 10-2-1 Sketch of Pilot Briquetting Machine

10-2-2 Results of Briquetting Test

Tables 10-2-7 through 10-2-10 present the results of experiments by the pilot machine for almond-shaped, the commercial machine for almond-shaped, the pilot machine for pillow-shaped coal briquettes, and results of briquetting test without biomass by the commercial machine.

It is evident from Table 10-2-10 that briquetting coal without biomass turned out to be impossible. Their physical strength is too weak to withstand very gentle handling. Cement is not effective for giving cohesiveness.

Table 10-2-4 shows the most suitable conditions for molding coal briquettes derived from the results of briquetting tests including the results of the bench-scale test.

Table 10-2-4 Most Suitable Conditions for Molding Coal Briquettes

	Condition
Kinds of Coal	ROM Coal or Washed Coal
Particle Size of Coal	less than 2mm
Moisture of Coal	less than 13 percent
Ratio of Coal to Biomass	8 to 2
Kinds of Biomass	Bgasse or Wheat Straw
Particle Size of Biomass	less than 2mm
Moisture of Biomass	less than 8.5 percent
Content of Desulfurizing Agent	5 to 8.5 percent *
Content of Coating Agent	4 to 8 percent *

Note: * The blending ratios of desulfurizing agent and coating agent are the ratios of their amounts to the sum amount of coal and biomass.

It should be noted whether washed or ROM coal is used does not make any difference to the briquetting performance. It was also confirmed that slaked lime is superior to limestone in desulfurizing; Table 10-2-5 compares their effects. The difference in their effects may be noted in the analyses of combustible sulfur, that portion of sulfur which escaped without being caught; higher values are shown for limestone. Regarding the blending ratios between coal and biomass, increasingly more rigid briquettes may be manufactured by increasing the ratio of biomass; however, the ratio of eight to two gives sufficient strength; moreover, the burning test of eight-to-two blends gave better results than those containing more biomass. It was found that the moisture contents of coal before briquetting greater than 13 percent increase spring back of the product and also particle sizes greater than 2 mm increase spring back; both of which give a worse molding performance.

Table 10-2-5 Comparison of Limestone and Slaked Lime

Coal Sample, %	P-3	80	P-1~P-5	80
Bagasse, %		20		20
Desulfurizer, kind	LS	SL	LS	SL
, %	5	5	15	15
Moisture, %	14.7	15.2	6.9	6.3
Ash, %	8.5	10.9	33.3	47.3
Total sulfur, %	1.5	1.4	4.1	3.6
Incombustible sulfur, %	0.8	1.6	0.9	3.5
Combustible sulfur, %	1.0	0.1	3.5	0.3

Table 10-2-6 shows the results of briquetting tests, compositions, conditions of the ingredients, and important operating conditions which are finnaly selected as best for commercial application.

Table 10-2-6 Briquetting Test Results of Coal Briquette Samples Finally Selected as Suitable for Burning Test

Ex.No.	Coal				Biomass				Desulf.			Grade	RPM		Remarks
	Lot	%	P	M	K	%	P	M	K	%	M		Roll	Feedor	
2-29	1 thru 5	80	2	11.6	B	20	2	8.2	S	15	5.4	E		28	C.S 162 over
2-30	1 thru 5	80	2	11.6	B	20	2	8.2	S	20	5.4	E		30	C.S 162 over
2-31	3	80	2	8.6	B	20	2	8.2	S	7	5.4	E		35.5	Ditto and Washed coal

Table 10-2-7 Pilot Machine Test (Almond-shaped)

Ex.No.	Coal				Biomass				Desulf.		Grade	RPM		Remarks
	Lot	%	P	M	K	%	P	M	K	%		Roll	Feedor	
1- 1	1 thru 5	70	3	23	B	30	2	18.1	S	10	I	7	62	
1- 2			-	- 1-1 Repeat - -							I	7	45	
1- 3	2	75	3	27	B	25	3	18.1	S	5	I	7	85	
1- 4	4	70	3	25	W	30	3	12.1	S	5	I	0.25/3.7	85	Roll rpm reduced
1- 5	4	80	3	25	W	20	3	12.1	S	5	B	7	51	Strength insufficient
1- 6			Mixture of 1-1 and 1-2								B	7	26	
1- 7	4	80	3	25	B	20	3	18.1	S C	5 5	B	7	35	Strength insufficient
1- 8			Mixture of 1-3 and 1-7								B	7	38	Strength insufficient
1- 9				1-8 Repeat					S	5	B	4.3	26	
1-10	1 thru 5	75	3	-	B	25	3		-	-	I	-	-	
1-11				1-10 Report					-	-	G	3.7	79	
1-12	5	75	1		B	25	1	16.5	-	-	E	3	79	Particles small
1-13	3	75	3	20.4	B	25	1	18.1	-	-	G	5	45	
1-14	2	80	2	15	B	20	1.5	6.2	S	5	B			
1-15	1,2,4,5	80	2	15.5	B	20	2	6.9	S	5	B			
1-16	1 thru 5	85	2	-	B	15	2	6.9	S	10	E	6.8		
1-17	1 thru 5	80	2	-	B	20	2	6.9	S	10	E			
1-18	3	75	2		B	25	2	6.9	S	5	E	7.0	85	Washed coal
1-19	3	80	2		B	20	2	6.9	S	5	E	6.8	85	Washed coal

Note: Lot 1/5 indicates P-1 through p-5.
P: 3 indicates that the maximum particle size is 3mm.
M: 23 indicates that the maximum moisture content is 23 %.
K: B and W indicate bagasse and wheat straw, respectively.
K: S and C indicate slaked lime and cement, respectively.
Grade: I, B, G and E indicate insufficient, bad, good and excellent, repectively.

Table 10-2-8 Commercial Machine Test (Almond-shaped)

Ex.No.	Coal				Biomass				Desulf.			Grade	RPM		Remarks
	Lot	%	P	M	K	%	P	M	K	%	M		Roll	Feedor	
2- 1	1	75	2	18.3	B	25	1.5	6.2	S	5	18.0	B		39	
2- 2	1	80	2	18.3	B	20	1.5	6.2	S	5	18.0	B		34	
2- 3	1	85				15					6	B		22.5	C.S less than 60
2- 4	2	85	2	11.9	B	15	1.5	6.2	S	5	18.6	G		36.5	C.S 155
2- 5	2	82	2	11.9	B	18	1.5	6.2	S	5	18.6	E		36.5	C.S 189
2- 6	2	80	2	11.9	B	20	1.5	6.5	S	5	18.6	E		38	C.S 179
2- 7	2	82	2	11.9	B	18	3	6.5	S	5	18.6	B		39	
2- 8	2	80	2	13.5	B	20	3	6.5	S	10	18	B		36.5	
2- 9	2	80	2	13.5	B	20	2	8.5	S	10	5.4	E		34.5	C.S 236
2-10	2	80	2	13.5	B	20	2	8.5	S	10	0.9	E		33.5	C.S 213
2-11	2	80	2	13.5	B	20	2	8.5	S	15	0.9	E		28.5	C.S 282
2-12	1	80	2	15.5	B	20	2	8.5	S	10	5.4	G		27	C.S 148
2-13	3	80	2	11.1	B	20	2	8.5	S	10	5.4	E		31	
2-14	5	80	2	11.1	B	20	2	8.5	S	10	5.4	E		31	
2-15	2	80	2	12.5	B	20	2	8.5	S	10	5.4	E		31	
2-16	4	80	2	11.2	B	20	2	8.5	S	10	5.4	E		30.5	
2-17	1	80	2	12.6	B	20	2	8.5	S	10	5.4	E		31.5	Coal dry pretreat
2-18	3	80	2	12.9	B	20	2	8.5	S	10	5.4	E		30.5	
2-19	2	80	2	12.9	W	20	2	5.9	S	10	5.4	E		28	
2-20	2	80	2	14.3	C	20	2	9.7	S	10	5.4	B		20	
2-21	1	80	2	12.0	B	20	2	8.5	S	10	5.4	E		28.5	
2-22	3	80	2	11.1	B	20	2	8.5	S	10	5.4	E		31.5	
2-23	4	80	2	11.2	B	20	2	8.5	S	10	5.4	E		30.5	
2-24	1	80	2	12.6	B	20	2	8.5	S	10	5.4	E		32.5	Coal dry pretreat
2-25	3	80	2	12.9	B	20	2	8.5	S	10	5.4	E		30.5	
2-26	2	80	2	14.3	W	20	2	5.9	S	10	5.4	E		28.5	
2-27	3	80	2	8.6	B	20	2	7.6	S	10	5.4	E		35.5	Washed coal
2-28	1 thru 5	80	2	11.6	B	20	2	8.2	S	15	5.4	E		28	C.S 162 Over
2-29	1 thru 5	80	2	11.6	B	20	2	8.2	S	15	5.4	E		28	C.S 162 Over
2-30	1 thru 5	80	2	11.6	B	20	2	8.2	S	20	5.4	E		30	C.S 162 Over
2-31	3	80	2	8.6	B	20	2	8.2	S	7	5.4	E		35.5	Ditto and Washed coal

Table 10-2-9 Pilot Machine Test (Pillow-shaped)

Ex.No.	Coal				Biomass				Desulf.			Grade	RPM		Remarks
	Lot	%	P	M	K	%	P	M	K	%	M		Roll	Feedor	
3-1	5	80	2	5.7	B	20	2	9.2	S	10		E	10	37	C.S 250
3-2	2	80	1	10.4	B	20	2	9.2	S	10		E	6	67	C.S 295
3-3	1	80	2	12.4	B	20	2	9.2	S	10		E	6	85/97	C.S 200
3-4	3	80	2	11.1	B	20	2	9.2	S	10		E	6	85/97	C.S 368
3-5	4	80	2	9.2	B	20	2	9.2	S	10		E	6	95/95	C.S 365
3-6	1 thru 5	80	2		B	20	2	0.2	S	10		E	6	85/97	C.S 250

Table 10-2-10 Industrial Machine Test Without Biomass and With Cement (Almond-shaped)

Ex.No.	Coal				Desult			Cement	Grade	RPM		Remarks
	Lot	%	P	M	K	%	M	%		Roll	Feedor	
4-1	1	100	3	26.0	S	5		10	B	7	28	Too fragile
4-2	1	100	3	23.9	S	5		10	B	7	22	Too fragile
4-3	2	100	2	12.9	S	12.5	5.4	-	B	10	22	C.S 21.4 Too fragile
4-4	1	100	2	15.5	S	10	5.4	10	I	-	-	Not briquetted

CHAPTER 11 BURNING TEST

The burning tests of the experimentally produced coal briquettes were carried out concurrently with the experimental production of coal briquettes. The objectives of the burning test are these shown below:

1. To observe the burning performance of the best coal briquettes and to decide whether the coal briquettes are acceptable in the Pakistani environment,

2. To develop by actual burning tests designs of stoves suited to burning coal briquettes in Pakistan,

3. To evaluate the burning quality of experimentally produced coal briquettes and make adjustments of the blending ratios and other conditions of experimental production to arrive at the optimum composition and other conditions of coal briquettes,

4. To determine the thermal efficiency of burning coal briquettes and compare it with that of burning kerosene to provide one of the criteria for setting the consumer price of coal briquettes.

11-1 Observation of Burning Performance and Market Acceptability

11-1-1 Observation of Burning Performance

The burning of the recommended briquettes was observed and evaluated as follows:

(1) Ignition

The coal briquettes can be easily ignited by such kindling as paper or dry bagasse; the coal briquettes can reach the steady-state burning condition in five minutes.

(2) Smoke

The coal briquettes generate some smoke during the initial stage of combustion; the amount of smoke may be regarded as tolerable in places where firewood is normally burned, though the amount of smoke considerably varies with the design of stoves. Approximately ten minutes after ignition, the volatile matter in the coal briquettes is exhausted and the coal briquettes burn without generating smoke.

Generation of sulfur dioxide, an irritating smoke, at the consuming ends can be controlled to a high degree by adding appropriate amount of slaked lime.

(3) Strength of fire.

The flame of the coal briquettes is found as strong as that of firewood or even that of kerosene.

(4) Generation of soot

The coal briquettes generate some soot but far less than coal; the soot generated is found much lighter than that of oil and fluffy.

11-1-2 Market Acceptability

The desired quality of coal briquette set forth as the target quality level by PROJECT SCHEME is satisfied by the coal briquettes of the optimum composition if burned in the stoves of recommended design. If burned in the hoof-shaped stoves most common in Pakistan, the coal briquettes burn with a considerable amount of smoke during the initial period of combustion; however, emission of irritating sulfur dioxide gas can be controlled to an acceptable level by addition of slaked lime. Therefore the coal briquettes could be regarded as acceptable by some consumers given the average kitchen of Pakistan is of open structure. However, this type of stove is not suited to the burning of coal briquettes because there is no way of controlling the amounts of primary and secondary air. The coal briquettes, if burned in the experimentally produced stoves, Types D, E, F. ST-1 and ST-2, give thermal efficiencies approximately 70 percent of that of the most common kerosene stoves in Pakistan. In this type of stove the coal briquettes burn well but with some smoke at the initial period of combustion. The coal briquettes burns quite well in the stoves of recommended design and the smoke can be controlled well.

Overall, the quality of the coal briquettes may be evaluated as acceptable to the consumers; however, the stoves of recommended design should be made easily available at cheap prices to obtain the best performance of the coal briquettes. In addition, this conclusion takes into consideration the present conditions of the average Pakistani kitchens, generally of semi-open structure allowing smoke to escape to the outside rather than linger in the kitchens. Smoke is annoying even though it is made not irritating to the eyes and throat; this should be seriously considered as an drawback particularly when the coal briquettes are compared with kerosene. Therefore, the project promoters should put a lot of effort in making stoves of the recommended design available to the consumers.

11-2 Development of Stove for Coal Briquette

11-2-1 Existing Stoves

One kerosene stove and two stoves for burning solid fuels purchased in Pakistan were tested in order to obtain data for developing recommended designs of stoves for burning coal briquette and evaluate the market acceptability of the coal briquettes.

(1) Pakistan kerosene stove

The kerosene stove has an adjustable wick; the strength of the fire is controlled by moving it up or down. Refer to Figure 11-2-1 for design. This stove burns kerosene well. Thermal efficiency of this kerosene stove was measured by heating three liters of water in a household whistling kettle from 21 C up to the boiling point. This operation was repeated four times and consumption of kerosene was measured. The entire operation took 112 minutes and consumed 220 grams of kerosene.

The thermal efficiency is calculated as:

Thermal efficiency

= 4x(3.0kg)x(1.0kg/l)x(1.0kcal/kg,C)x(100-21C) /((0.22kg)x(10,270kcal/kg))x100

= 42.0 %

The rate of heat liberation based on gross or net heat of combustion is:

Hh=(0.22kg)x(11,030kcal/kg)/(112/60h)=1,300kcal/h

Hu=(0.22kg)x(10,270kcal/kg)/(112/60h)=1,212kcal/h

(2) Pakistani cooking stove

This stove is very common in Pakistan. The stove measures 185 mm across and 220 mm high; the roaster is 70 mm deep. Refer to Figure 11-2-2 for design. The roaster is so shallow that if a small pan is used the flame could muffle the entire pan; therefore, a good portion of the heat contained in the flame could escape without being duly transferred to the pan. This stove could burn coal briquettes but generates considerable amounts of smoke, particularly during the initial period of burning. This condition is far from being ideal; however, in view of the smoke being made not irritating by adding slaked lime and the kitchens allowing smoke to escape, the coal briquettes may be considered to be acceptable to some consumers with such stoves.

(3) Quetta Stove

This stove is used mainly in Quetta area for heating and cooking. See Figure 11-2-3 for design. The stove has a chimney to draw the smoke outside. This type of stoves are made in various sizes by cottage industries and sold on the market. The one used for the experiment was purchased in Quetta which measures 160 mm across and has a grate 120 mm across. In a representative experiment, 1.5 kg of almond type coal briquettes were charged with 0.2 kg of firewood as kindling and ignited. With the primary air inlet fully open, ignition was easy and the briquettes burned at the maximum rate of 2 kg/hour. Smoke was generated during the initial 20 minutes. Smoke from burning coating agent pre-dominated during the first 10 minutes of this, thereafter the smoke turned white and was scarcely discernible by the naked eye. Since this stove draws it outdoors, smoke does not present any practical problem and the coal briquettes should be sufficiently acceptable to consumers. This type of stoves is, however, in use in an area very remote from the project area, therefore their users represent little promise as a market.

11-2-2 Experimental Stoves

A number of stoves were made in search of the best design for burning coal briquettes. These stoves were made and tested one after another in such a manner that the defects of the previous design were amended by the next one. The eight designs tested were shown by Figures 11-2-4 to 11-2-11. Figure 11-2-9 and Figure 11-2-11, namely Type F and ST-2, show the recommended designs finally arrived at. These final designs may be considered to get the most out of the coal briquettes. The commercial production of the recommended design would not be beyond the capability of many cottage industries of Pakistan.

Table 11-2-1 Summary of Experimental Stoves

Model	Figure	Main feature	Results
A	11-2-4	Many holes for secondary air	Smoke not decreased
B	11-2-5	Upper roaster contracted by orifice with 8 holes for secondary air	Smoke not decreased
C	11-2-6	Insulator outside Cylinders to rectify gas flow Many holes on upper roaster to assist combustion	Smoke not decreased
D	11-2-7	90 holes on upper roaster	Smoke decreased
E	11-2-8	Similar to Fig.11-2-7 Diameter smaller	Same as above
F	11-2-9	Outer shell added to previous	Smoke decreased further Thermal efficiency increased
ST-1	11-2-10	Separable gas and carbon combustion chambers Insulator outside Chimney Detachable cylinders to rectify gas flow Holes to induce tertiary air	Smoke decreased further Thermal efficiency increased
ST-2	11-2-11	Similar to Fig.11-2-10 Double-hull structure Insulator between hulls Holes to introduce primary, secondary and tertiary air Lattice to rectify gas flow	Smoke decreased further thermal efficiency increased

Table 11-2-2 describes the experimentally produced coal briquette used for burning test for the various designs of experimental stove. Appropriate amounts of the coal briquettes indicated on Table 11-2-2 were placed in the stove on which were placed kindling such as paper, firewood or bagasse. Three or four minutes after the ignition it was confirmed that the coal briquettes caught fire; then a kettle was placed on the stove. In the case of separable stoves, either 1 kg of almond-shaped coal briquettes or 1.5kg of pillow-shaped coal briquettes were burned. When the coal briquettes exhausted the volatile matter

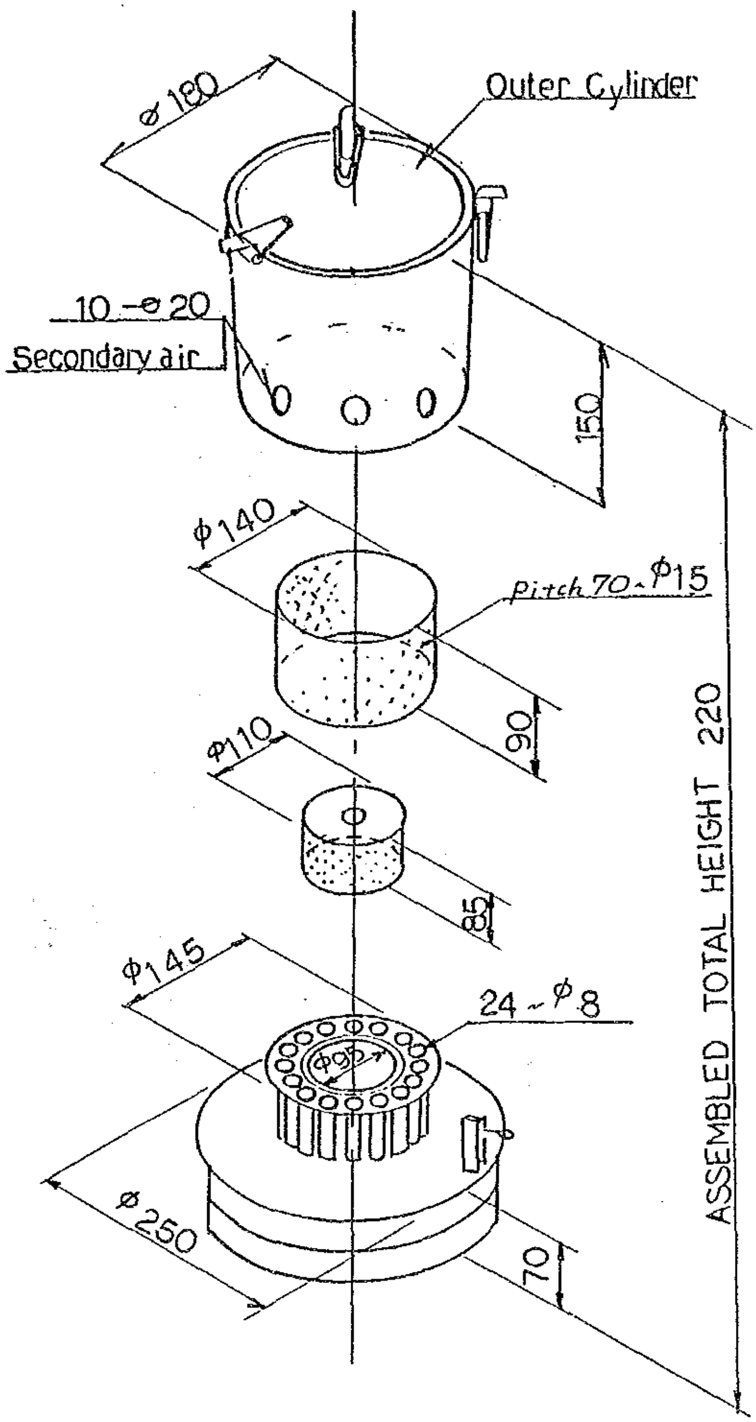


Figure 11-2-1 Pakistani Household Kerosene Stove

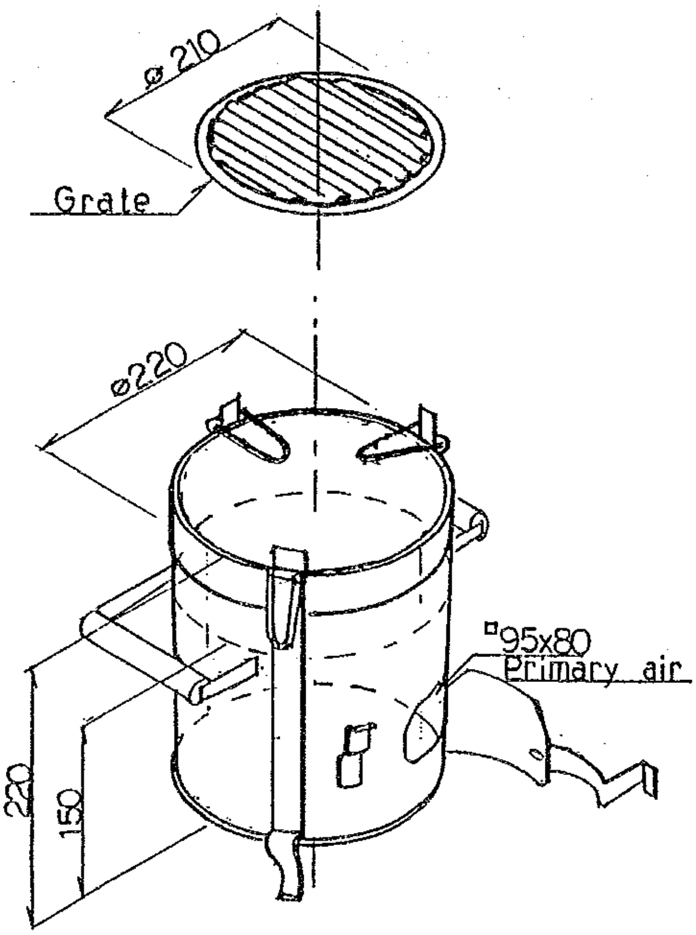


Figure 11-2-2 Pakistani Cooking Stove for Solid Fuel

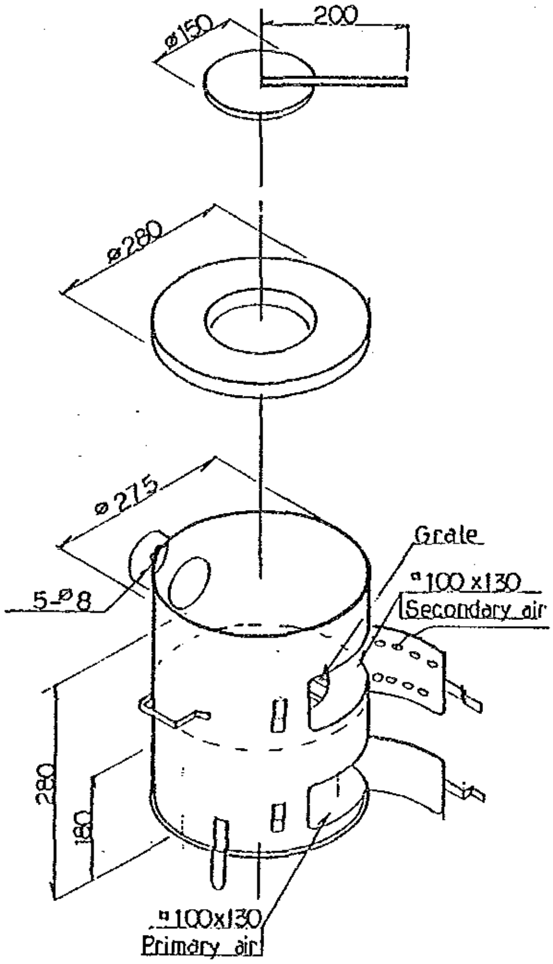


Figure 11-2-3 Quetta Stove

and began to burn without flame the upper portion of the stove was detached. Before the upper portion was detached, all the air inlets were open; when the upper portion was detached all the air inlets except for the primary air inlet were closed. The exhaust gas was analyzed for carbon monoxide, carbon dioxide, sulfur dioxide, oxygen and smoke. Thermal efficiency was measured by raising the temperature of three liters of water to the boiling point.

(1) Ignition

Firewood cut into small pieces, bagasse and paper were tested as kindling, of which firewood furnished best results if 50 to 100 grams were used. Bagasse also furnished good results.

(2) Heat liberation

Heat liberation was measured by the time required to heat water in the kettle. The measurements vary with the stove, amount of fuel loaded, quality of briquettes, and other conditions such as amount of air or ambient temperature. Table 11-2-3 shows the thermal efficiency of boiling water with experimental stoves. In general, time required to boil water depends on the amount and the kinds of coal briquette placed in the stove.

A typical pattern of burning briquettes in the stoves without chimney is represented by Ex. No. 11 of Table 11-2-3 which burned 1.0 kg of the briquettes designated as No. 2-11 of Table 11-2-2. The rate of heat liberation is greatest during the initial 30 minutes of combustion when the volatile matter burns; in every 11 to 12 minutes three liters of water is boiled. Then char takes over the volatile matter; during the period of char combustion, it takes 14 to 15 minutes to boil three liters of water. As char burns out, it takes increasingly longer to boil water. If 0.5 kg instead of 1.0 kg of briquettes is fed, it takes 15 to 25 minutes to boil three liter of water on or after the second run: the rate of heat liberation varies with the amount of coal briquettes charged. To emulate the heat liberation of the Pakistani household kitchen for cooking speed, one charge of more than 500 to 600 grams of coal briquettes is needed. The rate of heat liberation may be adjusted, of course, to a limited degree by adjustment of the openings of air inlets to the stoves.

In the case of stoves with chimney, ST-1 shown in Figure 11-2-10 for example, 1.0 kg of the same briquettes could boil three liters of water four times, or the same with stoves without chimney except for EX. No. 11. However, it takes longer with stoves equipped with chimney to do the same job. On the fifth run the fire was out when the temperature was raised to 62 or 64 C. The pillow-shaped coal briquettes turned out to be unsuited because of them being too large to burn well.

