(4) Slaked lime

Slaked lime is produced and processed into products at Crush Stone Sales Ltd., 8 km away from Lusaka. The products are available in 25 kg bag and can therefore be loaded or unloaded quite easily. Slaked lime is transported either by truck or pickup.

6.2.3 Raw materials for clay stoves

The field survey and subsequent experimental production of clay stoves have confirmed that Chamba Velley clay makes a good raw material for the clay stoves. Chamba Valley is a suburb of Lusaka and the transportation of clay is by road.

So far several transportation systems have been discussed. The use of such equipment as heavy-duty vehicles and belt conveyors for loading, unloading and moving work cannot be economical and should be ruled out in view of the small quantities involved.

6.3 Conditions for Calculation of Transportation Cost

Here the conditions for calculation of the cost of transporting the raw materials for coal briquettes and clay stoves are explained.

6.3.1 Definition of transportation cost

In general, the unit cost of transportation by railroad or by road does not mean the comprehensive transportation costs of goods, broadly interpreted as defined previously in 6.2.1; rather, the unit cost generally concerns actual movement of the goods. As the present report interprets transportation as covering all operations needed to move goods from one place to another, what is referred to as cost herein shall consist of the three types below.

1) Loading and unloading
2) Short-distance transportation for loading
3) Transportation

In calculating the cost, February/March 1986 is used as the reference period.

6.3.2 Transportation Cost

A total of eight transportation systems have been set up for coal briquettes and one system for clay stoves. Cost may be calculated for each element. Table 6.3.1 shows composition of cost for the transportation systems set-up.

Table 6-3-1 Cost Composition of Systems

		(1) Loading and unloading	(2) Short-distance transportation for loading	(3) Transportation
Coal slurry	1)	x	x	x
	2)	x	x	x
	3)	x		x
Molasses	1)	x		x
	2)	x		x
Bagasse	1)	x	x	x
	2)	x		x
Slaked lime		x		x
Clay		x		x

(1) Loading and unloading

If labor is used for these operations, skilled labor is not necessary. Therefore, the annual salary is 2,000 Kwachas (K). Simple tools as shovels will be good enough and NCSR can prepare them without difficulty.

(2) Short-distance transportation for loading

Movement here can be of two types; i.e., transportation within Maamba and that needed for getting the cargo ready for railroad transportation. Here, transportation by means of a ropeway system is also included in this category.

1) Within Maamba

worker	K 2,000/person
driver	K 5,000/person
facility	
cart, frame car, etc. *	K 1,000/unit
dump trucks ** (10t)	K200,000/unit
fuel (diesel)	K1.88/l
distance traveled per liter	5 km

2) By railroad

driver	K 5,000/person
facility	
dump trucks (10t)	K200,000/unit
fuel (diesel)	K1.88/l
distance traveled per liter	5 km

* Service life: 3 years

** Service life: 10 years

The estimates above assume NCSR's operation. If a sub-contractor is hired, the fixed fee, variable fee, manpower cost (per driver), and transportation unit cost, i.e., K0.5/t/km, set forth by Contract Haulage Limited (CH), the largest carrier of the nation, are to be used.

3) By ropeway

According to the MCL's records, the cost is K4.76/t for 1984-1985 and K6.08/t for 1985-1986, the latter is used for this feasibility study.

(3) Transport cost

1) Railroad

The conditions used in calculating the cost of transportation by railroad are as follows (Railway Traffic Book of ZR):

1. Wagons and tank cars will be borrowed.
2. Loading of coal slurry will be done by ZR. Loading of molasses and bagasse will be done by NCSR although talks will be necessary for this arrangement.
3. Unloading will be done by NCSR.
4. Weight measurement will be done by ZR.
5. Wagons and tank cars hold 40 t and 11 t, respectively.

Under these conditions, the breakdown of the cost is as follows:

Freight

1. Wagon measurement	K10.00/wagon
2. Documentation	K 5.00/trip
3. Wagon rental	K10.00/wagon
4. Tank rental	K13.40/tank

The freight for (1) coal slurry and (2) molasses and bagasse is calculated as follows.

(1) Masuku to Lusaka	K52.50/t
Batoka to Lusaka	K39.90/t
(2) Mazabuka to Lusaka	K24.30/t

2) Road

Operations similar to the short-distance transportation cost (2) 2) above are assumed.

6.4 Recommended Transportation System and Transportation Cost

6.4.1 Calculation of transportaion cost

Coal briquettes need as raw material coal slurry, molasses, bagasse, slaked lime and clay stoves clay; these raw materials must be transported from their places of origin to the plant site in a manner most desirable technically and economically. The method and result of calculation are shown for each raw material. The unit is K/Year.

(1) Coal Slurry

(a) Case 1 (Ropeway, railroad, road)

The coal slurry is transported by hand cart from the slurry pond to the ropeway station. It is assumed that one workman can transport 300 tons of slurry a year using one hand cart and that the hand cart is depreciated in three years. The cost of transportation by hand cart is obtained by:

Manpower	T/300 x 2,000 (K/Y) =	6.67T
Depreciation	T/300 x 1,000 (K/cart)/3Y =	1.11T
Total		7.78T

If the cost of depreciation is exempted the total cost is that of manpower only, or 6.67T.

The transportation cost for the ropeway is 6.08T.

The railroad transportation cost from Masuku to Lusaka over 321 Km consists of:

Transportation cost		52.5T
Wagon measurement	T/40 x 10 (K/car) =	0.25T
Documentation	5(K/Service) x 24(service/Y) =	120
Wagon rental	T/40 x 10 (K/Car) =	0.25T
Total		120 + 53T

The transportation cost from Lusaka Station to the plant site over 2km consists of the following if the operation is undertaken by NCSR:

Driver		5,000
Labor	2,000 (K/Head Y) x 2(H) =	4,000
Maintenance		2,000
Depreciation		20,000
Fuel	4 (km)/5 (km/l) x 1.88 (K/l) x T/10 =	0.15T
Total		31,000 + 0.15T

If the depreciation is exempted the cost comes to 11,000 + 0.15T.

If the transportation is contracted the cost is:

Freight 0.5 (k/km.t) x T (t) x 2 (km) =	1.0T
Labor 2,000 (K/Head.Y) x 2 (H) =	4,000
Total	4,000 + T

The above calculations may be summarized as:

Contract	4,120 + 67.9T
Direct with depreciation	31,120 + 67.0T
Direct without depreciation	11,120 + 65.9T

(b) Case 2 (Road, railroad, road)

Transportation from Maamba to Batoka, 88km, is by truck; from Batoka to Lusaka, 226km, is by rail; from Lusaka to the plant site, 2km, is by truck. The basis of calculation used above are also used here. This case has to assign two different trucks to transportation between Maamba and Batoka and that between Lusaka and the plant site. The labor force needed for loading and unloading the slurry is 5 persons. The result of calculation is summarized below:

Contract	10,120 + 85.4T
Direct with depreciation	64,120 + 47.2T
Direct without depreciation	24,120 + 47.2T

(c) Case 3 (Road)

Transportation from Maamba to the plant site, 352km, is done by one truck and 5 labors. The transportation cost is given by:

Contract	10,000 + 176T
Direct with depreciation	37,000 + 26.5T
Direct without depreciation	17,000 + 26.5T

(2) Bagasse

Bagasse is supplied by the Nakambala Sugar Estate together with molasses and these two are carried by the same truck for road transportation. The weights of bagasse and molasses are about 9 to 1; therefore, 90% of the fixed expenses is charged to bagasse and 10% to molasses.

(a) Case 1 (Railroad, road)

Transportation cost is calculated in a manner similar to the transportation of coal slurry with the results that:

Contract	3,720 + 25.8T
Direct with depreciation	28,020 + 24.9T
Direct without depreciation	10,020 + 24.9T

(b) Case 2 (Road)

The results of the calculation is:

Contract	7,200 + 61T
Direct with depreciation	27,900 + 8.93T
Direct without depreciation	9,900 + 8.93T

(3) Molasses

The transportation cost is calculated in a manner similar to the transportation of bagasse. Molasses bears 10% of the fixed expenses.

(a) Case 1 (Railroad, raod)

Contract	520 + 26.5T
Direct with depreciation	3,220 + 25.5T
Direct without depreciation	1,220 + 25.5T

(b) Case 2 (Road)

Contract	800 + 61T
Direct with depreciation	3,100 + T
Direct without depreciation	1,100 + T

(4) Slaked lime, clay

The volumes of slaked lime and clay are both small and can be transported by the same truck and labors that used for bagasse and molasses. The fixed expenses are not charged to slaked lime and clay. The distances of transportation are 8km for slaked lime and 7km for clay. The costs of transportation are:

(a) Slaked lime

Contract	4T
Direct	0.6T

(b) Clay

Contract	3.5T
Direct	0.5T

6.4.2 Recommended transportation scheme

The following amounts of raw materials are needed to produce 1,000 tons per year of coal briquettes and 4,000 pieces per year of clay stoves:

Coal slurry	1,214 tons/year
Bagasse	940
Molasses	123
Slaked lime	28
Clay	51.2

Using these figures transportation costs are calculated for all the cases studied as shown in Figure 6-4-1 which indicates that if depreciation is exempted the direct operation by NCSR's own trucks proves to be least expensive.

Table 6-4-1 Summary of Transportation Cost

(Unit: K/year)

	Contract	Own Fleet	Own Fleet*
Coal Slurry			
Case-1	86,551	112,458	91,123
Case-2	113,796	121,421	81,421
Case-3	223,664	69,171	49,171
Bagasse			
Case-1	27,972	51,426	33,426
Case-2	64,540	36,294	18,294
Molasses			
Case-1	3,780	6,357	4,357
Case-2	8,303	3,223	1,223
Slaked Lime	112	17	17
Clay	179	26	26

* Excluding depreciation

6.4.3 Transportation cost and plant location

The above calculations assume the plant site to be Lusaka. Here transportation costs are calculated if the plants are located at Maamba or Nakambala. In case of locating the plant in Lusaka the transportation cost proves to be least expensive in case NCSR owns its own fleet of trucks but without depreciation expense. The same holds true with other candidate locations and the transportation is calculated for direct operation by truck without depreciation only. The premises used for the above calculation also apply. In addition the following premises are established:

1) The transportation cost of coal slurry is zero if the plant is located at Maamba.

2) The transportation costs of bagasse and molasses are zero if the plant is located at Nakambala.

3) Slaked lime and clay are also available at Maamba and Nakambala, hence their transportation costs are zero.

4) Coal briquettes products are transported by truck. Transportation cost of clay stoves is neglected.

With the above suppositions the transportation costs are calculated as given in Table 6-4-2. The transportation cost is lowest if the plant is located at Nakambala; Lusaka and Maamba are about even.

Table 6-4-2 Comparison of Transportation Cost

(Unit: Kwachas/year)

Plant Site	Lusaka	Nakambala	Maamba
Coal Slurry	49,171	31,031	0
Bagasse	18,294	0	23,906
Molasses	1,223	0	1,303
Product	0	20,926	37,470
Lime	17	0	0
Clay	26	0	0
Total	68,731	51,957	62,679

7. INFRASTRUCTURE

The infrastructure that pertains to this coal briquettes development project is analyzed in this chapter firstly in broad perspective against the nation's present general state of affairs and secondly in more detail with reference to the findings by the field survey particularly with respect to those that directly concern the transportation route and plant site.

7.1 Present Status of Infrastructure

7.1.1 Transportation and Communications

As a landlocked nation, transportation with outside of Zambia tends to be affected by policies initiated in the neighboring nations. Domestic transportation is also largely limited to trunk lines. The route that connects important areas from Livingstone through Lusaka to the Copper Belt, in particular, serves as the most important trunk line and also as the center of communication. Transportation in Zambia may be by rail, road, or air. A brief discussion is made on rail and road below.

(1) Railroad

The railroads in Zambia are managed by two separate organizations. One is a subsidiary of ZIMCO, called the Zambia Railways Limited (ZR), which has a total length of 1,273 km, of which 848 km is found between the Victoria Falls Bridge in the nation's southern border with Zimbabwe and the Copper Belt in the northern center; the remaining 425 km is composed of branches. The other is the Tanzania-Zabmia Railway Authority (TAZARA), which controls a total length of 1,860 km between the northernmost point of the ZR line and Dar es Salaam Harbor of Tanzania.

Figure 7-1-1 Railroad Map of Southern Africa

Table 7-1-1 Comparison Between ZR and TAZARA

	ZR	TAZARA
Length (km)	1,273	1,860
Gauge (mm)	1,067	1,067
Passenger (thousands)	1,748	975
Freight (1,000 ton)	5,087	900
No. of cars		
Locomotive	84	102
Freight	6,316	2,149
Passenger	105	100

Some of the ZR's infrastructure which was handed over from the former Rhodesia Railways is generally old and obsolete. The chronical shortage of foreign exchange caused by the poor copper markets worldwide makes procurement of spare parts for system maintenance difficult; under such conditions, ZR is faced with an urgent need to improve efficiency of operations of locomotives and various facilities and equipment.

The TAZARA is a relatively new railway system. The construction started in 1970 and the operation started in 1976. It is a joint venture with equity shared equally by Zambia and Tanzania. The ZR and the TAZARA have an agreement whereby freight cars of both systems can run on both lines.

(2) Roads

Zambia has a total road length of 37,000 km, and the roads are under the supervision of the Office of Roads within the Public Works Bureau and the respective state governments. The table below shows the nation's present road conditions.

Table 7-1-2 Type and Length of Roads

	Paved	Gravel	Earth	Total (km)
Principal Trunk Road	2,894	46	172	3,112
Trunk Road	1,991	1,840	216	4,047
Country Road	698	6,806	16,258	23,762
Local Road	-	-	5,714	5,714
Total (km)	5,583	8,692	22,360	36,635

The four roads that run to north, south, east and west from Lusaka form the backbones; the one, in particular, running along the Copper Belt is the most important as in the case of railroads. The trunk roads within such major cities as Lusaka and Kitwe often consist of four or more lanes; in the outskirts, however, most have no more than two lanes. The road density, i.e., road length (km) divided by nation's area (km^2), is 0.05; the figure is near the African average, but only 15% of the roads are paved. The nation recognizes the importance of improving the road infrastructure. Lack of fuel is also a major concern.

(3) Communications

Internal and external communication alike has been greatly facilitated, thanks to the satellite systems. Government-run the Zambian Broadcasting Service is the only broadcasting station and radio broadcast is made in seven local dialects in addition to English. About 200,000 receivers are now in use. Television is broadcast by the Zambian Television Service, and about 90,000 sets are in use. Another TV station is in service solely for educational programs. The nation has about 80,000 telephone circuits and about 16,000 telex circuits. Telephone service is in great demand these days; and connections are not necessarily smooth within the city of Lusaka.

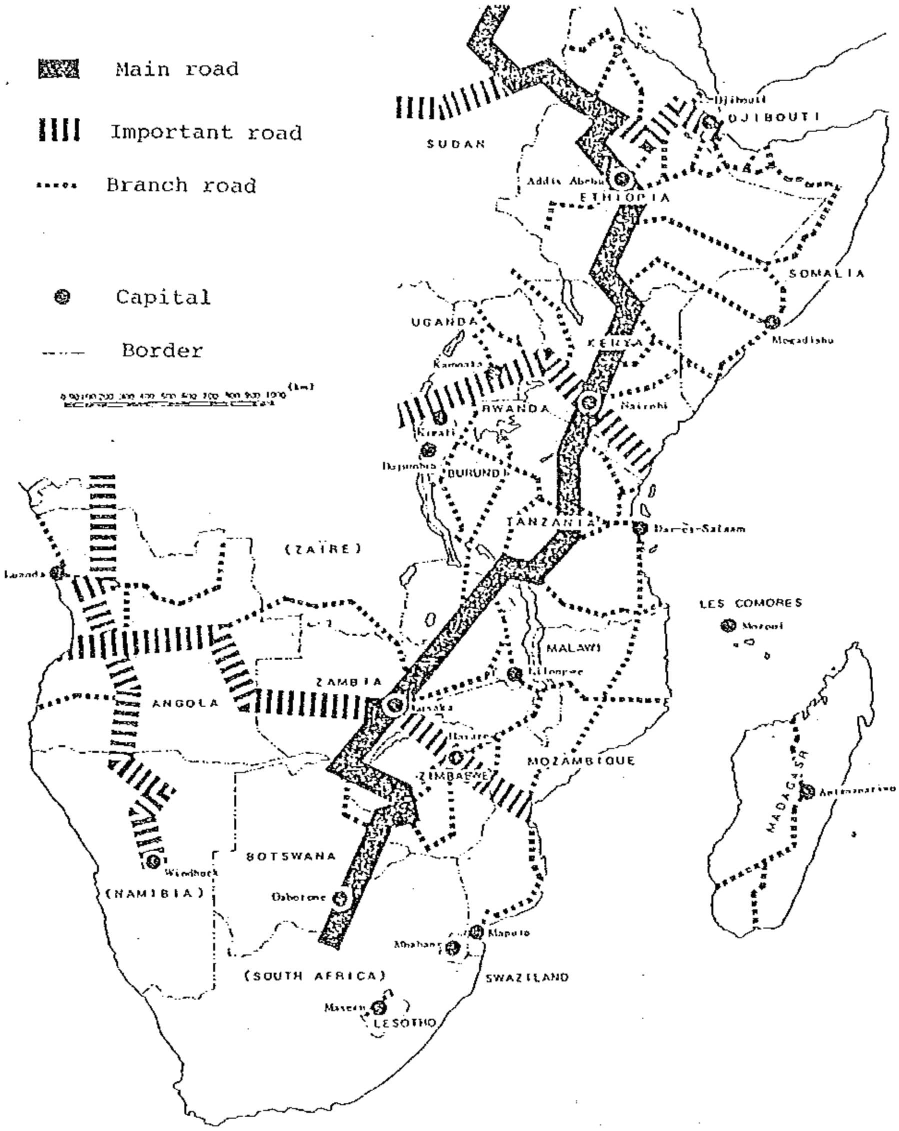


Figure 7-1-2 Trunk Road Networks of South and East Africa

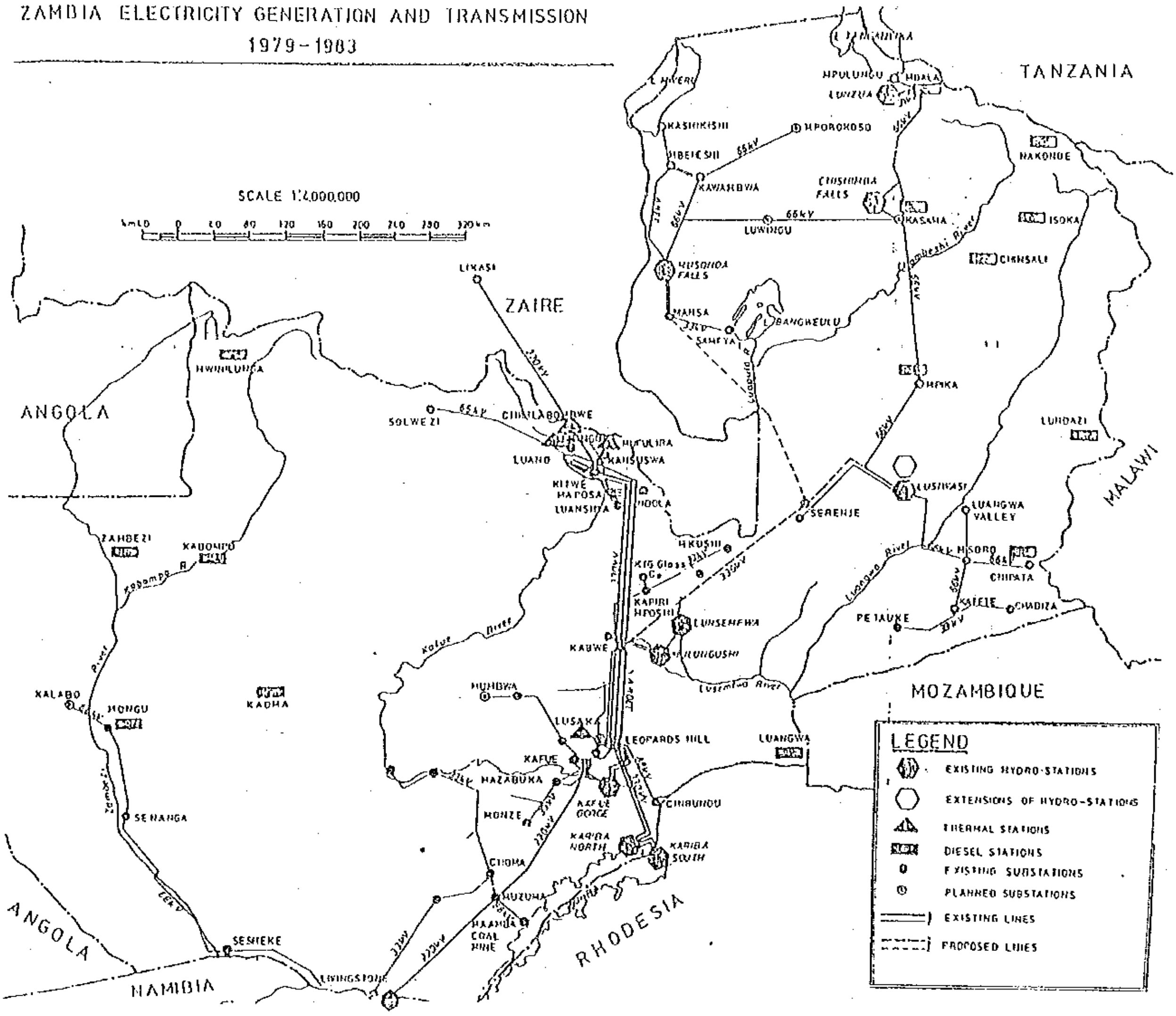


Figure 7-1-3 Generation and Transmission of Electricity in Zambia

7.1.2 Electricity

As for electricity, the nation is in a favorable position. Lake Kariba is the world's largest man-made lake, and water is abundant thanks to the nation's topography which include the Victoria Falls and Kafue River.

The hydroelectric power generation potential is 4,000 mega watt (MW), of which 600 MW is by Kariba North Bank, 900 MW by Kafue Gorge, and 110 MW by the Victoria Falls. The nation generates as much as 10,000 MWh of which about 40% is exported to Zimbabwe and others, Zaire for example.

Distribution systems are consolidated within cities and along trunk roads. Although mid- to upper-class residential areas are electrified, other areas still do without electricity. In the future, a nationwide power network needs to be established so as to help eliminate the wide difference in access to electricity.