Table 11-2-2 Coal Briquette Used for Burning Test with Experimental Stove

Ex. No.	Low Heating Value kcal/kg	Shape	Remarks
2-11p	3,800	Almond	Paraffin Coated
2-10	3,693	Almond	
2-11	3,540	Almond	
2-11p	3,796	Almond	Paraffin Coated
2-27	4,706	Almond	Washed Coal
2-27p	4,717	Almond	Washed Coal
3-5	3,924	Pillow	
3-5p	4,165	Pillow	Paraffin Coated
3-6	3,480	Pillow	
3-6p	3,799	Pillow	Paraffin Coated

Table 11-2-3 Thermal Efficiency of Water Boiling with Experimental Stove

Ex.No.	Stove	Time Required to Heat Water(min.)						Thermal Efficieycy* (%)
		1st	2nd	3rd	4th	5th	6th	
1	C	16	14	15	19	(22-66)	-	28.8
2	C	17	12	18	23	(22-35)	-	26.3
3	D	15	10	19	20	(22-86)	-	30.5
4	D	21	13	16	22	(22-69)	-	29.1
5	D	18	15	15	20	(20.5-73)	-	33.4
6	D	20	15	18	26	(21.5-60)	-	31.7
7	E	18	15	17	21	(20-74)	-	29.5
8	E	20	27	(20.5-58.5)	-	-	-	32.9
9	E	21	31	(21-58.0)	-	-	-	33.1
10	F	17	12	14	15	(21-84)	-	34.1
11	F	12	11	15	14	33	(20.5-55.8)	36.7
12	F	13	25	(20.5-45)	-	-	-	30.7
13	F	12	15	(18.5-76)	-	-	-	26.9
14	ST-1	23	15	18	30	(21-62)	-	30.3
15	ST-1	20	13	15	35	(21-64)	-	28.3
16	ST-1	19	17	20	22	-	-	-
17	ST-1	28	19	21	20	-	-	-
18	ST-1	27	23	20	29	(18-45)	-	22.7

Note: The two figures in parenthesis indicate respectively temperatures of water before and after heating, hence the boiling point was not reached. The total heat transferred to water including the last run where the boiling point was not reached is used to calculate thermal efficiency.

(3) Thermal efficiency of water boiling

The stoves without chimney, or Type C through F exhibited thermal efficiencies in boiling water ranging from 26 to 37 percent when the coal briquette charge was 1 kg; but they showed somewhat lower efficiencies of 27 to 33 percent when the fuel charge was 500 grams. Types D, E, and F all showed thermal efficiencies of higher than 70 percent of the thermal efficiency of kerosene stove which was found to be 42 percent. The stove without chimney, Type ST-1, showed a lower efficiencies from 23 to 30 percent, presumably because of the greater heat allowed to escape through the chimney. Also, the burning of the briquettes of the highest heating value, Ex. No. 2-27 made from the washed coal, showed a lower efficiency of approximately 23 percent. These latter two phenomena should not be interpreted as indicating the fundamental defects of stoves with chimneys nor of the coal briquettes of the higher heating value. It rather shows that the burning conditions need to be adjusted to different stoves and different fuels.

(4) Smoke and effluent gas

(a) Stove without chimney

The stoves without chimneys were evaluated by the observations of the experts who conducted and stood by the experiments. The results were not quantified but could be more reliable in a sense that their responses may be regarded as representing the possible responses of the Pakistani consumers when they burn the coal briquettes. Smoke was generated in the initial period of the experimental combustions; smoke generated from combustion of coating agent was at first rather conspicuous but gradually diminished and completely disappeared in approximately 30 minutes. Those coal briquettes with sulfur under control by addition of slaked lime generated smoke which did not irritate the eye or throat at all. In a semi-open place similar to Pakistani cooking places smoke did not linger but readily dissipated itself to outside. It was found by the buring test that the combustible sulfur of the product coal briquettes should be made lower than 1 wt% or even much lower by addition of an appropriate amount of slaked lime in order for the smoke not to be irritating.

(b) Stove with chimney

A Ringelmann smoke detector was used to measure the concentration of smoke in the chimney. Table 11-2-4 gives the readings of the smoke detector.

Table 11-2-4 Ringelmann Reading
(In Case of Type ST-1)

Ex. No	Initial	Volatile matter burning: Average	Volatile matter burning: Maximum
2-11	0.2 to 0.5	0.08	0.18
2-11P	2.00	0.16	0.30
3-6P	0.30	0.18	0.34
3-5P	2.00	0.52	1.20

Except for the initial period of burning the Ringelmann readings lower than 1 were obtained, with only one exception of 1.2, for all fuel tested; the levels of smoke indicated by these Ringelmann readings are barely discernible by the naked eye. The emission of sulfur dioxide, or SO_2, can be suppressed by addition of an appropriate amount of slaked lime as shown in Table 11-2-5. The levels of R, or the ratio of carbon monoxide, or CO, to carbon dioxide, or CO_2, and nitrogen oxides, or NOx, were very low as indicated by Figure 11-2-12 through 11-2-15.

Table 11-2-5 Level of Sulfur Dioxide (In Case of Type ST-1)

(Unit: PPM)

Ex. No.	Volatile Matter Burning Maximum	Volatile Matter Burning Average	Char Burning Maximum
2-11	740	474	722
2-11P	1,320	846	889
3-6P	534	348	585
3-5P	712	460	473

In the course of designing the experimental stoves, it was found that the conventional solid fuel stoves sold in the market places of Pakistan can be easily modified to burn the coal briquettes rather well.

- In case of the stoves without chimney, installation of an easily separable outer duct and inner duct is recommended to rectify the long flame of the briquettes.

- In case of the stoves with chimney, providing secondary and tertiary air inlets improves the thermal efficiency.

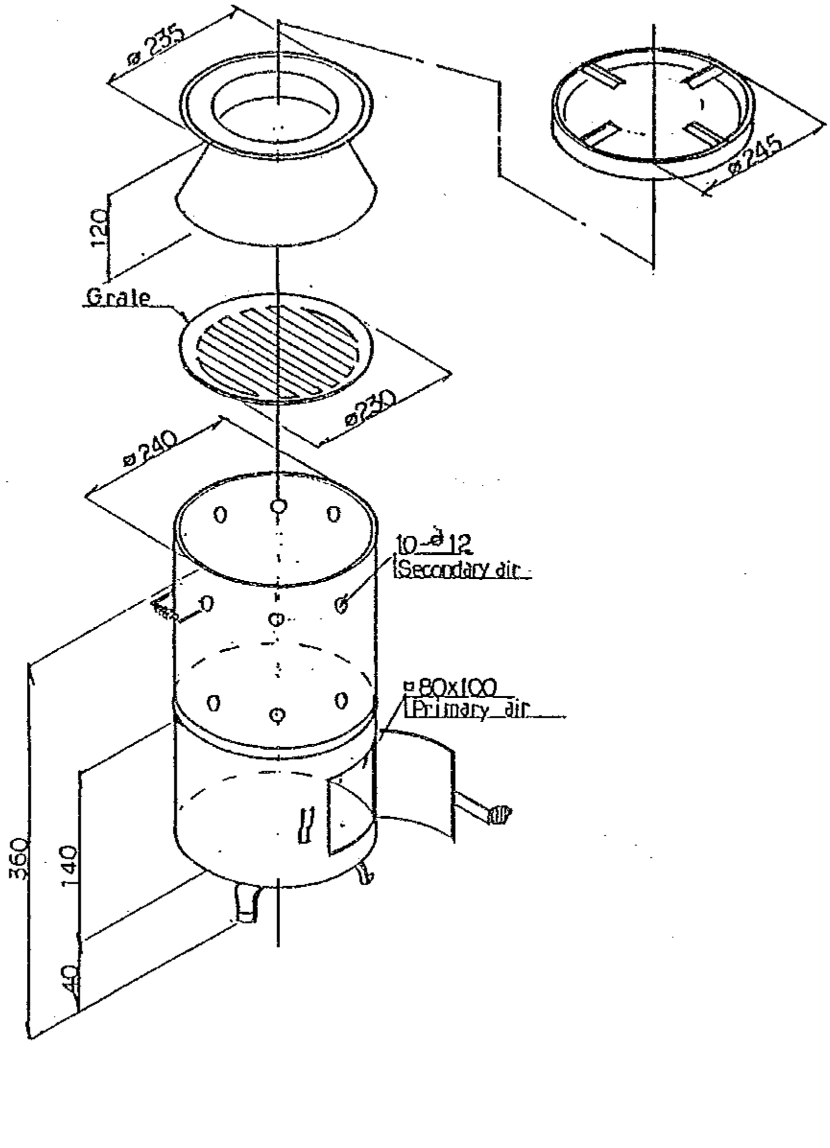


Figure 11-2-4 Type A Portable Cooking Stove

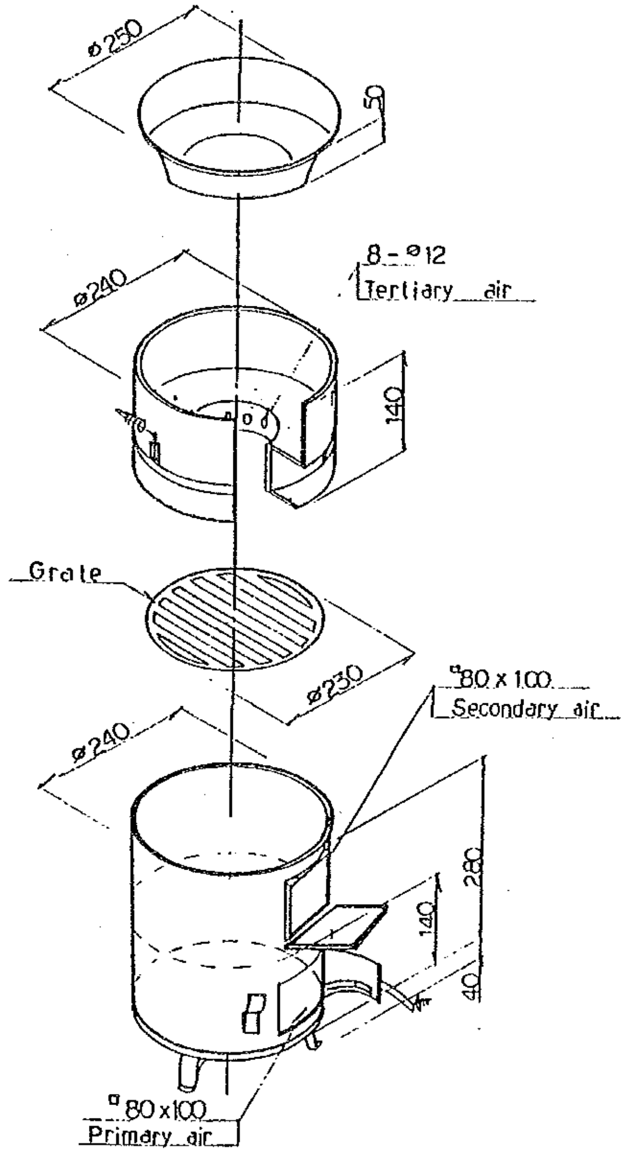


Figure 11-2-5 Type B Portable Cooking Stove

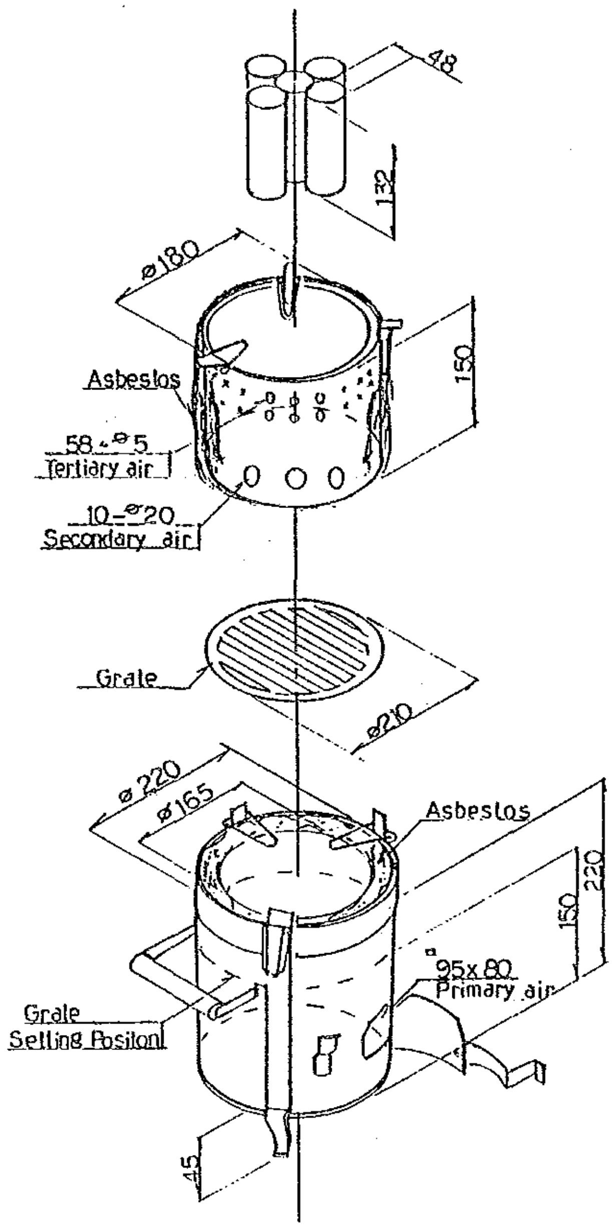


Figure 11-2-6 Type C Portable Cooking Stove

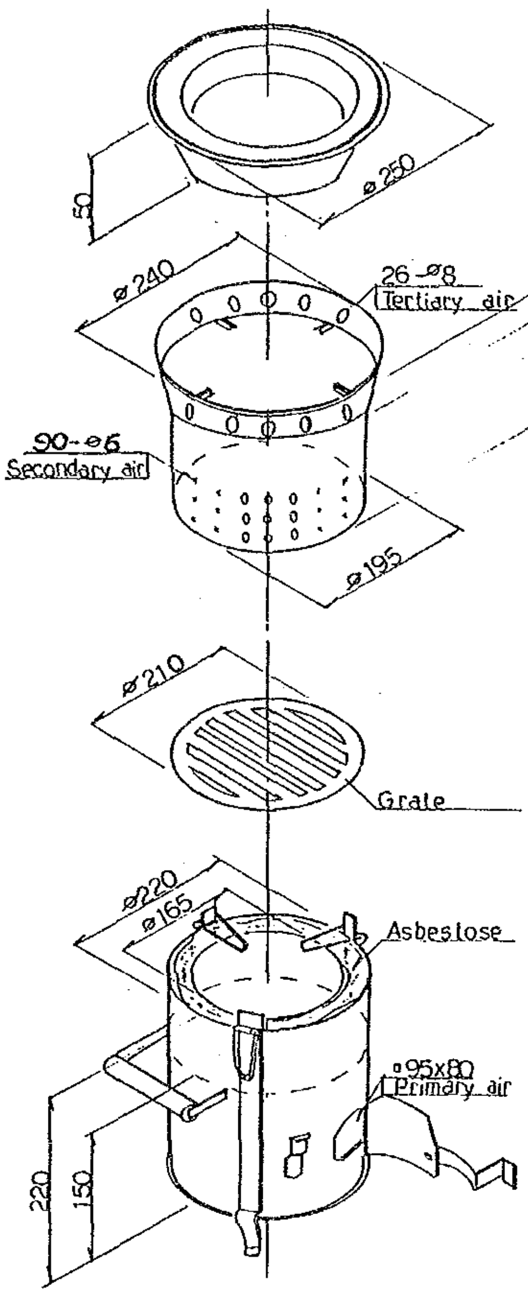


Figure 11-2-7 Type D Portable Cooking Stove

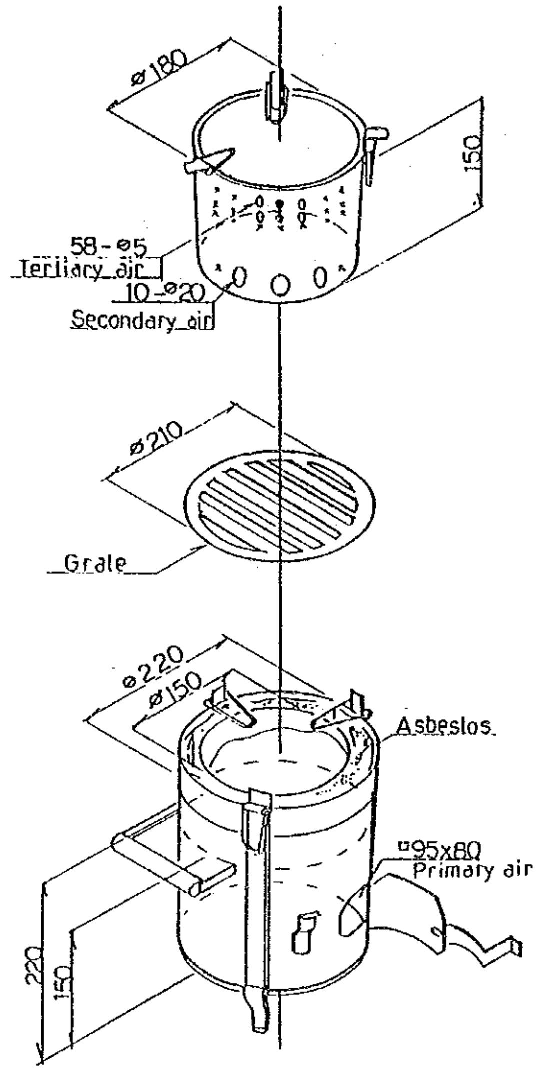


Figure 11-2-8 Type E Portable Cooking Stove

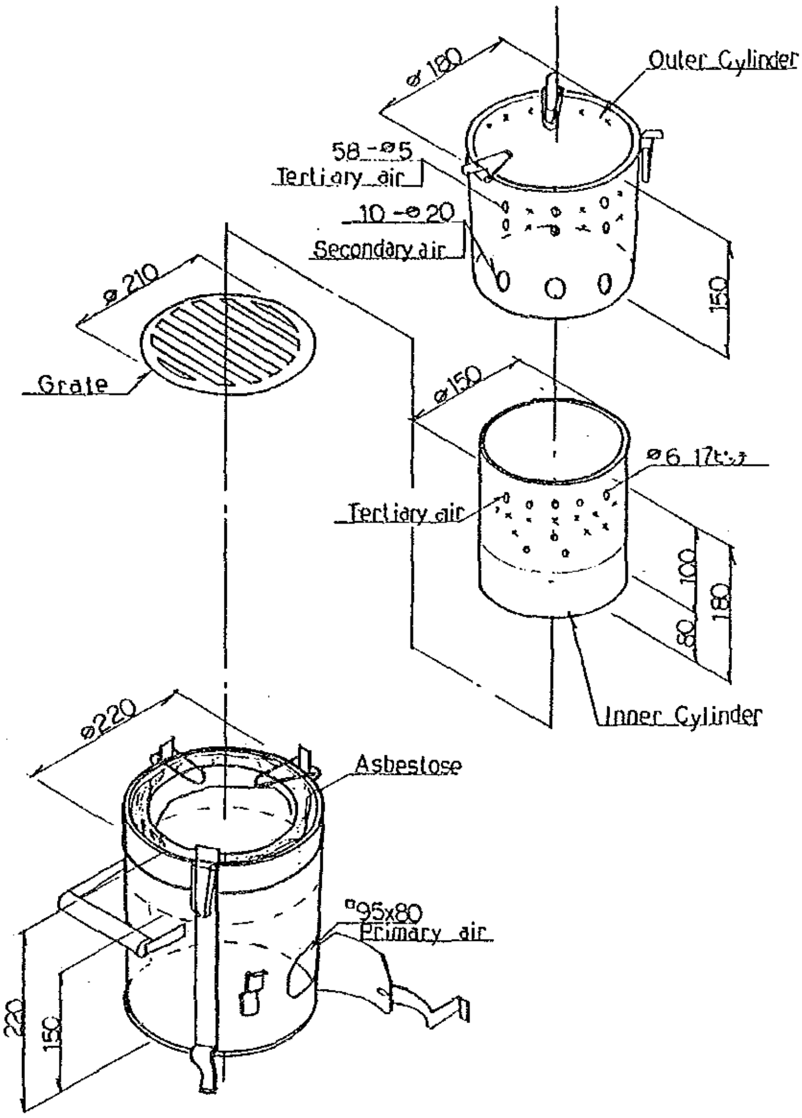


Figure 11-2-9 Type F Portable Cooking Stove

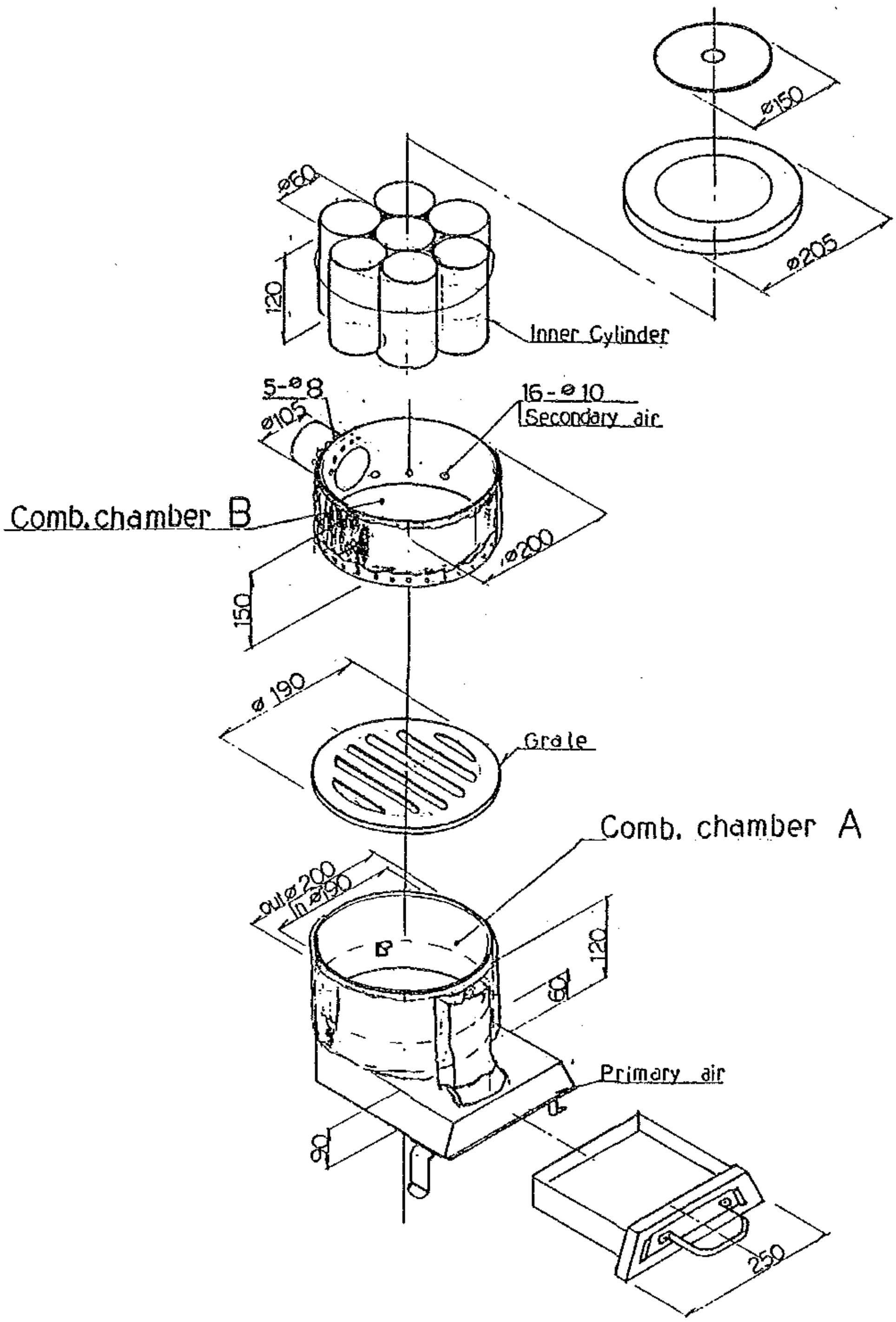


Figure 11-2-10 Separable Cooking Stove with Chimney (Type ST-1)

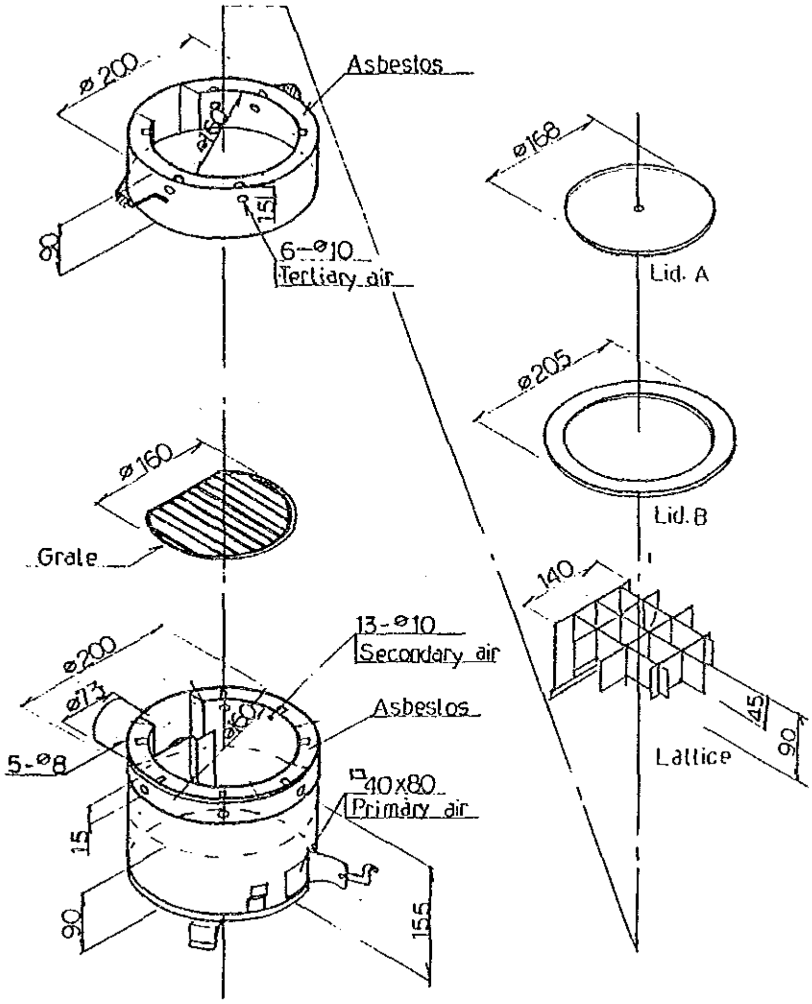


Figure 11-2-11 Separable Cooking Stove with Chimney (Type ST-2)

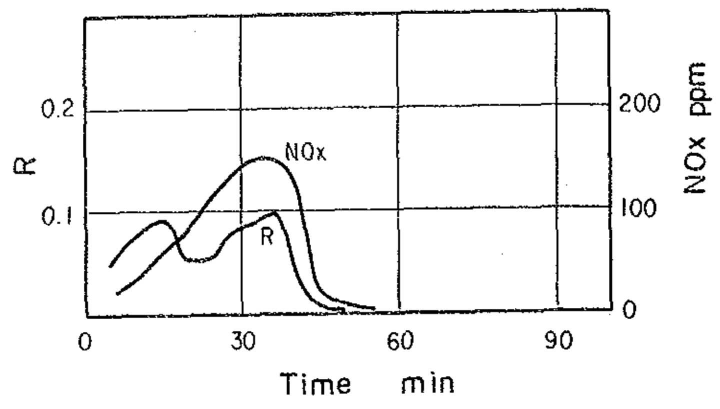


Figure 11-2-12 R and NOx Level with Ex. No. 2-11

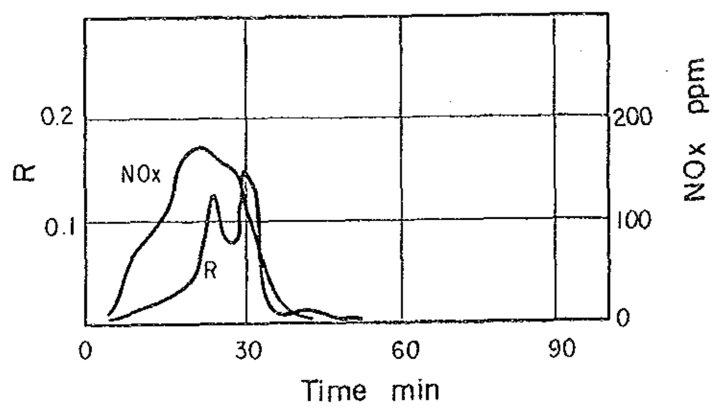


Figure 11-2-13 R and NOx Level with Ex. No. 2-11p

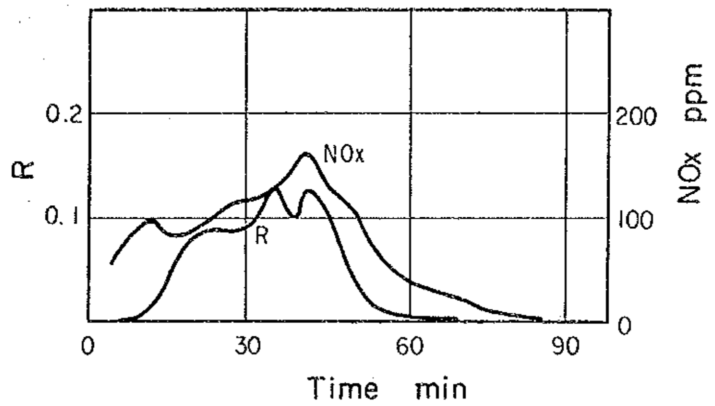


Figure 11-2-14 R and NOx Level with Ex. No. 3-6p

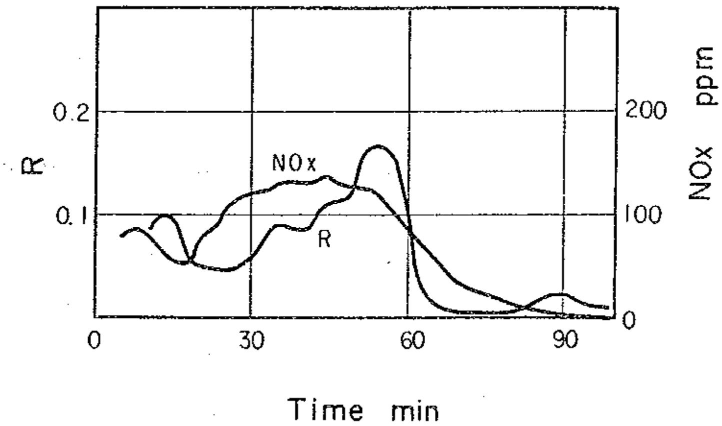


Figure 11-2-15 R and NOx Level with Ex. No. 3-5p

11-3 Evaluation of Burning Quality of Coal Briquettes

11-3-1 Method of Burning Test

To evaluate the burning quality of coal briquettes, observation by the experts who conducted or stood by the experiment was given the highest weight. In addition, an exhaust gas analyzer and Ringelmann smoke detector were used to measure concentrations of oxides of sulfur, carbon monoxide, carbon dioxide and smoke. The arrangement of these instruments is schematically shown on Figure 11-3-1.