7.1.3 Housing

(1) Demography and concentration of population in cities

Zambia has a population of about 5.7 million according to the 1980 census with a density of 7.5 persons/km^2. About 43% of the total population live in cities; the figure is very high. Zambia ranks among the highest of the African countries in concentration of population in large cities. The flow of labor forces from rural to urban areas still continues; the trend is particularly noticeable along the Copper Belt and in Lusaka.

The population grew, during the period between 1969 and 1980, at an average annual rate of 3.1% nationwide but at 6.7% in cities. The table below shows the distribution and density of population.

Table 7-1-3 Distribution and Density of Population (1980)

Province	Area (km^2) (thousands)	(%)	Area (km^2) (thousands)	Population density Persons per km^2
Central	514	9.0	94	5.4
Copper Belt	1,249	22.0	31	39.9
Eastern	656	11.6	69	9.5
Luapula	613	7.3	51	8.2
Lusaka	694	12.2	22	31.7
Northern	678	11.9	148	4.6
North-Western	302	5.3	126	2.4
Southern	686	12.1	85	8.0
Western	488	8.6	126	3.9
Zambia Total	5,680	100.0	753	7.5

(2) Housing in Lusaka

The concentration of population in the city of Lusaka is very serious, and the government puts priority in the provision of housing side by side with consolidation of public transportation systems. This nation does not produce enough lumber for construction purposes and, therefore, has depended greatly on import as in the case of steel products. Although concrete materials and asbestos products are domestically produced, many of the construction materials and products need to be imported. With the exception of some privileged class and foreigners, employers, as a rule, are supposed to provide employees with housing or housing allowances. Houses in urban areas are classified into those which are planned and managed by the City Council and those which are not.

The houses managed by the council are sometimes further divided into high-, middle-, and low-class houses with sites, facilities and equipment and those only with the sites and main utilities provided.

In the case of the latter, people tend to build shanties and dwell without permission in areas without definite plans for the sites. Some of these areas form squatter areas. Middle- and high-class houses account for about 20% of the total and are equipped with electric stoves. The remaining about 80% of the houses use charcoal and firewood as domestic fuel.

7.2 Infrastructure for Material Transportation

The coal slurry exists in Maamba, Bagasse and Molasses in Nakambala; and suitable clays occur in Lusaka and Neganega. Drawing upon these resources, coal briquettes and clay stoves will be produced. For this reason, Maamba, Nakambala, and Lusaka are named as candidates for plant site. The transportation routes that connect these regions run a length of 350 km or more. The transportation on this route may be serviced either by railroad (including ropeway) or by road, or a combination of the two. For the purpose of analysis in this feasibility study the entire transportation route is broken down into 9 sections according to means of transportation, road condition, existence of bridge, availability of alternatives, and possible switchover to different means of transportation. The present state of the infrastructure over these sections is discussed below.

7.2.1 Maamba-Batoka

The section is a trunk road with a length of 66 km and a width of about 12 m, of which the pavement is 7 m wide; the gutters and guardrails are not sufficiently provided, however. The pavement is not thick enough. There are scattered holes which are repaired as necessary. Bridges are built at four points of the section and they are all of concrete. The abutments of these bridges are sturdy designed to the British Standards. The bridges will not present problems. Near the half way point of this section, the road crosses two swamps. At one point, there is a large drain built of piles of stones. Although it is not structurally satisfactory, it may be considered not to present immediate problems.

The other point shows signs of past floods and the pavement is damaged over a span of 100 m. Although vehicles may have to move on the flooded road during the rainy season, they can nevertheless travel on the section.

7.2.2 Maamba-Masuku

There is a branch of the ZR near Maamba from Choma to Masuku Station, which serves as a loading station of coal. A ropeway system is installed between the Maamba Collieries and Masuku Station over a distance of 11.7 km. Along the system, a maintenance road with a length of 28 km and a width of 3.5 m is provided. The road, however, is left unpaved and runs through mountainous areas with steep slopes and sharp curves. It is difficult to use this road for transportation of coal slurry without additional work for improvement. If railroad is to be used for moving coal slurries, the ropeway system must be used. By the ropeway system slurries can be moved from the slurry ponds and loaded to freight cars automatically by means of the conveyors, ropeway and conveyors used consecutively. The system, however, may not last long enough as they should, since, unlike coal, coal slurries contain sulfur which could corrode the buckets.

7.2.3 Masuku-Batoka

The section has a 95 km railroad and an 89 km feeder road. Two trains are operated every day on a regular basis. In addition, there are extra operations of trains from time to time. The infrastructure of the section is without noticeable problems and is free from floods.

The road, on the other hand, is not paved and is 6 m wide with the exception of some mountanous areas where the road is only 3.5 m wide. The road was used in the past for the transportation of coal from Masuku Station and is still passable. The condition of the road is poor and the road may not be considered to be a good route. The freight station in Batoka could allow changes in the means of transportation.

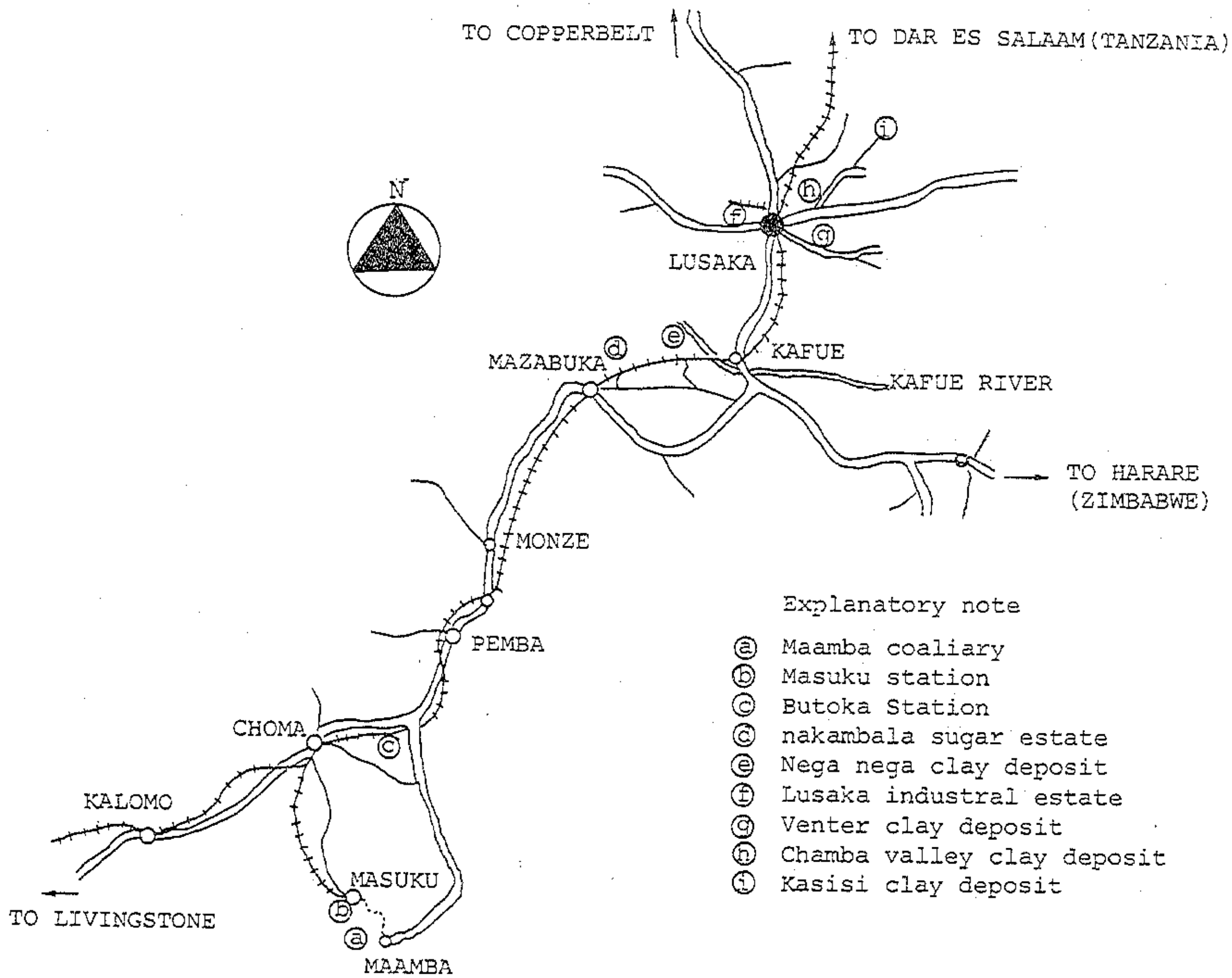


Figure 7-2-1 Material Production Sites and Transportation Routes

7.2.4 Batoka-Mazabuka

Both railroad and road of this section are part of the trunk line of the nation and are also free from floods during the rainy season. The small bridges at three points along the section are free from problems. The roads are paved for a width of 7 m. Bushes grow on both sides; although maintenance is not necessarily adequate, the space along the road is amply provided. The cross section of the general trunk road has three layers of subbase coarse, base coarse, and surface; the trunk road, however, has insufficient gravel in the base coarse and can be damaged easily.

The land along the section is used mainly for farming and grazing and, near Mazabuka, large-scale farms for sugar and corn exist. The freight station in Mazabuka is used mainly for the loading of agricultural products, and warehouses for the crops are also found. The Nakambala Sugar Estate Site is located next to the station.

7.2.5 Mazabuka-Kafue

Throughout the section, the topography generally consists of hills with thickets of various trees. Much of the area's charcoal is produced along this section of the route. The condition of the road is the same as that between Batoka and Mazabuka; but with its hilly topography, this section has more curves and slopes. The small bridges found at three points are free from problems.

7.2.6 Neganega Clay Site-Kafue

The approach to Neganega Clay Site is through a feeder road which branches out from the Mazabuka-Kafue trunk road at a point 12 km from Kafue. The site can be reached following the feeder road for 20 km and another 1 km of a country road. The feeder road is 16 m wide and is not paved and rough sporadically, but not to such an extent to affect the traffic very much. A large abandoned brick factory stands at the entrance to the country road; from that point on, bushes cover the road and travel other than by jeep is not possible.

7.2.7 Kafue-Lusaka

At Kafue, the trunk road branches into two directions, one toward Zimbabwe and the other toward Mazabuka; therefore, the traffic is busy over this section. The road has two lanes with a length of 44 km and a paved width of 7 m. On entering Lusaka the road has four lanes and is kept in good condition.

There is a fertilizer plant in Kafue and, along the roads, Chilanga Cement Plant and other large plants are found here and there. Factories are more common on entering Lusaka area. Utilities main lines for water and power to Lusaka and Copper Belt run along the road in this section.

7.2.8 Kasisi Clay Site-NCSR

The Kasisi Clay Site is reached by taking a left turn at a 4 km point from NCSR to the International Airport and following a 5 km of feeder road and a 3 km of country road. The site is in the outskirts of Lusaka, and bus services are also available. Although the feeder road is not paved, it is kept in good condition under a good management. The country road, on the other hand, does not allow access by vehicles other than jeeps and landrovers; small rivers are found along the way and access has to be made on foot during the rainy season.

7.2.9 Venta and Chamba Valley Clay Sites-NCSR

The Venta Clay Site is located about 2 km from NCSR and the Chamba Valley Clay Site is situated about 6 km from NCSR; both are within the city. Both also own a brick factory nearby and have large clay deposits.

Table 7-2-1 Infrastructure related to Transportation

	Route & Distance (km)	Availability Width (m)	Condition of Surface	Condition of Bridge	Flooded Place	Maintenance	Route & Distance (km)	Available Station	Available Stockyard
1. Maamba-Batoka	66	Yes 7	Paved good	4 (concrete)	1 35 km from Maamba	Soil sand filling	-	-	-
2. Maamba-Masuku	28	Yes 3.5	Not paved Bad	0	2	Cutting & filling	11.7 (ropeway)	Yes	Open air
3. Masuku-Batoka	89	Yes 6	Not baved Not good	3 Not good	2	Soil filling	95	Yes	Open air
4. Batoka-Mazabuka	128	Yes 7	Paved Good	3 Good	0	Soil & sand filling	130	-	Warehouse
5. Mazabuka-Kafue	81	Yes 7	Paved Good	3	0	ditto	48	Yes	Open air
6. Kafue-Lusaka	44	Yes 7	Paved Good	1 (steel truss) Good	0	complete	48	Yes	Open air
7. Neganega Clay Depo.-Kafue	rural 1 connect 20 main 12	No Yes Yes	Bush Not paved Paved	0 1 Not good	1	Soil filling	0	Yes	Open air
8. Kasisi Clay Depo.-NCSR	rural 3 connect 5 main 4	No Yes Yes	Bush Not paved Paved	0	-	No soil filling complete	-	-	-
9. Venter & Chamba Valley clay Depo.	In the city	Yes 7	Paved Good	0	0	complete	-	-	-

7.3 Coal Briquettes Consuming Area (Lusaka)

Paid workers in cities may be regarded as constituting the largest group of potential consumers of coal briquettes. As they mostly cannot afford to own electric stoves for cooking and heating. At present, charcoal is used as household fuel; in the light of this, a study needs to be done to see how coal briquettes may fit in their lifestyles. With this in mind, the existing infrastructure will be discussed in terms of housing and surroundings that are available to them.

7.3.1 Land Utilization and Compound

The city of Lusaka has a population of about 600,000 and is divided into 51 townships (parishes). As to land utilization, the city's commerical district is found in the west along Cairo Road, industrial district in the northwest adjacent thereto, and the administrative district in the center of the city called Cathedral Hill. Other sections of the city are used as residential districts. The city built its infrastructural networks with the two areas above as its centers; as a whole, the network is consolidated with good spatial considerations. The concentration of the population is not very dense. Although the city has a quiet atmosphere with good aesthetics, there are such districts as those in the northwest, Chawama in the southwest, and Kalingalinga in the west where there are concentrations of low-cost houses and shanties with a population density of higher than 70 persons/ha.; these houses tend to stand in units called compounds. Chaisa, Malabodi, Mandegu, and Liranda in the northwest, in particular, are heavily populated with a density of 120 persons/ha.

In general, compounds are planned, designed, and constructed by the City Council. The council also manages them after occupation, collects rents, and supervises them as a whole. As such, an extention office of the City Counsil is usually found within each compound. Some low-cost compounds are rented or sold by the City Council after consolidation of the infrastructure and construction of the houses; in others site and infrastructure are prepared by the City Council but houses are built by the inhabitants. According to the land system of this nation the entire land is owned by the nation and leasable to the users for a term of 99 years.

7.3.2 Infrastructure for Compounds

Compounds are developed by unit, ranging in area form 2 to 10 ha. Compounds are enclosed and, although not necessarily adequate, their infrastructure is provided. However, the quality of the infrastructure leaves much to be desired as explained below.

(1) Roads in the compound:

In most compounds a main road, about 6m wide and unpaved, is laid around the compound. Service roads lead to individual houses mostly in an orderly manner. There are cases where service roads are not orderly laid out. All roads, except the main road, are closed to automobile traffic. The roads do not present inconvenience except for the rainy season when the road conditions are disagreeable.

(2) Power supply:

The city of Lusaka has adequate electricity supply; however, the electrification of individual houses is not sufficient as described in 7.1.3. Particularly, the housing compounds regarded as marketing targets of the present project are not sufficiently electrified even with respect to lighting. The power lines are provided to the main roads, but rarely beyond this to reach individual houses, because wiring to individual houses are installed at the expense of the inhabitants who cannot always afford to bear the cost.

(3) Water supply:

The city receives water from Kafue. The city water is not completely reliable because of not infrequent pump failures and inadequate water purification facilities. Many compounds have wells to supplement city water supply.

Within the compound, there are several community drinking fountains, from there people normally carry home water in bucket. Not all houses are plumbed.

(4) Drainage and waste water:

Rain water is drained by ditches dug along the roads. Other types of foul water is disposed of only locally. Some houses have their own toilets, others share community toilets. In either case, a cesspit is dug below the toilet from which foul water is absorbed in the ground. These toilets are moved after they have been used for a certain period.

7.3.3 Environment within the compound

The houses in the low-cost housing compound provided by the 7 - 21 formal sector of the city are generally of the standards shown in Table 7-3-1. The total area is $275m^2$; the area of the house is $66m^2$.

Table 7-3-1 Standard of Housing Compound

Use	Area (sq.m.)	Percentage
Gardening and storage	165	60
Outdoor living	22	8
Outdoor housework and hobbys	22	8
House (interior)	66	24
Total	275	100

The conditions of the compound formed by squatter settlements are below the above standards; but in both cases, a relatively high ratio of empty space, lot area/building area, is maintained. Many of the empty spaces around the houses are used by the inhabitants to grow vegetables or to build chicken cages. The conditions of the houses, utilities and environments are generally poor. They could barely support inhabitants' everyday life. The question is how to improve the houses and infrastructure in the future. There are already many problems with respect to health and safety.

7.3.4 House structure

Figure 7-3-1 shows a typical example of development of the common houses in Lusaka. Many of the houses in the housing compounds resemble those shown in Figure 7-3-1, the size being dependent on the financial capability of the owner.

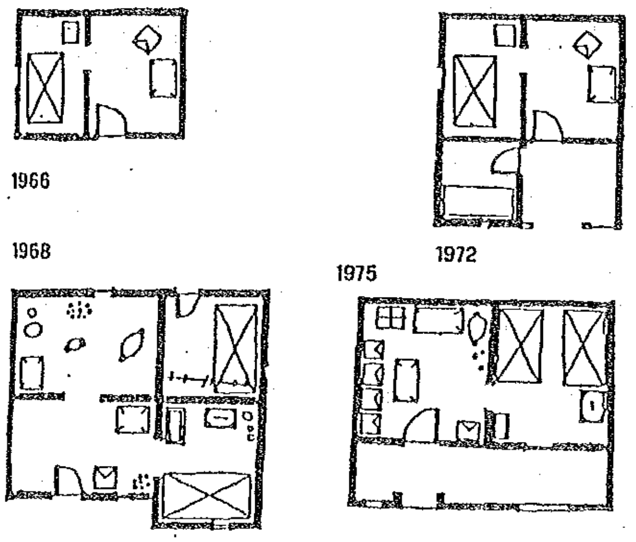
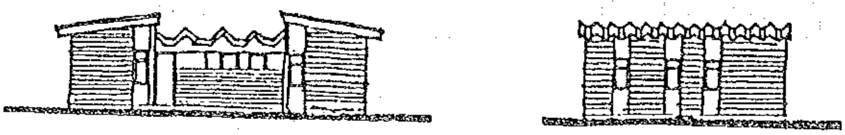
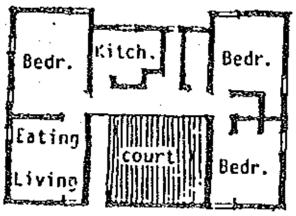


Figure 7-3-1 Development of Low-cost House

Figure 7-3-2 shows a representative plan for a low-cost houses provided by the formal sector of the city; they constitute higher class houses in Lusaka: the houses are built of either concrete blocks. The roofs are mainly of steel plate or slate board. The floor is of raised earth, press-hardened mixed with cement. Windows and doors are made of wood. Steel and aluminum are not used because they are imported and expensive.





Low-Cost-House Type 302

Plinth area = 63,0 sq.m.
Largest house type for junior civil servants

Figure 7-3-2 Typical Plan of Low-cost Formal-sector House

In these houses charcoal is burnt for cooking and heating. Cooking is done in the kitchen or unfloored part of the house, or in thec court as shown in the sketch below. Use of coal briquettes in the houses of such a structure instead of charcoal would not present any problem as far as smoke and smell of coal briquettes do not differ significantly from those of charcoal.

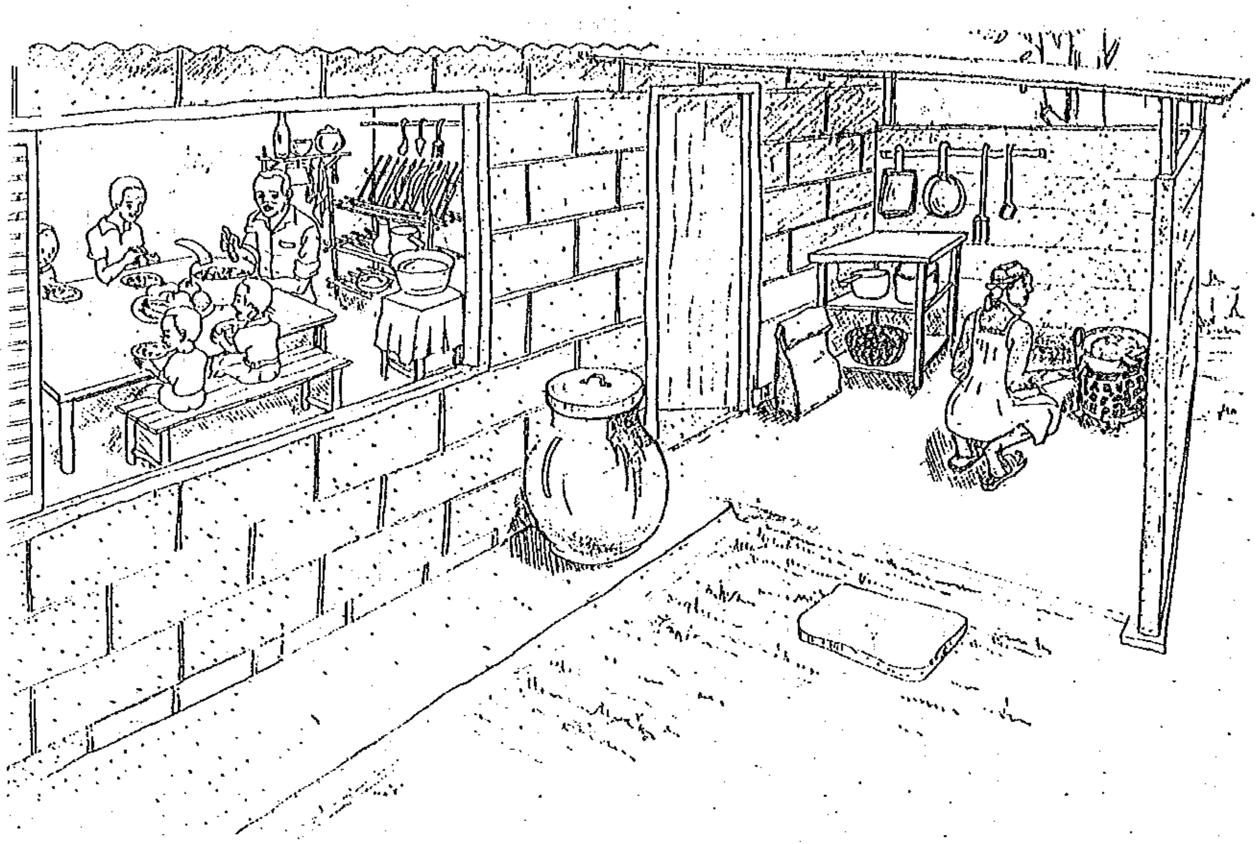


Figure 7-3-3 Cooking Style

9. CLAY STOVE MATERIAL AND PRODUCTION

Production of clay stoves has long been a part of heritage in areas covering Japan, South and East Asia, and India. Clay stoves were generally made by farmers and some of them were made available to city dwellers. People used such stoves for cooking food in their own ways burning such fuels as hay, twigs, corn stalks, and charcoal.