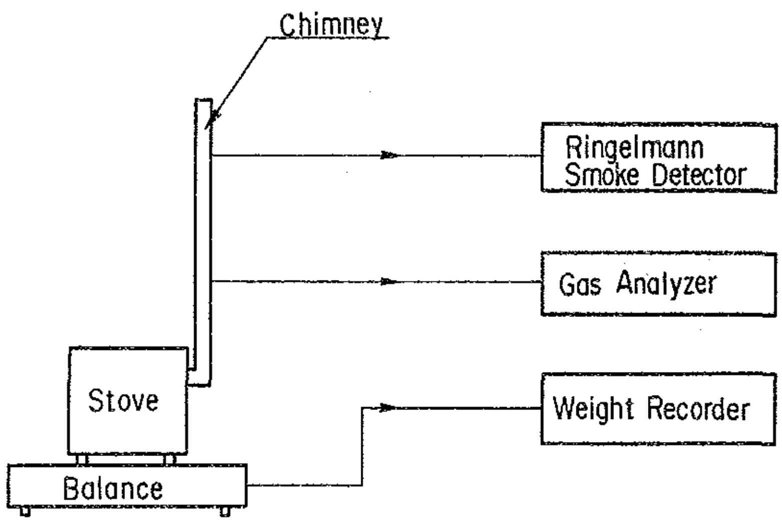


Figure 11-3-1 Arrangement of Instrument for Burning Test

For the burning test, Type F and Type ST-2 stoves were used. The amounts of coal briquettes placed in them per run were 1.0 kg and 0.5 kg, respectively and 50 grams of firewood cut into small pieces and a piece of newspaper were used as kindling. It took 4 to 5 minutes after ignition until the fire spread across the roaster, after which thermal efficiencies of boiling water were measured. The hood was dismantled from the stove when the volatile matter was exhausted. At that time the air inlets of stoves were fully opened to realize the maximum burning rate. . Simultaneously, the rate of consumption of fuel, or rate of decrease in the weight of fuel to be exact, was measured. The level of smoke was measured by observation and Ringelmann smoke detector. The flue gas was sampled for analysis of SOx, NOx and CO at 30 cm above the upper edge of the stove in case of the stove without chimney and from the center of ascending flue gas at 40 cm above the outlet of the stove or inlet to the chimney in case of the stove with chimney.

11-3-2 Candidate Coal Briquettes Experimentally Produced

In parallel with the experimental production of coal briquettes, a number of burning tests were conducted one after another in order to find the optimum blending ratio of raw materials. In the course of these tests, the most promising candidate coal briquettes were selected. The blending ratio of raw materials they contain, their shape, size and volume, and their chemical composition are shown in Tables 11-3-1 through 11-3-3, respectively.

Table 11-3-1 Blending Ratio of Raw Materials in Candidate Coal Briquettes

Type of Coal Briquette	Raw Material	Blending Ratio (%)
A	ROM Coal (Lot P-1 thru P-5)	67.2
	Bagasse	16.8
	Slaked Lime	12.6
	Coating Agent	3.4
	Total	100.0
B	ROM Coal (Lot P-1 thru P-5)	63.5
	Bagasse	15.8
	Slaked lime	15.8
	Coating Agent	4.9
	Total	100.0
C	Washed Coal	72.1
	Bagasse	18.0
	Slaked Lime	6.3
	Coating Agent	3.6
	Total	100.0

Table 11-3-2 Shape, Size and Volume of Candidate Coal Briquette

	Condition
Shape	Almond shape
Size	37mm x 21mm x 13mm
Volume	Approximately 6 cm^3

Table 11-3-3 Chemical Composition of Candidate Coal Briquette

Type of Coal Briquette		A	B	C
Moisture,	%	8.3	6.4	7.1
Ash,	%	39.8	41.6	16.9
Total Sulfur (Dry),	%	4.2	4.0	2.7
Incombustible Sulfur (Dry),	%	3.0	3.5	1.9
Combustible Sulfur (Dry),	%	1.2	0.5	0.8
Total Heating Value,	kcal/kg	4,250	4,230	5,420
Low Heating Value, kcal/kg,	kcal/kg	4,020	4,010	5,160
Carbon,	%	37.9	32.7	59.1
Hydrogen,	%	3.7	3.2	4.3
Nitrogen,	%	0.5	0.5	0.9
Sulfur,	%	1.0	0.6	0.6
Oxygen,	%	11.1	11.8	21.0

11-3-3 Results of Burning Test

The results of the burning tests on coal briquettes A, B, and C by means of the method aforementioned are summarized in Table 11-3-4. The thermal efficiency in water boiling exceeded 30 percent when 1.0 kg of candidate coal briquettes were placed in the stove without chimney, corresponding to approximately 80 percent of the thermal efficiency of the Pakistani household kerosene stove (42 percent), and the time required to boil water was very short. Contratrily, in case of the stove with chimney, the thermal efficiency in water boiling was approximetely 20 percent, a low figure, due to a large heat loss through the chimney.

The period of smoke generation as detected by Ringelmann detector was comparatively long with both stoves although it depended on the amount of coal briquettes placed. The Ringelmann reading, however, exceeded 2.0 in the initial period when the stove with chimney was used, and was less than 1.5 in all cases when the stove without chimney was used as shown on Figures 11-3-2 through 11-3-7. When the coal briquettes made from the Lakhra coal were burned, the color of smoke in the gas* leaving the chimney was white unless the reading exceeded 2.0, and was slightly white when the reading ranged from 1.0 to 1.5, and was at a level almost undetectable by the eye when the reading was less than 1.0. Therefore, the coal briquettes are practically usable.

(Note: The exhaust gas* was discharged through the hood in case of the stove without chimney and through the chimney in case of the stove with chimney.)

Overall, the stoves experimentally produced to meet the life style of Pakistan can burn coal briquettes well but with some smoke in any cases; however, the experts who conducted or stood by the experiments confirmed that any irritating smells were not produced. Thus the amount and kind of smoke emitted is considered to be acceptable in view of the fact that these stoves are used in the semi-open kitchens found in the standard households of Pakistan.

Table 11-3-4 Results of Burning Test for Candidate Coal Briquettes

Ex. No.	Type of Coal Briquette	Weight (g)	Type of Stove	Time Required to Boil Water (min.)						Thermal Efficiency of Water Heating* (%)	Period of Smoke Generation (min.)	Max.SOx (ppm)	Max.CO (ppm)	Max.NOx (ppm)
				1st	2nd	3rd	4th	5th	6th					
#1	A	1,000	F	15	12	24	22	28	(17.5-62)	34	32	104	0.07	28
#2	A	500	F	16	27	(19-58)	-	-	-	30	18	105	0.05	27
#3	B	1,000	F	14	10	32	37	42	(18.5-73.5)	35	36	50	0.08	24
#4	B	500	F	11	13	(19-62)	-	-	-	31	13	60	0.06	28
#5	C	1,000	F	14	11	18	20	35	(16-85)	30	30	80	0.10	35
#6	C	500	F	10	14	(16-76)	-	-	-	28	13	30	0.08	28
#7	B	1,000	ST-2**	35	37	36	(16-48)	-	-	19	46	447	0.20**	100
#8	B	1,000	ST-2	28	42	(16-76)	-	-	-	13	22	487	2.2	114
#9	C	1,000	ST-2	26	22	20	29	(16-62)	-	20	20	480	1.2	120

Note: * Thermal efficiency of water heating is calculated using the total heat transferred to water including that of last run where temperature is raised from the lower figure to the higher figure in the parenthesis.

** Burning condition was adjusted by means of opening or closing of the primary air inlet.

If only the decrease in the period of smoke generation is desired, the coating agent consisting mainly of light fuel oil should not be used. The coal briquettes can ignite and build up to a strong flame rapidly enough. But this is not recommended.

The maximum level of SOx generation by the experimental stoves is shown in Table 11-3-4, and is further summarized as shown in Table 11-3-5.

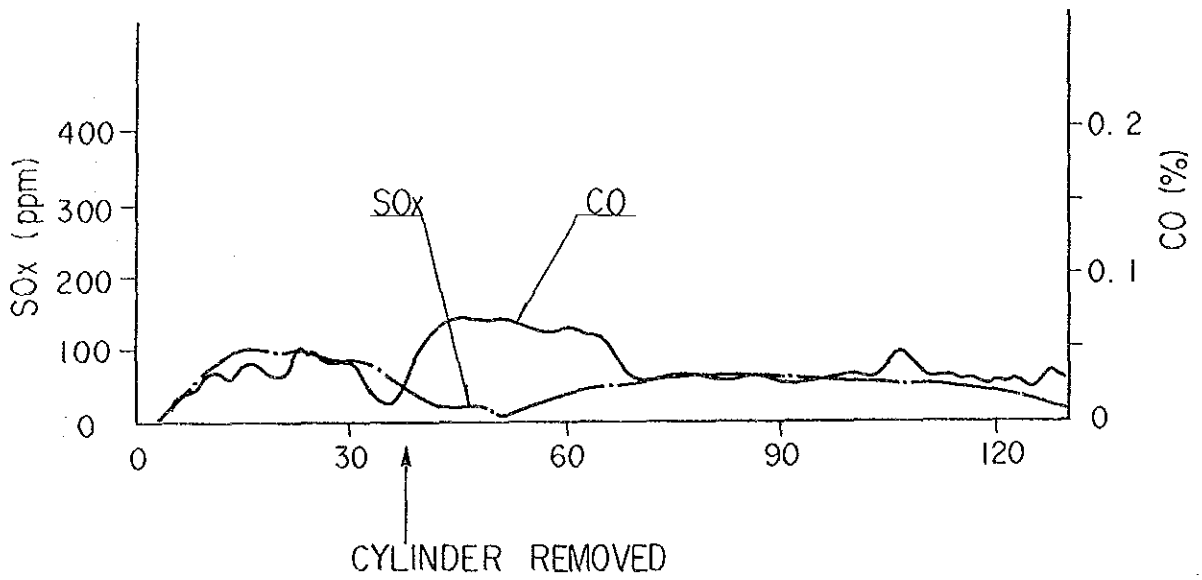
Table 11-3-5 Maximum Level of SOx

Type of Coal Briquette	Coal (%)	Slaked Lime (%)	Type of Stove (%)	Max.Level of SOx (PPM)
A	ROM 67.2	16.8	without Chimney	Approximately 100
B	ROM 63.5	15.8	-Ditto-	50 to 60
C	Washed 72.1	18.0	-Ditto-	30 to 80
B	ROM 63.5	15.8	with Chimney	450 to 470
C	Washed 72.1	18.0	-Ditto-	Approximately 480

As shown in Table 11-3-5, the level of SOx is higher in the case of the stove with chimney than in the case of the stove without chimney. The candidate coal briquette B placed in the stove without chimney sustained a low level of SOx generation as shown in Figure 11-3-2 through 11-3-7. During the tests, the typical irritating smell of SOx was rarely observed in the test laboratory.

Concerning the other effluent gases such as NOx, CO, as shown in Table 11-3-4 and Figure 11-3-2 through 11-3-7, no serious levels were observed. No significant amount of NOx was generated in all types of coal briquettes and stoves. The level of CO was low in all types of coal briquettes placed in the stove without chimney, but high in the stove with chimney especially when the burning condition was not controlled. The latter was caused by the fact that the secondary and the tertiary air flow rate to the primary air flow rate remained at a low level. However, this can be taken care of by putting the top of the chimney out to the outside.

Overall, it can be considered that the levels of smoke and other effluent gases generated in this burning test were sufficiently low, taking into account that the burning mechanism of coal briquettes is different from those of gas fuel and liquid fuel and thus entirely smokeless burning can rarely expected. Therefore, it is judged that the target of the experimental production of coal briquettes was achieved from the view point of the results of burning tests, and evaluation of burning quality of coal briquettes.



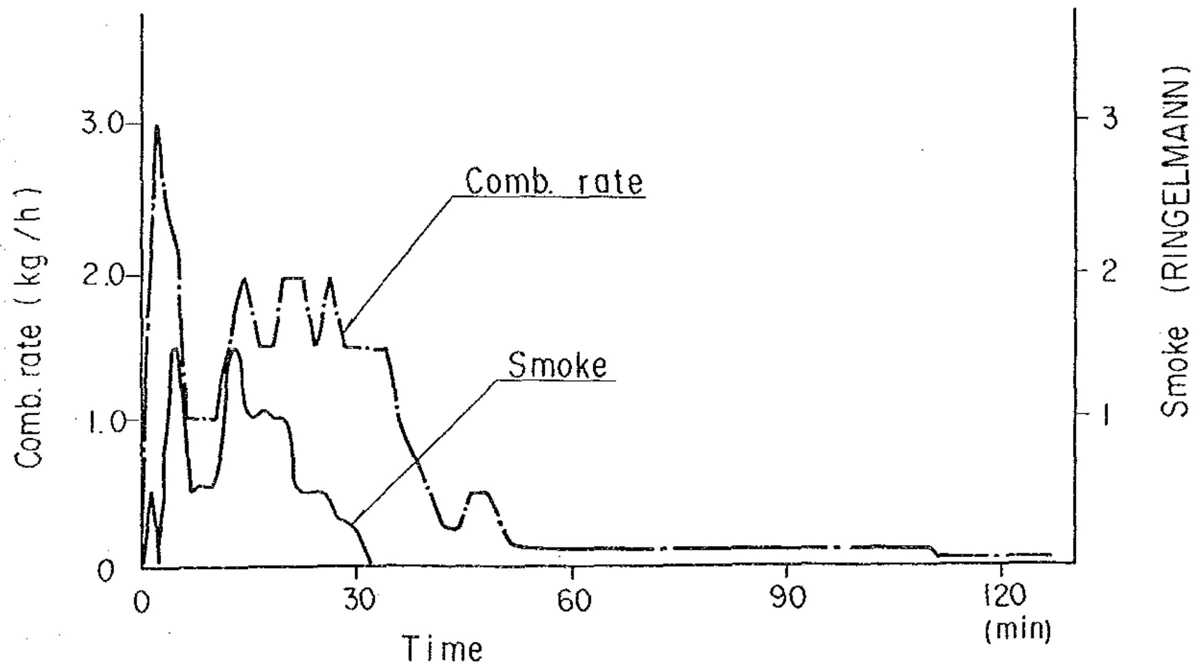


Figure 11-3-2 Levels of SOx, CO, Combustion Rate and Smoke with Ex.No.#1

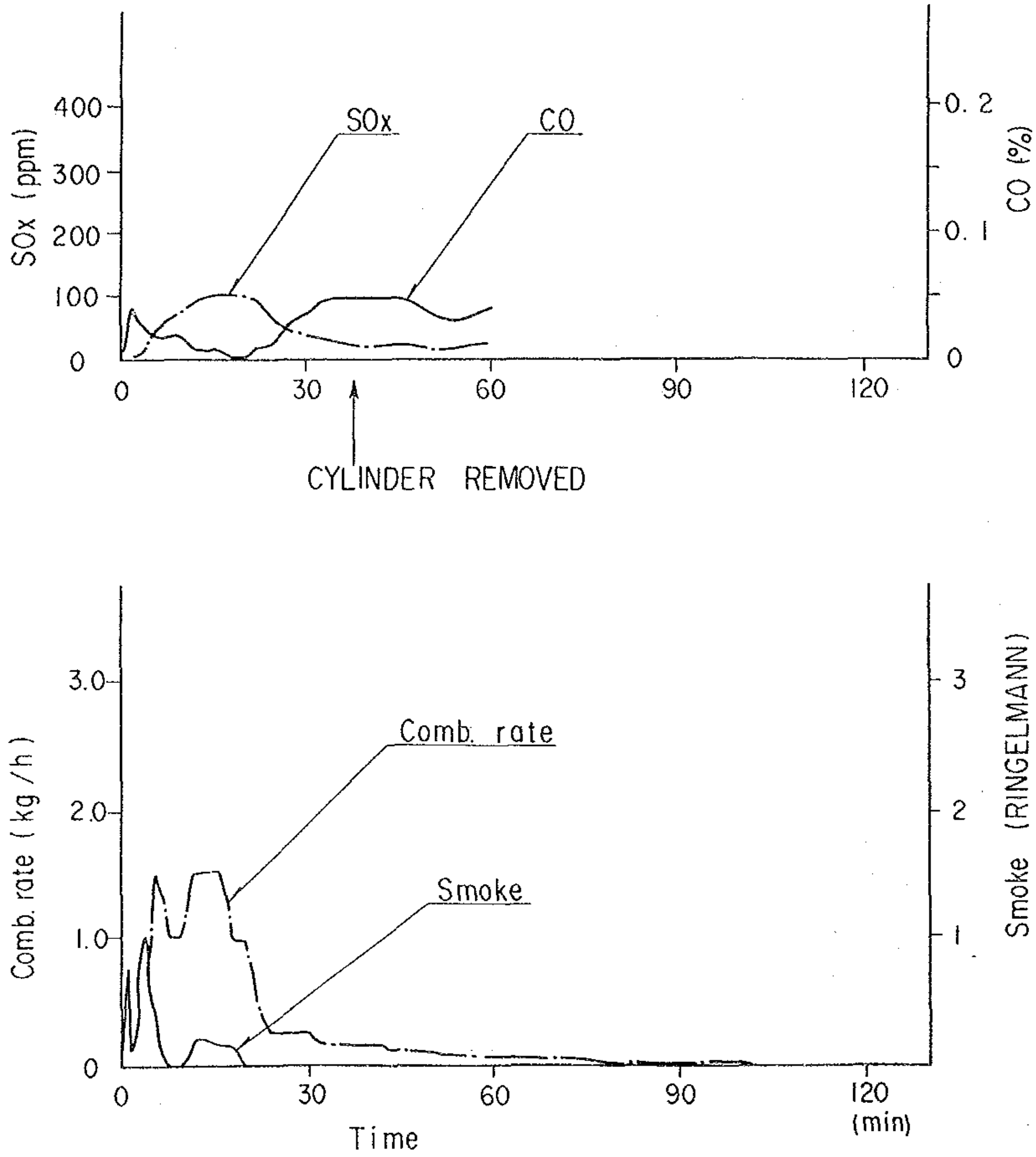


Figure 11-3-3 Levels of SOx, CO, Combustion Rate and Smoke with Ex.No.#2

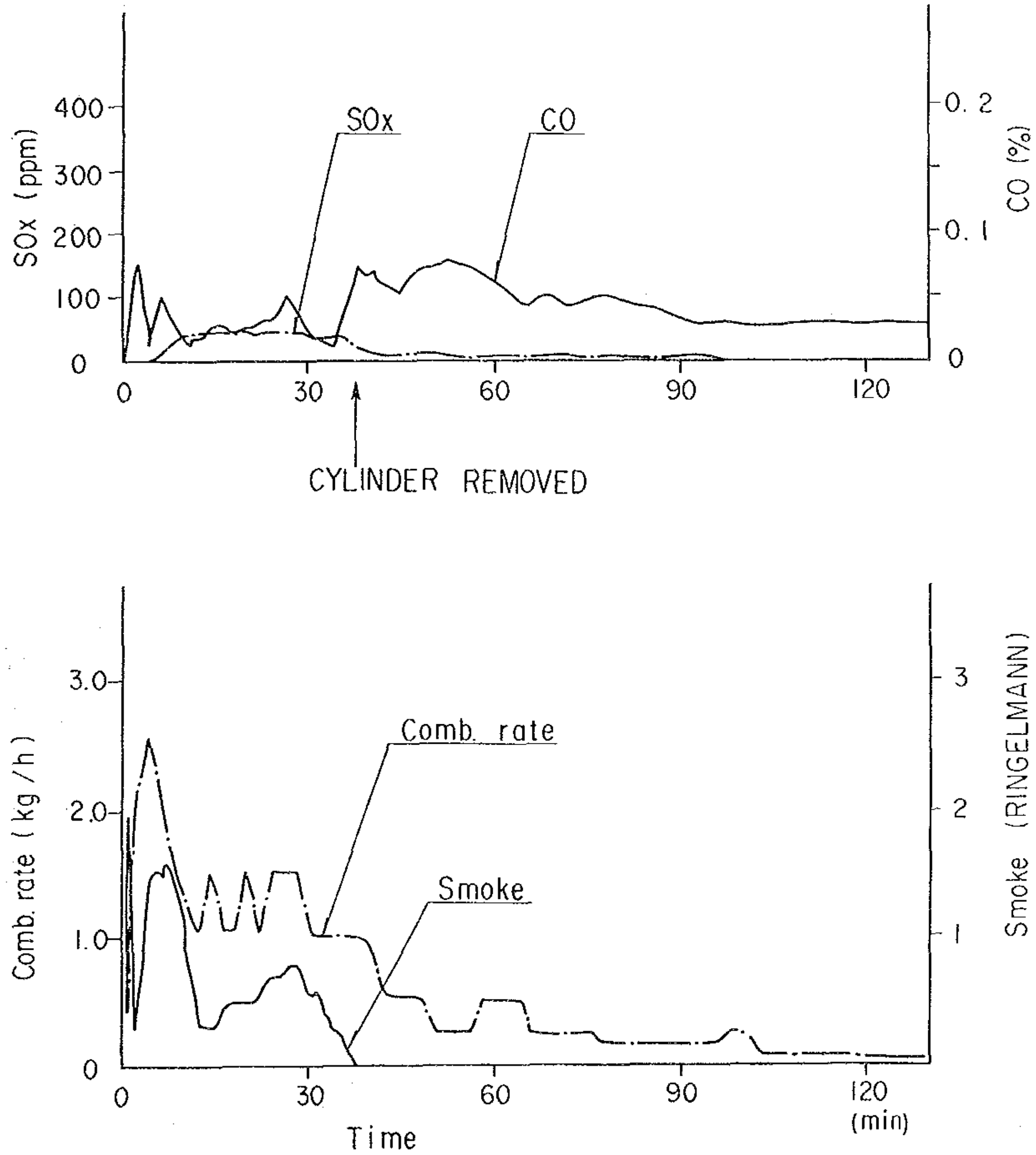


Figure 11-3-4 Levels of SOx, CO, Combustion Rate and Smoke with Ex.No.#3

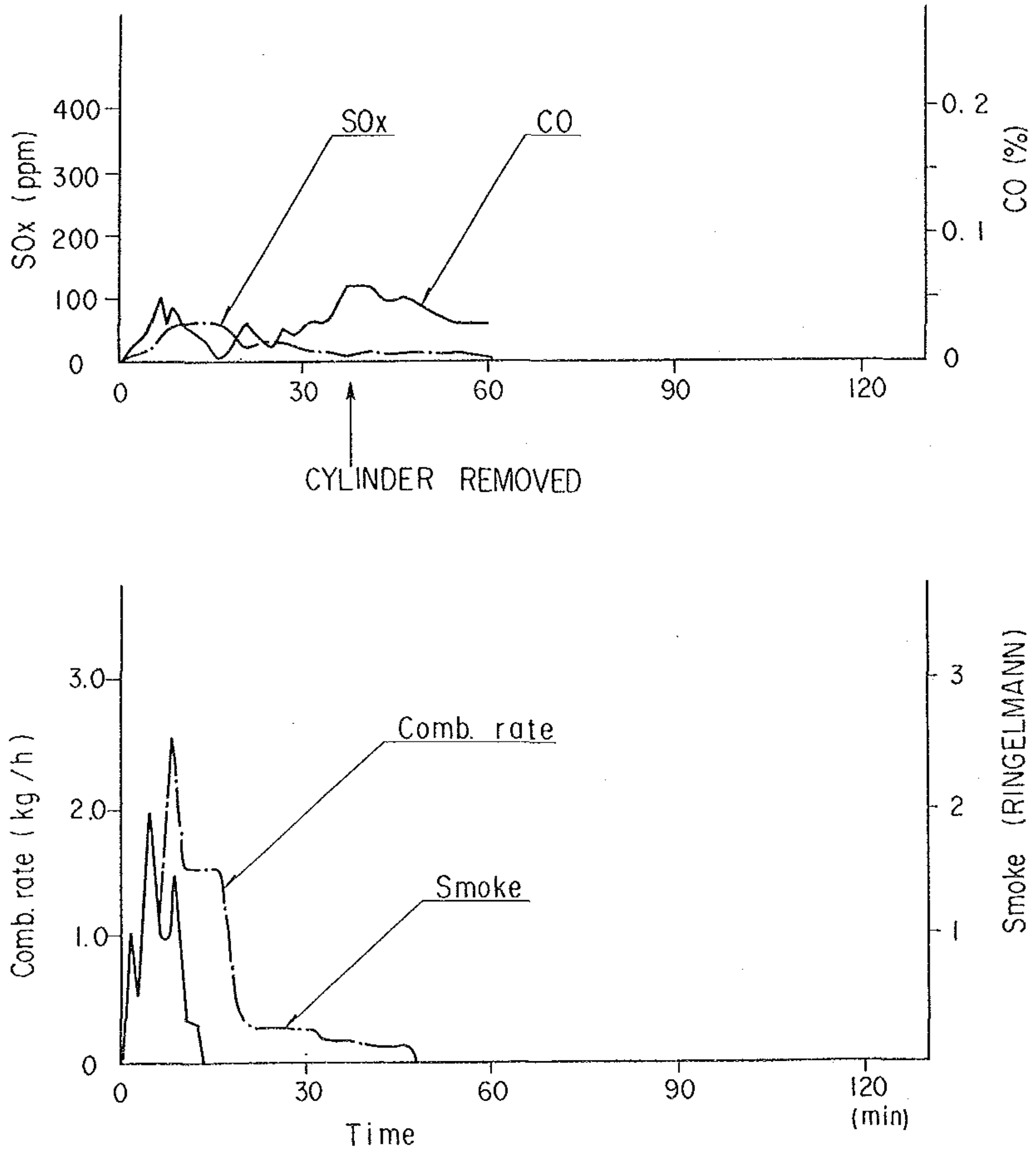


Figure 11-3-5 Levels of SOx, CO, Combustion Rate and Smoke with Ex.No.#4

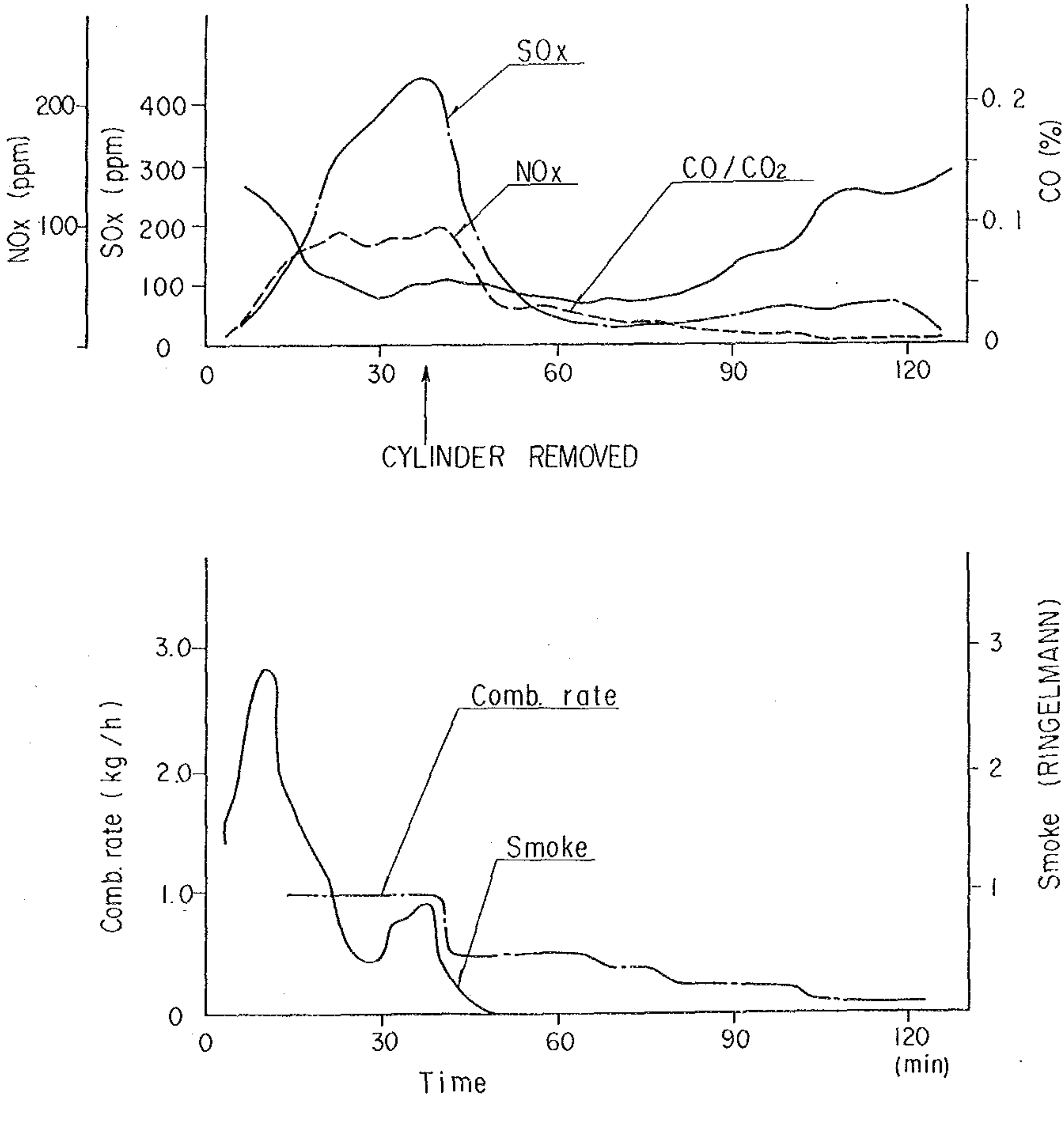


Figure 11-3-6 Levels of SOx, CO, Combustion Rate and Smoke with Ex.No.#7

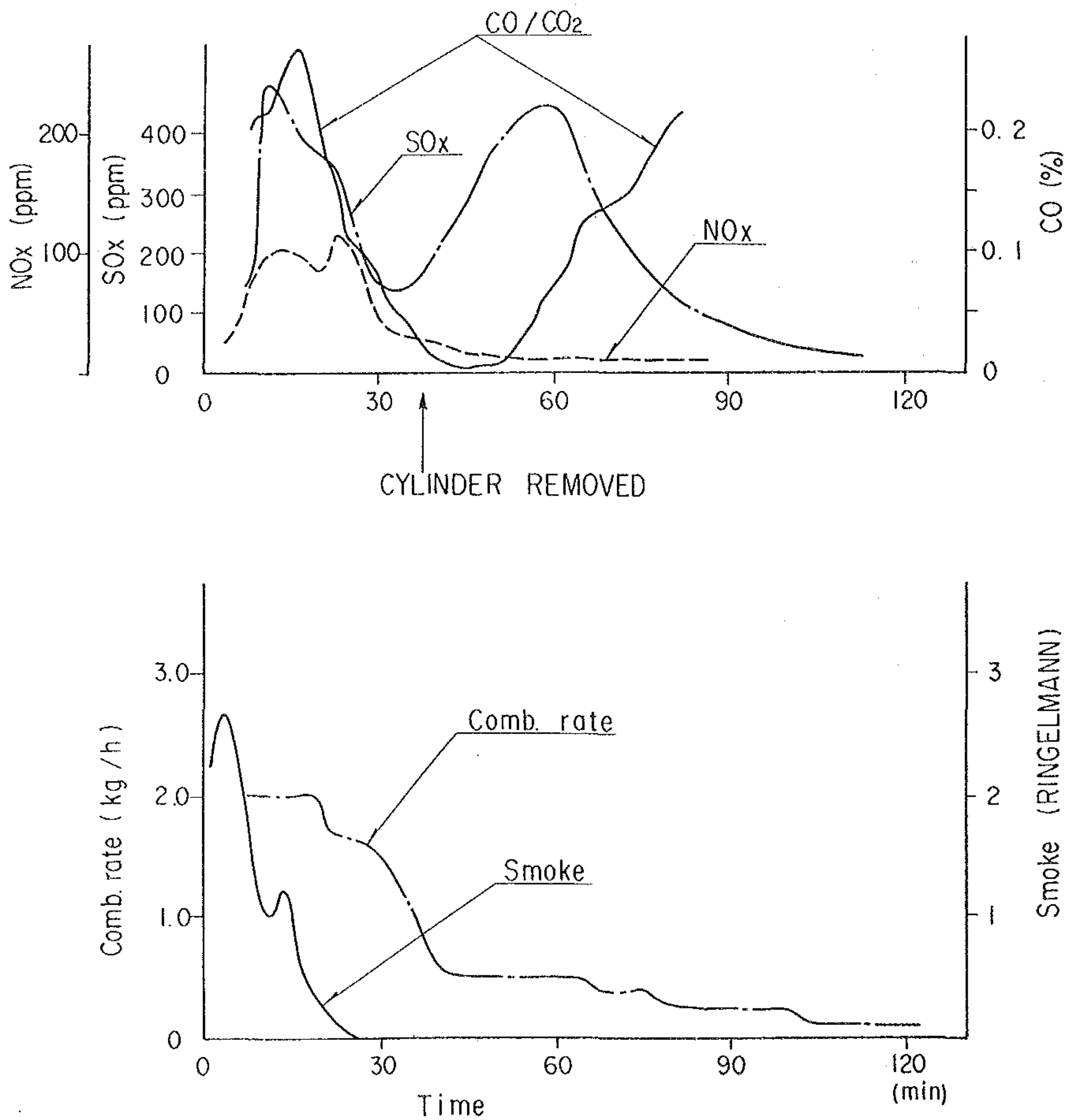


Figure 11-3-7 Levels of SOx, CO, Combustion Rate and Smoke with Ex.No.#8

CHAPTER 12 CONCEPTUAL DESIGN OF COAL BRIQUETTE MANUFACTURING

12-1 Major Premises for Conceptual Design

12-1-1 Basis of Conceptual Design

The conceptual design of this project is conducted on a unit capacity of 50,000 tons per year of coal briquette production. The 50,000-ton-per-year plant has two twin briquetting machines, each with 25,000-ton-per-year capacity. This feasibility study investigates three cases; Case 1, Case 2 and Case 3, Cases 1 and 3 starting at 50,000 and Case 2 at 100,000 tons per year. The 100,000-ton-per-year plant consists virtually of two 50,000-ton-per-year plants, because the technically proven maximum sizes of many pieces of equipment used in this plant are just adequate for 50,000-ton-per-year plant; except for the briquetting machine, for which the maximum capacity of 25,000-ton-per-year is appropriate.

Contrary to the coal briquette plant, coal washing plants are usually very large, the smallest standard capacity for modular design being about 100 tons per hour which is too large for this project. This project uses a 30-ton-per-hour coal washing plant of customized design. This capacity can sufficiently process enough raw coal in the daytime to satisfy one day's requirement of the feed to the briquetting plant which operates 24 hours a day.

To summarize, the basis for the conceptual design is as shown in Table 12-1-1.

Table 12-1-1 Basis for Conceptual Design

	Briquetting plant	Washing plant
Capacity, tons/year	50,000	62,500
Operating period, days/year	300	300
hours/day	24	6.94
Running rate,%	100	100
Product rate, tons/hour	6.94	
Feed rate, tons/hour	-	30
Shifts per day	3	1

12-1-2 Manufacturing Process

The determination of the manufacturing process reflects the results of the studies of other chapters, particularly CHAPTER 5, RAW MATERIALS FOR COAL BRIQUETTES, 9, RAW MATERIAL TEST AND EVALUATION, 10, EXPERIMENTAL PRODUCTION OF COAL BRIQUETTES, and 11, BURNING TEST. Moreover, the following is given due consideration.

1. The washing of coal is incorporated to increase the heating value of the product and decrease the sulfur content and thereby addition of slaked lime.

2. The volatile matter is retained so that the coal briquettes may burn with a powerful flame during the initial period of combustion to make an effective use of heat content and to reduce the investment cost.

3. The kinds of machines best suited to the process are selected; for example, a briquetting machine of extremely high pressure to make briquettes without using binders and crushers and driers suited to coal and bagasse to crush them into small particles.

4. Locally procurable machines are used as much as possible.

5. The machines and equipment should be easy to operate under the local conditions to ensure uniform quality of the products.

12-1-3 Quality of Raw Material and Blending Ratio

Here, conditions of the raw materials and product are defined for the purpose of conceptual design. As discussed in CHAPTER 8, PROJECT SCHEME, the raw materials finally selected are Lakhra coal, bagasse, slaked lime, slack wax and light fuel oil.

(1) Lakhra coal and bagasse

Based on the results of raw material test and experimental production of coal briquettes, the design conditions of feed coal and bagasse are defined as Table 12-1-2.

Table 12-1-2 Design Conditions of Feed Coal and Bagasse

	Coal	Bagasse
At briquetting plant inlet		
Maximum particle size,mm	10	preferably 20
Total moisture,%	33	50
Moisture to evaporate,%	24	45.4
Moisture to retain,%	9	4.6
Bulk density, kg/l	0.75	0.20
At drier outlet		
Moisture,%	12.0	8.5
Bulk density, kg/l	0.67	0.09
At crusher outlet		
Maximum particle size, mm	2	2
Moisture,%	12.0	8.5
Bulk density, kg/l	0.75	0.10
Specific heat, Kcal/kg,C	0.3	0.4

(2) Slaked lime

Quality of slaked lime is set as in Table 12-1-3 based on the analysis of the sample.

Table 12-1-3 Design Condition of Slaked Lime

Particle size, %	
less than 0.15mm	95 min
less than 0.075	70 min
CaO content,%	90 min
Moisture content,%	5 max
Bulk density, kg/l	0.4

(3) Slack wax

From the estimated quality of slack wax normally produced as by-product of lubricating oil of Arabian light origin, the quality of slack wax is assumed as shown in Table 12-1-4.

Table 12-1-4 Design Condition of Slack Wax

Specific gravity	0.87 to 0.94
Heat of fusion, Kcal/kg	35
Melting point,C	54
Specific heat, Kcal/kg C	0.69
Gross heat of combustion, kcal/kg	11,000

(4) Light fuel oil

According to the ASTM specifications to which light fuel oil conforms, the quality of this stock is set as in Table 12-1-5.

Table 12-1-5 Design Condition of Light Fuel Oil

Specific gravity	0.82 to 0.90
Gross heat of combustion, Kcal/kg	11,000

(5) Blending ratio

Based upon the result of the experimental production of coal briquettes, the blending ratios for the purpose of conceptual design is set as shown in Table 12-1-6.

Table 12-1-6 Blending Ratios of Raw Materials

	Blending_ratio	Moisture_content,%
Coal	80	12.0
Bagasse	20	8.5
Subtotal	100	
Slaked lime	7.0(1)	5.0
Coating agent (3)	5.6(2)	

Note:
(1) Blending ratio of slaked lime was calculated to neutralize 3 percent of sulfur contained in the washed sulfur, and varies with sulfur content of coal.
(1) and (2) Blending ratios to the above subtotal
(3) Slack wax and light fuel oil in a ratio to one to 7.3

12-1-4 Product Coal Briquette

(1) Size and shape of product

The size and shape of the product coal briquette are defined as shown in Table 12-1-7 to give the desired burning quality.

Table 12-1-7 Shape and Size of Product Coal Briquette

Shape	Almond
Size,mm	
width	37 to 41
length	21 to 25
height	12 to 16
Bulk density,kg/l	0.65 to 0.75
Real density,kg/l	1.3 to 1.6

(2) Typical property of product

Table 12-1-8 gives the typical properties of the product coal briquette.

Table 12-1-8 Typical Property of Product Coal Briquette

(Unit : %)

Moisture	7.1
Ash	16.9
Total Sulfur (Dry)	2.7
Incombustible Sulfur (Dry)	1.9
Combustible Sulfur (Dry)	0.8
Collapse Strength, kg	162
Toal Heating Value, kcal/kg	5,420
Low Heating Value, kcal/kg	5,160
Carbon	59.1
Hydrogen	4.3
Nitrogen	0.9
Sulfur	0.6
Oxygen	21.0

12-2 Conceptual Design

12-2-1 Outline of Process

Figure 12-2-1 shows the outline of the process developed based upon the major premises for conceptual design aforementioned and also from the material and heat balances shown below.

(1) Coal line

The feed coal is washed to reduce ash and sulfur contents before being fed to this line. The coal is dried and crushed to less than 2 mm and stored in a working silo.

(2) Heat gas line

The raw coal is burned to generate a hot air stream to be introduced to the coal and bagasse driers as a drying medium. The flue gas is exhausted to atmosphere.

(3) Bagasse line

The raw material bagasse is fed to this line to be dried and crushed to less than 2 mm and stored in a working silo.

(4) Slaked lime line

Slaked lime, the desulfurizing agent, is purchased in powder form in bag. The bags are piled under the shelter and fed to the silo as necessary.

(5) Mixing and briquetting

The powdered coal, powdered bagasse and slaked lime are withdrawn from their silos at controlled rates and mixed thoroughly and briquetted. The briquettes fresh from the briquetting machine have rims which are removed in a trommel; the rims removed are returned to the mixer to be fed to the

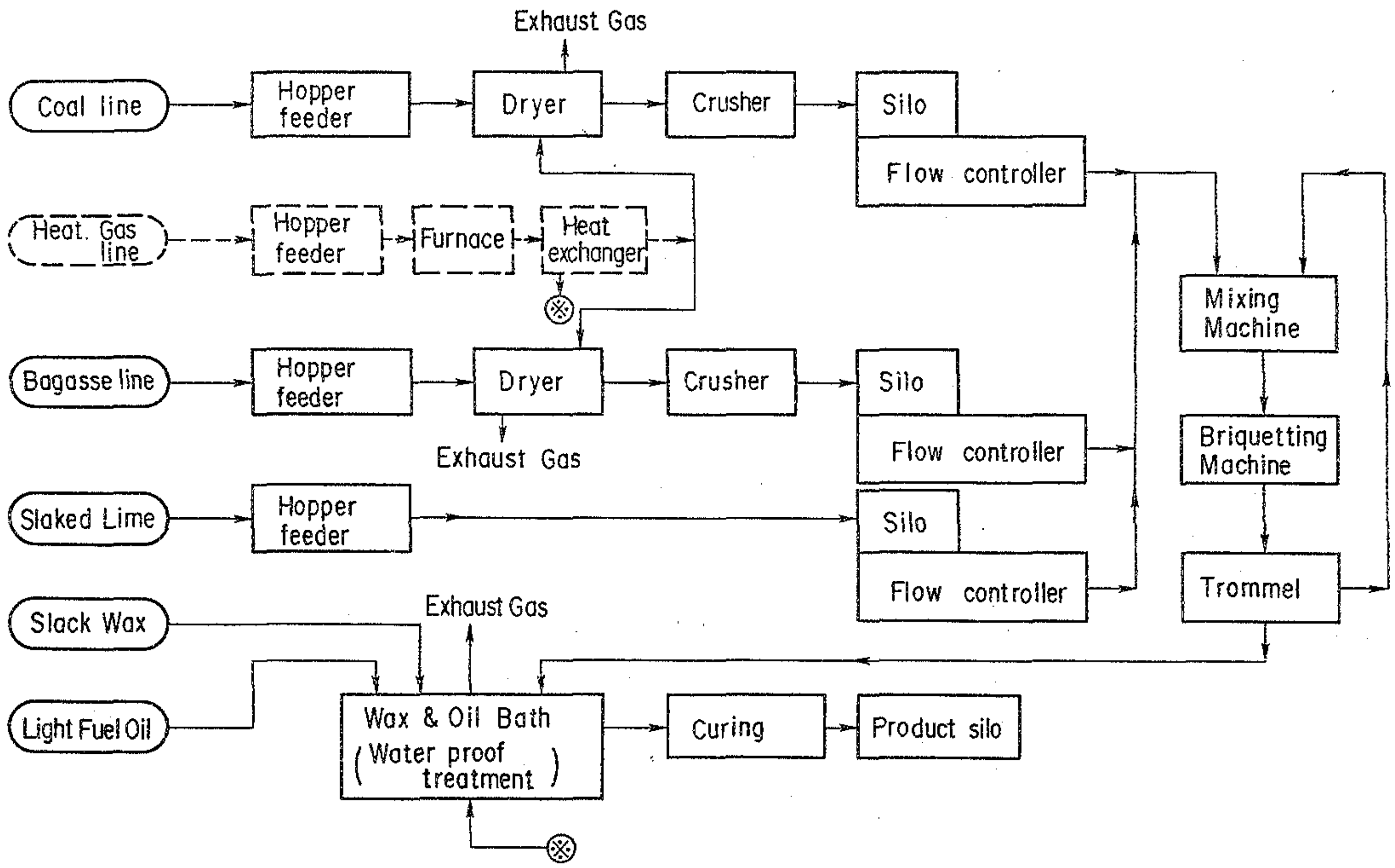


Figure 12-2-1 Outline of Process

briquetting machine again. The briquettes without rims proceed to the next step in the process.

(6) Coating with wax

The coal briquettes from the trommel were immersed for one to two seconds in a hot bath of slack wax dissolved in a light fuel oil. The slack wax is maintained in a molten state by using exhaust heat of the air heater. The finished coal briquettes are cooled by air.

(7) Product storage

The product briquettes are stored in the product silos and shipped in bulk by truck.

12-2-2 Material Balance, Heat Balance and Process Flow

(1) Material balance

The overall material balance for this project has been developed based on the major premises for the conceptual design as shown in Table 12-2-1.

(2) Heat balance

The coal washing process does not need any external heat supply; the operation is done under the ambient temperatures throughout the process. The coal briquette manufacturing process requires external heat supply for drying coal, drying bagasse, and heating the bath for wax coating; furthermore, the slack wax inventory may require occasional heating to melt the content. Coal is burned to provide heat of drying; the exhaust heat will be utilized to heat the coating bath and slack wax tank.

Tables 12-2-2, 12-2-3, 12-2-4 and 12-2-5 show calculations of heat duties of coal drier and bagasse drier, requirement of coal to provide such heat, and caluculation of the heat duty of coating bath, respectively.

The heat duty of the coating bath is very small; therefore, exhaust heat will be recovered from the effluent gas from the hot air generator and supplied to the bath. A hot oil circulation system is installed between the hot air generator and the bath.

(3) Process flow diagram

Figures 12-2-2(A) and 12-2-2(B) show the process flow diagrams developed for coal washing and coal briquette manufacturing developed based upon the material and heat balanced thus prepared.

(4) Arrangement of facilities

Figure 12-2-3 shows the arrangement of major facilities in the process flow.

Table 12-2-1 Overall Material Balance

	(1) Comp	(2) Feed to Wash	(3) Spent to Disposal	(4) Feed to Drier	(5) Dried feed	(6) Drier load	(7) to Wash	(8) to Spent	(9) to Drier	(10) Dryed feed	(11) Drier load	(12) to Briquette	(13)
	%	kg	kg	kg	kg	kg	t/y	t/y	t/y	t/y	t/y	t/y	t/h
Coal													
Moisture	20.0	200.0	75.0	125.0	68.0	57.0	12,500.0	4,687.5	7,812.5	4,250.0	3,562.5	4,250.0	0.59
Ash	25.0	250.0	200.0	50.0	50.0		15,625.0	12,500.0	3,125.0	3,125.0		3,125.0	0.43
Sulfur	5.0	50.0	35.0	15.0	15.0		3,125.0	2,187.5	937.5	937.5		937.5	0.13
Net coal	50.0	500.0	65.0	435.0	435.0		31,250.0	4,062.5	27,187.5	27,187.5		27,187.5	3.78
Subtotal	100.0	1,000.0	375.0	625.0	568.0		62,500.0	23,437.5	39,062.5	35,500.0		35,500.0	4.93
Wash water		200.0	75.0	125.0		125.0	12,500.0	4,687,5	7,812.5		7,812.5		
Bagasse													
Moisture	50.0			130.0	12.0	118.0			8,125.0	750.0	7,375.0	750.0	0.10
Dry bgsse	50.0			130.0	130.0				8,125.0	8,125.0		8,125.0	1.13
Subtotal	100.0			260.0	142.0				16,250.0	8,875.0		8,875.0	1.23
Slaked lime													
Moisture	5.0				2.5							156.0	0.02
Dry lime	95.0				47.5							2,969.0	0.41
Subtotal	100.0				50.0							3,125.0	0.43
Coating agent													
Wax												300.0	0.04
Light oil												2,200.0	0.31
Subtotal					40.0							2,500.0	0.35
Grand total					800.0							50,000.0	6.94

Note:
For (2),(3),(4),(5) and (6), the basis of calculation is 1,000kg feed to the coal washing.

Table 12-2-2 Calculation of Coal Drier Heat Duty

	(1) Flow t/h	(2) Spec.Ht kcal/kg.C	(3) Temp.Rise C	(4) Sen.Ht	(5) Lat.Ht	(6) Total Ht
				---- 1,000 Kcal/hour ---		
Moist. retained	0.59	1.0	80.0	47.2		47.2
Moist, evap.	0.49	1.0	80.0	39.2	264.1	303.3
Undrained water	1.09	1.0	80.0	87.2	587.5	674.7
Dry coal	4.34	0.3	80.0	104.2		104.2
Total load	6.51			277.8	851.6	1,129.4

Note: Heat of vaporization of water at 100C 539 Kcal/kg

Table 12-2-3 Calculation of Bagasse Drier Heat Duty

	(1) Flow t/h	(2) Spec.Ht kcal/kg.C	(3) Temp.Rise C	(4) Sen.Ht	(5) Lat.Ht	(6) Total Ht
				---- 1,000Kcal/hour ---		
Moist. retained	0.10	1.0	80.0	8.0		8.0
Moist. evap.	1.02	1.0	80.0	81.6	549.8	631.4
Dry bagasse	1.13	0.4	80.0	36.2		36.2
Total	2.25			125.8	549.8	675.6

Table 12-2-4 Coal Requirement as Plant Fuel

Heat load, 1,000kcal/hour	
to dry coal	1,129.4
to dry bagasse	675.6
total	1,805.0
Heat of combustion of coal, kcal/kg	
Gross, dry coal	4,418
Gross, at 20% moisture	3,530
Net, at 20% moisture	3,226
Heat input, 1,000 kcal/hour	
Total heat duty	1,805.0
Required heat input at 40% drier efficiency	4,512.5
Required heat input at 90% combustion efficiency and 60% heat transfer efficiency	8,356.5
Required coal input,tons/hour	2.59

Table 12-2-5 Calculation of Heat Duty of Coating Bath

	(1) Flow t/h	(2) Spec.Ht kcal/kg.C	(3) Temp.Rise C	(4) Sen.Ht 1,000Kcal/hour
Slack wax	0.04	0.69	70.0	1.9
Light oil	0.31	0.50	70.0	10.9
Total	0.35			12.8

Note:
(3) The temperature is raised from 20 to 90 C.
(4) The coal briquettes enter the bath at 90 C.
(5) Heat loss to the surrounding is neglected.