At first the field survey team learned that in Zambia people are not in the habit of using clay stoves and metal stoves are in general use in many households. The same also holds true of Tanzania, Kenya, and all other East African countries. According to Dr. Yamba, Director of the Engineering Department of the University of Zambia, production of clay stoves was once tried in Kenya; however, the stoves failed to be accepted because of their tendency to break on repeated uses. The failure can be attributed to the selection of a wrong clay. The weathered clay of volcanic ashes found all around Mt. Kilimanjaro contains volcanic debris impregnated with moisture. Stoves made of such a clay tend to develop upon baking cracks which grow on repeated uses for cooking and eventually lead to the destruction of the stoves.

In Japan, stoves were generally made of red clay and baked without glazing at 550°C to 600°C until the 1940's. During the late 1940's, red clay was replaced by diatomaceous earth. At present, more than 95% of the stoves are made of diatomaceous earth. Stoves made of this material have good thermal characteristics; on the other hand, however, they have low heat resistance, tendency to develop cracks due to thermal expansions and contractions, and are not very durable.

The information provided by the Mining Department of the University of Zambia and the Geological Investigations Bureau of the Ministry of Mines of Zambia shows no sign of existence of diatomaceous earth. Interviews with professors and researchers of Geology Department supported this view. In order to be practical, the study team decided not to look for diatomaceous earth. Since that time the survey was geared to finding promising red clays and sandy materials. Also studied were availability of suitable natural gypsum, an important material for making molds, its quality and the technology for the production of plaster of Paris and plaster molds for shaping stoves. In addition, the type of fuels to be used, support by NCSR for analysis and test on raw materials and products were looked into.

9.1 Investigation on Materials for Clay Stoves

Investigations were made of the availability of clays suitable for stove production around the following candidate locations for the pilot plant:

1. Maamba Collieries
2. Nakambala Sugar Plant
3. Lusaka

Figure 9-1-1 indicates the areas surveyed.

9.1.1 Clay near Maamba Mine

The area around the coal mine consists of hilly land with gentle slopes with low bushes and grass all over. The surface soil is of red clay with gneiss, serpentine, and fist-size crushed stones. A ropeway system runs for a distance of 11.6 km between the mine and the coal loading point. An unpaved maintenance road runs along the ropeway system. The survey team surveyed across the three hills over the area and has found out that over the entire area the surface soil consists of clay with small and crushed stones. A trench found on the way, 20 m high and 500 m long, exhibited such a formation of soils. By way of conclusion, it was judged that the clay of this area is not suited to stove production. The area near Masuku, the coal loading station and the terminal point of the ropeway system, was also investigated. A report by the Department of Geology of the Ministry of Mines has a record of mining white kaoline. At a point 2.5 km northeast of the station on a hill along the railroad is a past mining pit 50 m by 50 m and 8 m deep. The operation is discontinued. A clay of kaoline was seen in 10 cm thickness between unweathered host rocks. This type of white clay contains little impurity and is generally regarded as of good quality. However, because of its

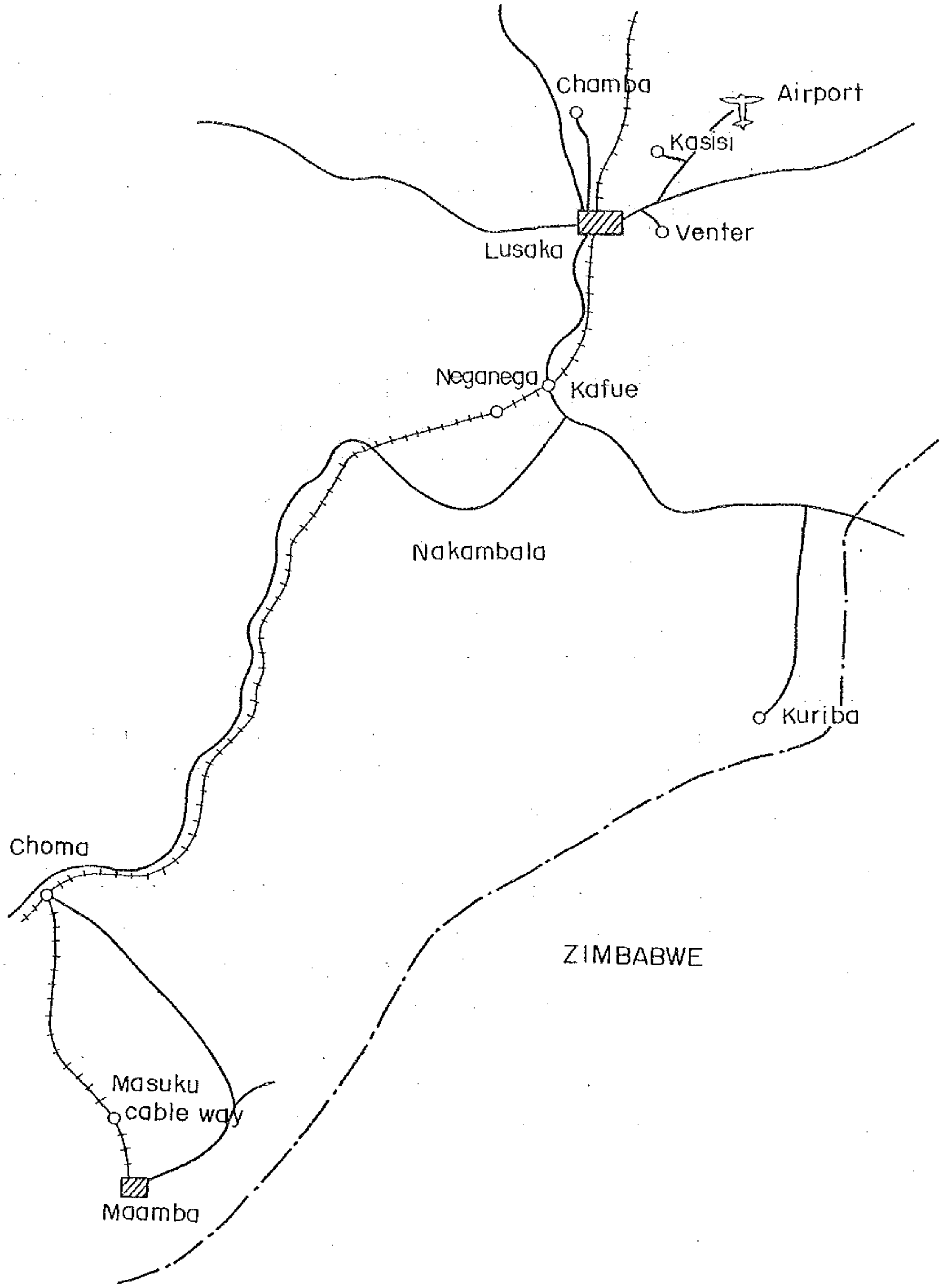


Figure 9-1-1 Location Map

low consistency, only a limited amount is used by the Zambian ceramic industry. This clay is not suited for stove production because of its low consistency and high temperatures required for baking.

The area along the national highway leading to Lusaka was surveyed up to Choma. All the clays were found to contain gravels. No suitable clay was found in Maamba Area.

9.1.2 Clay near Nakambala Sugar Estate

Large-scale sugar plantation covers much of this area. Layers of clay suitable for the production of such clay products as red brick occur; however, mining of clay is not possible because of the land being used for farming. A large brick factory, now out of operation, stands next to Neganega Station located 10 km north of the sugar plantation.

Quality of the clay used by the factory is good for brick production and; therefore, it should be good for stove production. The six years of operation left a pit of clay mining 30 m by 60 m and 10 m deep. Moreover, the Ministry of Mines has information which confirms the existence of this clay to a depth of 20 m.

If this area is selected as the coal briquettes/stove project site, the clay in the area should be good enough for stove production in terms of both quality and volume. A test done in Japan on the finished bricks left inside the factory showed good heat resistance.

To transport this clay to other locations would require addition of a service road and bridge, though only for a distance of 150 m. Besides, acquisition of mining rights may take time.

9.1.3 Clay near Lusaka

There are a number of small to medium brickworks operating on large-scale. Their products are used for the construction of government buildings, schools, modern houses and are one of the most important construction materials in Zambia.

The clays used by these brickworks should be good for stove production and were therefore investigated.

The principal deposits of clay are found in the north and east of the city of Lusaka distributed in eight locations, of which the combined reserves are estimated at 4 million cubic yards, or 10 million tons, according a report by the Ministry of Mines (1967). Three locations, which seemed to allow easy mining and shipping, were chosen for investigation.

Table 9-1-1 Reserve of Clay Near Lusaka

	Estimated Reserves
1. Chamba Vally	5,000 (thousand tons)
2. Venter Village	500
3. Kasisi Village	200

Source: Ministry of Mines

At Chamba and Venter clay is mined on a large scale by motored excavators. Both areas produce about 3 million bricks a year.

Although the baking temperature is low at about 500°C and therefore the strength is not enough, the bricks are accepted by the market without any problem.

Stove production requires a baking temperature of 800°C or higher to give the products sufficient strength and heat resistance. Judged from the quality of the bricks produced in Chamba and Venter, the clays were considered to be very promising for stove production.

Samples collected from these locations were baked at 800°C, 850°C, and 900°C at Industrial Mineral Research of NCSR with satisfactory results at all temperatures. The baked test pieces were repeatedly heated to 200°C and cooled rapidly four times and no change was observed.

At Kasisi a couple of families started cottage industries to manufacture bricks. Sandy clay with the right amount of sand, when mixed to Chamba and Venter clays, could improve heat resistance. By an investigation on a piece of land 50 m by 50 m, the presence of a layer of sandy clay was confirmed to a depth of 1.5 m.

The survey on the three locations all confirmed the presence of sufficient amounts of clay from which stable supplies can be expected. Besides, the tests conducted at Industrial Mineral Research gave good results. There is no anticipated difficulty in mining and delivery of clay to the pilot plant.

In the light of these results, it was concluded at the stage of the field survey to be desirable to use clays from the above three locations if the project site is in Lusaka.

9.2 Investigation on plaster of Paris

Shaping of clay to stoves normally uses plaster of Paris. Plaster of Paris used in Zambia is mostly imported with domestic product used marginally. The domestically produced plaster of Paris tends to be weak, undurable, inferior to the imported goods. One company in Lusaka, however, processes gypsum to produce plaster of Paris by baking; the company is capable of producing 3 tons per day, which is sufficient to meet the domestic demand. The factory is equipped with various crushers and a German kiln necessary for processing gypsum into plaster of Paris.

The domestic plaster of Paris still leaves much to be desired in quality. It is not fast enough to set after mixed with water; the molds are only half as strong as those made of the imported. This is due to the high content of clay impurities in the natural gypsum from which the plaster of Paris is produced. It is, however, possible to improve the quality by removing impurities by water washing, better control of the baking temperature and time, and improvement in the ageing process after baking.

Industrial Mineral Research of NCSR uses home-made plaster of Paris prepared from the domestic gypsum; the plaster of Paris, however, is not noticeably different from the imported in terms of strength and hardness. The Ministry of Mines indicates the presence of good gypsum deposits with low impurity content. The local supplier would become able to produce a plaster of Paris of satisfactory quality suited for use in the production of clay stoves if technical assistances are provided for the selection of gypsum.

9.3 Fuel for Clay Stove Baking

The method of baking clay stoves is determined more or less by the type of fuel used. The temperature needed to bake the stoves, i.e., 800°C, is rather low compared to the baking of general unglazed pottery. Zambia produces coal which is used for the refining of copper, baking of bricks, and other industrial purposes, and also exported to the neighboring countries. Although there is still room for domestic consumption, the transportation and distribution systems are not necessarily adequate to encourage extensive domestic consumption. The existing ceramics factories, private or governmental, use electricity for baking the products.

In the present project the baking temperatures are low and the production is small. It is more advantageous and efficient to employ a relatively maintenance-free electric kiln than an expensive coal-burning kiln. In addition, the electric kiln is simpler to operate, easier to learn how to control operating conditions which would result in better yields by minimizing faulty products.

9.4 Support by NCSR

NCSR is to implement the project. This feasibility study assumes that NCSR will provide a full technical support to the pilot plant even though the plant is situated outside the NCSR premises. In particular, NCSR is expected to conduct raw material analysis and product inspection to maintain the quality of products, and research and development activities aimed at improvement of the product and process. The field survey was successfully conducted thanks greatly to the devoted assistance by the staff of NCSR. Judging from NCSR's present activities, NCSR may be regarded as fully capable of meeting such expectations. NCSR is adequately equipped with various apparatus for experiments. The researchers, no doubt, are highly educated and disciplined and, therefore, should prove to be capable of conducting various researches and experiments in regard to materials analysis, search for better compositions, experimental production, and quality tests.

The NCSR researchers can easily get skilled in various tests and analyses specified by international industrial standards of which the Japanese Industrial Standards is one. Industrial Mineral Research of NCSR is expected to play the role of the nucleus for development research of clay stoves. The researchers of NCSR demonstrated sufficient knowledge and experience capable of meeting the needs for highly professional research and development activities, including refining of raw materials and manufacturing of test products.

Besides, NCSR has a technician with experience in the making of plaster molds and shaping of stoves. He will be able to perfect his skill with a relatively short period of training. NCSR is equipped with facilities for the production of ordinary ceramic ware but not with those for clay stoves; therefore, introduction of some new equipment is necessary for the development of stoves. In order to acquire the general knowledge and experience required for the production of clay stoves, overseas training would be necessary.

9.5 Results of Field Tests

Along with the field survey, the following experiments were carried out using the facilities and equipment of Industrial Mineral Research:

1) Comparison in thermal efficiency between the mbaula and a Japanese clay stove
2) Baking tests on clay samples collected

3) Thermal shock tests on baked clay test piece.

9.5.1 Comparison in thermal efficiency

A Japanese clay stove made of diatomaceous earth and a Zambian steel mbaula are compared for thermal efficiency. Charcoal of an equal amount, 300 g, was burnt in the mbaula and Japanese clay stove and a pot containing 2.5 liter of tap water was placed on the mbaula and the Japanese stove each. The results were:

1. The charcoal lasted 1 hour and 30 minutes with the mbaula and 2 hours and 10 minutes with the Japanese stove.

2. The maximum temperature of the water attained by the mbaula was 66°C and that attained by the Japanese stove was 90°C.

3. The amount of water evaporated by burning 300 g of charcoal was 314 g for the mbaula and 1,197 g for the Japanese stove.

(Note: The experiment was not conducted on a strict reproducible condition.)

As far as the results of the test indicates, the Japanese clay stove has a heat efficiency three times that of the mbaula or higher.

9.5.2 Tests on clay samples

Clay samples were tested for shrinkage on drying and burning, breakage strength, and water absorption. Chamba clay, highest in consistency of all the clays, exhibited the greatest strength and best water absorption, but mixtures of sandy and consistent clays proved to be better in heat resistance and thermal shock.

Table 9-5-1 Test on Clay Near Lusaka

Clay	Total shrinkage	Water Absorption (%)	Modulus of Rupture (Lb/in^2)
Chamba Single	11.3	17.71	211.413
Chamba Mixed	9.8	19.22	155.852
Venter Single	8.9	46.76	85.512

Venter and Kasisi clays were sent to Japan along with Chamba clay which demonstrated the best results, because these clays might be needed to give heat and thermal shock resistance. Not just single clays but their mixtures needed further tests.

9.5.3 Tests on thermal shock

Baked test pieces were heated to 200°C on an electric stove and cooled repeatedly to observe development of cracks. The temperature used was low. The test noticed nothing of a problem.

9.5.4 Tests on setting (Zambian plaster of Paris)

Plaster of Paris prepared by Sanpoo Industries Limited was tested for setting time and hardness. The present product is not good enough for the production of plaster molds for shaping clay to stoves. The table below shows the results of quality tests conducted in Zambia in comparison with quality of the typical Japanese plaster of Paris.

Table 9-5-2 Quality of Sampoo Industries Plaster of Paris

Mixing ratio		Setting time min.		Setting temp. °C		Rupture strength kg/cm2	
Water	Plaster	Zambia	Japan	Zambia	Japan	Zambia	Japan
80	100	20	15	31	36	11.43	24
75	100	12	14	37	36	13.34	26
70	100	8	12	39	34	10.25	28

Repture strength is less than half and setting times are longer compared with the typical Japanese plaster of Paris. For practical purpose, the insufficient quality of Sampoo Industries' product could be a problem. The service life of molds would be short. However, the quality can be improved by an appropriate technical assistance. This feasibility study, therefore, decides to use this local plaster of Paris.

So far the result of the field survey on the raw materials and plaster of Paris are summarized. It was concluded that the clays occurring near the city of Lusaka now used for brick making would be suitable for the production of clay stoves. Samples of candidate clays were sent to Japan to be subjected to analysis and various test, and experimental production of clay stoves and service tests.

9.6 Clay Stove Material and Production

In Japan, clay stoves had been produced by hand since long time ago. In Southeast Asian countries, hand-made clay stoves are sold in city markets side by side with kerosine and electric stoves. In addition, water vases, cooking pots, and planting pots, all made of clay and by hand, are found among modern industrial products.

In contrast, very few clay or porcelain products are used in Zambia. Although the study team did not have time to ascertain, Zambia does not seen to have developed traditional techniques to produce and use clay products. Such being the case, it is better to introduce a mechanized modern technique than transplant a handicraft technique.

The design of clay stoves may be of single frame structure or double frame structure. For the sake of attaining better thermal insulation, longer service life, and good control of secondary air flow to assist combustion, the double frame structure is selected. The outer frame is equipped with a groove to hold the inner frame in position. The inner frame holds such fuel as charcoal and coal briquettes. The inner frame, as a matter of course, should be strong enough to resist rapid heating and cooling and, in addition, provide good termal insulation. The inner frame is replaceable in case of damage. Shown below is vertical section of double-frame clay stove.

The conceptual design of the manufacturing process consists of the five processes below.

1. Treatment of raw clay
2. Shaping
3. Finishing
4. Baking
5. Making of plaster molds

The figure on the next page shows the sequence of these processes.

9.6.1 Treatment of raw clay

Clay delivered to the pilot plant is piled outdoors and exposed to sunlight and rainwater, or weathered, to eliminate soluble salts contained in the clay. This will facilitate the shaping operation and reduce the chances of cracking during drying. As a rule, therefore, use of fresh clay out of pits should be avoided. The raw material clay should be weathered for at least half a year, stockpiled at the plant site. The sufficiently weathered clay is put into a box feeder. As will be explained in Chapter 11, grog, or powdered firebricks, is added to the feed at 20 percent. This is also placed in the box feeder. The supply of different raw materials to the feeder is controlled according to the prescribed composition. From the feeder, the clay is sent to the roll crusher by means of belt conveyors at a rate compatible with the