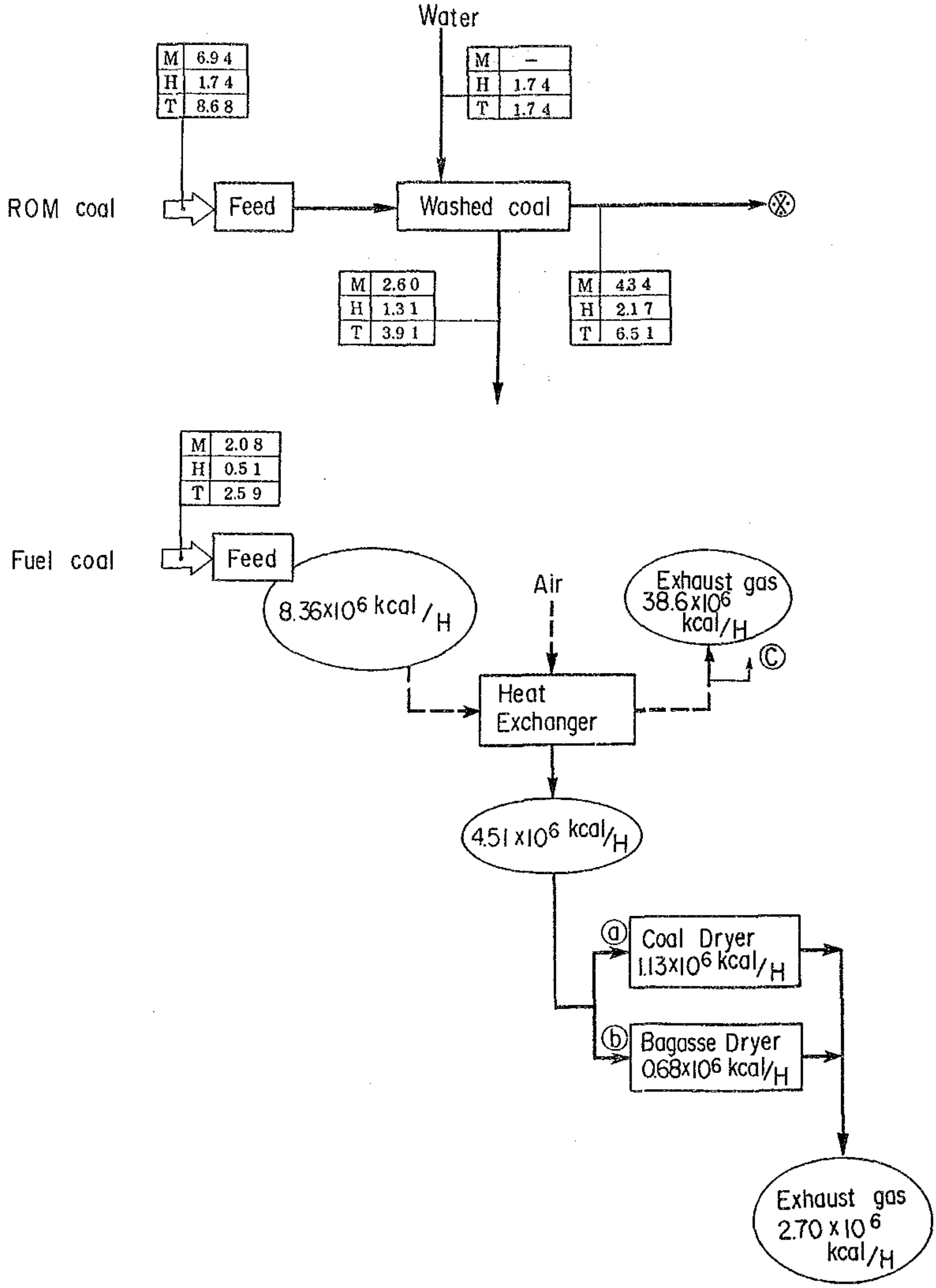


Figure 12-2-2(A) Process Flow Diagram

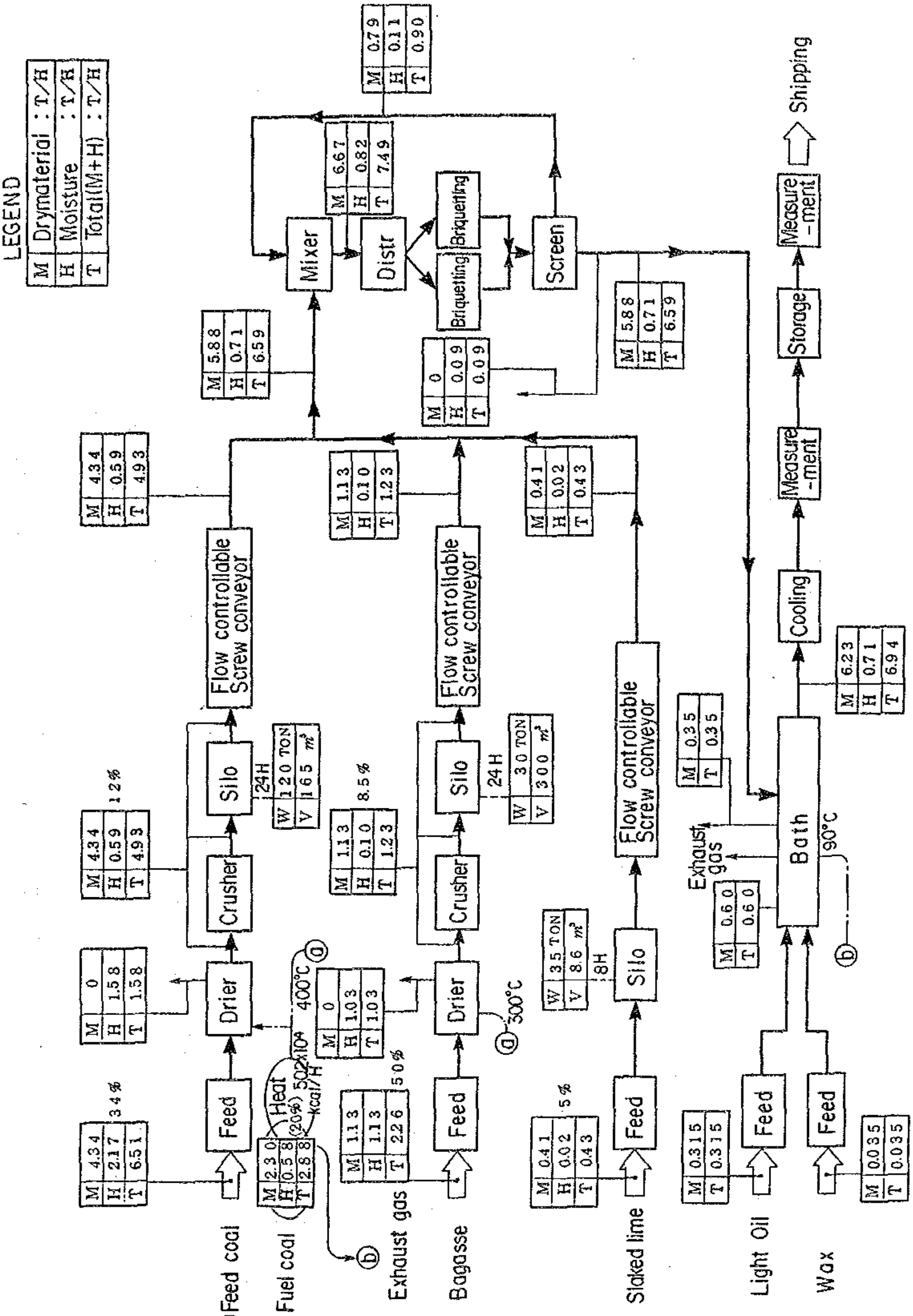


Figure 12-2-2(B) Process Flow Diagram

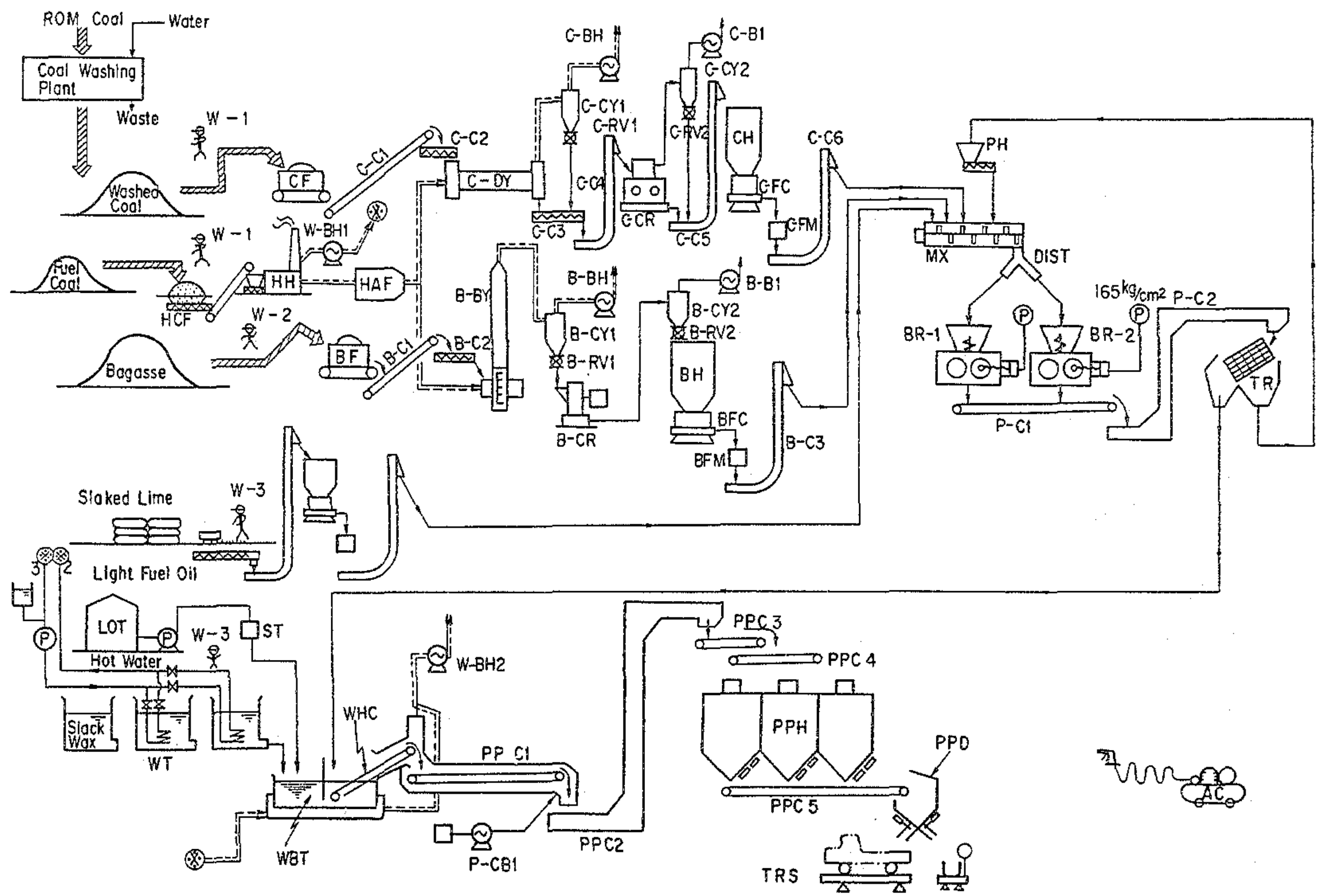


Figure 12-2-3 Arrangement of Major Facilities in Process Flow

12-3 Major Equipment List

Table 12-3-1 lists major equipment.

Table 12-3-1 Major Equipment List

Equipment		Specification
1. Raw coal washing		30 tons/h, plain water
2. Coal preparation		
CF	coal feeder	4.8 tons/h, 6.5m^3/h, 6.5m^3 hopper
C-C1,2	coal conveyer	
C-DY	rotary drier	moisture 33% to 12%, load: 1.58 tons/h
C-CY1	cyclone	Dia 1.2m x 2
C-RV1	rotary valve	(1.5 tons/h, 3m^3/hour) x 2
C-C3,4	coal conveyer	5 tons/h, 7.4m^3
C-CR	coal crusher	ibid
C-CY2	cyclone	Dia 0.75m
C-RV2	rotary valve	2 tons/h
C-B1	exhaust blower	60 m^3/min
C-C5	coal powder conveyer	5.0 tons/h, 6.6 tons/h
CH	coal powder hopper	165m^3
3. Bagasse preparation		
BT	bagasse feeder	2.26 tons/h, 11.3m^3 with a hopper
B-C1,2	bagasse conveyer	2.26 tons/h, 11.3m^3
B-DY	bagasse drier	1.03 tons/h
B-CY1	cyclone	Dia 1.0m x 3
B-RY1	rotary valve	(1.23 tons/h, 14m^3)x3
B-CR	bagasse crusher	1.23 tons/h
B-CY2	cyclone	Dia 1.0m
B-RV2	rotary valve	1.23 tons/h
B-B1	exhaust blower	120 m^3/min
BH	bagasse hopper	300m^3
4. Slaked lime preparation		
LF	unpacking feeder	1.5 tons/h, 3.75m^3
L-C1	lime conveyer	ibid
LH	hopper	9m^3
5. Hot air generation		
H-CF	fuel coal feeder	8 tons/h, 13m^3
HH	furnace	9.4 x 10^6 Kcal/h
HAF	hot air generator	4.6 x 10^6 Kcal/h
C-BH	blower for coal	250 m^3/min
B-BH	blower for bagasse	360 m^3/min
W-BH1	blower for wax	120 m^3/min
W-BH2	exhaust heat blower	200 m^3/min

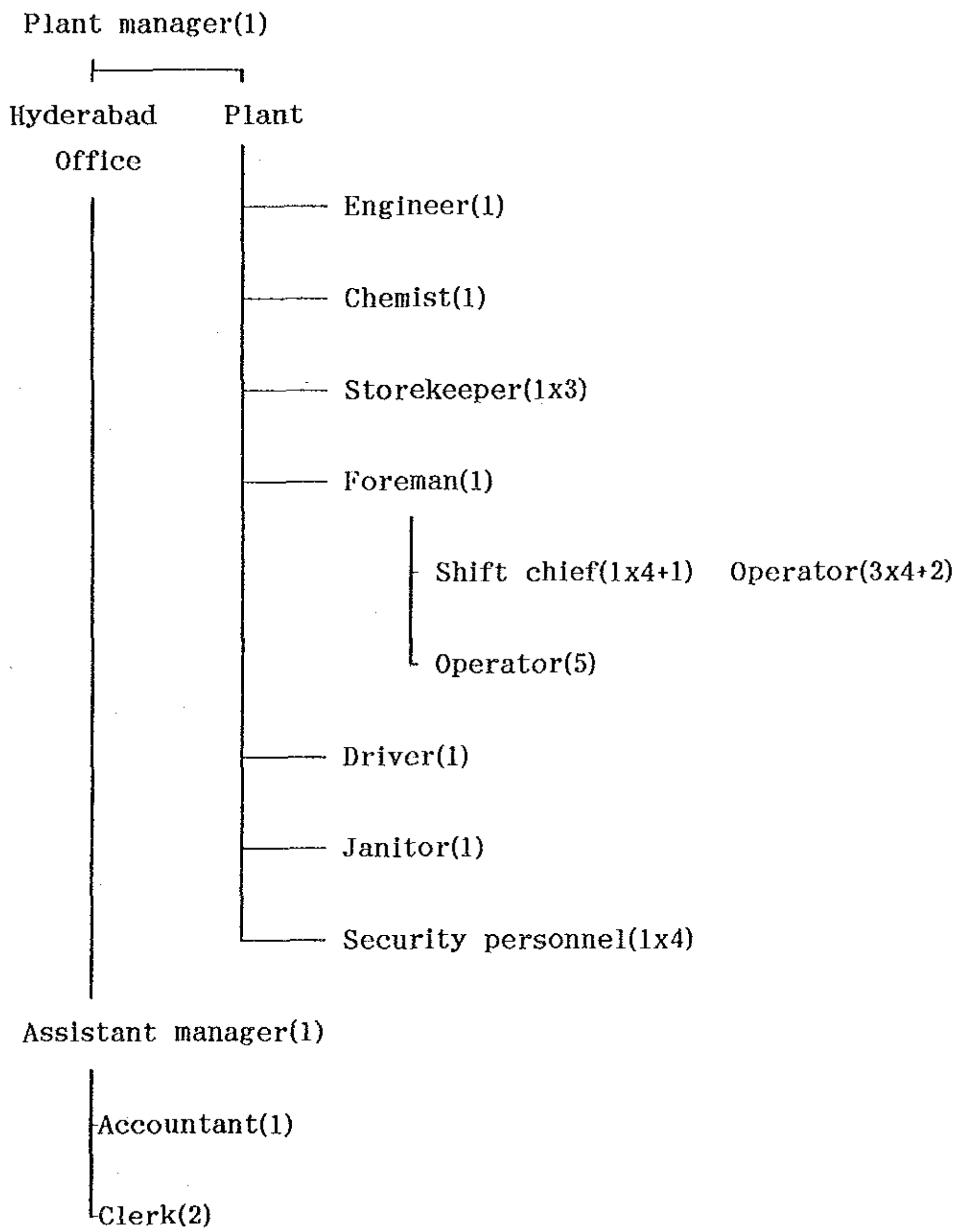
Table 12-3-1 Major Equipment List (Continued)

Equipment		Specification
6. Mixing and briquetting		
CFC	flow-controlling coal withdrawer	4.0 to 5.9 tons/h
CFM	coal flow meter	ibid
C-C6	conveyer	ibid
BFC	flow-controlling bagasse withdrawer	1.0 to 1.5 tons/h
BFM	bagasse flow meter	ibid
B-C3	conveyer	ibid
LFC	slaked lime flow-controlling withdrawer	0.3 to 0.5 tons/h
LFM	slaked lime flow meter	ibid
L-C2	conveyer	ibid
MX	mixer	7.49 tons/h
DIST	distributor	ibid
BR-1,2	briquetting machine	ibid
P-C1	product conveyer	ibid
P-C2	product conveyer	ibid
TR	trommel	ibid
PH	recycle hopper	2 m^2
7. Wax coating		
LOT	solvent tank	90 m^3
P	solvent pump	1 m^3
ST	service tank	2 m^3
WT	wax tank	90 m^3
WMC	wiremesh conveyer	6.94 tons/h, stainless
PP-C1	cooling conveyer	with duct hood
PC,B1	cooling fan	80 m^3/min
XX	flow meter	with integrator
8. Product storage		
PP-C2	product conveyer	6.94 tons/h bucket-type
PP-C3	product conveyer	6.94 tons/h belt conveyer
PP-C4	shuttle conveyer	6.94 tons/h with belt conveyer
PPFM	product flow meter	impulse-type
PPH	product silo	500 m^3
PP-C5	product conveyer	20 tons/h
PPD	shipping damper	20 tons/h
TRS	truck scale	
9. Auxiliary equipment		
Air compressor		3.7kw
10. Text apparatus		
Oven		
Furnace		
Balance		
Thermometer		
Miscellaneous		

12-4 Organization and Manning

12-4-1 Organization

Figure 12-4-1 presents proposed organization for the operation of the first plant.



Note: Figures in parentheses indicate the number of persons.

Figure 12-4-1 Organization Chart

12-4-2 Assignment

Plant manager:
The plant manager is responsible for operation and safety of the plant. He is also the coordinator with PMDC head office and marketers/distributors.

Plant engineer:
The plant engineer must be a capable engineer; he prepares monthly, weekly, and daily operation plans; he plans maintenance and renovation; he studies technical aspects of operation; he helps maintain the safety of operation from technical side.

Chemist:
The chemist is responsible for ensuring the quality level of the product. He watches the quality of feedstocks and keeps the plant manager and plant engineer well informed of the quality of the feedstock and product so that they may be able to take necessary actions.

Storekeeper:
The storekeeper is responsible for maintaining inventories of the raw materials and product at proper levels; he procures raw materials. He keeps records of ins and outs of the raw materials and product.

Foreman:
The foreman is responsible for daily operation; in other words, his responsibility is to meet the production and quality standards. He manages operators.

Shift chief:
The shift chief is responsible for the normal shift operation; he reports to the foreman. He manages shift operators.

Shift operator:
The shift operators are responsible for routine operation of the plant; the routine operation includes feeding raw materials to the plant, feeding fuel coal to the furnace, adjusting the flow

rates of various materials, controlling the operating conditions of the machines, delivering the product to the trucks, etc. The shift operators also execute minor maintenance works.

Day operator:
The day operator is responsible for the operation of the coal washing plant.

Janitor:
The janitor performs at the instruction of superiors miscellaneous works which include serving tea, filing documents, cleaning the office, carrying messages to the mine office, etc.

Guard:
The guards work 24 hours a day on shift. Their responsibility is to maintain safety and protect the plant and personnel from dangers arising from outside.

Assistant manager:
The assistant manager normally stays at the Hyderabad Office. He has under his supervision one accountant and two clerks. The responsibility of the Hyderabad Office includes: receiving orders and transfer them to the plant, coordination with the dealers of coal briquettes, keeping books on the account of the plant, clearing accounts for the purchase of raw materials, etc.

Accountant:
The accountant reports to the assistant manager keeps books on incomes and expenses.

Clerk
The clerks report to the assistant manager and take care of all general affairs.

CHAPTER 13 PLANT CONSTRUCTION

13-1 Local Conditions of Construction Works

The industry of Pakistan has been developed mainly in Punjab and Sind where 93 percent of the industrial output is produced. The field survey team studied the capability of local heavy industries which could supply machines and equipment for the plant and conditions of civil and building works principally around Islamabad and Karachi.

13-1-1 Machinery and Equipment for Manufacture

The survey team visited the following local heavy industries:

KSEW (Karachi Shipyard & Engineering Works Ltd.), Karachi
HMC (Heavy Mechanical Complex Ltd.), Taxila
HFF (HFF Engineering Ltd.), Taxila

As the name indicates, the main business of KSEW was marine engineering but the scale of shipbuilding activities is being reduced due to the recent depression of shipbuilding industry. Presently it is engaged in the manufacturing of various types of machines, mainly fabrication and assembly of machines and steel structures. They have an assembly shop, a fabrication shop and an inspection section, and various kinds of the machine tools are furnished in these workshops.

HMC is located at Taxila, 40 kilometers to the west of Islamabad. Founded in 1971, it is fully owned by the government of Pakistan. Its manufacturing facilities consist of fabrication shops, machine and assembly shops, a heat treatment shop, forge shop, galvanizing shop and miscellaneous ancillary shops in its spacious 21-hectare plant premises. Besides manufacturing sections, they also have planning, designing, inspection and management sections and are able to furnish consistent engineering services. The main products are cement plants, sugar mills, petrochemical plants, boilers and construction equipment such as road rollers and mobile cranes. Their other objectives are fabrication and erection of steel structures and steel towers for power transmission. These services are done generally on a turnkey contract basis to both the domestic customers and to neighboring countries. Various kinds of manufacturing machines have been furnished in the plant: a hydraulic press made in the People's of Republic of China with a 3,000 tons capacity and the latest West German machinery, for example.

Operation is in two shifts and the annual production is 17,500 tons. A total of 3,500 employees consist of 200 engineers, 250 supervisory staff and 2,000 skilled workers. About ten percent of the engineers are from the F. R. of Germany and the People's Republic of China and the remainder of the workers are Pakistanis.

All the workshops have central inspection sections and in addition, a Central Testing Laboratory is provided for checking the quality of all products manufactured by the plant. The standards of this laboratory work conform with the standards of many other countries; it inspects the quality of not only the plant's own products but also of other companies' products, using chemical analysis, physical tests, etc. HMC' products enjoy good reputation for quality but they have occasionally fall behind delivery schedule for reasons beyond their control.

HFF Engineering is a foundry and forging plant adjacent to HMC at Taxila. The plant produces machines for small-scale plants but its main objectives are castings and forgings. Judging from the observation of the plant and its products, HFF is capable of manufacturing high quality products.

It is ascertained that the conditions of the manufacturers in the country such as scale of businesses, range of facilities, quality and quantity of products are quite acceptable.

13-1-2 Civil and Building Works

There are a large number of construction works being done in Islamabad, and Karachi. There are a series of buildings being constructed along a few hundred meters of the main street of Islamabad. They are buildings of medium height with an impressive appearance. In Karachi city, many high-rise buildings are under construction everywhere. Most of them are constructed by local contractors.

The building structure is simple; reinforced concrete is used for columns, beams and floors and concrete block layers used for external and internal wall. Construction machines like cranes are not extensively employed. Timber and bamboo are used for scaffolding.

There are many local consultant firms who design buildings and large-scale development projects. It is necessary to submit plans for buildings to the authority concerned for approval. Since the construction of the coal briquette plant does not require complicated works, the contractor and construction materials can be selected locally.

13-2 Availability of Manufacturing Machinery and Equipment and Construction Materials

13-2-1 Manufacturing Machinery and Equipment

The major equipment for the coal briquette plant consists of hoppers, crushers, dryers, furnaces, mixing machines, blowers, briquetting machines and electric instruments. Since other types of plants such as cement plants and sugar mill plants basically consist of the similar components, it can be judged that the local manufacturers, as explained above, who have completed many such projects are adequately capable of manufacturing equipment of the coal briquette plant. However, the Pakistani heavy industry has had no experience in constructing a coal briquetting plant. Therefore, this feasibility study investigates two cases of procuring machinery--coal washing plant and mixing/briquetting machine, namely Case A as a base case which imports key machinery for the first plant only and Case B as an alternative case which uses all domestically made machinery.

13-2-2 Construction Materials

The following main construction materials, which are used for common grade buildings, are available locally, regardless of being domestic or imported product.

(1)Structural materials
- (Domestic) cement, aggregate, reinforcing bar, small size steel frame, brick, concrete block
- (Imported) large size steel frame, reinforcing bar, stainless aluminum product

(2)Finishing materials
- (Domestic) water proofer, steel window, steel door, flooring ceiling, wall
- (Imported) high grade finishing materials

(3)Building equipment
- (Domestic) lighting fixture, electric line, pipe fitting, ventilator, kitchen system, plumbing fixture

(Imported) air conditioning unit, communication system

There is an import restriction on some construction materials and equipment. The domestic materials and equipment are specified by one of the Pakistan Standard (PS), the British Standard Specifications (B.S.) and the American Society for Testing and Materials Specifications (A.S.T.M.). Since the project requires only ordinary materials in small quantities, they can all be obtained locally.

13-3 Design and Construction Requirement

Pakistan has the Building Code of Pakistan issued by the Environment and Urban Affairs Division, Ministry of Housing and Works, regarding construction works. This code prescribes the procedures such as submission of plan for approval, supervision of work, construction and completion for construction, planning, structural designing, plumbing, heating, ventilation, air conditioning, machinery, fire prevention, and safety measurement. These regulations are enacted based on the B.S., A.S.T.M., American Concrete Institute (ACI) and with special consideration for meteorological and local conditions of particular region. The Building Code of Pakistan is summarized as follows;

(1) Material Standard

This code stipulates the following local materials referring to relevant Pakistan Standard (P.S.) for local materials such as: cement, aggregates, reinforcing bars, terrazzo, concrete blocks, painting materials, asbestos cement roofing sheets, steel plates, glass, PVC pipes, PVC cables, lighting fixtures, and transformer.

This code also stipulates manufacturing machinery and equipment for plant referring to B.S. and A.S.T.M.

(2) Structural design standard

The nation is divided into four blocks which have different seismic coefficients. In the most severe seismic region, a seismic coefficient of 0.1 is applied to the normal types of buildings. The candidate site, Lakhra area, is located in the seismic region of a smaller coefficient of 0.05.

The CP-3 of the B.S. is introduced for calculation of wind pressure. According to the meteorological data, the average wind velocity in Lakhra area is 5 meters per second which exerts a small wind pressure. However, the Code requires the use of minimum wind velocity of 40 meters per second for inland and 50 meters per second for coastal area when designing the building structures.

(3) Other requirement

Lakhra area has no other regulation such as pollution measurement and safety control.

13-4 Implementation of the Project and Supervision of Construction

13-4-1 Implementation of the Project

After the source of finance is decided, the project will be executed in following steps:

Preparation of basic design by consultant
Preparation of tender documents
Selection of contractor
Detailed design by contractor
Manufacture of plant machinery and equipment
Civil and building works
Completion and operation trial

The consultant appointed for this project will prepare the basic design and tender documents for selection of a contractor and evaluate the tenders submitted by tenderers. Then the consultant will assist the client in negotiating with them and in concluding a contract with the successful tenderer.

During the construction period, the consultant will approve the detailed design submitted by the contractor and supervise the construction works; conduct consultation prior to commencement of construction, conduct inspection of machinery, equipment and materials, and checks upon erection, operation trial and issue completion certificates.

Since the local companies have not experience in constructing a coal briquette plant, a foreign supervisor will be dispatched during erection of machinery and equipment and civil and building works. In addition, an expatriate professional will be dispatched for training the local staff to ensure successful startup of the plant.

13-4-2 Form of Contract

Generally used forms of contract for the construction works are, for example, lump sum contract, unit price contract, and turnkey basis contract. The lump sum contract is usually used for building construction and the unit price contract is for civil works. In the turnkey basis contract, the contractor shall have full responsibility for and must guarantee for design and supply of machinery and equipment, civil and building works, and commissioning, etc., if stipulated in the contract. In this project, the civil and building works are small compared with manufacture and installation of plant machinery but have to be well coordinated with the latter. Therefore, turnkey basis contract with a machinery and equipment supplier as main contractor is recommendable in view of its efficiency.

13-4-3 Organization for Construction

The construction of the project will be executed by a main contractor as shown in Figure 13-4-1. The main contractor awarded by tender has full responsibility for execution of the works, i.e., procurement of process equipment and spare parts, installation and adjustment of process equipment, and trial operation.

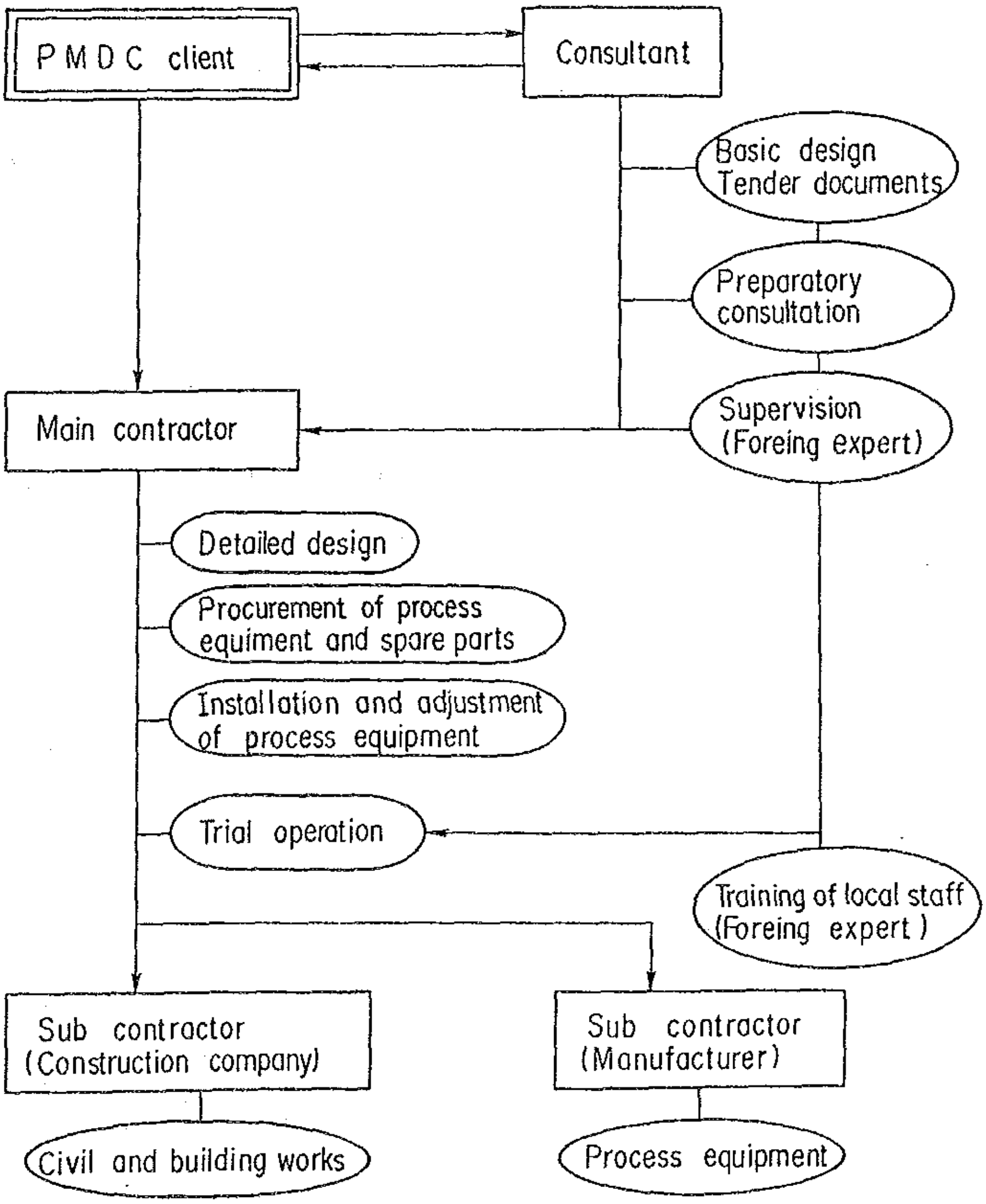


Figure 13-4-1 Construction Organization

13-5 Strategy for Plant Construction

The proposed plant site is located at the PMDC' concession, Lease No. 88, as shown in Figure 13-5-1. The plant facilities consist of the briquetting plant, buildings i.e., office, dormitories, and the supplementary facilities such as water tanks and reservoirs, roads, piping, etc.

13-5-1 Size and Capacity of Facilities

This study proposes for consideration two initial capacities; one starts at 50,000 tons of plant capacity and the other at 100,000 tons per year capacity. Both cases will finally expand to 300,000 tons production per year capacity. The initial size and capacity of the facilities are shown in Table 13-5-1.

For the plant expansion, 25,000 tons per year capacity is designed as one unit for the manufacturing equipment and 50,000 tons per year capacity for other facilities except those are designed for larger capacities. Then the plant will be expanded by an appropriate combination of these units according to the expansion schedule. The numbers of facilities will be added according to the future extension plan as per Table 13-5-2.

The four resident officials in Hyderabad will use the present PMDC office and extension of the office will not be required as additional resident officials are not necessary throughout all extension plans.

13-5-2 Outline of Facilities

Construction materials will be selected locally and special construction methods will be avoided in order that construction works will be executed by a local company. Outline of the main facilities is as follows;

(1) Plant shelter

Foundations and floor slab:	Reinforced concrete
Column and roof truss:	Structural steel
Walls:	Concrete blocks
Roofing:	Corrugated asbestos cement sheets

(2) Office, dormitories, and toilets

Foundations and floor slab:	Reinforced concrete
Columns:	Structural steel
Walls:	Concrete blocks
Roofing:	Reinforced concrete with water-proofed mortar

(3) Water tank, precipitator: Reinforced concrete

(4) Oil tank

Body:	Steel frame
Foundations:	Reinforced concrete

(5) Machine foundations: Reinforced concrete

(6) Building facilities

Lighting level	
Plant area:	200 to 300 lux
Office:	100 to 500 lux
Open area:	10 to 20 lux
Ventilations	
Common space:	Natural ventilation Power ventilation will be partially provided.
Air-conditioning	
Dormitory(A):	Window-type air-conditioner

(7) Access road and roads on premise

Pavement:	Gravel pavement or simplified asphalt pavement

13-5-3 Plot Plan and Building Plan

The plot plans and the building plan are shown in Figure 13-5-2 and Figure 13-5-3.

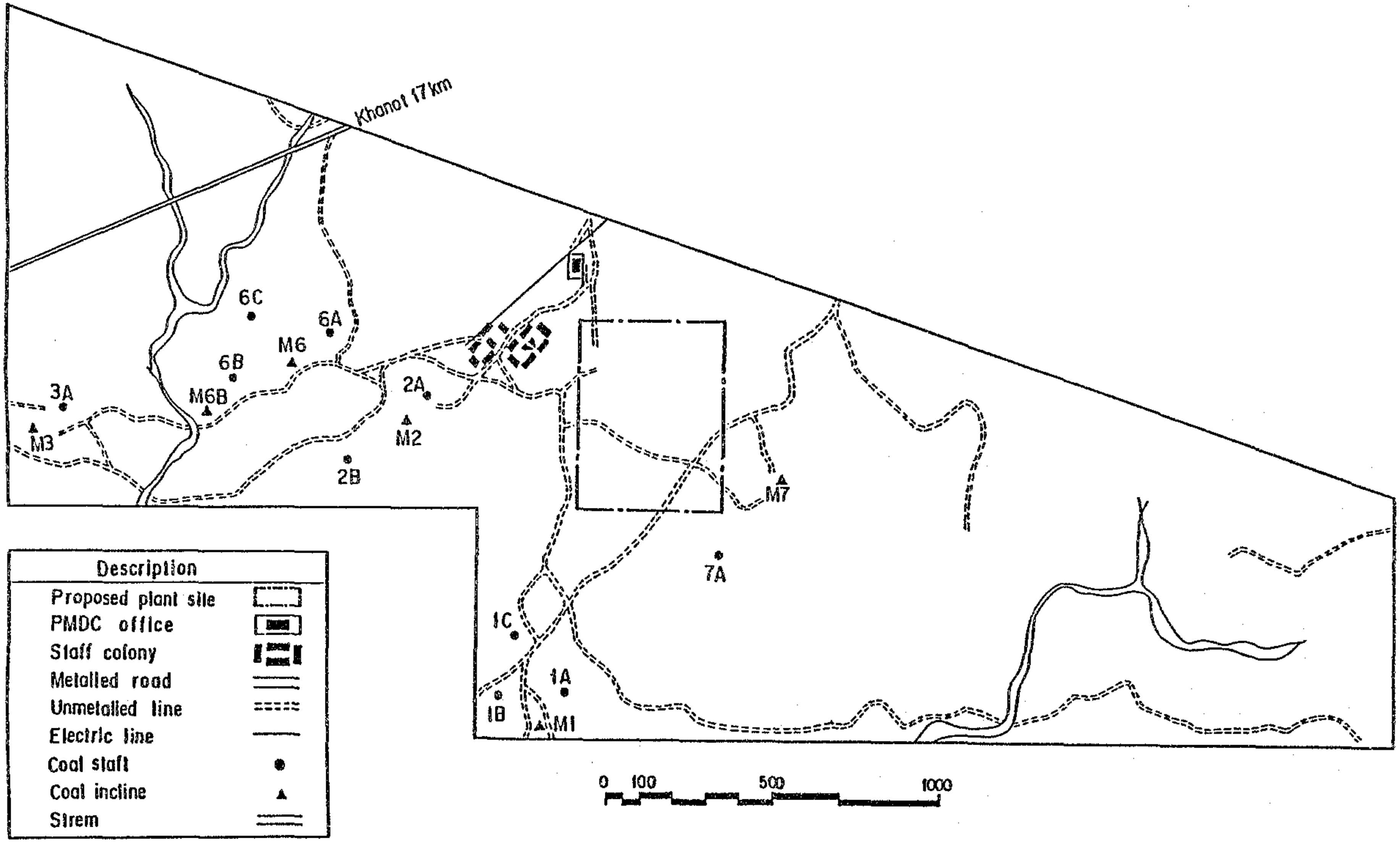


Figure 13-5-1 Location Map of Proposed Plant Site

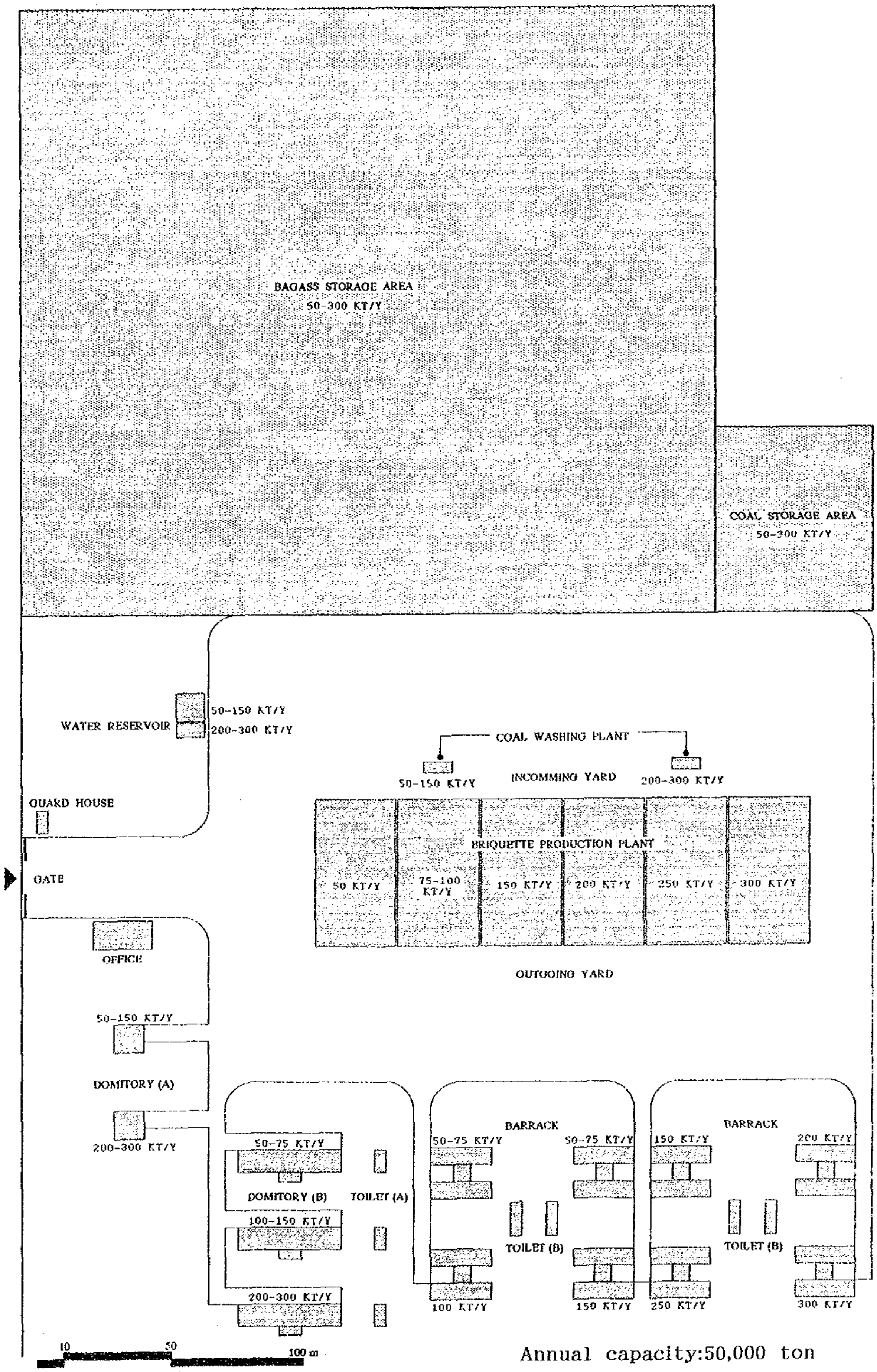
Table 13-5-1 Size and Capacity of Plant facilities

Items	Sizes and Capacities			
	CASE 1, 3 50,000 ton		CASE 2 100,000 ton	
1.Raw material storage				
.Coal storage area	Area	400 m^2	Area	800 m^2
.Bagasse storage area	Area	10,000 m^2	Area	20,000 m^2
2.Plant				
.Coal washing plant	30 t/h	1 set	30 t/h	1 set
.Briquette production plant	50 kt/y	1 building	50 kt/y	2 buildings
	Floor area	1,650 m^2	Floor area	3,300 m^2
3.Common facilities				
.Office	Occupants	14 persons	Occupants	14 persons
	Floor area	210 m^2	Floor area	210 m^2
.Dormitory(A)	Occupants	3 persons	Occupants	3 persons
	Floor area	110 m^2	Floor area	110 m^2
.Dormitory(B)	Occupants	34 persons	Occupants	51 persons
	Floor area	320 m^2	Floor area	640 m^2
.Barrack	Occupants	66 persons	Occupants	111 persons
	Floor area	300 m^2	Floor area	600 m^2
.Toilet (A)	Floor area	30 m^2	Floor area	60 m^2
.Toilet (B)	Floor area	50 m^2	Floor area	100 m^2
.Guard house	Floor area	32 m^2	Floor area	32 m^2
4.Supplementary facilities				
.Water reservoir	Capacity 100m^3	1 set	Capacity 100m^3	1 set
.Thickener	Capacity 100m^3	1 set	Capacity 100m^3	1 set
.Light oil tank	Capacity 20m^3	1 set	Capacity 20m^3	2 sets
.Wax tank	Capacity 20m^3	1 set	Capacity 20m^3	2 sets
.Power supply system	Capacity 1,200kVA	1 set	Capacity 1,200kVA	2 sets
5.Infrastructure				
.Access roads	Simple pavement	9,000 m^2	Simple pavement	9,000 m^2
.Outdoor construction	Area	12,000 m^2	Area	18,000 m^2
.Piping on premise		1,000 m		2,000 m

Table 13-5-2 Numbers and Capacities of Facilities in Future Extension Plan

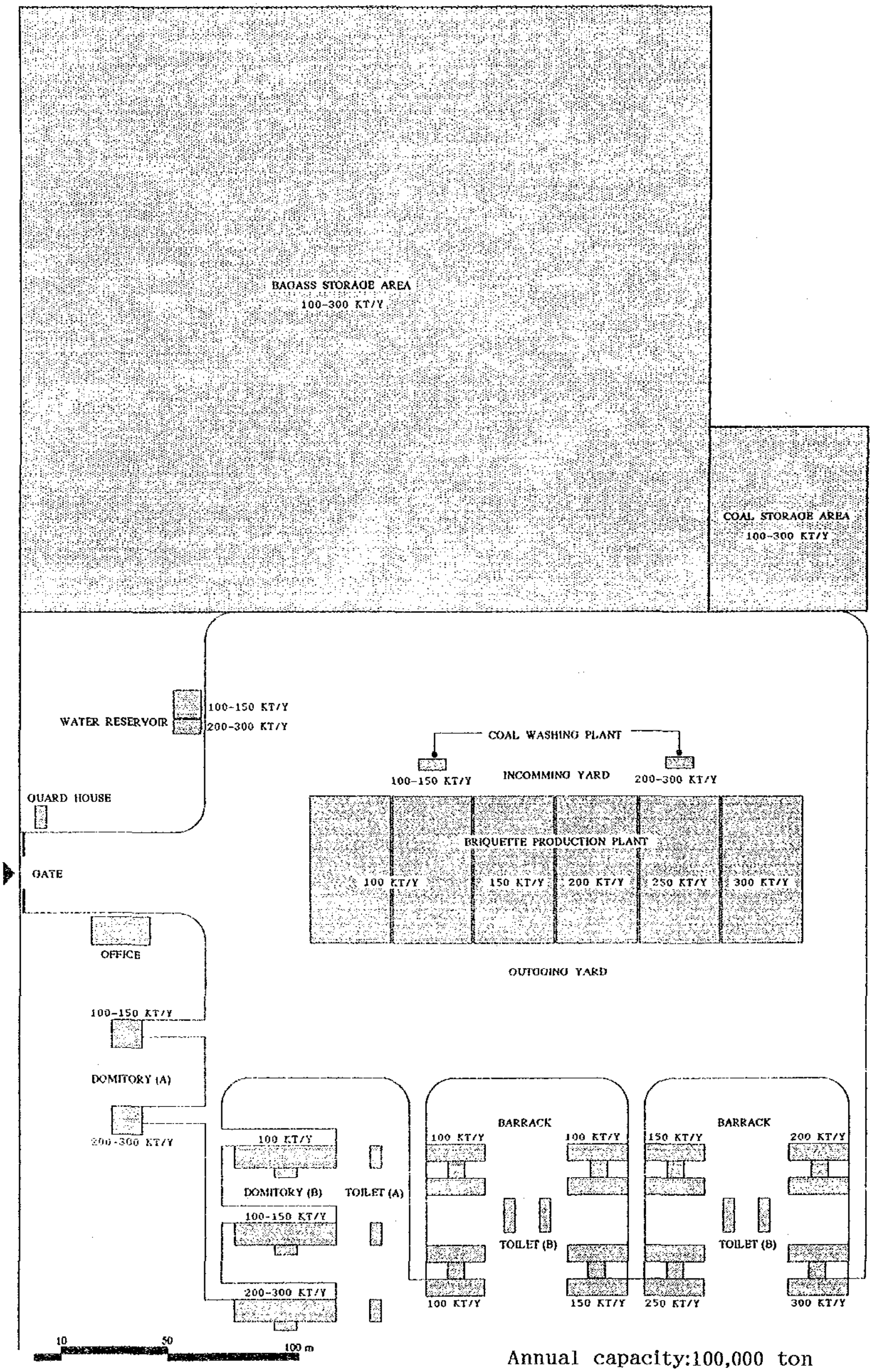
Facilities \ KT/Y	50	75	100	150	200	250	300
Coal wahing plant	1 set	1 set	1 set	1 set	2 sets	2 sets	2 sets
Briquette prodution plant	1 bldg	2 bldgs	2 bldgs	3 bldgs	4 bldgs	5 bldgs	6 bldgs
Office	1 bldg	1 bldg	1 bldg	1 bldg	1 bldg	1 bldg	1 bldg
Dormitory (A)	1 bldg	1 bldg	1 bldg	1 bldg	2 bldgs	2 bldgs	2 bldgs
Dormitory (B)	1 bldg	1 bldg	1.5 bldgs	1.5 bldgs	3 bldgs	3 bldgs	3 bldgs
Barrack	2 bldgs	2 bldgs	3 bldgs	5 bldgs	6 bldgs	7 bldgs	8 bldgs
Toilet (A)	1 bldg	1 bldg	2 bldgs	2 bldgs	3 bldgs	3 bldgs	4 bldgs
Toilet (B)	1 bldg	2 bldgs	2 bldgs	3 bldgs	3 bldgs	4 bldgs	4 bldgs
Guard house	1 bldg	1 bldg	1 bldg	1 bldg	1 bldg	1 bldg	1 bldg
Water reservoir	1 set	1 set	1 set	1 set	1.5 sets	1.5 sets	1.5 sets
Thickener	1 set	1 set	1 set	1 set	2 sets	2 sets	2 sets
Light oil tank	1 set	1 set	2 sets	3 sets	4 sets	5 sets	6 sets
Wax tank	1 set	1 set	2 sets	3 sets	4 sets	5 sets	6 sets
Power supply system, kVA	1,200	1,200	2,400	3,600	4,800	6,000	7,200