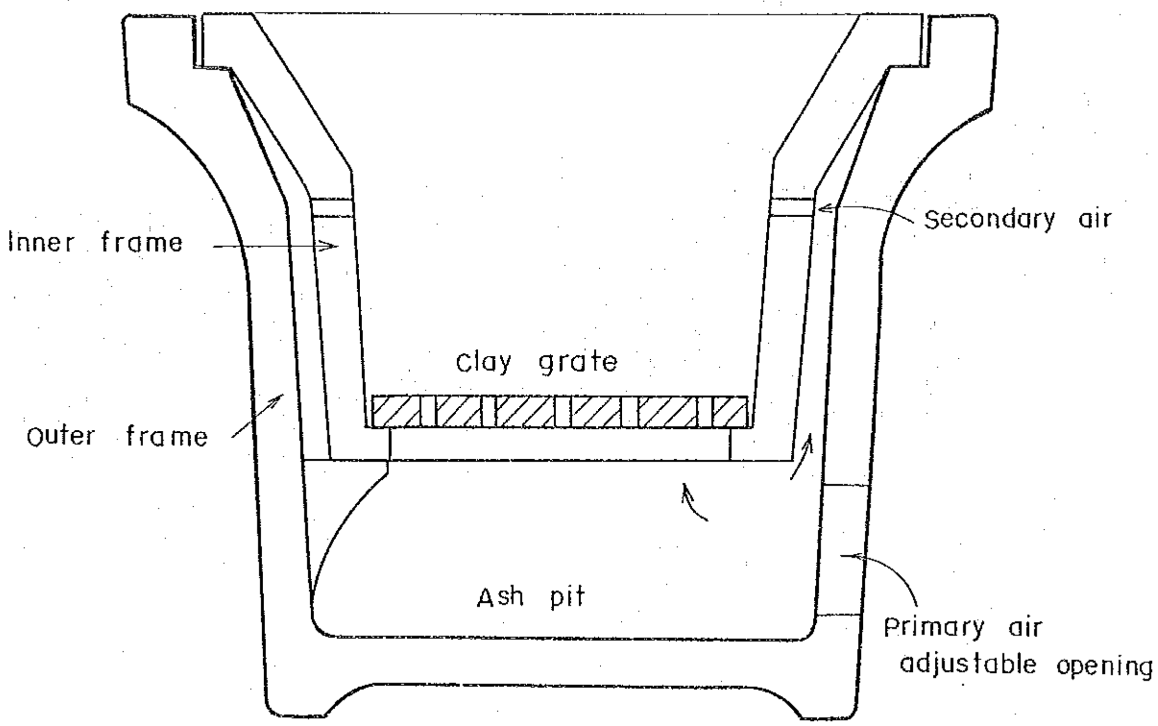


Figure 9-6-1 Double-Frame Clay Stove

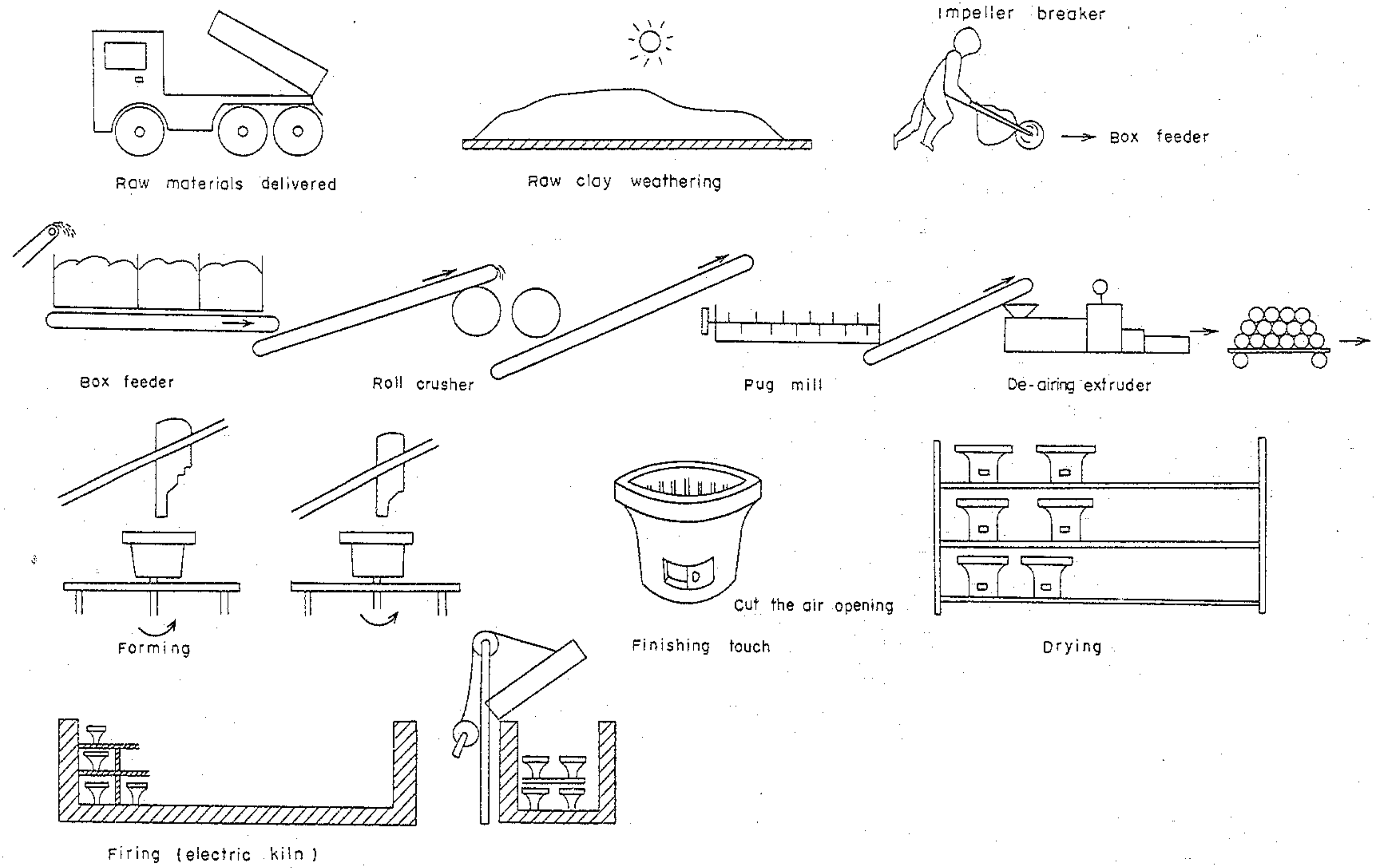


Figure 9 - 6 - 2 Clay Stove Production Flow

production volume. The roll crusher reduces lumps of clay smaller thereby averages the mositure contained in the clay by primary crushing and mixing. This process is repeated as necessary. The clay is then kneaded in the pug mill, which homogenizes the clay and moisture by cutting the clay into pieces by rotating thin blades. The moisture is measured and controlled so that the clay may have right stiffness for the purpose. The operation is controlled using a moisture meter. However, a well-experienced worker can judge the right moisture content by feeling the clay by hand. The clay with the right amount of moisture, kneaded to prescription, is sent to the de-airing extruder. The de-airing extruder has a vacuum chamber in which air bubbles trapped in the clay are eliminated. This prevents tears and deformations after stoves are shaped. The de-airing extruder produces homogeneous well-kneaded clay in the shape of column which is cut into the specified length so that one piece may be sufficient for the shaping of one clay stove.

9.6.2 Shaping of clay stoves

he treated clay is shaped into stoves by means of a motored vertical jigger. A plaster mold prepared in advance is placed on the jigger and a necessary amount of clay is placed in the mold and rotated. The template cut to the shape of the inner cross section of the stove is pushed against the clay. The clay should be rather soft with a moisture content of 32 to 33%. This operation is done both for inner and outer frames. Approximately 120 minutes after shaping, a portion of the moisture in the clay in contact with the mold is absorbed by the plaster mold and the clay becomes somewhat hard. At the same time, the clay shrinks making it easy to remove it from the mold. It is necessary to keep a sufficient number of plaster molds to permit shaping operation as scheduled. In the case of this project, 80 molds will be prepared.

The adjustment of the template position, rotation of the jigger, and control of water spray all call for experience and skill. An average worker can master the skill and become able to operate the jigger by a training of about two months.

9.6.3 Finish work

Both outer and inner frames shaped by the jigger are left indoors for about 24 hours until they become leather hard. The finishing involves cutting of primary air door through the lower side of the outer frame and fixing of the inner frame support. The inner frame is provided with air grooves and secondary air holes. Both are handworks requiring experience and skill which should take one to two months to master. The primary air door also serves to facilitate removal of ashes beside control of the primary air by adjustment of its opening.

These finishing works require gauges and special-shape cutters. Therefore, who does the work does not make much difference as long as he is skilled. Once skilled, one worker can finish 60 or more stoves a day.

9.6.4 Baking of clay stoves

After finishing, the clay stoves are dried at ambient temperatures for six to seven days. When drying is complete, the clay stoves are inspected and defective ones are removed. They are placed in the electric kiln and baked. The specifications of the kiln are:

Kiln effective capacity	1.5 m x 0.7 m x 1.0 m
Power consumption	50 kW
Number of stoves baked at a time ...	30
Baking temperature	800°C
Baking time	8 to 9 hours

Production capacity can easily be increased by the addition of kilns. The temperature is measured by thermocouples and pyrometers. Unattended automatic control is possible with electric kilns.

9.6.5 Making of plaster molds

The plaster molds will be imported during the initial stage of the project. However, the imported molds will be replaced by the locally produced molds as training of the workers proceeds. The work consists of making original models, case molds, and working molds. Preparation of the original models and case molds calls for a certain degree of skill. Capable workers should be chosen from the beginning of the project and trained over some period of time. Making of working molds, though requiring attentive works, needs just two to three months of training.

9.6.6 Training of supervisors for production site

In addition to the well-maintained machinery and good workers, adequate instruction and quality control by the middle management is indispensable to maintenance of quality of the products. As clay stove production involves manual controls of various kinds, the operators' attention directly affects the quality of the products. In order for them to be able to give right instructions, the middle management should experience themselves in all aspects of the operation and grasp them. Therefore, the middle managers should take part in the experimental and development tests before the start of the project so that they may become thoroughly familiar with the processes and important checkpoints.

9.7 Possible Utilization of Extra Capacity

Production of 4,000 clay stoves corresponds to only 20 pieces, or 200 kg, a day. Even the smallest available machines are arranged, the production, if operated efficiently, can be about one ton a day. In other words, the present project utilizes only 20% of the available capacity.

This project will be a pioneer in the field of stove production. The project may well be a driving force in the development of similar industries in Zambia. There are ways open for effectively utilizing this extra capacity to the interest of the nation.

What the clay stove pilot plant could produce, only with the introduction of plaster molds, are cooking pans, water vases, flower pots, etc. The introduction of presses and metal molds, further, will enable production of roof tiles, pavement tiles, unglazed dressing tiles and, with extra extruders, clay pipes.

10. PROJECT SCHEME

10.1 Project Scheme as Definition of Project

It is first of all necessary to define this pilot plant project in order to be able to proceed with conceptual design, financial and economic evaluation and overall evaluation. In other words, this project must be defined by specifying the size of the project or annual production of the products, site, raw materials, qualities of the products, methods of transportation of the raw materials and products, and prices of the products.

At the stage of the preliminary survey mission by JICA, the project was not strictly defined leaving to the subsequent feasibility study a more precise and specific definition of the project which should incorporate the results of the field survey, the intention of NCSR, the results of the home-office works, and other necessary considerations. Therefore the study team established a tentative project scheme during the field survey by temporarily deciding the size of the project, site and target prices of coal briquettes and clay stoves of the project only and agreed with NCSR on condition that these could change subject to the outcomes of the home-office work. The tentative project scheme consists of the followings:

1) Coal briquettes pilot plant

Site:	Namununga industrial site in Lusaka
Annual production:	Nominal 1,000 tons per year with some allowance for extra capacity
Raw material:	Maamba coal slurry, bagasse, molasses, lime
Target price:	200 Kwachas per ton

2) Clay stoves pilot plant

Site:	Namununga industrial site in Lusaka
Annual Production:	Nominal 4,000 pieces per year but mechanical capacity will have a considerable allowance
Raw material:	Clay produced in Lusaka area
Types of stoves:	Three
Target price:	8 Kwachas/piece

The approaches to arrive at the above tentative project scheme and the rationale are given in the progress report prepared and presented to NCSR at the closing stage of the field survey.

It was agreed between NCSR and the study team that the tentative project scheme might be modified as necessary reflecting the outcomes of the home-office work. But, in effect, the study team sees no need to modify the tentative project scheme but added other conditions that have become firm as a result of the home-office work. The finalized project scheme is as follows:

1) Coal briquettes pilot plant

Site:	Namununga industrial site in Lusaka
Annual production:	Nominal 1,000 tons per year with some allowance for extra capacity
Raw material:	Maamba coal slurry, bagasse, malasses, slaked lime
Target price:	200 Kwachas per ton
Quality:	Smokeless and odorless, easy to burn, not inclined to die down after lighting up

Raw materials mix(wt ratio):	carbonized coal slurry	90
	carbonized baggase	10
	molasses	13
	slaked lime	3

Transportation

Raw material:	Own trucks
Product:	Own pick-up

2) Clay stoves pilot plant

Site:	Namununga industrial site in Lusaka
Annual production:	Nominal 4,000 pieces per year but mechanical capacity will have a considerable allowance
Raw material:	Principally Chamba Valley clay
Target price:	8 Kwachas per piece
Quality:	Sturdy, heat resistant and heat insulating
Raw material mix(wt%):	Chamba Valley clay: 80 Grog, 20
Types of stoves:	Three; large, medium and small

Transportation

Raw material:	Own truck
Product:	Own pick-up

The approach to arrive at the above project scheme and rationale are explained below.

10.2 Location of Pilot Plant

Firstly, location should be decided at Maamba or Nakambala where either of the most important raw material is available or at Lusaka, the capital and the greatest market, where NCSR is located. Advantages and disadvantages in economy and administration associated with the the selection of location should be evaluated and NCSR's intention should be respected. Secondly, the best site is selected in the selected location.

10.2.1 Economic factors affecting location

What affect economics are transportation cost, investment cost, and administration cost. To produce one ton of coal briquettes a total of 2.3 tons of raw materials are required, which means that from the viewpoint of transportation economics the plant should preferably be located as close to the raw material producing area as possible. The amounts of raw materials required for the production of 1,000 tons of coal briquettes are found to be as follows as a result of the experimental production:

Coal slurry	1,214 tons
Bagasse	940
Molasses	123
Slaked lime	28
Total	2,305

The transportation costs for 1,000 tons coal briquettes varies with location as follows:

Location	Transportation cost (k)	
Lusaka	69,831	incr. 17,874
Nakambala	51,957	0
Maamba	71,174	19,217

Thus, the transportation economics favors Nakambala with Lusaka and Maamba about even.

Concerning clays for stove manufacture, clays of good quality have been identified in Lusaka; accordingly, Lusaka is the only choice for the location as far as the clay stove portion of the project is concerned.

The investment cost for plant construction increases in the order of Lusaka, Nakambala and Maamba. The investment and associated costs are as given below:

Location	Total Capital Requirement (1,000K)	Capital-related cost (1,000K/Y)	Increment (K/Y)
Lusaka	63,577.9	9,537	0
Nakambala	66,756.8	10,014	477,000
Maamba	69,935.7	10,490	953,000

The incremental costs in capital related cost associated with locating the plant in Maamba and Nakambala far exceed the savings in transportation cost as compared with locating the plant in Lusaka. This feasibility study conducts the financial analysis ultimately by disregarding the investment and investment-related costs. Therefore on the surface the capital investment and investment-related costs do not appear in the cash flow tables; nevertheless, the penalty in capital cost of such a magnitude cannot be disregarded but should be given a due consideration which it deserves. The administration cost, small as it is compared with the transportation cost and capital-related cost, is of course lowest at Lusaka and highest at Maamba, and perhaps between the two at Nakambala as long as the pilot plant is managed by NCSR. In summary the economic consideration favors Lusaka as most advantageous.

10.2.2 Problems with administration

The study team actually took a round trip from Lusaka to Maamba over a distance of 350 km and realized that it takes almost one full day to go one way in either direction. It would be no easy matter for NCSR headquartered in Lusaka to manage the pilot plants if they should be located at far away Maamba. To nominate capable persons and assign them to Maamba may also be a problem for NCSR. This pilot plant project should make further research and development; and it would be quite doubtful that the project can satisfactorily accomplish such an objective if the project is located in Maamba where management of NCSR is not present.

10.2.3 Intention of NCSR

Reflecting the problems with management written above NCSR says that it is virtually impossible to satisfactorily manage the pilot plants if they are located in Maamba. NCSR strongly desires that the plants be located in Lusaka by all means.

10.2.4 Candidate site in Lusaka

As stated above, economic and administrative consideration as well as NCSR's intention favor Lusaka as the site. There are three conceivable candidate sites in Lusaka which are a piece of land in an industrial area to the south of George Town which NCSR has already taken possession of, a portion of NCSR premises, and a portion of Namununga Industrial Area. The first candidate site, as detailed in Chapter 8, proved unsuited on technical ground. The second candidate site, a portion of NCSR premises, besides requiring construction of an approach road, is in such an attractive environment that industrial activities, no matter how small they are, would be out of place. The third candidate site, a portion of Namununga Industrial Area, is very conveniently situated for receiving the raw materials and shipping the products. It is in an industrial area and would not cause any environmental problems. A little bit apart from NCSR but both are within the city, there is no significant inconvenience with respect to communication and transportation between NCSR and the plants. The land immediately available is only 7,000 m2 in area, short of the required area of 12,000 m^2. However, the unused land next to the site presently held by the Zambia Railways Limited could be lent or purchased as needed. In summary, Namununga Industrial Area is the best candidate available and is chosen for the site in this study. The conceptual design is based on this choice.

10.3 Size of the Project

The size of the project, or annual production of coal briquettes and clay stoves, is determined by consideration on a number of factors, of which the size of the market is the most decisive. The coal briquettes are a substitute for charcoal, so are clay stoves for mbaulas. The principal market is Lusaka where some 150,000 tons of charcoal is consumed annually. The experimental production of this feasibility study has confirmed technical feasibility of producing coal briquettes quite competitive in quality with charcoal. However, the total consumption of charcoal in Lusaka, or 150,000 tons per year, should not be interpreted as indicating the potential demand immediately replaceable by coal briquettes. Both coal briquettes and clay stoves are entirely new products unknown to the Zambians. In a society like Zambia where mass media are not fully developed, even in Lusaka where diffusion of information may not be considered to take place fast, a new product can hardly be expected to permeate the market very quickly. The project should be sized at a reasonable capacity so as not to run a marketing risk.

Equally important is a consideration on the nature of this project being a pilot plant project instead of a commercial plant project and NCSR as a research and development organization with its scope of activity defined as such.

10.3.1 Coal briquettes plant, appropriate capacity as pilot plant

For a pilot plant of this nature intended for research and development, throughput may be considered to be a maximum of 1.0 ton per hour. Let it be assumed that the throughput is 0.5 or 1.0 ton per hour, effective operating hour of the plant is 6 hours out of 8 hours of working hour, operation day is 10 days or 20 days per month, or in other words, 720 hours or 1,440 hours per year. On such a set of assumptions the following matrix may be developed.

Plant Capacity (ton/hour)	Annual Production (ton) 720 hours per year	1,440 hours per year
0.5	360	720
1.0	720	1,440

As a pilot plant, an annual production of 1,000 tons would be appropriate.

10.3.2 Marketing consideration

Here a discussion is presented on the possibility of marketing 1,000 tons of coal briquettes a year. This guestion concerns marketing effort on the part of NCSR but on conditions that NCSR does not have to make a desperate effort. The price of coal briquettes at the plant is set at 200 k/ton (February/March 1986 price), a value fully competitive with the wholesale price of charcoal at Lusaka.

The size of the market, distribution channel and price of charcoal in Lusaka are discussed in Chapter 4, MARKET AND SUPPLY DEMAND. What is called open market is the most essential in charcoal distribution at retail ends in Lusaka. A group of charcoal dealers, free merchants, play the most important role in charcoal distribution. They purchase charcoals from producers of their sellers, bring them to the market, store them, sell them to retailors. Some of them keep selling quarters in the open markets and retail them. These merchants are basically free and behave in accordance with market mechanism; in other words, they seek to buy cheap and sell high. However, the prices they buy or retail do not vary very much from one place to another as far as the field survey team was able to see.

There are 35 open markets in Lusaka of which 28 of them sell charcoal. Shops are grouped by commodify, so are charcoal shops. There are 167 charcoal shops in 28 open markets. One shop sells about one ton of charcoal a day on average.

A practical strategy to sell coal briquettes in the open markets is to make arrangements with fuel dealers to let at least one tenth of these charcoal shops in these open markets sell coal briquettes. Thus, at least 16 retail shops will be selling coal briquettes to consumers. This constitutes the most important marketing channel.

As stated in Chapter 4, MARKET AND DEMAND SUPPLY, there are roadside cooked food sellers in the open markets. Charcoal is also retailed in the townships and compounds in addition to the open markets. These will also be the targets for coal briquettes marketing. An official distribution channel, through NIEC stores, will be used although less intimate with general consumers. Coupled with promotion activities as mentioned in Chapter 4 effectively performed, these marketing channels may be considered to be very effective for selling 1,000 tons per year, or 2.7 tons per day on an average, of coal briquettes in Lusaka where the present demand for charcoal is some 150,000 tons, although an incubation period of one to two years would be necessary before all these combined efforts really show effect.

10.3.3 Size of clay stove pilot plant

The project scheme sets the annual production of clay stoves at 4,000 pieces inclusive of large, medium and small types. Being a pilot plant instead of full-fledged commercial plant, the size should be suited for research and development purpose. The pilot plant will consists of a series of equipment arranged according to the operation sequence. Supposing that the smallest pieces of equipment available in Japan are arranged the capacity of the plant will comfortably be several times the contemplated size of 4,000 pieces a year. The operation planned for this project is not to run simultaneously all the equipment continuously feeding raw materials. Instead, a crew of very limited number of operators, 2 persons, accomplish unit operations one after another, each work unit timetabled. An operation analysis by the study team indicates that, even by this step-by-step operation instead of continuous operation, production of 4,000 pieces per year is easy. Since the plant consists of the smallest pieces of equipment available, it does not make sense to make facilities even smaller.

The amount of clay plus grog required is about 60 tons, although this number may vary to some extent depending upon the ratio of production of large, medium and small sizes. Excavation, procurement, receiving and stockpiling of such a small amount of raw material clay do no pose any problem. Neither storage and shipment of product nor supply of electricity and water presents any difficulty. With this amount of production NCSR still has a plenty of time left for the pilot plant to be operated for research and development purposes to seek alternative raw materials, shapes and production method.

In short, the plant and operation easily accommodates production of 4,000 or even more clay stoves. However, production of more clay stoves would not necessarily be suited to the nature of NCSR. When the demand grows big enough in the future, technology should be transferred to private producers to promote production in large scale by private industralists.

Nextly, the production of 4,000 clay stoves is analyzed from the market standpoint. One outstanding feature of the clay stoves is that the clay stoves are just as good for charcoal burning as coal briquettes burning. One experiment conducted by the study team during the field survey indicated that a Japan-made clay stove was about three times as thermally efficient as a mbaula for burning charcoal. The outer skin of clay stoves do no become hot and thus safer. Therefore, there will be generated a demand for clay stoves for burning charcoal. One drawback that can be conceived of clay stoves is that being a porcelain clay stoves may break by being subjected to unduly shocks or forces resulting in shorter life than mbaula. Even if it is admitted that clay stoves do not last as long as mbaulas, money saved in fuel consumption by improvement of thermal efficiency will more than offset the cost of clay stoves.

In Japan about two clay stoves are consumed for every one ton of coal briquettes, the following Zambian conditions should be taken into consideration in forecasting the demand of clay stoves.

1) The commonest cooking heater in Japan is a gas stove. In addition to gas stoves a variety of heaters using electricy are actually in use. Therefore, a household using coal briquettes would not need more than one clay stove. While in Lusaka charcoal is the main fuel for the middle and low income brackets. One stove in one household does not necessarily suffice. The possibility of one household purchasing two clay stoves is considered.

2) The ex-factory price of clay stoves is set at a level which will enable the clay stoves to compete with mbaulas at the retail end. There is possibility of clay stoves selling in preference to mbaulas for burning charcoal. Estimated 87,000 pieces of clay stoves sell in Lusaka every year.

3) Coal briquettes do not burn well in mbaula but should be burnt in clay stoves. Spread of clay stoves among general consumers would pave the way for acceptance of coal briquettes by the consumers. Therefore, promotion activity of clay stoves is all the more important.

It is therefore forecast that after an incubation period of one to two years, sale of 4,000 clay stoves is feasible from marketing standpoint.

10.3.4 Project size versus investment cost

The pilot plant of coal briquettes as well as of clay stove consists almost entirely of the smallest pieces of equipment available. It does not do any good to try to reduce capacity in order to reduce the investment cost. In other words, reducing the capacity does not reduce investment cost.

10.4 Raw Material Composition

The raw material compositions adopted are based upon the results of the experimental production. Crushed firebricks will be blended in a small amount in the clay. Used firebricks will be produced as replacement of refractory takes place at cement factories, oil refinery or a fertilizer plant. Since the requirement of firebricks is so small procurement of used brick would be possible. All other raw material are sufficiently available.

10.5 Target Price

The target price of coal briquettes and clay stoves, 200 k/ton and 8 k/piece respectively, are for 1986 February/March price when the field survey was conducted. These target prices have been established so as to make them competitive with charcoal and mbaulas. In other words, the price should be attractive enough to induce free merchants to come to NCSR to purchase in wholesale coal briquettes or clay stoves to sell them at profit. During the period of the field survey, charcoal was priced at 309 k/ton and 370/380 k/ton at wholesale Lusaka and at an open market in Lusaka, respectively. The price of mbaula varies with size form 5 to 30 k/piece. The prevailing price of mbaulas, about 20 cm across, most commonly used was 12 to 15 K. It is quite possible for those free merchants to buy in wholesale from NCSR at target price, 200 k/ton for coal briquettes and 8 k/piece for clay stoves, to sell them with good profit at open markets.