Note) bldg:building



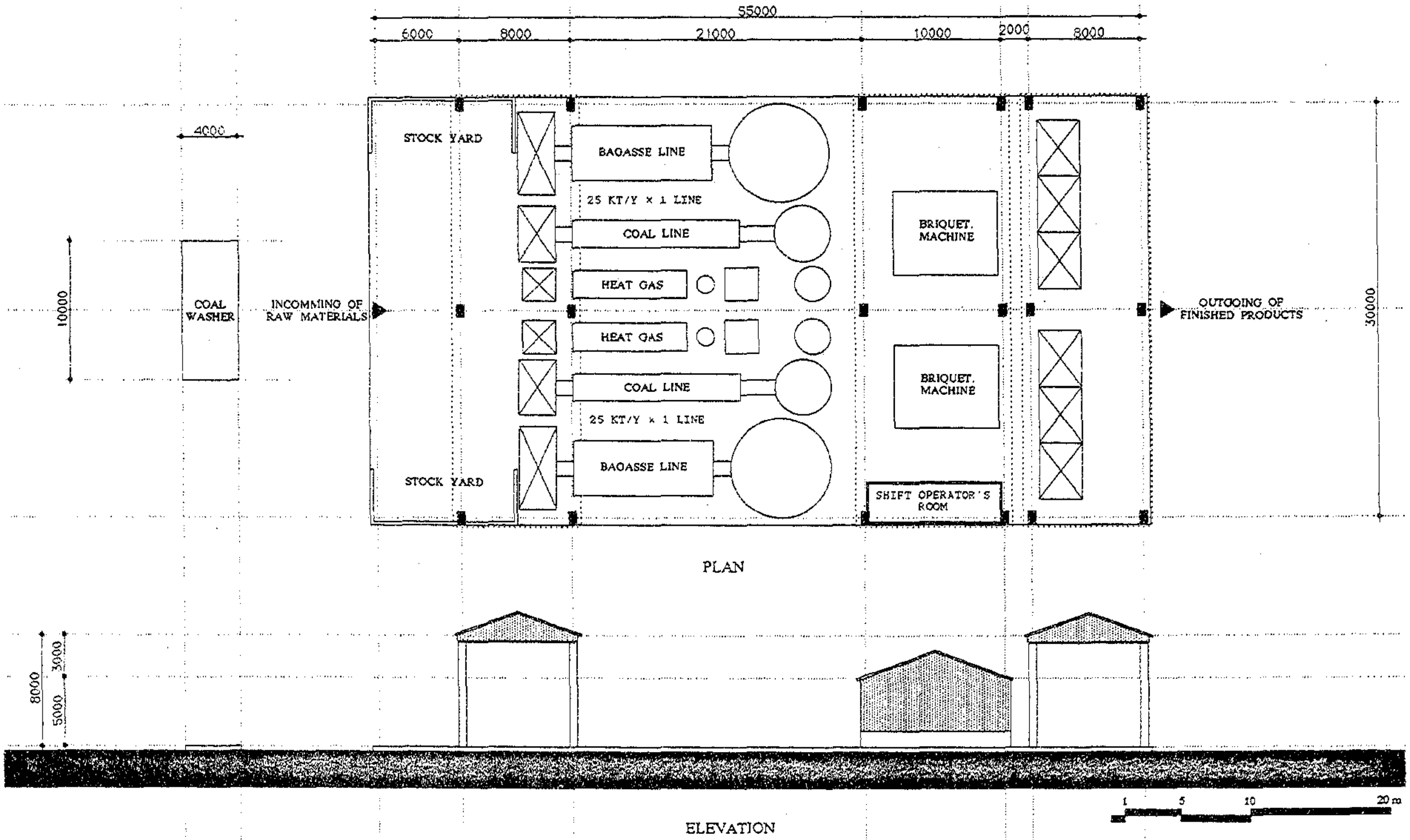
Annual capacity:50,000 ton

Figure 13-5-2(1) Plot Plan



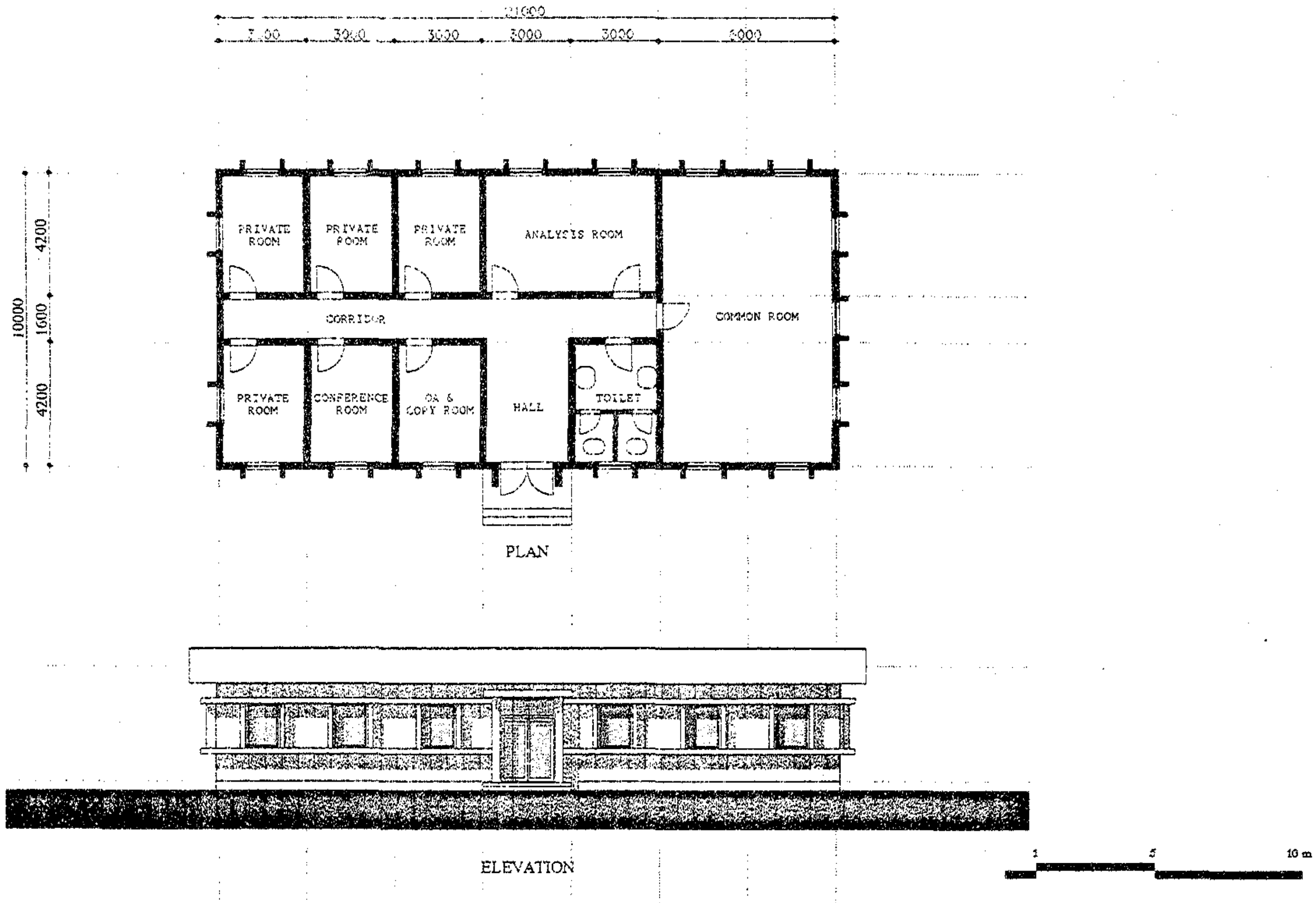
Annual capacity:100,000 ton

Figure 13-5-2(2) Plot Plan



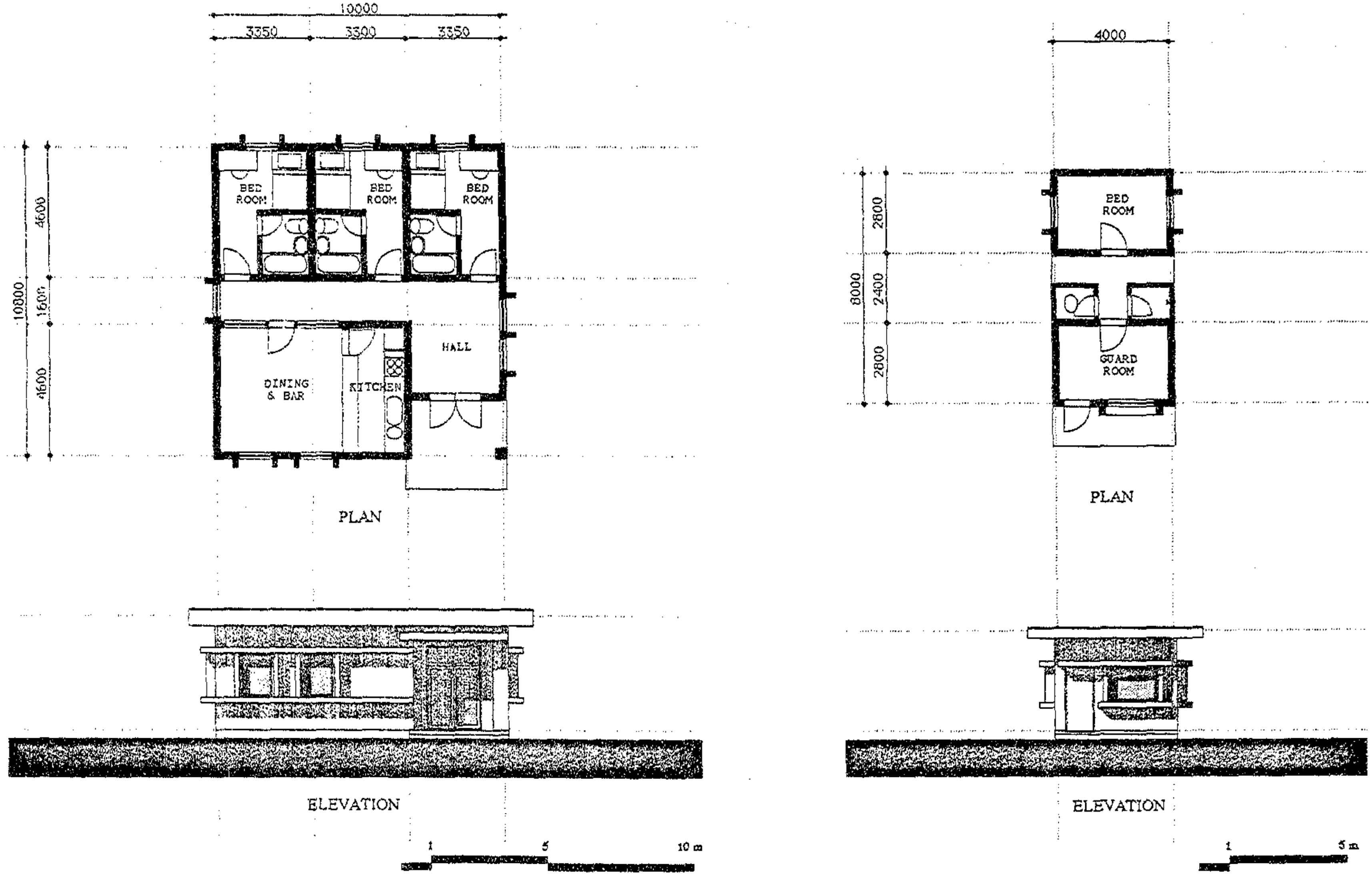
BRIQUETTE PRODUCTION PLANT

Figure 13-5-3(1) Building Plan



SITE OFFICE

Figure 13-5-3(2) Building Plan



DOMITORY (A)

GUARD HOUSE

Figure 13-5-3(3) Building Plan

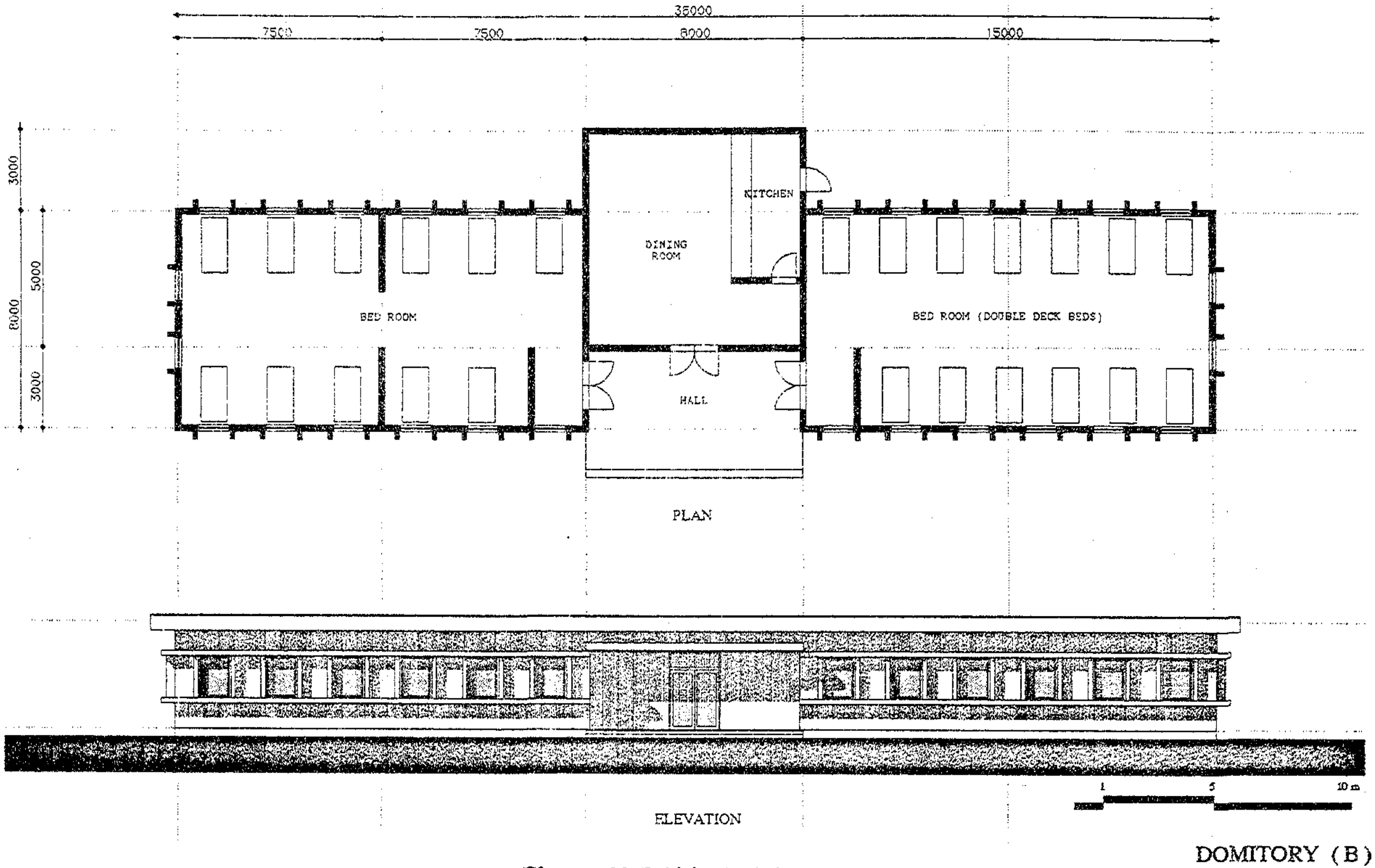
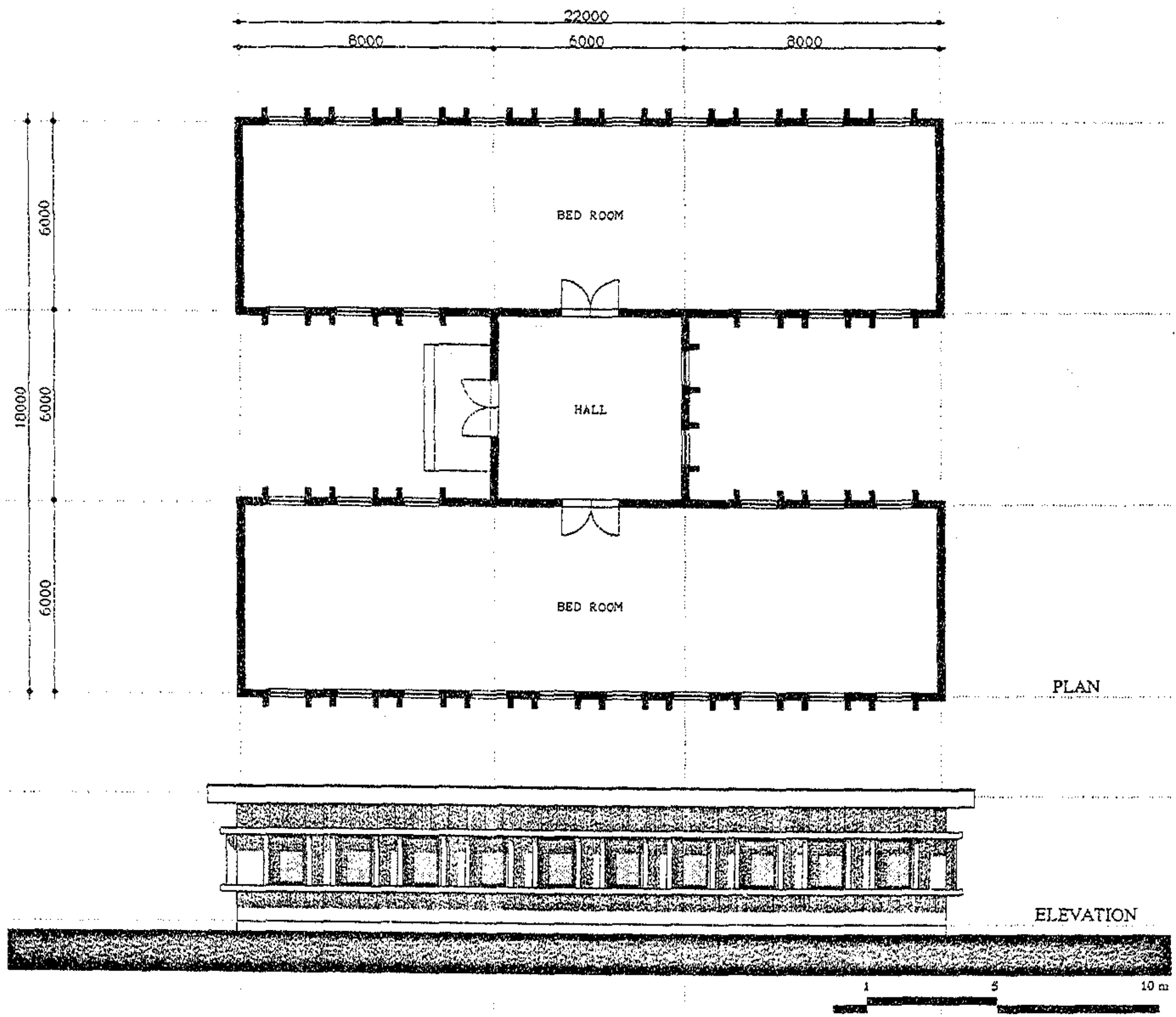
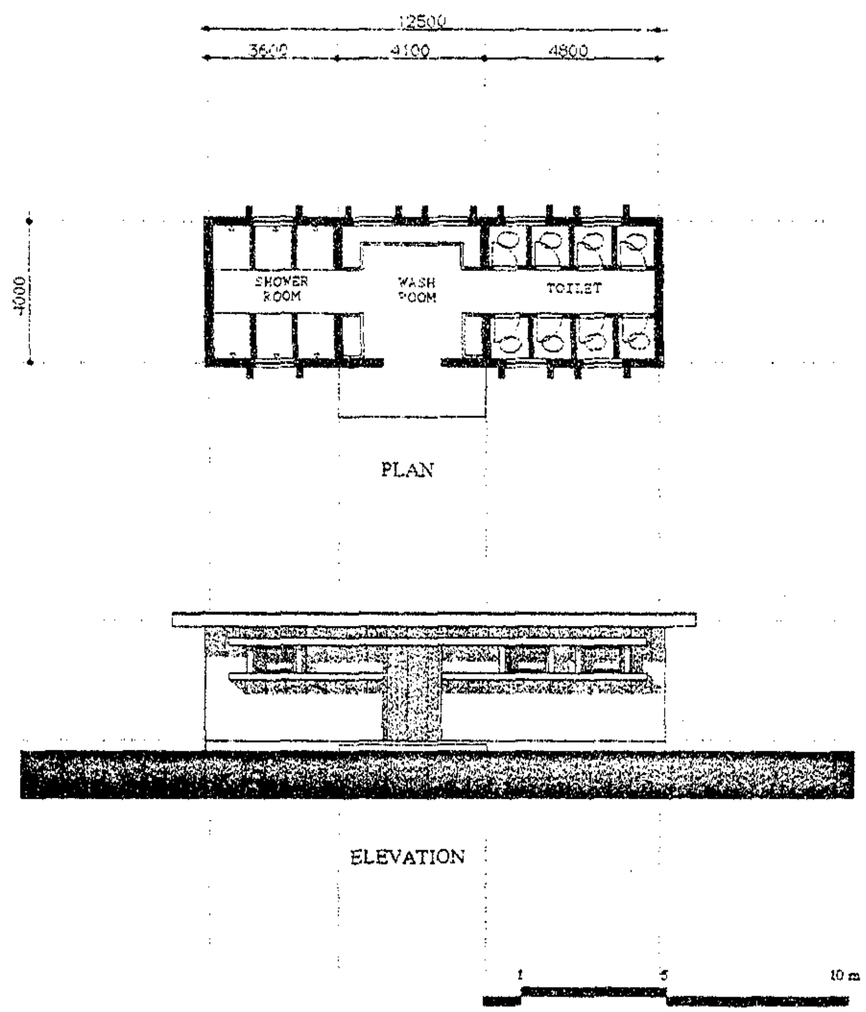


Figure 13-5-3(4) Building Plan

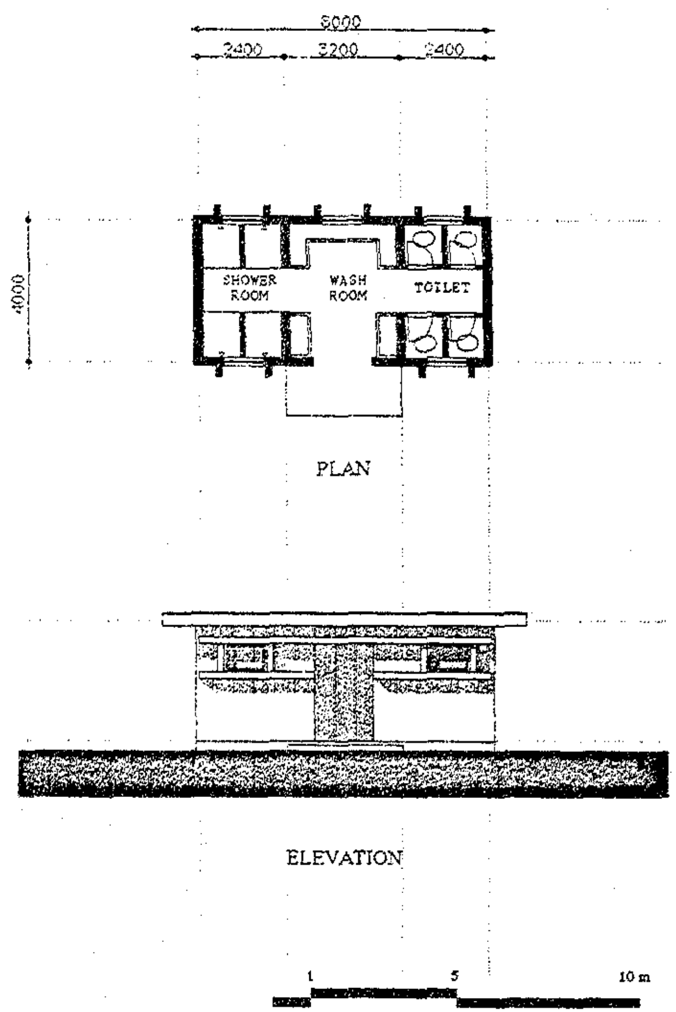


BARRACK

Figure 13-5-3(5) Building Plan



TOILET (A)



TOILET (B)

Figure 13-5-3(6) Building Plan

13-6 Construction Schedule

Contractor shall be selected through tendering based on the consultant's tender documents. Construction schedule covering signing of contract, commencement of construction, operation trial and commissioning is shown in Table 13-6-1.

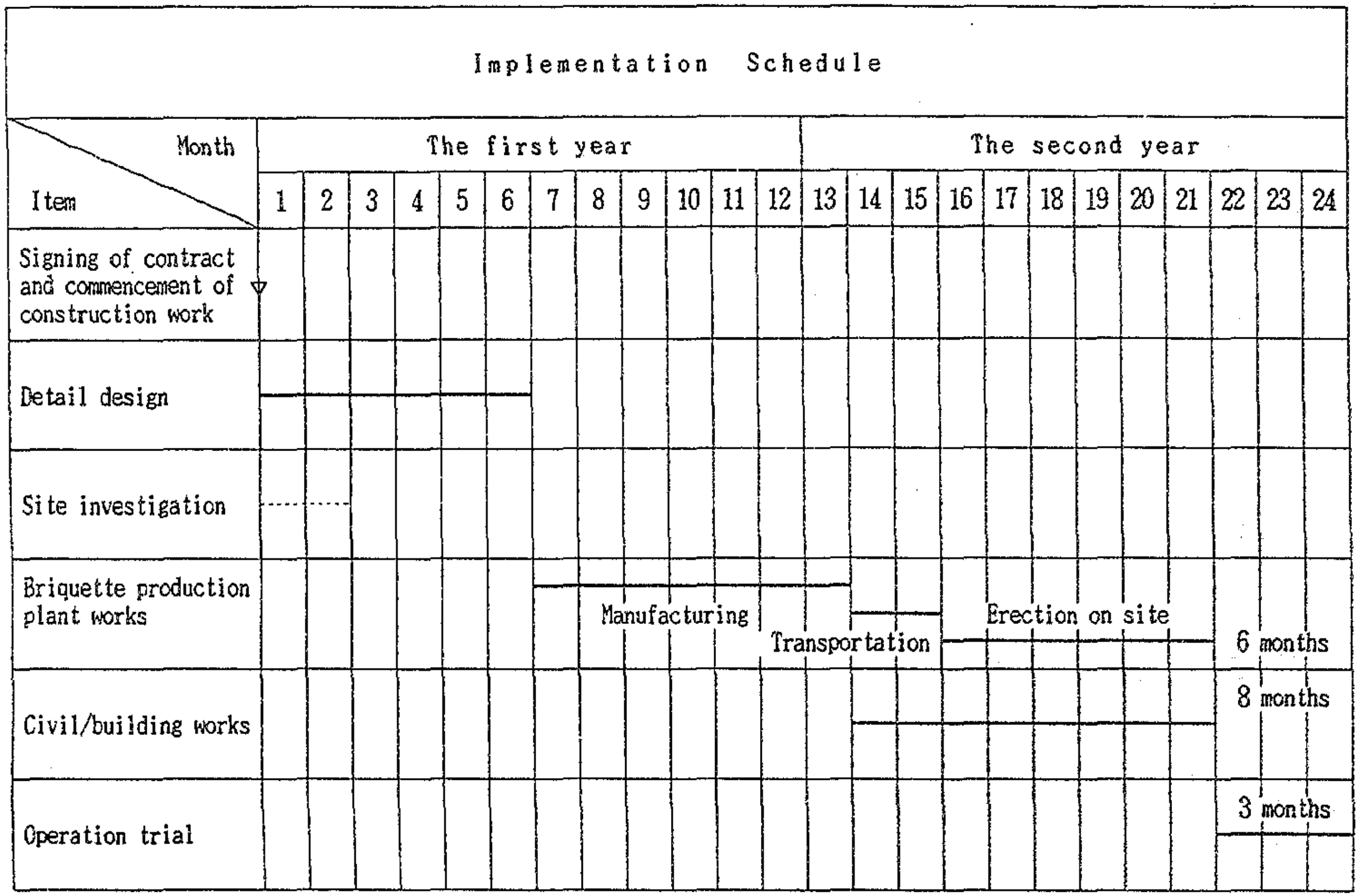


Figure 13-6-1 Construction Schedule

13-7 Unit Cost and Estimation of Plant Cost

13-7-1 Unit Cost

Table 13-7-1 shows unit costs of major items for construction works determined during the site survey period.

13-7-2 Estimation of Cost of Machinery and Equipment

The estimated costs of manufacturing machinery and equipment consist of their costs of procurement, transportation and spare parts as shown in Tables 13-7-1 and 13-7-2. The estimation is based on the rates as of July 1988.

13-7-3 Estimation of Civil and Building Works

The estimation of the costs for civil and building works is based on the unit costs as shown in Table 13-7-1.

The estimations include the following works:

(1) Site preparation
(2) Simple pavement work for roads on premise
(3) Fence erection work
(4) Work for soil water treatment facilities

The estimates do not include the following works:

(1) Site measurement and soil exploration will be done by the client.
(2) Rain water drainage system are not required due to small precipitation.

13-7-4 Engineering Fee and Other Costs

Cost for engineering services described in clause 13-4-1 are shown in Table 13-7-4. In these estimations, it is assumed that the basic design for only import machine will be done by expatriate professionals in Cases 1A, 2A and 3A and otherwise by local professionals.

Table 13-7-1(1) Unit Cost for Construction Works

Item	Unit	Unit price(Rs.)
1. Earth work		
1.1 Excavation		
(1) By machine	m^3	25.00
(2) By hand	m^3	35.00
1.2 Back fill with compaction	m^3	55.00
1.3 Disposal of surplus soil	m^3	27.00
1.4 Gravel (20-60 mm) Rate of purchase	m^3	160.00
1.5 Sand " " "	m^3	106.00
2. Concrete work		
2.1 Cement		
(1) Type-I Ordinary portland	ton	1491.00
(2) Type-V Sulphate resisting		1793.00
2.2 Concrete		
(1) 28 days strength 180 kg/cm^2 (cement type I)	m^3	1000.00
(2) 28 days strength 180 kg/cm^2 (cement type V)	m^3	1000.00
(3) 28 days strength 210 kg/cm^2 (cement type I)	m^3	1100.00
(4) 28 days strength 240 kg/cm^2 (cement type I)	m^3	1200.00
2.3 Form work		
2.4 Reinforcing steel bar		
(1) Deformed bar	ton	16300.00
(2) Round bar	ton	16100.00
3. Structural steel work Grade ss-41, with bolts, gusset plates, anchor bolts, and all related works	ton	22000.00
4. Masonry works (with surface mortar t=25 mm)		
4.1 Concrete block		
(1) t=100 mm	m^2	110.00
(2) t=150 mm	m^2	155.00
(3) t=200 mm	m^2	210.00
4.2 Brick		
(1) t=100 mm 115 mm (4 1/2)"	m^2	96.80
(2) t=150 mm 225 mm (9 1/2)"	m^2	172.16
(3) t=200 mm 340 mm (13 1/2)"	m^2	279.76
5. Painting		
5.1 Oil paint on steel	m^2	50.00
5.2 Oil paint on wooded surface	m^2	55.00
5.3 Emulsion paint on concrete and mortar	m^2	50.00
5.4 Acid proof paint on steel	m^2	45.00
5.5 Acid proof paint on concrete and mortar	m^2	45.00

Table 13-7-1(2) Unit Cost for Construction Works

Item	Unit	Unit price(Rs.)
6. Protective layers including finishing		
6.1 Plastering t=20 mm 1:1:6 (cement lime sand to vertical surface)	m^2	54.00
6.2 Plastering t=20 mm 1:1:6 (cement lime sand to soffit)	m^2	60.00
6.3 Vinyl tile to floor	m^2	414.26
6.4 Liquid surface hardener	m^2	8.17
7. Exterior finishing		
7.1 Corrugated asbestos cement sheet for roof and wall with all accessories	m^2	150.00
7.2 Rib profile steel roofing sheet (t=0.9 mm including flushing)	m^2	200.00
7.3 Rib profile steel siding sheet (t=0.9 mm including flushing)	m^2	220.00
8. Water proofing (Bituminous W/P, 3 layers, including reflecting protective coating)	m^2	125.00
9. Doors and Windows including hardware, glazing, etc.		
9.1 Hand operated roller shutter	m^2	600.00
9.2 Steel flash door	m^2	540/ =860
9.3 Wooden flash door (solid)	m^2	1000.00
9.4 Wooden louver door	m^2	1100.00
9.5 Aluminum door	m^2	1700.00
9.6 Steel window	m^2	516.00
9.7 Wooden window	m^2	590.00
9.8 Aluminum window	m^2	1100+400
9.9 Wooden flash toilet booth	m^2	165.00
9.10 Frosted glass t=4 mm	m^2	200.00
9.11 Clean glass t=4 mm	m^2	200.00
9.12 Wired frosted glass		
10. Miscellaneous works		
10.1 Eaves gutter including all accessories	m	375.00
10.2 PVC downspout 150 mm, dia.	m	175.00
10.3 Embedded steel	ton	18000.00
10.4 Wrought timber ceiling		
(1) Trim 30x 30 mm Soft wood	m	6.00
(2) Casing 25x100 mm Soft wood	m	15.00
(3) Jamb & head 40x200 mm Hard wood	m	58.00
(4) Carcassing	m^2	n.a.
10.5 Anti-termite poisoning	m^2	26.90