10.6 Product Quality

Coal briquettes are a substitute for charcoal. For the sake of safety and handiness, the quality of coal briquettes is designed to be smokeless and odorless on combustion. Coal briquettes should be easy to set fire and should not die down once they light up. The sizes of clay stoves are decided to meet the sizes of mbaulas in use. The quality is, however, designed to be best to the extent economically allowed without reference to mbaulas.

10.7 Transportation

As discussed in Chapter 6, TRANSPORTATION, the cost of transportation per ton of coal briquettes is found to be as follows:

		With Depreciation (K)	Without Depreciation (K)
(1)	Mainly by rail	119	
(2)	By road on contract	297	
(3)	By road by own fleet of vehicles	109	70

The production expense such as manpower and utility excluding transportation amounts to 113 k. To achieve the target price of 200 k/ton the third method of transportation is the only viable method and therefore is adopted.

11. EXPERIMENTAL PRODUCTION

11.1 Experimental Production of Coal Briquettes

11.1.1 Objectives of experimental production

The ultimate objective of the experimental production of coal briquettes is to establish technical and ecnonomic possibility on an experimental basis of producing coal briquettes meeting the required quality from the local raw materials; namely, the Maamba coal slurry, the bagasse and molasses of Nakambala Sugar Estate, and local slaked lime which were collected and sent to Japan during the field survey.

More specifically, the objectives of the experimental production of coal briquettes are to achieve the followings:

1) To confirm whether the Maamba coal slurry can be used without carbonization or the Maamba coal slurry produces upon combustion so much smoke and odor that it needs carbonization before it can be briquetted

2) To establish optimum carbonization method and operating conditions if carbonization is proven to be indispensable

3) To decide whether the bagasse can be blended into the briquettes or it has to be carbonized before it can be blended into the coal briquettes; and to decide whether blend of the carbonized bagasse is needed to improve the burning quality of the coal briquettes; and to search for the optimum carbonization method and operating conditions.

4) To test the molasses as binder and find solutions if there is any problem

5) To test the local slaked lime as fixer of sulfur

6) To establish the briquetting method after all those above are solved, and confirm the briquettes are rigid enough

7) To study problems associated with drying and find solutions to problems, if any

8) To conduct burning and other performance tests of the experimentally produced briquettes and find solutions at root, in other words in the above respective operations, to the problem with the briquettes, if any; and ultimately to establish a manufacturing process of coal briquettes and quality which satisfy, or compromises, the required qualities and economics of production; and to make the results of the experimental production reflected in the conceptual design of the pilot plant

11.1.2 Performance and results of experimental production

In conclusion, the objectives of the experimental production have been successfully achieved by using part of the operating commercial plant and experimental equipment. The numbers of the following descriptions on the results correspond those of the objectives.

1) The Maamba coal slurry is found to so liberally produce smoke and disagreeable odor that it cannot be used without prior carbonization.

2) By a series of carbonization experiments and subsequent burning tests of the coal briquettes produced from carbonized coal slurry, an optimum carbonization method and operating conditions are established which eliminate smoke and odor on one hand but still retain acceptable burning quality of the carbonized coal slurry on the other.

3) Bagasse is found to be too smoking and to contain too long fibers to practically allow mixing of bagasse into the coal briquettes. It is found desirable that the carbonized bagasse is blended with the carbonized coal slurry in ratios of 10/90 to 15/85 to improve the

burning quality of the finished coal briquettes. The optimum method and conditions for carbonization of bagasse is established.

4) Molasses is found to be usable as binder. In addition, a method has been established to prevent generation of smoke that could otherwise be generated by combustion of sugar remaining in the briquettes.

5) The local slaked lime can be used as a sulfur fixer and shape stabilizer.

6) The Zambian raw materials can be briquetted by the press coal briquetting process and the strength of the briquettes is satisfactory.

7) The normal process of drying wet briquettes after molding by hot air above 110°C is found applicable to this project.

8) By following the above procedures a production process which could satisfy the desired quality has been established.

11.1.3 Caking property of Maamba coal slurry

A sample of dried Maamba coal slurry was placed in a red-heated crucible and carbonized. The carbonized product was closely investigated.

1) The slurry did not melt, but sintering of coal was recognized. This means that the weathered Maamba coal slurry is non-caking. The button produced by sintering can be crushed by pressing between finger tips. It expanded slightly during sintering.

2) The slurry do not sinter depending on heating conditions partially retaining the state of powder.

3) Therefore, the Maamba coal slurry is a non-caking coal and cannot be briquetted without an appropriate binder.

11.1.4 Carbonization of coal slurry

(1) Generation of smoke and odor of uncarbonized coal slurry

The coal slurry was briquetted without carbonization and the product briquettes were burnt. They produced a volume of smoke and disagreeable odor showing evidently that carbonization process to eliminate smoke and odor is indispensable.

(2) Fluidized carbonization

Carbonization tests were performed by a continuous fluidizing carbonization device having a reactor whose I.D. is 100mm to obtain char to be used for manufacturing coal briquettes to be subjected to test burning and simultaneously obtain data that could be used for conceptual design of the pilot plant.

Figure 11-1-1 shows the structure of the carbonization reactor used for the experiment.

The dried coal slurry is fed to the top of the reactor through the rotary feeder, and is carbonized while staying in the fluidized bed maintained at high temperatures. The smokeless char produced is discharged to the receiver through the overflow pipe. The heat required for carbonization is supplied by partial combustion of the coal slurry with air. The reactor is heated electrically to prevent heat loss. The gas produced as a result of carbonization is burned in the reactor after separation of particulate matters through the cyclone. Table 11-1-1 shows the results of the experiment.

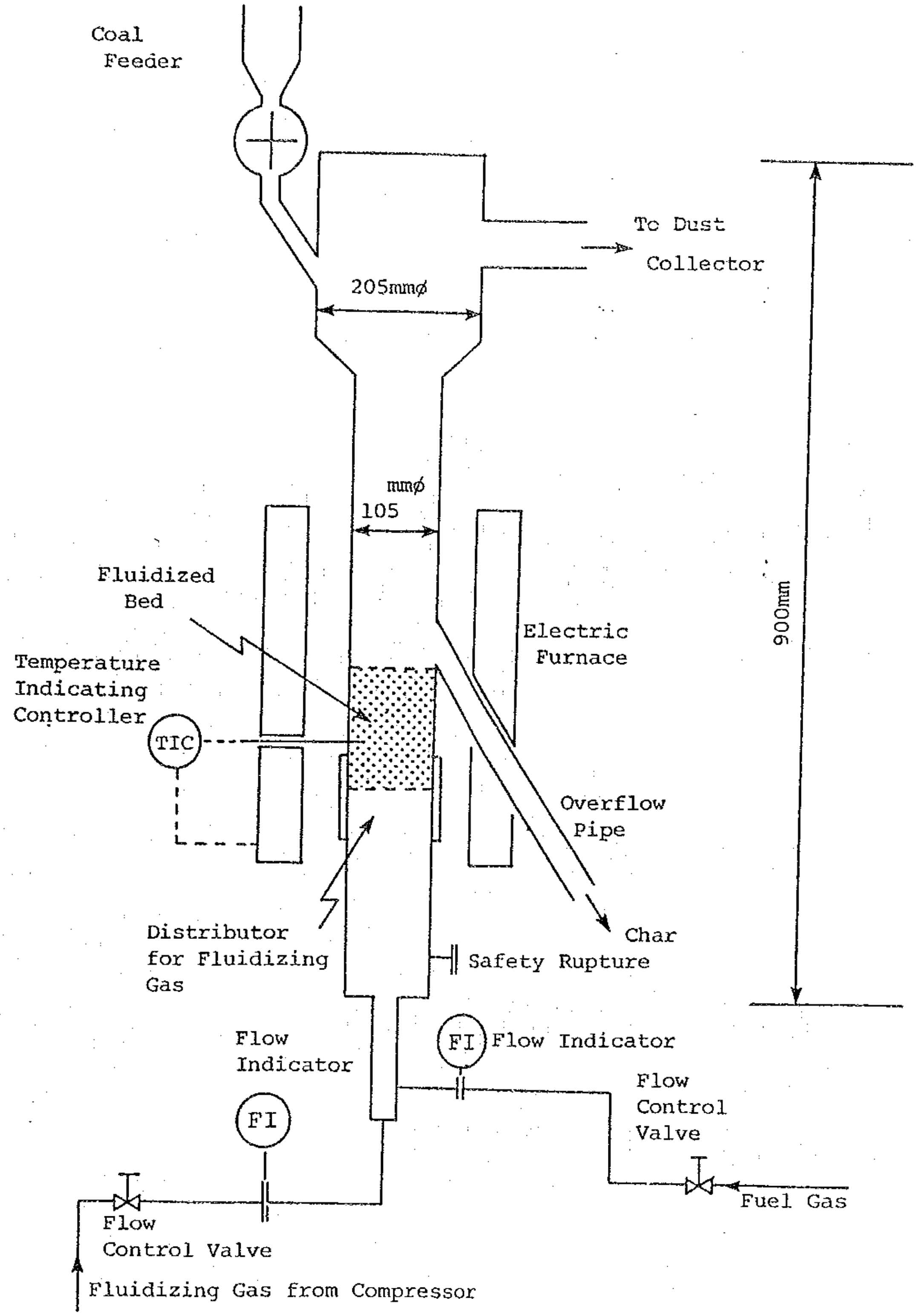


Figure 11-1-1 Structure of Carbonization Reactor

Table 11-1-1 Operating Condition and Results of Slurry Carbonization

	Coal Feed Rate Kg/H	Fluidi-izing Gas Rate M3/H	Carboni-zation Tempe-rature oC	Carbon-izaton Time Min	Char Yield %	Proximate Analysis Mois-ture %	Ash %	Volatile Matter %	Fixed Carbon %	Heat-ing Value Kcal/Kg	Note
1	4.0	3.0	450	16	80	-	-	-	-		Smoking
2	3.8	2.2	510	15	64	-	-	-	-		Not smoking
3	5.5	2.7	520	10	79	3.57	24.52	13.03	58.68	5464	"
4	6.0	2.2	530	7	79	3.57	24.52	13.03	58.68	5464	"
5	6.2	2.5	570	8	79	3.57	24.52	13.03	58.68	5464	"
6	7.5	2.7	570	7	70	3.70	25.52	12.77	58.01	5300	"
7	6.2	2.5	500	10	65	3.25	24.15	14.32	58.28	-	"
8	9.7	3.0	510	8	71	3.25	24.15	14.32	58.28	-	"
9	10.0	3.1	500	7	76	3.10	23.28	15.05	58.57	-	"
10	7.8	3.1	500	5	82	3.07	20.60	15.48	60.85	5739	"
11	8.3	3.4	500	6	85	2.65	19.93	15.85	61.57	5832	"
12	9.0	2.9	490	4	83	3.20	23.42	15.58	57.79	5568	"
13	9.0	3.0	490	5	81	3.20	23.42	15.58	57.79	5568	"
14	9.0	2.9	500	5	84						
15	8.2	3.1	520	6	82	3.56	23.63	14.12	58.69	5572	"
16	8.2	3.1	520	6	85	3.21	24.55	14.36	57.88	5529	"
17	9.5	3.3	480	4	87	2.86	22.82	16.05	58.27	5738	"
18	9.4	3.3	480	4	86	2.94	23.15	15.92	57.99	5702	"
19	8.1	3.2	480	5	83	3.04	23.41	15.77	57.78	5724	"
20	8.0	3.2	480	5	87	3.12	22.88	15.95	58.05	5787	"
21	9.2	3.4	490	4	87	2.78	23.24	16.24	57.74	5812	"
22	9.0	3.4	490	4	86	2.84	22.15	16.00	59.01	5903	"
23	8.0	3.3	480	4	85	2.99	20.72	16.49	59.80	5936	"
24	7.9	3.3	480	4	84	3.15	20.34	16.14	60.37	5954	"
25	8.0	3.3	510	5	80	3.24	21.56	15.19	60.01	5820	"
26	8.1	3.3	510	5	82	3.03	22.15	15.14	59.68	5791	"
27	8.5	3.3	510	4	85	3.07	22.33	15.25	59.35	5883	"
28	8.8	3.3	510	4	85	2.89	22.47	15.43	59.21	5878	"
29	8.7	3.3	510	5	82	2.80	23.15	15.87	58.18	5829	"
30	8.7	3.3	510	4	87	2.80	23.15	15.87	58.18	5829	"

The experiment was conducted over temperature range of 450 to 600°C. It has been confirmed by experiment that continuous fluidized carbonization is possible.

The result of the experiment may be summarized as follows:

1) Carbonization was performed under the feed rate of dried coal slurry of 3 to 10 kg/hr.

2) The gas generated from carbonization of the coal slurry has such an irritating odor that if the gas leaks in the room one can hardly stay in the room to continue experiment.

3) The yield of carbonization is 75 to 90% depending on carbonization conditions and recovery rate of very fine particles.

4) Smokeless char was obtained under the carbonization conditions shown in the table. The optimum conditions are found to be around 500°C and 10 minutes contact time.

5) The coal slurry became grey or light-brown ash at around 600°C after being red heated.

6) In conclusion, a carbonized coal fine that can be used for manufacture of coal briquettes was obtained. At the same time the data necessary for conceptual design of the pilot plant was obtained.

11.1.4 Drying, storage and carbonization of bagasse

(1) Drying of Bagasse

The bagasse contains about 50% moisture as produced by the mill. The bagasse could contains even more moisture by absorbing rain water while piled outdoors. In actual process, the bagasse has to be dried either statically, by forced ventilation or even by exposure to direct sun light. Drying experiments simulated to these three methods of drying were conducted.

For the static drying experiment a rectangular vessel 60mm (longitudinal side) x 65mm (lateral side) x 15mm (depth), or 58.5cm^3, was used. The vessel is open upwards and the sides and bottom were covered with aluminium foil. A sample of 58.5cm^3 weighing 14.1g, or bulk specific gravity of 0.24 was placed in the vessel which was placed in a naturally ventilated or through-flow room at temperatures varying from 15 to 20°C and the weight of the sample was measured over a period of 160 hours. The sample used contained a relatively high moisture content assuming bagasse to be collected after a rainfall.

The test results are shown in Table 11-1-2. At 28.5% the fibers do not hold together even when pressed; at 11.6% the bagasse looks as dry as it can be.

Table 11-1-2 Static Drying of Bagasse

Time, Hr	0	0.5	10	35	83	95	160
Sample Weight, g	14.1	13.9	12.1	9.5	6.9	4.9	3.9
Moisture content, %	75.1	74.8	71.1	63.1	49.2	28.5	11.6

As can be seen from the table, the static rate of drying is terribly slow.

Drying by forced ventilation was tested next. The results are as shown in Table 11-1-3.

Table 11-1-3 Drying of bagasse by forced ventilation

Time hr	0	0.5	1	2	4	10	13
Sample weight, gr	2.50	2.10	1.85	1.55	1.25	0.65	0.5
Moisuture content, %	82	79	76	71	64	31	10.0

Note: temperature, °C 28
air speed, m/sec 1
bagasse layer thickness, mm 15

Compared with natural static drying forced ventilation could reduce the time to one tenth.

To experiment solar drying on a small sample could lead to errors; therefore, two drumfulls of bagasse sample was used.

Table 11-1-4 Solar drying of bagasse

Sample (Drum)	Weight (kg)	Test area (m^2)	Drying time (Hr)	Dry weight (kg)
No.30	68	8.1	8	28
No.26	44	6.3	8	15.5

For the latter sample, Drum No. 26, the rate of drying is 0.56 kg/m^2.hr or 340 kcal/m^2.hr, a rather high rate even considering the effect of wind blowing at 0.5 to 2 m/sec during the experiment. If one more day is spent for nearly perfecting the air drying, the value will be reduced to approximately 200 kcal/m^2.hr.

Assuming that the heat of combustion of the dry bagasse is 3,500 kcal/kg, the heat required for hot air drying will be 1,500 to 2,000 kcal/kg if the bagasse contains 50% moisture, and 3,000 to 4,000 kcal/kg if the moisture content is 66%.

The conceptual design of the pilot plant assumes feeding a dry bagasse having a moisture content between 10% and 20% to the plant. For this purpose, an outdoor space is set aside for solar drying. Besides, drying racks totally made of steel to spread wet basasse on under fan ventilation will be installed indoors. And also a hot air dryer to further dry the air-dried bagasse by forced hot air will be provided.

(2) Carbonization of bagasse

The carbonization of the bagasse used the same equipment used for coal slurry carbonization as well as other equipment fabricated as necessary. The only differences when the equipment for coal carbonization is used are bigger feeder and discharge outlets to accommodate the bulky bagasse.

Table 11-1-5 shows the results of the test carbonization of bagasse to obtain smokeless bagasse char to be used for experiemental briquettes manufacturing.

11.1.5 Briquetting and drying of briquettes

The char, or carbonized coal slurry, carbonized bagasse, molasses and slaked lime are mixed with addition of an amount of water and briquetted by application of pressure. The mixing ratio employed was: 25 to 100% char, 0 to 25% carbonized bagasse, 10 to 15% molasses, and 0 - 3% slaked lime. Over these mixing ratios coal briquettes were successfully produced; in other words, these components were blended, shaped into briquettes, and dried into usable briquettes. Drying temperatures of 110°C or higher were necessary.

A piston-type and a rotating molding machines were used for molding briquettes. A hot air circulating dryer was used forthe drying test. No critical problem was encountered in both molding and drying tests. The bagasse char requires a particular caution in handling because of its bulky nature. The briquetting machine is preferably of rotary type.

Table 11-1-5 Test Carbonization Results of Bagasse

	Bagasse Feed Rate Kg/H	Gas Rate m3/h	Carbo-nization Tempe-rature oC	Carboni-zation Time* h	Char Yield %	Proximate Analysis Moisture %	Ash %	Volatile Matter %	Fixed Carbon %	Heating Value KCal/Kg
1	0.96(10L/H)	0.2	550	48	20	4.84	19.81	17.02	58.33	6010
2	0.53(6L/H)	0.1	550	24	22	5.61	16.32	18.48	59.59	6130
3	1.0 (12L/H)	0.2	530	24	21	4.62	18.56	19.21	57.61	6050
4	1.0 (12L/H)	0.2	500	20	22	4.70	17.36	20.10	57.84	5980
5	1.8 (1L/H)	0.4	500	6	20	4.69	23.64	18.02	53.65	5339
6	1.8 (1L/H)	0.4	500	6	23	5.30	21.48	18.57	54.65	5477
7	1.8 (1L/H)	0.4	500	6	19	5.02	17.87	19.45	57.66	5791
8	1.8 (1L/H)	0.4	500	6	20	5.74	20.73	18.86	54.67	5522
9	1.8 (1L/H)	0.4	500	6	17	5.26	19.19	18.67	56.88	5726
10	1.8 (1L/H)	0.4	500	6	22	4.92	17.38	20.73	56.97	5867
11	1.8 (1L/H)	0.4	520	4	21	5.19	18.35	17.74	58.72	6055
12	1.8 (1L/H)	0.4	510	4	21	5.17	19.06	18.26	57.51	5811

* Drying time & reaction time

11-1-6 Smoke removal from dried coal briquettes

The coal briquettes produced from the carbonized coal slurry with 10% bagasse char and 10% molasses by normal drying and molding produce smoke from the initial stage of combustion for 15 to 20 minutes; therefore, they can hardly be called smokeless coal briquettes. Accordingly, the coal briquettes need a process to eliminate smoke after molding and drying. Smoking is caused by the decomposition of sugars during the combustion of the briquettes, which would not occur if the briquettes were carbonized after molding instead of carbonizing the raw materials first and then briquetting them, because in the former case the sugars would be carbonized during carbonization. Nonetheless, the process of carbonizing the raw materials before briquetting is by far the more economical in terms of energy consumption and also of capital cost; it gives technically better results.

Test results of the experiment show that smoke may be eliminated by heating the briquettes at 270°C for 20 minutes. This temperature is 150 to 350°C lower than the carbonization temperature of coal, meaning that this treatment is more economical than carbonization of green briquettes in time, energy consumption and capital investment.

When the component to produce smoke is removed, the weight of the briquette is reduced as shown in Table 11-1-6.

Table 11-1-6 Weight loss due to de-smoking

	Weight (g)	%
Dried briquette	52.1	100
After treatment at 270°C for 15 min.	47.6	91
After equilibrium with atmospheric moisture	50.0	96

With the treatment of smoke removal, nearly 10% of weight reduction is recognized.

11.1.7 Burning test of product coal briquettes

The product coal briquettes must satisfy the following requirements:

1) Practically smokeless and odorless

2) Easy to set fire

3) Able to burn at an appropriate rate without leaving unburnt carbon

4) Strong enough to withstand transportation and handing

5) Storable without moisture absorption, weathering or spontaneous firing

6) Mass-producible and economical

The coal briquettes experimentally produced were tested for the above criteria by actually burning them. By a series of experiments the following raw material ratio may be regarded as standard to produce coal briquettes of acceptable quality:

	Weight ratio
Char, carbonized Maamba coal slurry	85 to 90
Carbonized bagasse	10 to 15
Molasses	10 to 13
Slaked lime	0 to 3

11.2 Experimental Production of Clay Stoves

11.2.1 Clay analysis

Prior to the experimental production of clay stoves, the clays imported from Zambia were tested and analyzed. The results of the analyses are as shown below. The chemical analyses, X-ray diffraction analyses, particle size distribution tests, and refractoriness tests were carried out by Aichi Prefecture Tokoname Ceramic Research Center.