Table 13-7-1(3) Unit Cost for Construction Works

Item	Unit	Unit price(Rs.)
11. HVAC system		
11.1 Wall mounted ventilation fan		
(1) Fan size 200 mm, Air volume 500 m^3/h	set	600.00
(2) Fan size 300 mm, Air volume 1,500 m^3/h	set	800.00
(3) Fan size 500 mm, Air volume 6,000 m^3/h	set	1000.00
(4) Fan size 800 mm, Air volume 10,000 m^3/h	set	1200.00
11.2 Roof mounted ventilation fan		
(1) Fan size 500 mm, Air volume 3,600 m^3/h Static pressure 5 mmAg	set	4000.00
(2) Fan size 700 mm, Air volume 14,600 m^3/h Static pressure 5 mmAg	set	5200.00
(3) Fan size 900 mm, Air volume 19,600 m^3/h Static pressure 5 mmAg	set	6500.00
(4) Fan size 1,000 mm, Air volume 23,000 m^3/h Static pressure 5 mmAg	set	7500.00
11.3 Window type air conditioner (power supply single phase 220 V)		
(1) Capacity 2,000 kcal/h 1 ton	set	15000.00
(2) Capacity 3,000 kcal/h 1 1/2 ton	set	18000.00
(3) Capacity 5,000 kcal/h 1 ton	set	22000.00
12. Electrical works		
12.1 Lighting fixtures		
(1) Fluorescent lamp 20wx2	set	350.00
(2) Fluorescent lamp 40wx2	set	350.00
(3) Incandescent lamp 100wx1	set	60.00
12.2 Socket outlet (with box)		
(1) Single phase 220V-15A 3 poles	set	35.00
(2) 3 phase 380V-10A 4 poles (Circuit breaker)	set	700.00
12.3 Switch with box 220V-10A 2 poles	set	25.00
12.4 Knife switch with box 3P-10A	set	350.00
12.5 Molded circuit breaker		
(1) 2P-20A	set	700.00
(2) 2P-50A	set	700.00
(3) 3P-50A	set	700.00
12.6 Cable (600V)		
(1) 3.5 mm^2 - 2C	m	30.00
(2) 5.5 mm^2 - 2C	m	70.00
(3) 14 mm^2 - 4C	m	100.00
12.7 PVC wire (600V)		
(1) 3.5 mm^2 4 mm^2	m	5.00
(2) 22 mm^2 25 mm^2	m	23.00
(3) 38 mm^2 50 mm^2	m	51.00
(4) 80 mm^2 95 mm^2	m	92.00

Table 13-7-1(4) Unit Cost for Construction Works

Item	Unit	Unit price(Rs.)
13. Plumbing works		
13.1 Plumbing fixtures		
(1) Wash basin	set	1000.00
(2) Kitchen sink	set	1200.00
(3) Water closet	set	1500.00
(4) Toilet fan	set	800.00
13.2 Piping materials		
(1) PVC pipes 150 mm dia.	m	175.00
(2) Steel pipes 50 mm dia.	m	93.50
(3) Steel pipes 150 mm dia.	m	459.34
(4) Concrete pipes 100 mm dia. R.C.C.	m	60.00
(5) Concrete pipes 200 mm dia. R.C.C.	m	70.50
(6) Concrete pipes 300 mm dia. R.C.C.	m	87.00
14. General item		
14.1 Site survey	m^2	0.10
14.2 Setting out	m^2	4.00
14.3 Cost for incoming power supply	sum	1500.00/kW
14.4 *Connection for water supply*	*sum*	*5000*
14.5 Provision of the contractor's yard including fencing	m^2	
14.6 Contractor's site office	m^2	645.00
14.7 contractor's store	m^2	430.00
14.8 Contractor's latrine	m^2	450.00
14.9 Contractor's workshop	m^2	450.00
14.10 Contractor's laboratory	m^2	450.00
14.11 Concrete compressive test	pcs	25.00
14.12 Load bearing test	sum	15000.00
14.13 Standard penetration test	sum	900.00
14.14 Internal scaffolding	m^2	16.14
14.15 External scaffolding	m^2	21.52
14.16 Concrete road pavement t=150 mm	m^2	350.00
14.17 Concrete road pavement t=200 mm	m^2	460.00
14.18 Rain water drainage canal 300x300	m	230.00
14.19 Wire net fence h=2m with foundation	m	120.00
14.21 Concrete block fence h=2m with foundation	m	1250.00

Table 13-7-2(1) Estimation of Manufacturing Machinery and Equipment (Case A)

(Unit:Rupee)

	CASE 1A, 3A 50,000 ton			CASE 2A 100,000 ton		
	Cost for machinery	Transportation	Spare parts	Cost for machinery	Transportation	Spare parts
Coal washing plant	--	--	--	--	--	--
(CIF Karachi,¥)	(65,460,000)	45,000	(3,273)	(65,460,000)	45,000	(3,273)
Crushers	2,785,000	7,000	223,000	2,785,000	7,000	223,000
Belt conveyors (three sets)	480,000	2,100	38,000	480,000	2,100	38,000
Coal treatment equipment	8,400,000	18,900	672,000	16,800,000	37,800	1,344,000
Bagasse treatment equipment	9,000,000	21,000	720,000	18,000,000	42,000	1,440,000
Heat gas line equipment	8,400,000	21,000	420,000	16,800,000	42,000	840,000
Mixing & briquetting equipment	8,073,000	14,000	404,000	16,146,000	28,000	807,000
(CIF Karachi,¥)	(118,499,000)	21,000	(5,925)	(236,997,000)	42,000	(11,850)
Paraffin coat equipment	1,800,000	7,000	90,000	3,600,000	14,000	180,000
Exhaust gas equipment	4,200,000	7,700	210,000	8,400,000	15,400	420,000
Light oil tank	380,000	4,200	19,000	760,000	8,400	38,000
Wax tank	470,000	4,200	24,000	940,000	8,400	47,000
Power supply and control system	10,800,000	5,600	540,000	21,600 000	11,200	1,080,000
Total	54,788,000	178,700	3,359,000	106,311,000	303,300	6,458,000
(Foreign, Yen)	(183,958,000)	--	(9,198)	(302,457,000)	--	(15,123)
Erection cost for Plant	4,200,000			7,480,000		
Others	500,000			1,000,000		

Table 13-7-2(2) Estimation of Manufacturing Machinery and Equipment (Case B)

(Unit:Rupee)

	CASE 1B, 3B 50,000 ton			CASE 2B 100,000 ton		
	Cost for machinery	Transportation	Spare parts	Cost for machinery	Transportation	Spare parts
Coal washing plant	6,311,000	105,000	316,000	6,311,000	105,000	316,000
Crushers	2,785,000	7,000	223,000	2,785,000	7,000	223,000
Belt conveyors (three sets)	480,000	2,100	38,000	480,000	2,100	38,000
Coal treatment equipment	8,400,000	18,900	672,000	16,800,000	37,800	1,344,000
Bagasse treatment equipment	9,000,000	21,000	720,000	18,000,000	42,000	1,440,000
Heat gas line equipment	8,400,000	21,000	420,000	16,800,000	42,000	840,000
Mixing & briquetting equipment	21,000,000	44,800	1,050,000	42,000,000	89,600	2,100,000
Paraffin coat equipment	1,800,000	7,000	90,000	3,600,000	14,000	180,000
Exhaust gas equipment	4,200,000	7,700	210,000	8,400,000	15,400	420,000
Light oil tank	380,000	4,200	19,000	760,000	8,400	38,000
Wax tank	470,000	4,200	24,000	940,000	8,400	47,000
Power supply and control system	10,800,000	5,600	540,000	21,600 000	11,200	1,080,000
Total	74,026,000	248,500	4,321,000	138,476,000	382,900	8,066,000
Erection cost for Plant		4,200,000			7,480,000	
Others		500,000			1,000,000	

Table 13-7-3 Estimation of Civil and Building Works

Unit:Rupee

	CASE 1, 3 50,000 ton	CASE 2 100,000 ton
Water reservoir	350,000	350,000
Thickener	350,000	350,000
Tank foundations(two nos.)	100,000	200,000
Access roads	270,000	270,000
Outdoor construction	360,000	360,000
Pipings	150,000	150,000
Telecommunication	300,000	300,000
Power line	--	5,016,000
Plant buildings	1,930,000	3,860,000
Office	920,000	920,000
Dormitory (A)	540,000	540,000
Dormitory (B)	1,060,000	1,725,000
Barrack	900,000	1,350,000
Guard house	100,000	100,000
Toilet (A)	90,000	180,000
Toilet (B)	150,000	300,000
Consumables	285,000	449,000
Total	7,855,000	16,420,000

Table 13-7-4 Engineering and Supervisory Fee

Item	CASE 1A, 3A 50,000 tons		CASE 2A 100,000 tons	
	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)
Engineering fee				
Plant & machinery	7,665,000	2,192,000	12,602,000	4,252,000
Civil/buildings	--	573,000	--	1,199,000
Total	7,665,000	2,765,000	12,602,000	5,451,000
Supervision				
Plant & machinery	12,600,000	--	12,600,000	--
Civil/buildings	4,800,000	--	4,800,000	--
total	17,400,000	--	17,400,000	--

Item	CASE 1B, 3B 50,000 tons		CASE 2B 100,000 tons	
	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)
Engineering fee				
Plant & machinery	--	2,961,000	--	5,539,000
Civil/buildings	--	573,000	--	1,199,000
Total	--	3,534,000	--	6,738,000
Supervision				
Plant & machinery	3,600,000	--	3,600,000	--
Civil/buildings	4,800,000	--	4,800,000	--
total	8,400,000	--	8,400,000	--

CHAPTER 14 TOTAL CAPITAL REQUIREMENT

14-1 Overview

This chapter gives the total capital requirement, summing the capital investments required until the commencement of plant operation. In this study, the total capital requirement is defined as a sum of the following expenditures:

1) Plant construction costs,
2) Pre-operating expenses,
3) Initial working capital, and
4) Interest during construction period.

14-2 Basic Premises

Total capital requirement calculated on premises being described below is based on the prices at the time when the plant construction starts. The prices used are assumed to be constant from when the construction starts and throughout whole life of the project.

14-2-1 Price Basis

For the estimation of each cost item which constitutes the total capital requirement, prices as of July 1988 when the field survey was conducted are used as the calculation basis.

The prices used in cost estimation for the foreign currency portion of capital requirement, i.e., import of machinery and personnel expense for foreign experts such as supervisor and trainer are assumed to be constant until the time when the cost is incurred.

On the other hand, costs for the local Rupee currency portion are estimated on the basis of price escalation rates in Pakistan. Based on the growth rates of wholesale prices by commodities in

Pakistan since 1980 as shown in Table 14-2-1, domestic prices of machinery, building materials and transportation vehicles are assumed to escalate until the start of construction by 2.5, 3.6 and 4.5 % per annum, respectively.

Table 14-2-1 Wholesale Price Indexes in Pakistan

(Index : 1980-81=100)

Year	Commodity		
	Machinery	Building materials	Vehicles
1981(July)-82(June)	102.47	96.21	106.21
1982-83	106.20	95.76	107.52
1983-84	107.70	104.22	117.13
1984-85	108.43	111.41	117.46
1985-86	118.66	118.47	118.12
1986-87	116.06	123.41	129.88
Average growth rate(%p.a.)	2.51	3.57	4.45

Source : PAKISTAN STATISTICAL YEARBOOK 1988, FEDERAL BUREAU OF STATISTICS

Personnel expenses of local labors are estimated applying escalation rate of 3.5 % per annum according to the growth rate of average earnings of domestic plant workers as shown in Table 14-2-2.

Table 14-2-2 Index of Average Annual Earnings of Factory Workers in Pakistan

(Index : 1978=100)

Year	1979	1980	1981	1982	Average growth rate
Index	103.45	96.46	102.46	114.84	3.52 %p.a.

Source : PAKISTAN STATISTICAL YEARBOOK 1988, FEDERAL BUREAU OF STATISTICS

Note) Data for the years 1983 and onward was not available at the time of study.

14-2-2 Financing Sources

Total capital requirement is covered by equity and debt in the following ratio :

	Ratio(%)	Sources of financing
Equity	40	Government fund
Debt	60	Long-term loans

The foreign currency portion of capital is financed by long-term loan debt, whereas the local currency portion is covered by both equity and long-term loan debt.

For the purpose of calculating the interest during construction period, interest rates of long-term loans for foreign and local currency are assumed to be 14.0 and 14.6 %p.a., respectively. Furthermore, a 7.3 % exchange risk coverage fee adds to the interest rate for the foreign currency loan.

14-2-3 Supply Sources of Machinery and Services

As mentioned in 13-2-1, this study evaluates the project on the basis of two alternatives of procurement of machinery and services; namely Cases A and B. "A", the base case uses imported coal washing plant and mixing/briquetting machine for the first plant only, whereas "B", the alternative case uses all domestically produced equipment and facilities. Along with machinery, A and B differ in the services provided as:

	A	B
(1)Basic design, million Yen	40 (Expatriate)	none
(2)Operation and management training, million Yen	48 (Expatriate)	48 (Expatriate)
(3)Imported machine training and supervise, million Yen	24 (Expatriate)	none

14-3 Summary of Total Capital Requirement

Summing up the foreign portion estimated in Japanese yen currency and the local portion in rupee currency, total capital requirement is summarized in Table 14-3-1 for 50,000 ton (Cases 1 and 3) and 100,000 ton (Case 2) plants.

To obtain the plant construction cost, "OCTROI" tax is assumed to be assessed on all the machinery and equipment of the plant at the rate of five rupees per weight of 40 kilograms. In addition to the OCTROI, the following charge, duty and tax are assumed to be assessed on the imported machinery and equipment:

1) 11 percent of IQRA and surcharge
2) 20 percent custom duty and 12.5 percent sales tax

Table 14-3-1 Total Capital Requirement

(Unit : 1,000)

Items	Cases 1 and 3 : 50,000 ton/year				Case 2 : 100,000 ton/year			
	Cases 1A,3A (Base case)		Cases 1B,3B (Alternative case)		Case 2A (Base case)		Case 2B (Alternative case)	
	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)
Plant Construction Costs:								
(1)Machinery and equipment	183,958	70,316	0	78,070	302,457	132,675	0	145,948
(2)Vehicles	0	8,103	0	8,103	0	13,874	0	13,874
(3)Erection	0	5,035	0	5,035	0	9,084	0	9,084
(4)Structures and civil work	0	8,430	0	8430	0	17,623	0	17,623
(5)Engineering	47,665	2,962	0	3,786	52,602	5,839	0	7,218
(6)Supervision	17,400	0	8,400	0	17,400	0	8,400	0
(7)Commissioning	1,800	0	1,800	0	1,800	0	1,800	0
(8)Physical contingency	13,201	4,992	537	5,443	19,698	9,426	537	10,197
- Total Plant Cost -	264,024	99,838	10,737	108,868	393,957	188,522	10,737	203,944
Pre-operating Expenses	72,000	5,976	48,000	5,976	72,000	11,652	48,000	11,652
Initial Working Capital	18,396	10,462	0	12,228	30,246	19,856	0	22,866
Interest During Construction	63,461	1,196	8,765	2,888	87,878	3,111	8,765	5,684
Total	417,881	117,472	67,502	129,960	584,081	223,141	67,502	244,146

Note) Base case : Coal washing plant and mixing/briquetting machine are imported.
Alternative case : All machinery and equipment are domestically made.

14-4 Plant Construction Cost

The plant construction cost consists of the following items.

(1) Machinery and Equipment

As shown in Table 14-4-1, costs of machinery and equipment for the coal washing and briquetting plants and auxiliary facilities are:

Case 1A,3A - 184 million Yen and 70 million rupees
1B,3B - 78 million rupees
2A - 302 million Yen and 133 million rupees
2B - 146 million rupees

(2) Vehicles

Costs to purchase trucks for transportation of raw materials and tank lorries for water from those supply sources are included in the plant cost.

	Case 1,3	Case 2
Numbers of truck(Rs.525,000/vehicle)	12	21
Numbers of lorry(Rs.560,000/vehicle)	2	3
Base cost at 1988 price,thousand rupees	7,420	12,705
Price contingency(9.2%),thousand rupees	683	1,169
Cost for vehicles	8,103	13,874

(3) Erection

Expenditures on workers, materials and facilities required for erection and assembly of plant equipment and facilities amount to 5,0 million rupees in Cases 1 and 3 and 9.1 million rupees in Case 2.

Erection cost (Rs.thousand)	Case 1,3	Case 2
Coal washing and briquetting plant	4,200	7,480
Others	500	1,000
Base cost at 1988 price	4,700	8,480
Price contingency(7.1%)	335	604
Cost for erection	5,035	9,084

(4) Structures and Civil Work

Costs for construction of plant buildings and civil works amount to 8.4 million rupees in Cases 1 and 3 and 17.6 million rupees in Case 2.

Structure/civil work cost(Rs.thousand)	Case 1,3	Case 2
Buildings	5,975	9,424
Water reservoir,thickener and foundation	800	900
Road/outdoor construction and pipings	780	780
Telecommunication	300	300
Power line	-	5,016
Base cost at 1988 price	7,855	16,420
Price contingency(7.3%)	575	1,203
Cost for structure and civil work	8,430	17,623

(5) Engineering

Costs for local survey and designing of the plant are as shown below. Cost for basic design by expatriate is included in the engineering fee in Case A.

Engineering fee (Rs.thousand)	1A,3A	1B,3B	2A	2B
Plant and machinery	2,192	2,961	4,252	5,539
(Foreign portion,¥1,000)	(7,665)	-	(12,602)	-
Civil and buildings	573	573	1,199	1,199
Base cost at 1988 price	2,765	3,534	5,451	6,738
Price contingency(7.1%)	197	252	388	480
Cost for engineering (rupee portion)	2,962	3,786	5,839	7,218
Basic design by expatriate, ¥1,000	40,000	-	40,000	-

(6) Supervision

Personnel expenditures for supervisory works by foreign engineers during the plant construction period are:

Case 1A,2A,3A: 2,000,000 yen/man-month x 4.5 man-month
600,000 Yen/man-month x 14 man-month

Case 1B,2B,3B: 600,000 yen/man-month x 14 man-month

(7) Commissioning

The expenses required for the initiation and performance guarantee operation conducted when the plant is transferred to the owner by the contractor is accounted as personnel expenditures of foreign engineers in all cases:

600,000 yen/man-month x 3 man-month

(8) Contingency

The physical contingency as a counter-measure for the unexpected during the construction period, assumed as follows all equivalent to 5 % of total plant construction costs, is included in the plant construction cost.

Physical contingency	1A,3A	1B,3B	2A	2B
Local portion,Rs.thousand	4,992	5,443	9,426	10,197
Foreign portion,¥ thousand	13,201	537	19,698	537

Table 14-4-1 Machinery and Equipment Costs

(Unit : 1,000)

Items	Cases 1 and 3 : 50,000 ton/year				Case 2 : 100,000 ton/year			
	Cases 1A,3A (Base case)		Cases 1B,3B (Alternative case)		Case 2A (Base case)		Case 2B (Alternative case)	
	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)
1.Coal washing								
-Coal washing facilities	65,460	45	0	6,416	65,460	45	0	6,416
-Crushers	0	2,792	0	2,792	0	2,792	0	2,792
-Belt conveyors	0	482	0	482	0	482	0	482
2.Raw materials preparation								
-Coal treatment equipment	0	8,419	0	8,419	0	16,838	0	16,838
-Bagasse treatment equipment	0	9,021	0	9,021	0	18,042	0	18,042
-Heat gas line equipment	0	8,421	0	8,421	0	16,842	0	16,842
3.Briquetting								
-Mixing/briquetting equipment	118,499	8,108	0	21,045	236,997	16,146	0	42,090
-Paraffin coating equipment	0	1,807	0	1,807	0	3,614	0	3,614
4.Dust collection and recycling								
-Exhausted gas equipment	0	4,208	0	4,208	0	8,415	0	8,415
5.Auxiliary facilities								
-Liquid oil and wax tanks	0	858	0	858	0	1,716	0	1,716
-Power station and supply	0	3,600	0	3,600	0	7,200	0	7,200
-Control system	0	7,206	0	7,206	0	14,411	0	14,411
Total cost at 1988 price	183,958	54,967	0	74,275	302,457	106,613	0	138,858
Price contingency	0	2,782	0	3,759	0	5,399	0	7,030
(% of the total)	(0)	(5.06)	(0)	(5.06)	(0)	(5.06)	(0)	(5.06)
6.Tax and duty	0	12,567	0	36	0	20,664	0	60
(Total weight,ton)		(311)		(285)		(529)	0	(477)
Total machinery & equipment cost	183,958	70,316	0	78,070	302,457	132,675	0	145,948

14-5 Pre-operating Expenses

Following fees and costs are required as pre-operating expenses until the commercial operation starts.

(1)Training Fee

Personnel expenses 72 million yen(Case A) or 48 million yen (Case B) and 521 thousand rupees (Cases 1 and 3) or 742 thousand rupees (Case 2) are required for the technical training of plant operation rendered to operators by foreign experts:

Trainer :	2,000,000 yen/man-month	x	36 man-month(Case A)
			24 man-month(Case B)
Engineer :	5,000 rupees/man-month	x	24 man-month
Accountant :	5,000 rupees/man-month	x	24 man-month
Store keeper :	5,000 rupees/man-month	x	24 man-month
Chief operator :	2,000 rupees/man-month	x	30 man-month(Case 1,3)
			54 man-month(Case 2)
Operator :	1,600 rupees/man-month	x	114 man-month(Case 1,3)
			222 man-month(Case 2)

(2)Trial Operation Cost

For three month trial operation at 50 % running rate prior to the commercial operation, 5.5 million rupees in Cases 1 and 3 and 10.9 million rupees in Case 2 are required for raw materials and their handling and for utility:

(Rs. thousand)

	Case 1,3	Case 2
Raw materials	4,818	9,636
Utility	637	1,274

14-6 Initial Working Capital

To maintain smooth daily operation, some funds should be prepared before commencement of operation. Assets amounting as follows are assumed to be prepared as the net working capital on completion of the plant.

(1) Spare Parts

Spare parts required for two year operation are prepared.

	1A,3A	1B,3B	2A	2B
Spare parts,local(Rs.thousand)	7,461	9,385	14,186	17,402
Price contingency(5.1%)	377	475	718	881
Local spare-part cost	7,838	9,860	14,904	18,283
Spare parts,foreign(¥ thousand)	18,396	-	30,246	-

(2) Raw Materials Inventory

Raw materials required for 10-day operation are prepared as inventories as shown below:

(Rs. thousand)

		Case 1,3	Case 2
Coal	:	843	1,686
Bagasse	:	107	214
Slaked lime	:	75	150
Wax	:	29	58
Light fuel oil	:	211	421
-total-	:	1,265	2,529

(3) Cash

The following amounts all equivalent to approximately 1 % of plant construction costs are prepared as cash-in-hand.

	1A,3A	1B,3B	2A	2B
Cash-in-hand, Rs.thousand	1,359	1,103	2,423	2,054

14-7 Interest During Construction

The interest during plant construction period is calculated based on the borrowing schedule of long-term loans according to the disbursement schedule. Table 14-7-1 shows the disbursement schedule of total capital requirement including calculated interest during construction.

Table 14-7-1 Disbursement Schedule and Interest During Construction

(Unit : 1,000)

Project year	-2				-1				Total	
Disbursement period	1st half		2nd half		1st half		2nd half			
	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)	Foreign (Yen)	Local (Rupee)
Cases 1A,3A										
Plant Construction Cost	108,266	25,323	0	0	146,014	60,674	9,745	13,841	246,025	99,838
Pre-operating Expenses	12,000	70	12,000	70	24,000	70	24,000	5,766	72,000	5,976
Initial Working Capital	0	0	0	0	0	0	18,396	10,462	18,396	10,462
Interest During Construction	0	0	12,808	0	15,450	0	35,202	1,196	63,461	1,196
Total Investment	120,266	25,393	24,808	70	185,465	60,744	87,343	31,265	417,882	117,472
Case 1B										
Plant Construction Cost	0	28,693	0	0	5,053	66,388	5,684	13,841	10,737	108,868
Pre-operating Expenses	12,000	70	12,000	70	12,000	70	12,000	5,766	48,000	5,976
Initial Working Capital	0	0	0	0	0	0	0	12,228	0	12,228
Interest During Construction	0	0	1,278	0	2,692	0	4,795	2,888	8,765	2,888
Total Investment	12,000	28,708	13,278	70	19,745	66,458	22,479	34,724	67,502	129,960
Case 2A										
Plant Construction Cost	150,884	48,044	0	0	233,329	115,528	9,745	24,951	393,958	188,522
Pre-operating Expenses	12,000	70	12,000	70	24,000	70	24,000	11,443	72,000	11,652
Initial Working Capital	0	0	0	0	0	0	30,246	19,856	30,246	19,856
Interest During Construction	0	0	17,347	0	20,473	0	50,059	3,110	87,878	3,110
Total Investment	162,884	48,113	29,347	70	277,802	115,598	114,049	59,360	583,082	223,141
Case 2B										
Plant Construction Cost	0	53,687	0	0	5,053	125,308	5,684	24,951	10,737	203,945
Pre-operating Expenses	12,000	70	12,000	70	12,000	70	12,000	11,443	48,000	11,652
Initial Working Capital	0	0	0	0	0	0	0	22,866	0	22,866
Interest During Construction	0	0	1,278	0	2,692	0	4,795	5,684	8,765	5,684
Total Investment	12,000	53,756	13,278	70	19,745	125,377	22,479	64,942	67,502	244,146

CHAPTER 15 OPERATING EXPENSE

15-1 Overview

Operating expenses necessary for the production of coal briquettes are divided into two categories, variable and fixed costs. The former covers costs for raw materials such as coal, bagasse and slack wax, and for utilities like electricity and water. The later covers costs for direct labor, maintenance of machinery and equipment, insurance and other miscellaneous items not relating directly to operating rate of the plant.

To calculate the operating expense, all costs and prices used are as of 1990 when the plant construction starts.

15-2 Variable Operating Cost

Annual variable operating costs required for coal briquette production are summarized in Table 15-2-1. These costs are calculated on the assumption that 50,000 tons in Cases 1 and 3 and 100,000 tons in Case 2 of smokeless coal briquettes are produced in the plant operated at full capacity.

To obtain the variable operating expenses, prices of materials and utilities are estimated on the following assumptions:

(1) Raw materials
- (a) Coal price ex-mine is fixed at which PMDC proposes.
- (b) Bagasse price increases at the rate of increase of paper price, 1.9 percent per annum.
- (c) Slaked lime price which is influenced by the building material price increases at the growth rate of building materials, 3.6 percent per annum.
- (d) Slack wax and light fuel prices are assumed to be constant because they are closely linked with the government controlled oil price which is difficult to forecast.

(2) Utility, transportation and material handling

(a) Electric charges are assumed to be constant at those currently effective until the construction starts.

(b) Transportation charge for materials on contract is influenced mostly by labor and fuel costs. According to the growth rates of labor cost and motor fuel price, 3.5 and 3.4 percent per annum, respectively; therefore, the transportation and handling charges are assumed to increase by 3.5 percent per annum.

Table 15-2-1 Annual Variable Operating Cost

Items	Price (Rs./unit)	Consumption (/year)		Annual cost (Rs.1,000)	
		Case 1,3	Case 2	Case 1,3	Case 2
Raw materials					
Coal(ton)	312	81,150	162,300	25,294	50,589
Bagasse(ton)	198	16,250	32,500	3,209	6,419
Slaked lime(ton)	712	3,150	6,300	2,243	4,486
Slack wax(ton)	2,886	300	600	866	1,732
Light fuel(ton)	2,874	2,200	4,400	6,322	12,645
Utilities					
Electricity(kWh)	0.45	$5,2x10^6$	$10.4X10^6$	2,333	4,666
Demand charge(kW)	1,080	1,300	2,500	1,404	2,700
Water(ton)	14	12,250	24,500	172	343
Handling(ton)	6.25	97,400	194,800	609	1,218
Total variable operating cost				42,452	84,796

15-2-1 Raw Material Cost

(1) Coal

The project uses Lakhra coal as principal raw material and as fuel to dry raw materials. The coal is supplied at a price of 300 rupees per ton on wet base at mines and 11.7 rupees are required to transport one ton of coal to the plant site. Unit consumption of raw coal and fuel coal on wet base is 1.25 and 0.373 ton per ton of briquette, respectively; accordingly, annual coal cost required is 25.3 million rupees for 50,000 ton production (Cases 1 and 3) and 50.6 million rupees for