1) Chemical analysis

Chemical Analysis of Clay

(wt%)

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Ig.Loss
Chamba Valley red cly	66.1	18.3	5.04	1.06	0.36	0.52	0.16	1.62	6.82
Venter Plastic Clay	55.9	22.8	8.35	1.06	0.18	0.62	0.31	1.38	9.38
Venter Sandy Clay	65.9	16.5	5.32	1.11	0.66	0.62	0.19	1.20	8.78
Kasisi Sandy Clay	75.0	14.5	2.88	1.45	0.11	0.22	0.05	0.42	5.40

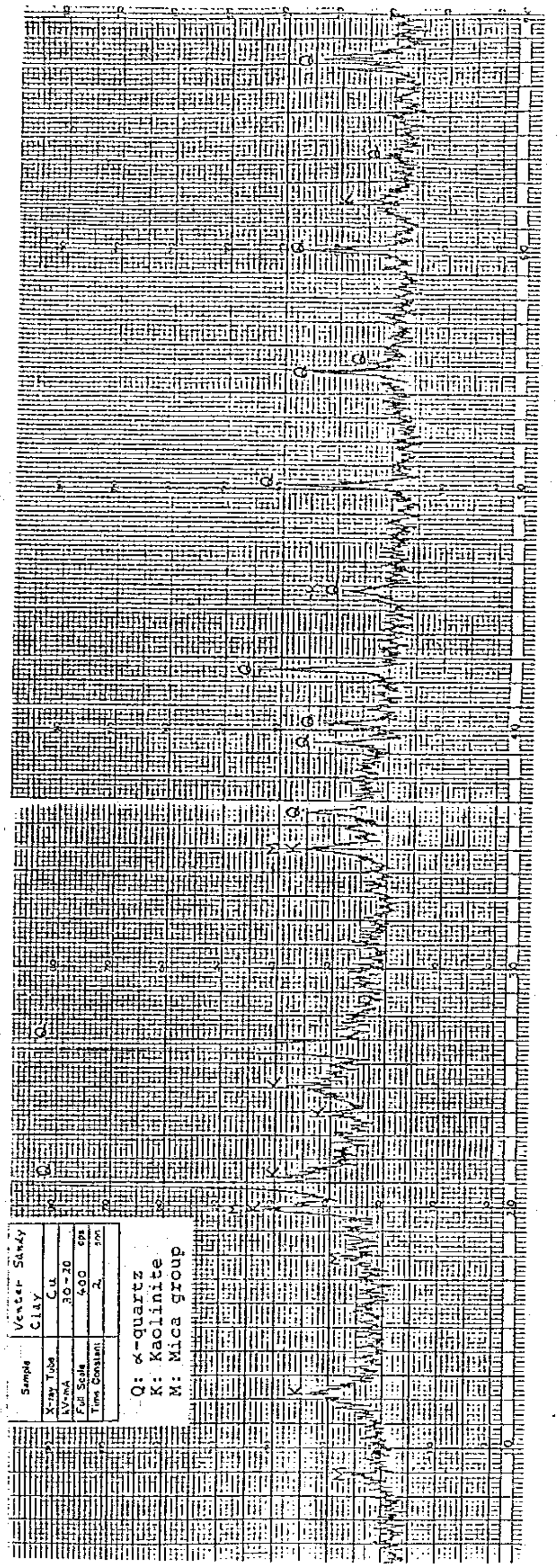
All, except for Kasisi sandy clay are similar to typical red clay analysis.

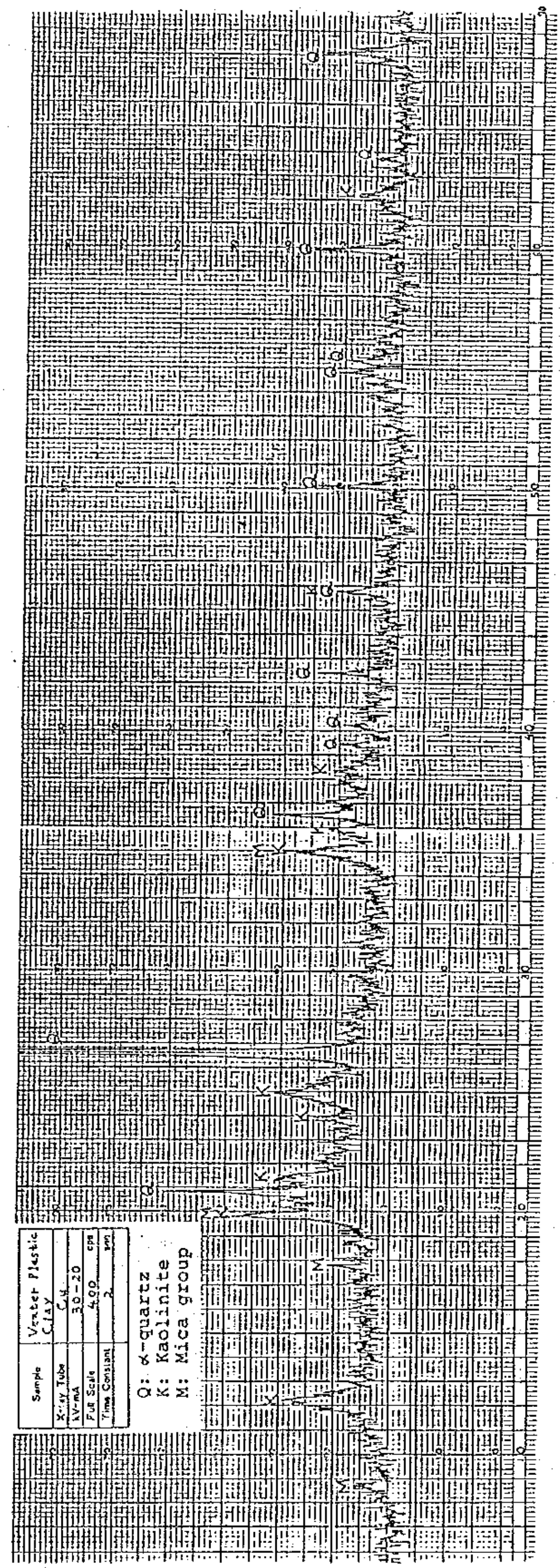
2) Mineral identification by X-ray diffraction

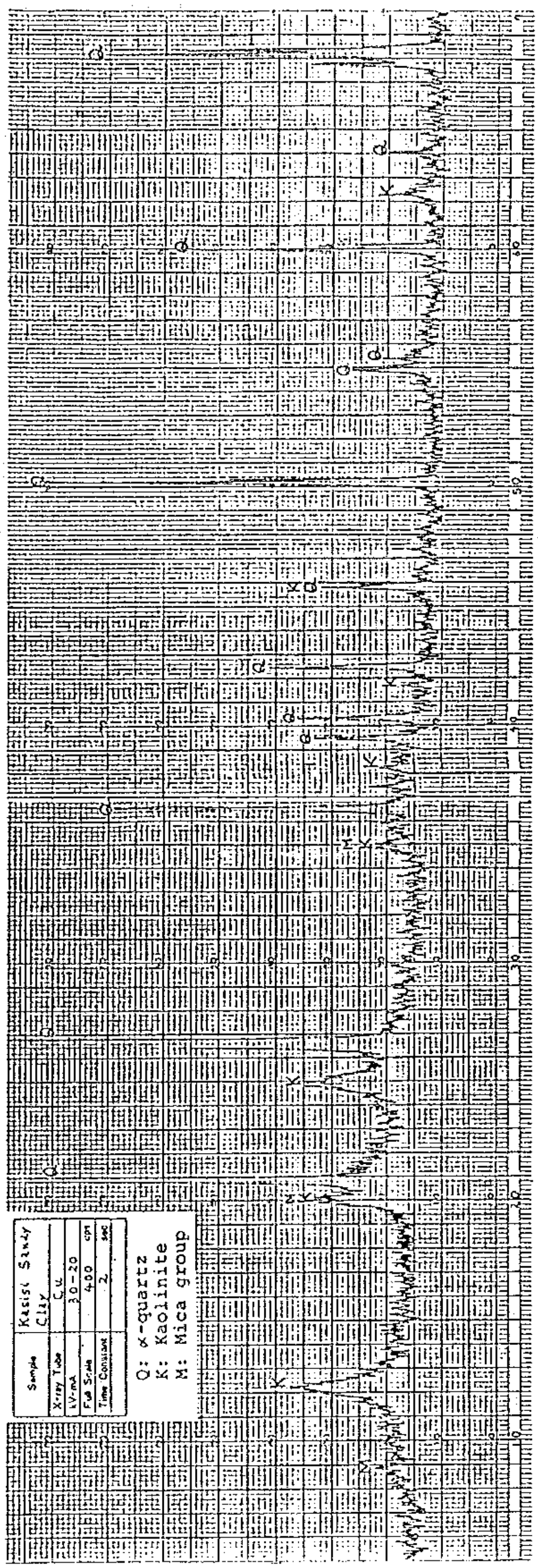
The results of the X-ray diffraction for mineral identification are as follows:

Clay Sample	Identified Minerals
Chamba Plastic Clay	-Quartz, Kaolinite, Mica group
Venter Plastic Clay	-Quartz, Kaolinite, Mica
Venter Sandy Clay	-Quartz, Kaolinite, Mica
Kasisi Sandy Clay	-Quartz, Kaolinite, Mica

Kaolinite constitutes the clay mineral for all clays. They are not noticeably crystalline in structure. Mica was identified which seems to be in the form of sericite in the case of Chamba clay. These represent desirable qualities as raw material for clay stoves. Mica can be clearly noticed with the naked eye with other clays. The X-ray diffractograms are shown below.


Sample | Venter Sandy Clay
X-ray Tube | Cu
kV-mA | 30-20
Full Scale | 400 cps
Time Constant | 2 sec
Q: α-quartz
K: Kaolinite
M: Mica group


Sample | Venter Plastic Clay
X-ray Tube | Cu
kV-mA | 30-20
Full Scale | 400 cps
Time Constant | 2 sec
Q: α-quartz
K: Kaolinite
M: Mica group


Q: α-quartz
K: Kaolinite
M: Mica group

3) Particle size distribution

The particle size distribution was determined by sieve and Andreasen pipette methods. The results are shown below:

Clay Sample	Greater than 250 micron	Between 250 and 44 micron	Smaller than 44 micron
Chamba Plastic Clay	1.8	19.8	78.4
Venter Plastic Clay	4.7	19.0	76.3
Venter Sandy Clay	4.9	27.4	67.7
Kasisi Sandy Clay	9.4	43.2	47.4

Particles smaller than 44 microns by sieve were further tested by the Andreasen Pipette method. In contrast to most clays, these samples have lesser mid-particle ranges and have relatively flat distribution curves. This is indicative of a character that the clays have good consistency but are susceptible to deformation and tear while drying.

4) Refractoriness test

The results of the refractoriness test are as given below.

Clay Sample	Refractoriness
Chamba Plastic Clay	SK 20
Venter Plastic Clay	30
Venter Sandy Clay	18
Kasisi Sandy Clay	28

Tested to JIS M8512

Venter plastic clay turned out to be more heat resistant than the sandy clays. The reason is unaccounted for. The refractoriness of Venter plastic clay should be lower in the light of the data of other clays.

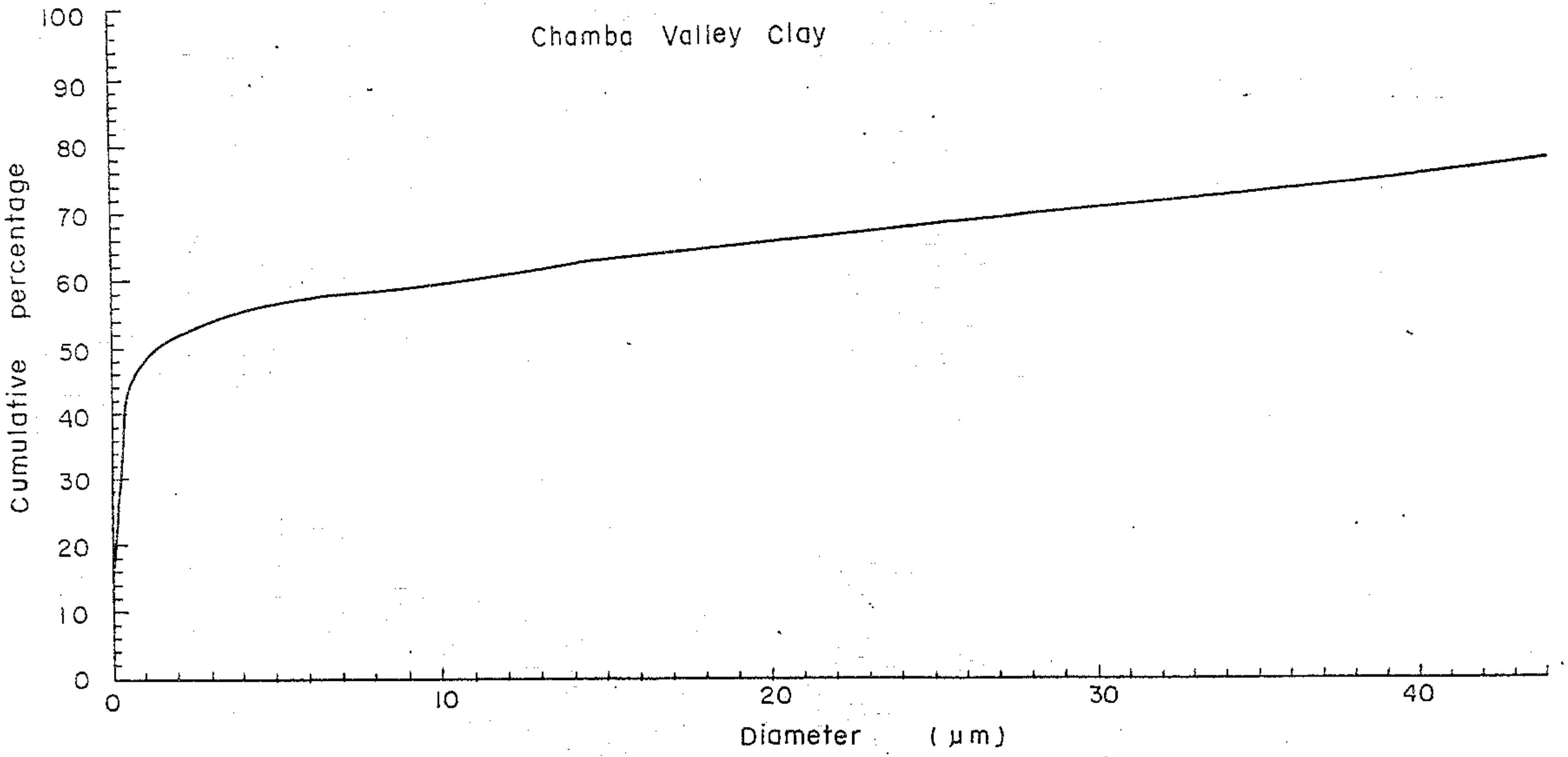


Figure . II - 2 - I Chamba Valley Clay Size Distribution

11.2.2 Baking test

Test pieces were prepared by adding 30% of water to thoroughly dried clay samples. Strength before and after baking, shrinkage after drying and baking were measured. The baking temperature is 800°C. The results are as given below.

	Unbaked Clay strength	Drying shrinkage	Total shrinkage aft.baking	Modulus of rupture kg/cm^2
Chamba Plastic Clay	good	7.02	7.1	42.60
Venter Plastic Clay	good	6.92	7.0	23.25
Venter Sandy Clay	good	6.90	6.95	26.10
Kasisi Sandy Clay	poor	6.45	6.6	17.19
Neganega Clay	good	6.45	6.54	21.34
Venter P + S (50:50)	good	6.70	6.80	26.72
Venter + grog	poor	4.95	5.0	21.70
Kasisi + grog	poor	5.65	5.7	8.59

Chamba plastic clay turned out to be the strongest followed by Venter sandy clay. Chamba plastic clay exhibited a smooth texture and light brown color. Venter clays contain a large number of limonite particles which cause radiating cracks emanating from the particles on baking which reduces rupture strength. Making stoves with Venter clays as the main ingredient, therefore, will have problems with strength and heat resistance. Promising compositions in view of the above were tried for clay stoves.

Two different compositions were tried for outer and inner frames. For outer frames, one mainly of Chamba clay and one mainly of venter clays were tested. For inner frame, grog was added to see its effect on heat resistance and thermal shock resistance

	Outer structure	Inner structure
	(1)	(2)
Chamba Clay	70	50
Kasisi Clay	30	30
Grog		20
	(3)	(4)
Venter Plastic Clay	40	30
Venter Sandy Clay	40	20
Kasisi Sandy Clay	20	30
Grog		20
Water	32%	
Burning temperature	800°C	

The results of the baking test are as given below.

Mix	Modulus of Rupture kg/cm^2	Heat resistance 500°C	Rapid cooling/heating 300 to 20°C
1	42.6	no crack	no crack
2	32.2	no crack	no crack
3	26.7	no crack	no crack
4	21.3	no crack	no crack

The results of the baking test shown above indicate that those with Chamba clay show the greatest modulus of rupture. The inner frame also shows good strength. Attempts to use mixtures of Chamba and Venter clay to minimize fluctuations of quality attributable to fluctuations of either clay ended in failure because of the limonite present in Venter clay.

Mixing ratio for strove (Chamba Clay)

Clay	Outer frame(%)	Inner frame(%)
Chamba Clay	60	50
Kasisi Clay	30	30
Grog	10	20

Mixing ratio for strove (Venter Clay)

Clay	Outer frame(%)	Inner frame(%)
Venter P. Clay	40	30
Venter S. Clay	40	20
Kasisi Clay	20	30
Grog		20

Two sets of outer frames and one inner frame for each composition were molded and baked at 800°C. One inner frame was cemented to the outer frame before baking while the other was simply positioned in the outer frame to permit observation of secondary air flow. Different compositions were tried for inner and outer frames but both were baked together under the same condition. The results of the baking test clearly indicated the importance of composition. The inner frames, either mainly of Chamba clay or Venter clay, were baked well without cracks which is considered to be attributable to grog blended. The strength is satisfactory, too. The inner frames were tested by burning charcoal and proved to be sufficiently durable without development of any crack and demonstrated good thermal insulation.

The outer frames composed of Venter plastic and sand clays and Kasisi clay developed a long crack that ran from the upper rim to the bottom. Evidently, the fine particles of limonite contained in Venter clay and reversible thermal expansion of the grains of sand contained in Kasisi clay caused the crack. The outer frames of Chamba clay, Kasisi clay, and grog also showed cracks of about one centimeter. The development of these cracks may be attributable to the difference in the baking shrinkage between the inner and the outer frames.

It may be surmised that although cracks did not develop in small test pieces but when the size becomes as large as that of stoves cumulative effects of thermal expansion of sand becomes significant enough to cause cracks. In the light of this, the use of Venter clay alone or in combination with sandy clay is not appropriate and should be avoided. Kasisi clay was blended into Venter clays in the hope that it could reduce baking shrinkage and also reduce the amount of grog. It was found, however, better not to use Kasisi clay to prevent cracking.

To streamline the operation, standardize the products and improve the yields, it would be desirable to use the same composition for outer and inner frames. Therefore, Chamba clay alone blended with grog was tested. Three clay stoves were made and baked under the following conditions:

Chamba clay	80%
Grog	20%
Baking temperature	800°C
Baking time	8 hrs.

All three were well baked without crack. Their thermal resistance test turned out quite satisfactory. This composition has been finally chosen for the production of clay stoves.

The stoves were baked unglazed at about 800°C. The sand in the clay exists in the form of silica (SiO_2); at this temperature the reaction to convert sand into silicate does not take place. This being the case, the thermal expansion of SiO_2 takes place between 670°C and 700°C and, when cooled again, SiO_2 returns to its original volume and causes cracks. If the baking temperature is raised clay stoves of fine texture will be produced which are also vulnerable to rapid heating and cooling.

Grog is, in the terminology of ceramic industry, crushed fire refractories formed by clay or rocks which had once been exposed to high temperatures. Grog does not exhibit any substantial changes at around 800°C. Accordingly, grog, if mixed with the raw material, could improve strength and thermal resistance of the stoves and thus their performance. Fire-brickes could presumably be obtained during the turnarounds of cement factories, copper smelters, the Kafue fertilizer plant and Indeni refinery as discard. Grog could be produced by grinding such firebricks.

The mixture of Chamba clay and grog turned out to be quite satisfactory. However, mixtures of Venter clay or Neganega clay with grog may be expected to give good results, as exemplified by the baking tests of inner frames.

To conclude, the experimental production of clay stoves of the present feasibility study confirmed the following composition and condition be adoped for the production of clay stoves:

Chamba clay, %	80 (dry base)
Grog, %	20 (dry base)
Baking temperature, °C	800
Baking time, hr.	8.

12. MANUFACTURING PROCESS AND FACILITIES

12.1 Coal Briquettes Production and Facilities

The conceptual design of the manufacturing process is established as explained below from the results of raw materials evaluation and experimental production of coal briquette.

12.1.1 Overall processing scheme

(1) Outline

As shown in Figure 12-1-1, the process consists of receiving, inspection and storage of the raw materials, drying and carbonization, compounding of the raw materials, briquetting of the compound, drying and de-smoking of the briquettes, testing, storage, packaging, shipping and delivery of the product briquettes.

The main raw materials are stored in their own pockets. A weather-tight tank is used for molasses. The bagged slaked lime is stored in the specified area. Due consideration is given to facilitate inspection and sampling for analysis and to ensure safety and fire-prevention. Also, ample space is allowed between the storage facilities and main equipment or storage area for spare parts

The carbonization gas, exhaust from de-smoking and spent carbonaceous dust are burned in the gas incinerator to generate a hot flue gas to be used for dryers.

(2) Material balance

Raw materials and intermediates required for the production of 1,000 tons product are shown in Figure 12-1-1.

12.1.2 Unit operation

(1) Receiving of raw materials

The received quantities of coal slurry and bagasse on dry base are calculated from their volumes and moisture contents. The quantities may be corrected as necessary by weighing the materials after they are dried. The ash content and particle size distribution are checked with the samples taken when received. The quantity of molasses can be measured by the level of the storage tank, temperature and specific gravity. The quantity of slaked lime is confirmed by counting the number of bags and testing the moisture content and insolubles content.

(2) Storage, water separation and drying of coal slurry

Coal slurry is received in the pockets. Free water may be separated during storage. Moist coal slurry is dried by hot air dryer. The ash content and particle size distribution are checked and adjusted by approipriate blending.

(3) Storage, air drying and solar drying of bagasse

The received bagasse is stored in the pockets. Moisture of bagasse is reduced as close to 10 to 20% as possible by air dryig and solar drying. Lots of different moisutre contents are kept separately.

(4) Storage of molasses and slaked lime

Molasses can be stored in a weather-tight tank placed outdoors. The quality is evaluated by moisture content, specific gravity, viscosity and color and adjusted. Bagged slaked lime is stored in a storage area. The quality is evaluated by ignition loss and insoluble residue.

(5) Carbonization of coal slurry

Coal slurry dried by hot air is fed to the fluidized carbonizer from the coal hopper by screw feeder. The product is withdrawn from the fluidized bed to the receiver through the overflow pipe and cyclone. After being cooled in the cooler, it is weighed and introduced to the mixing and pulverizing machine.

A portion of volatile carbonization products, a gas, is burned in the carbonizer and the rest leaves the carbonizer at the top to be introduced to the furnace to generate hot air for the dryers. Samples of char are burned in a crusible for smoking test.

(6) Hot air drying and carbonization of bagasse

The dried bagasse is further dried by the hot air dryer and then introduced to the carbonizer to make bagasse char. The operation is similar to that of the coal carbonization. Product bagasse char is cooled while avoiding contact with air and humidified to prevent dust from rising.

(7) Preparation and compounding for briquettes

The coal char, bargasse char, molasses and slaked lime are compounded with addition of water. Each constituent is weighed separately and mixed. Moldability is evaluated by molding tester.

(8) Briquetting

The compound is fed to the briquetting machine and briquetted. Appearance is checked for surface roughness, cracks, number of defects. Samples of briquettes are weighed and tested for compressive strength.

(9) Drying of biquettes

Molded briquettes are dried in the hot air dryer for 1 to 2 hours over 110°C.

(10) Smoke removal of briquettes

Dried briquettes are heated between 250 and 270°C for smoke remover. Hot briquettes are cooled below 100°C by air, and introduced to the storage bin.

(11) Product testing

(a) Appearance:

The percentage of briquettes that have defects should not be over 10%. Defective briquettes are removed by hand.

(b) Compressive test:

Compressive testers are used. Compressive strength over $50kg/cm^2$ is needed.

(c) Ignition and burning test:

Ignition time and burning duration is observed in an electric furnace. They are relative tests.

(d) Storage test:

Samples are stored for one month and no visually detectable change is allowed after one month storage. Five briquette samples per ton are taken.

(12) Storage of product briquettes

The product is held in the storage bins. A plate may be placed on each bin to make it air-tight for fire prevention. The bin is provided with a scale for process and shipping control.

(13) Packaging

Briquettes for special users are packaged in paper bag by weighing packaging machine. The bag is sewn by a sewing-machine.

(14) Shipping and delivering

Large or small size bulk shipping and bag shipping are intended. Shipping by bag is limited to high class markets and marketing promotion purpose.

12.1.3 Pollution control and safety

(1) Pollution control

This pilot plant is small in scale. The only conceivable problems are those associated with tar, dust and a noise. The gas generated at the carbonizer contains tar and some carbonaceous dusts; therefore, it is burned in the gas furnace. Exhaust gas from the dryer of coal slurry is treated by cyclones or bag filters. All exhaust gasses from the briquetting machines are treated by filter. Dusts generated around several pieces of main equipment are sucked with air and treated with filter. Operators should wear dust masks. The noise from blowers and fans are muffled with silencers. A settling pond which also serves as a fire pond is provided.

(2) Safety

(a) Fire protection:

Hydrants are installed at raw material storage areas, bagasse drying and main equipment areas. A pond is provided to retain effluent water to be used for fire fighting.

(b) Safety

Safety covers are provided for rotating parts of machines, belts and chain links. Platforms and passages are also provided with hand-rails to prevent operators from falling.

Main pieces of equipment are provided with rupture disks and electric shock proofing devices. Emergency oxygen masks, an airline masks and fire protection clothes are provided.

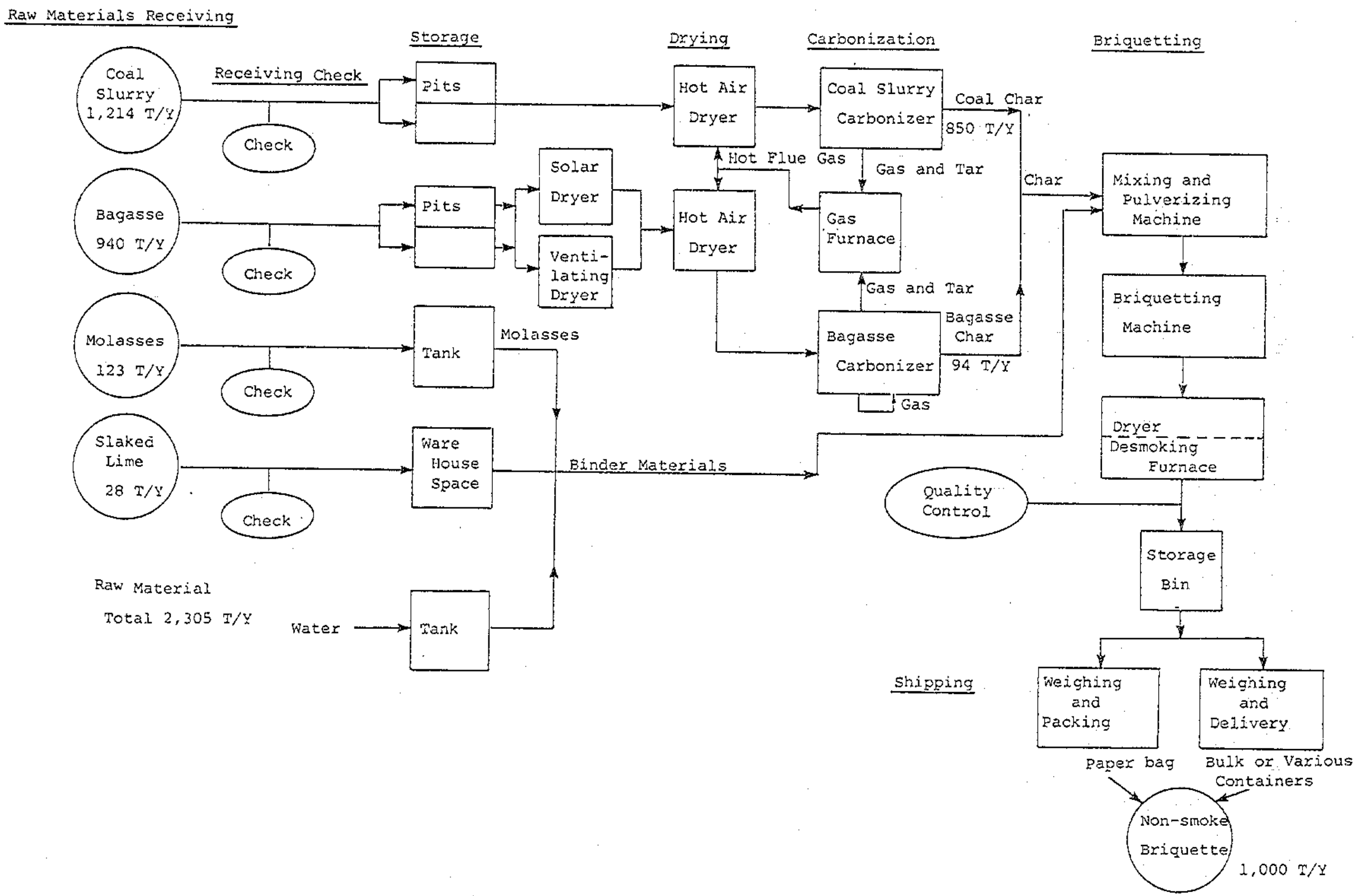


Figure 12-1-1 Flow Sheet of Non-Smoking Briquette Process

12.1.4 Equipment list

The list of major equipment for carbonization and briquetting are shown on Table 12-1-1 and 12-1-2, respectively.

Table 12-1-1 Equipment List of Carbonization

(1) Equipment List of Slurry Carbonization

	Equipment	Q'ty	Capacity or uses	Power(kW)
1	Power Screen	1	1.5t/h	1.5
2	Disintegrator	1	0.1	2.2
3	Roll Crusher	1	0.5	2.2
4	Dryer	1	1.5	0.75
5	Cyclone	1	-	1.2
6	Power Screen	1	1.5	1.0
7	Carbonizer	1	1.5	1.35
8	Cyclone	2	-	1.2
9	Char Cooler	1	1.2	1.5
10	Blower	3	-	18.5
11	Gas Furnace	1	-	-
12	Bag Filter	1	-	5.0
13	Others	-	-	-
				36.4kw

(2) Equipment List of Bagasse Carbonization

	Equipment	Q'ty	Capacity or uses	Power(kW)
1	Wet Bagasse Dryer	1	0.7t/h	5
2	Power Screen	1	0.7t/h	1.5
3	Bagasse Dryer	1	0.7t/h	1
4	Bagasse Carbonizer	1	0.7t/h	2.65
5	Cyclone	2	-	1.4
6	Char Cooler	1	250kg/h	1.5
7	Blower	2	-	12.0
8	Others	-	-	8.55
				33.6
	Carbonization Sub-Total			70kW

Table 12-1-2 Equipment List for Briquetting

	Equipment	Q'ty	Capacity or uses	Power(kw)
1	Blender	1	1.5t/h	15
2	Pulverizer	1	2.0	37
3	Power Screen	1	2.0	0.75
4	Circular Blender	1	2.0	15.0
5	W type Kneader	1	2.0	5.5
6	Binder Mixer	1	2.0	1.5
7	Fret Mill	1	2.0	33
8	Vertical Kneader	1	2.0	37
9	Briquetting Machine	4	1.5	30
10	Belt Conveyer	5		
11	Bucket Collector			
12	Dust Collector			
13	Others			82.25
14	Dryer	2		400
	Briquetting Sub-Total			657kw
			Total	727kw

12.2 Clay Stove Production and Facilities

The standard sequence of operation for the production of clay stoves is explained and schematically shown in 9.6, Clay Stove Material and Production. This chapter presents conceptual design and decides on the operation and equipment for the clay stove manufacturing portion of this project.

12.2.1 Refining of material

The raw material clays and grog are procured according to the ratios found best by the experimental production. The clays are stockpiled outdoors exposed to the weather for a period of at least half a year.

The amount of raw material necessary to produce 4,000 clay stoves a year, decided in relation to the project scheme, is calculated as follows:

4,000 units X 10 kg = 40,000 kg = 40 t/year; clay 32, grog 8 tons

For producing 40 tons of clay stoves, the following materials losses are considered.

Water in raw clay	25.0%
Loss during storage in yard	0.5
Loss during production	2.0
Production loss at 90% yield	10.0
Total	37.5

Therefore, net clay requirement is:

$$\frac{32}{(100 - 37.5)} \times 100 = 51.2t$$

Grog	8.0	
Total	59.2	nearly equal to 60 tons

The clay is refined by the machinery explained below.

(1) Box feeder

Well weathered clay and grog are fed into three hoppers according to the preset mixing ratio. The feeds are drawn out through the openings of scrape blades at the bottom of the hoppers by means of conveyors. The rate of withdrawal is controlled from 800 to 2,000 kg/h by adjusting the openings of the scrape blades.

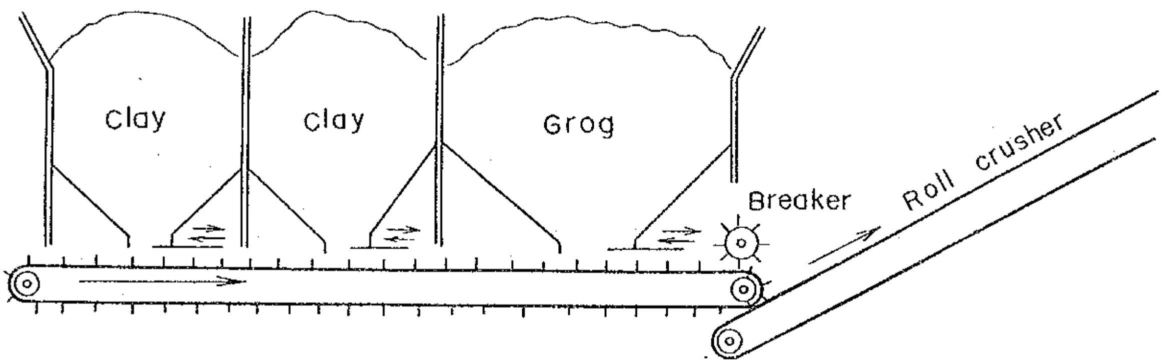


Figure 12-2-1 Box Feeder

(2) Roll crusher

The roughly mixed raw materials from the box feeder is fed by the conveyor to the roll crusher. Two rollers spaced at about 3 to 5 mm rotate inward. A mixture of dry and wet lumps is crushed by the rollers while traveling through the spacing and mixed more uniformly. Pebbles and foreign matters are crushed and reduced in size and mixed with the clay. It moisture is not uninformly distributed, this operation may be repeated.

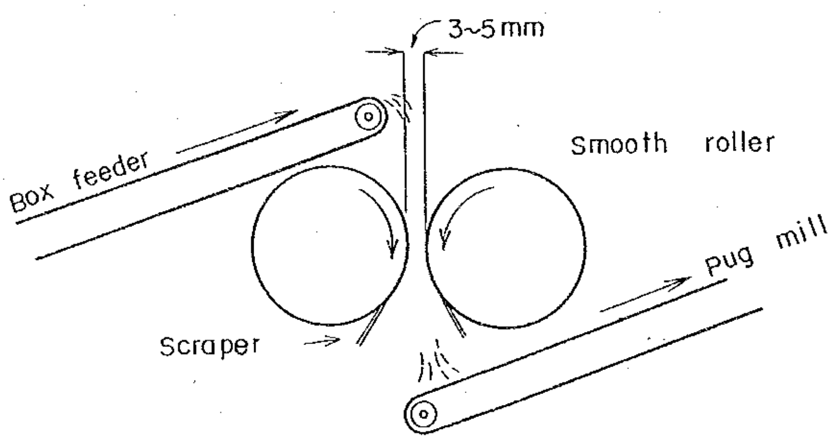


Figure 12-2-2 Roll Crusher

(3) Double-shaft pug mill

The crushed raw material from the roll crusher is milled by the double-shaft pug mill to a homogeneous mixture with addition of water to adjust water content to the desired level. A horizontal double-shaft type is employed. Two parallel rods studded with blades at intervals of 5 to 8 cm rotate inwards to cut the clay into pieces and to push it to the outlet. During this process, a necessary amount of water is added to bring the water to the pre-determined water content. The clay is finished in the form of paste with uniform texture. The speed at which clay is cut and pushed out is controlled by the angles of the blades.

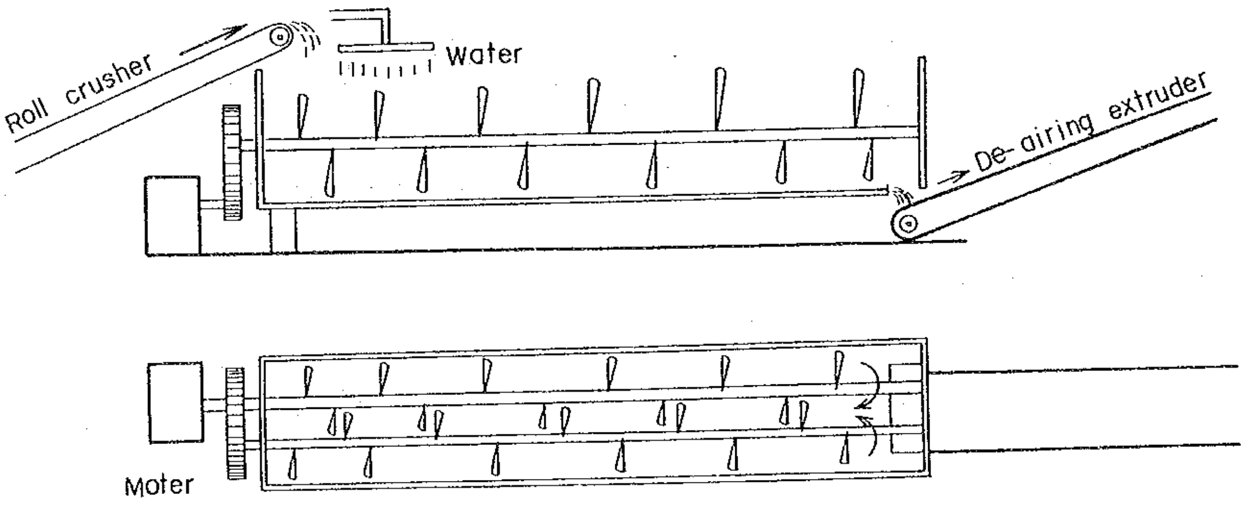


Figure 12-2-3 Double Shaft Pug Mill

(4) De-airing extruder

The clay becomes homogeneous at the outlet of the double shaft pug mill. The clay, however, still has entrained small air bubbles. These bubbles are eliminated at the vacuum chamber to give dense and consistent clay. The clay becomes easy to shape and less likely to tear or crack. The vacuum at the vacuum chamber should be maintained at about 720 mmHg.

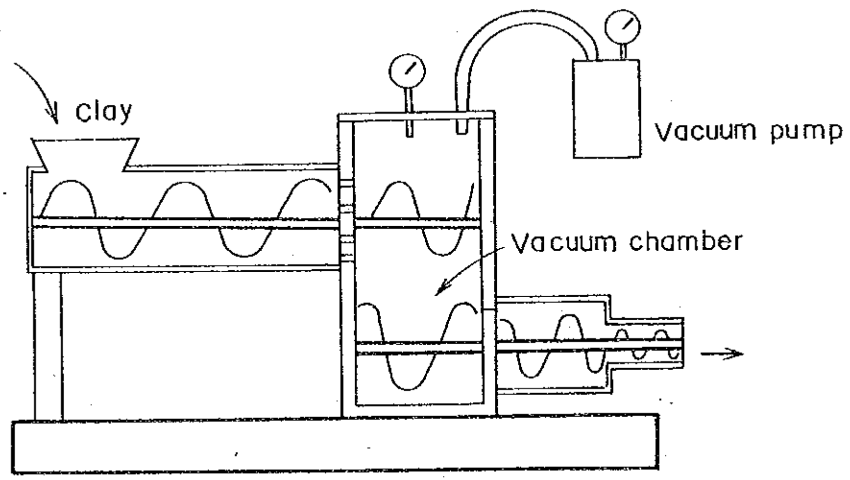


Figure 12-2-4 De-airing Extruder

12.2.2 Shaping

The jigger is used to shape the clay into clay stoves. In general, the water content of mixed clay varies according to the size of the products. In the case of clay stoves, a rather soft clay with a water content of 32 to 33% is used. As clay stoves are large and thick compared with ordinary ceramic ware, the clay needs to be soft enough to stretch and move inside the plaster jigger. It is also better to turn the jigger slowly. As a guide, the standard is 500 rpm for cups and 400 rpm for plates. The rotation for this case of clay stoves is 300 rpm to prevent possible tears caused by drying.

Before clay can be shaped, the template has to be fixed to the right position in order to give the correct thickness and size to the clay stoves. The amount of water used during the shaping process also affects the yields of the products. It takes about three months to learn the skill.

12.2.3 Finishing

When the shaped clay stoves becomes half-dry after being dried indoors, the primary air doors are cut through the frame. The outer and inner frames are put together and inner supports are fixed to the inner frame and the firing chamber inside the clay stoves is reinforced.

12.2.4 Baking

A three-tier shelf for supporing clay stoves is structured in the kiln. Each tier consists of ten 310mm x 320mm x 15mm refractory plates placed one next to the other. The tiers are spaced from each other by 32cm by pilars of refractory columns. On each shelf are placed 10 stoves in two rows. Care must be exercised to remove imperfect stoves before loading them into the kiln. The commonest defects found at this stage are cracks, clefts, chipping off of a portion of the stove, imperfect finishing. Baking is accomplished in three steps. For the initial one hour after the switch is on temperature is raised to 200°C with the door of the kiln about 20cm open to drive off the moisture which has still remained in the stoves after drying. It is important to confirm that there is no longer vaporization of moisture instead of depending on experience or time. After making this confirmation, the kiln is closed and the temperature is raised to 800°C over about 7 hours; the kiln is maintained at this temperature, or soaked, for about 2 hours. Then the temperature is gradually lowered. When the cooling is complete, the kiln is open and the baked stoves are withdrawn, inspected for cracks that may have developed during the baking by hearing the sound while tapping the stove by hand; and also apperance is observed. Detective products are removed.

12.2.5 Making of plaster molds

Plaster molds are made by the three processes explained below.

(1) Preparation of original model

Real-scale drawings of the models are prepared giving allowances for drying and baking shrinkages of the clay, which are 6.5 and 1.5% for the Zambian clay. The original models are made of plaster of Paris, carved by hand according to the real-scale drawings prepared. The round portions are cut by means of jiggers. The original models are made for outer and inner frames.

(2) Preparation of case mold

A large number of working molds are required for the production of clay stoves. The case molds are prepared to the original models. The case molds are also made of plaster of Paris; however, their purpose calls for greater strength. To endow additional strength, water content is reduced or a certain amount cement is added. Recently, a hard plaster for making case molds is available. This project, however, will use Zambian plaster of Paris with a lesser amount of water to increase strength. When case molds are made, they are coated with varnish to prevent wear and to facilitate separation from the working molds. The case molds are made in two pieces to enable removal of the working molds.

(3) Working molds

Potash soap or other stripping agent is applied to the case mold surface and the pieces of case molds are put together. Plaster is poured into the case molds and let stand for a while to harden to the shape of working molds. Plaster and water are in a ratio of 100 to 70. Plaster hardens in about 20 minutes after mixing with water with a temperature rise of 32°C to 36°C and expands somewhat to enable the plaster to be separated from the case molds easily. The working molds should be dried sufficiently before they can be used for shaping the clay.

12.2.6 Stove production facilities

The clay stove factory needs a building of 720 m^2; the layout of the workshop is given on the next page.

The ageing room on the drawing is a dark room in which processed clay is kept. It should be wide enough to accommodate a one-week supply of treated clay. The laboratory is used for research and tests for product development and quality control of the material.

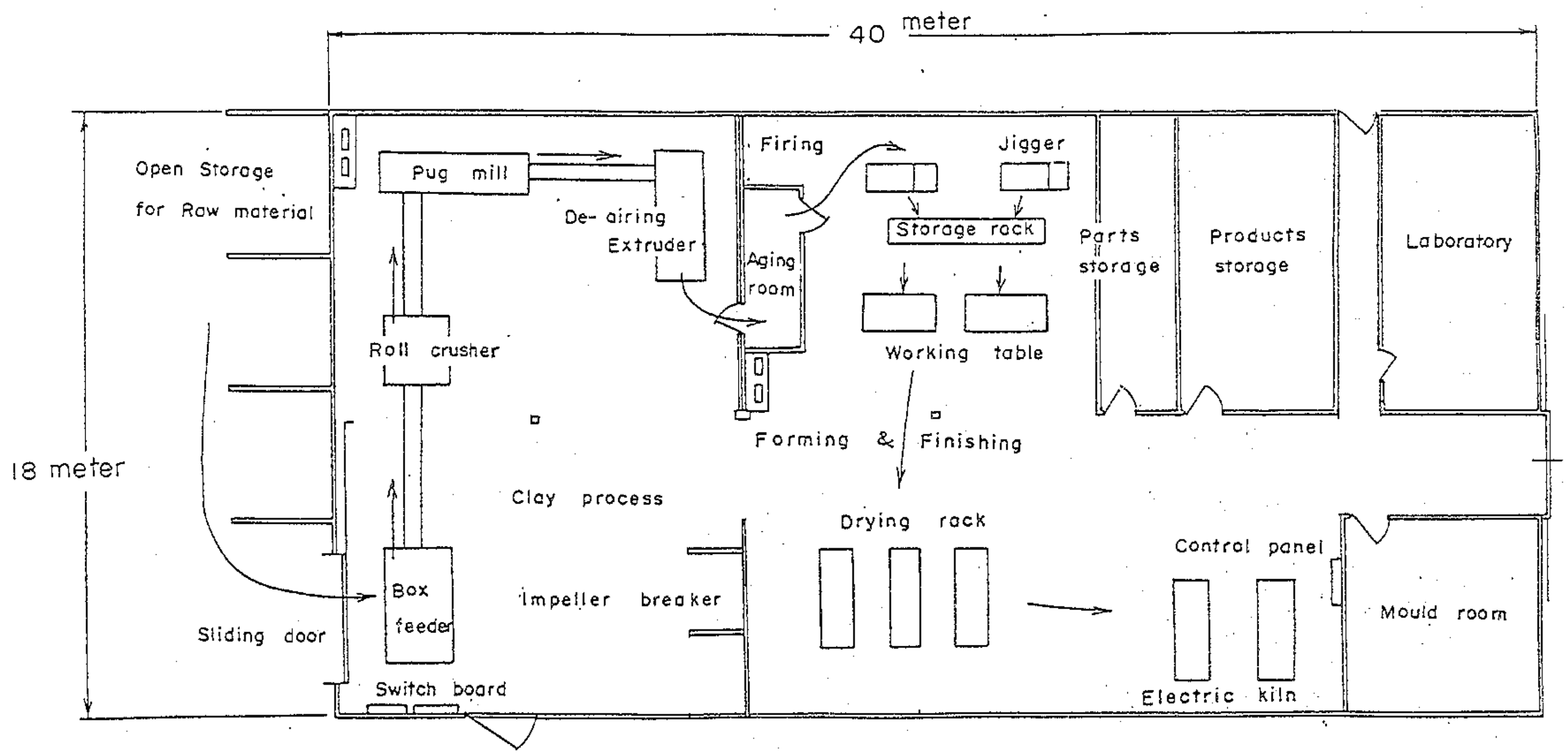
Below is a list of major equipment needed to produce clay stoves.

1. Machines and equipment

	Qt'y	Power
1) Impeller breaker	1	5.5
2) Box feeder (3-chamber; 2 t each)	1	9.0
3) Roll crusher	1	15.0
4) Double-shaft pug mill	1	7.0
5) De-airing extruder	1	11.5
6) Semi-automatic jiggering machine	2	3.0
7) Electric kiln (35kw, rectangular)	2	60.0
8) Belt conveyor (7 m)	8	6.0
9) Electric turn table for mold	2	1.5
10) Vacuum mixer	1	1.5
		120.0 KW

Layout of workshop for clay stove production

Total floor area 720 squ. meters



2. Other materials and Tools

For clay processing
Shovels, pushing cart, weight balance, spanner for forming, vise, files, hammer, machine tools for mold making, knife, cutter, pitcher, tug, compasses, ruler balance, graduated cylinder, plaster of Paris container;

For baking
Refractory shelves, kiln repairing materials

For general uses
Water supply system, Electric Power

The items above are used for producing clay stoves; further, the finishing of the shaped clay stoves needs gauges, knives, and other minor tools which should be made by the operators. The total power requirement is 120.0 kw, larger than ceramic factories in general because of the power needed for the baking process.

The floor of the clay process room needs to be cleaned occasionally; therefore, an indoor gutter is provided for drainage. The products will be packaged, simply by tying two pieces together by cord.

12.2.7 Manning

As a result of analysis on production, operation and time available, two technicians are found necessary for the operation of the clay stove pilot plant.

12.3 Associated Facilities

There is not very much of associated operation in this project. There is no need to generate electricity, steam, or to purify water by the plant itself.

The most important of all the associated operations is the daily operation and maintenance of the car fleet to keep the cars in operable conditions. For this purpose there is no particular facilities provided in the plant premises; but a vacant spot is set aside for the cars. The maintenance works beyond the capability of the pilot plant are taken care of by the NCSR car maintenance crue or garage shops in the city.

Other associated facilities are a gate office, office, restrooms, electric room, fence, gate, lighting system, air conditioning and ventilation systems, sanitation system, hydrant system, etc.

The plot plan is shown in Figure 12-3-1.

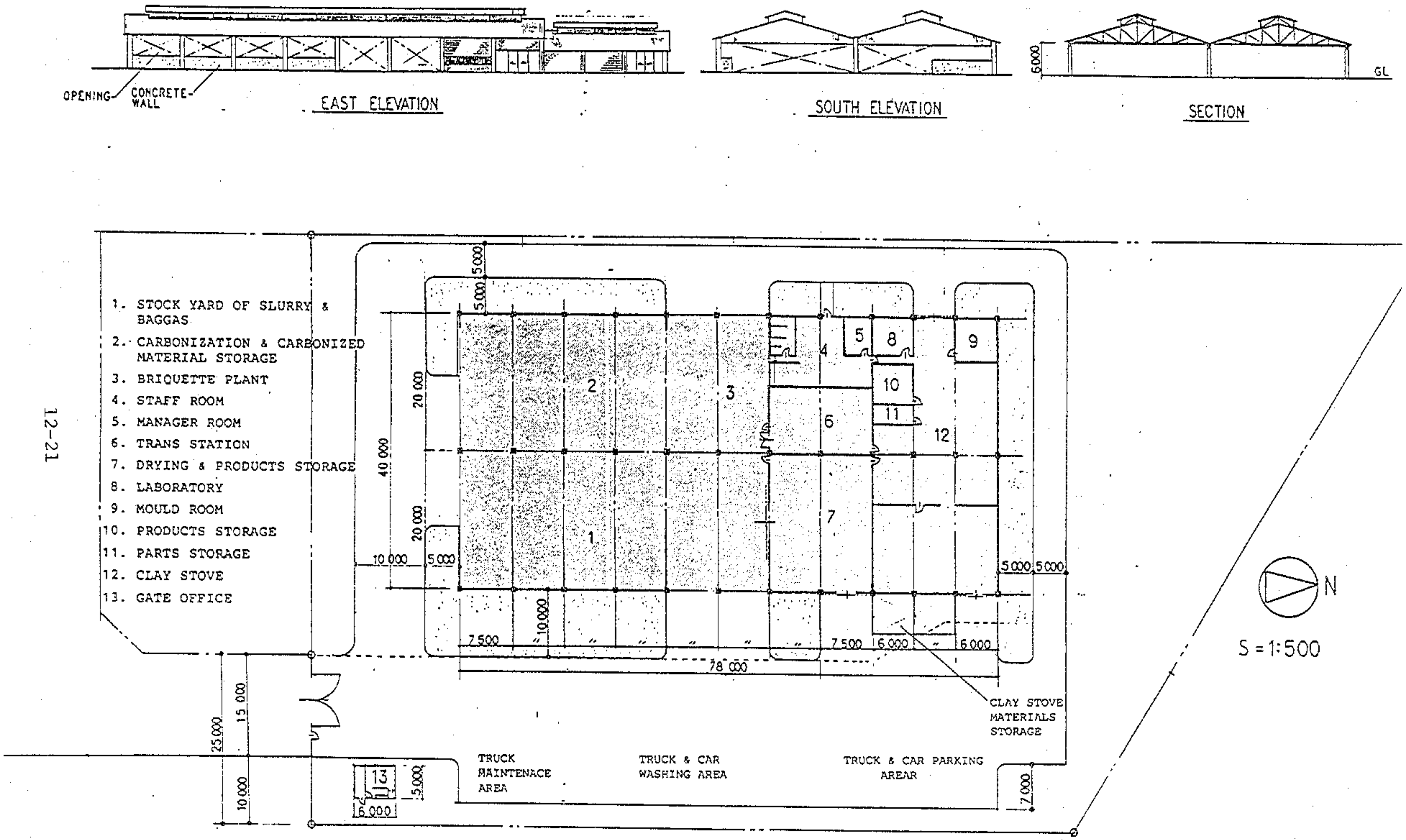


Figure 12-3-1 Plot Plan

ZAMBIA COAL BRIQUETTES FACTORY PROJECT
(PRELIMINARY)

13. CONSTRUCTION

13.1 Present Situation of Construction Work in Zambia

During the field survey, the constuction of large-scale plants was not seen presumably because of a shortage of foreign currency reserves caused mainly by the fall in price of copper, the main export product of Zambia.

The only noticeable projects around the Lusaka area were a housing complex being constructed along the Great East Road and a highrise office building under construction in the center of the city; the construction of the latter has been suspended several times due to a shortage of construction materials, the prevailing situation to be described later.

Coal briquettes plants or similar ones do not exist in Zambia. However, based on the field surveys of the Maamba Collieries, the Nakambala sugar plant, the Kafue fertilizer plant and the Neganega brick factory, the general situations surrounding the plant management, the equipment in use, power and energy may be summarized as follows. The planning of the coal briquettes plant should take into consideration such local situations in Zambia.

1) The plants are generally managed by the nationals, but there are cases where expatriates, mainly Europeans, perform advisory or supervisory roles.

2) Almost all the engineers and technicians are nationals, but Europeans are hired in the fields where technology or skill is not locally available.

3) The equipment in use appeared to be 10 to 15 years old; all the equipment was in working condition. (A part of the fertilizer plant is being repaired.)

4) It is difficult to obtain spare parts. Once there is a breakdown it takes rather long before the machinery is returned to the working condition again.

5) Although there is sufficient electric power, power failures are not entirely rare due presumably to insufficient maintenance of the transmission system.

6) The nation is dependent entirely on import for the supply of fuel oil. Several days in a year fuel oils are not available in the market.

7) There is no manpower shortage, but the present level of the workers' skill in general could not always meet the strict requirement of the modern construction work.

There are several construction companies around the Lusaka area that may be considered capable of carrying out the construction of this project. However, as will be explained later, this project consists more in the supply and installation of the process equipment than in the civil and building works. Moreover, since this is the first coal briquettes plant in Zambia, it would be better that foreign companies of experience assume the responsibility of main contractor with local companies as subcontractors considering the kinds of works required for installation, testing and adjustment of process equipment and coordination between installation of process equipment and civil and building works.

The following is a list of the main local companies:

Lewis Construction Co., Ltd.
Minestone Limited
Lendor and Burton Co., Ltd.
Allied Contractors Limited
Copperbelt Civil Engineering Co., Ltd.

13.2 Locally Available Materials and Equipment

Among the main materials and equipment necessary for construction, those used for brick or concrete block housing are locally available. All other materials and equipment are not produced domestically but imported, hence will be difficult to procure in such a big amount as one project like this may require.

Locally available materials and equipment:

- Cement
- Gravel and sand
- Slate (asbestos cement sheet)
- Brick and concrete block
- Other similar products

In other words, local procurement of even formwork materials will be difficult, not to mention reinforcing bars, structural steel and steel fittings materials. The budget for construction has to include as imported items lighting equipment, sanitary equipment, paint, glass, piping material, wiring material and air-conditioning systems, etc.

13.3 Design Standards

The following standards published by the Government Printing Center are the related rules and regulations (design standards) of Zambia applicable to plant construction.

1) CAP 475 Town and Country Planning
2) CAP 480 Local Government
3) CAP 514 Factory
4) CAP 535 Public Health

These are more or less akin to British standards. There will be no problems in international tendering and procurement if British standards are in principle applied to basic design and detailed design. This has been confirmed with the National Housing Authority and the Public Health Department of the Lusaka Urban Distric Council.

Approval of the the design drawings has to be obtained before constuction from the Public Health Department, Lusaka Urban District Council. However, the Design Calculation Sheets need not be submitted.

The following recommendations have been received from the Public Health Department of Lusaka as well as the NHA for the design criteria necessary for the preliminary design of the pilot plant.

1) Soil bearing capacity shall be 100KN/m^2.

2) Wind pressure shall be 30m/SEC.

3) Concrete compressive strength shall be 200kg/cm^2.

4) Reinforcing bar yield strength shall be of 250N/mm^2 (round bar) and 410N/mm^2 (deformed bar).

5) No earthquake shall be considered.

6) Imposed load on floor shall be of more than 0.25KN/m^2.

7) Top height of chimney shall be 10 ft. above the plant building top.

8) The plant building shall have an adequate ventilation system.

There are no specific regulations for plant equipment including electric equipment and the standards of the import nation are followed. However, this project should preferably employ consistent standards for all the equipment within the battery limit.

13.4 Preliminary Design

13.4.1 Outline of plant

The following is an outline of the pilot plants which should effectively realize the processing plans developed in Section 12-1 and 12-2.

Construction Site:	Namununga in Lusaka
Site Area:	Approx. 12,000 m^2
Total Floor Area of Building:	Approx. 3,150 m^2 (one-story house)
Building Summary	

a. Coal briquettes plant

Raw material pocket (about two week inventory)
Coal briquettes pilot plant
Drying plant and product storage area

b. Clay stove plant

Clay stoves plant
Product storage area

c. Common facilities

Electric room
Office, restrooms
Guardhouse

d. External work: Road, fence, gate, etc. (excluding plants)

e. Production equipment: See Chapter 12

f. Building Services:

Lighting system (Include outdoor lighting)
Air-conditioning and ventilation systems
Sanitation system
Hydrant system

g. Others:

Car washing space
Parking space
Car maintenance space

13.4.2 Specifications of preliminary design

Locally available materials will be employed to the extent possible and practical. Local labor will also be employed as much as possible. The following specifications are developed on such concepts.

Foundation:	Reinforced concrete (pad foundation)
Column, Beams:	Reinforced concrete
Roof truss:	Steel construction
Wall of raw material pocket:	Reinforced concrete
Other walls:	Bricks or concrete blocks
Roofing material:	Corrugated asbestos cement sheet
Floor:	Concrete trowel finish
Roads:	Concrete pavement
Fence:	Bricks or concrete blocks
Illumination level:	Plant 200 to 300 lx Office 300 to 500 lx Warehouse 100 to 200 lx Outdoor 10 to 20 lx
Cooling and heating:	Only the office and laboratory
Ventilation:	Natural ventilation with forced ventilation in isolated areas

The temporary office, material storage area, and construction equipment will be placed within the site area. However, the location of the material storage area will have to be shifted as the construction progresses.

13.4.3 Water and electricity consumption

The following is an estimate of the amounts of water and electricity that will be required during the operation period.

Electricity:

Overall equipment capacity - 950kW

(Process equipment-850kW, Building Services-100kW)

Demand factor: Simultaneous usage rate - 70%

Operating time: 8 hours/day, 300 days/year

Annual electric power consumption: Approx. 1.6 million kWh

Water: (Including operation and living use)

Daily water consumption: Approx. $10m^3$

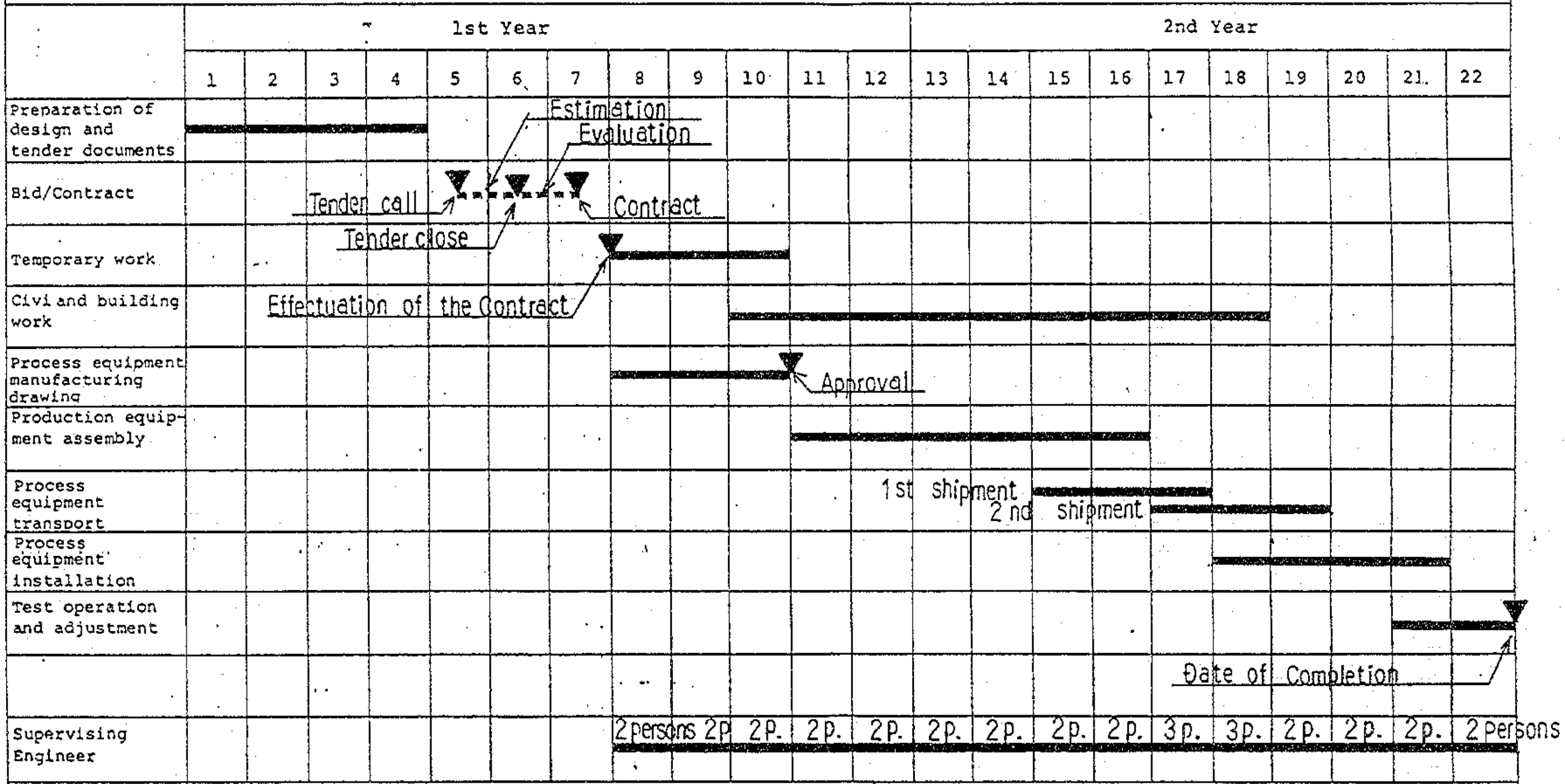
Annual water consumption: Approx. $3,000m^3$

13.5 Summary of Construction Schedule and Contractor's Organization

13.5.1 Summary of construction schedule

The construction schedule for this project is summarized in Table 13-5-1.

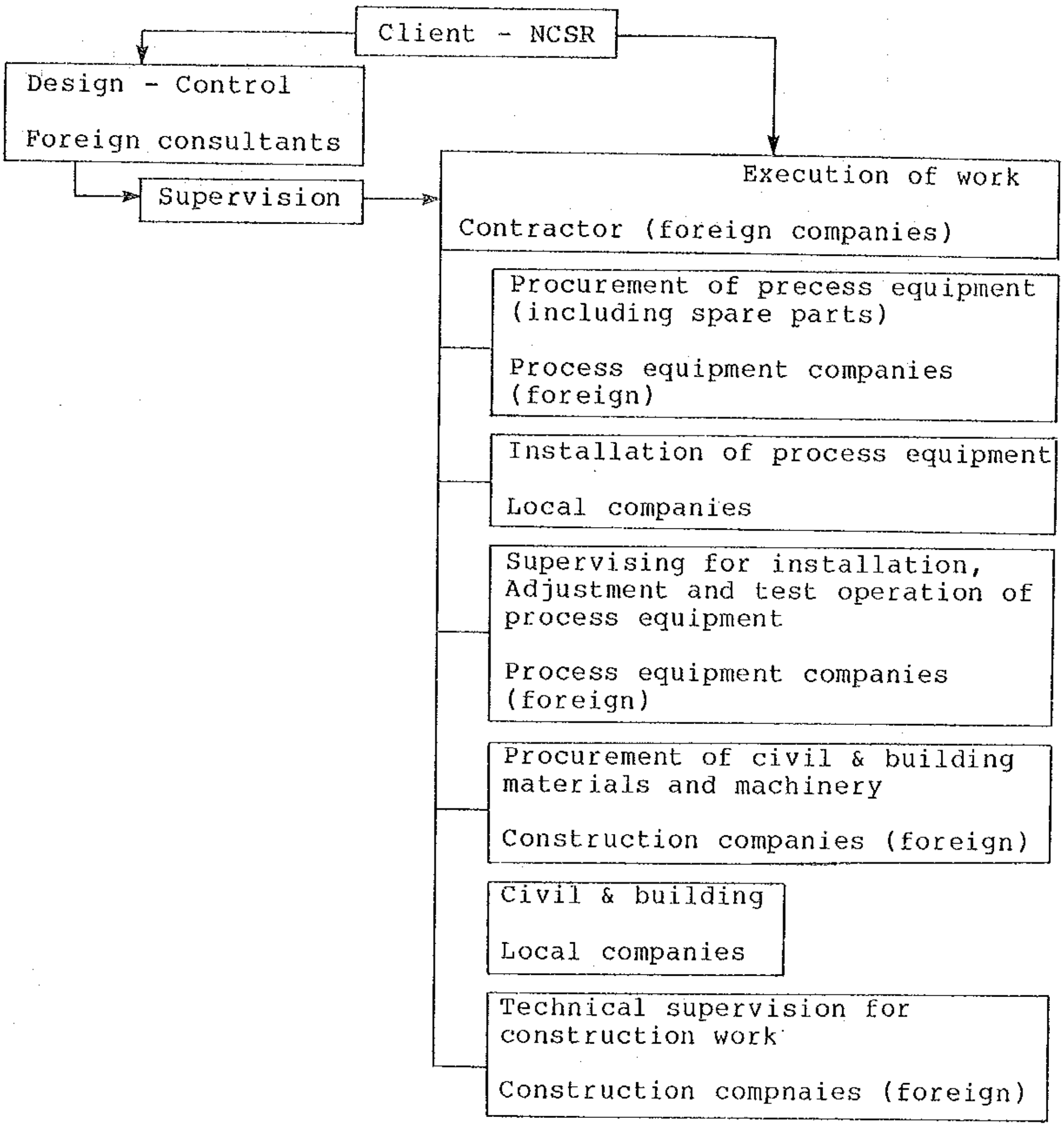
Construction Schedule for Zambia Coal Briquettes Process Plant (Reference only)



Note: One year after completion of the plant shall be disignated as the maintenance period and during that period two engineers shall be dispatched to the plant as operation guidance personnel.

13.5.2 Contractor's organization

The construction of this project would probably take the following form with foreign companies being the main contractors considering the characteristics of the works involved in procurement, installation, test operations and adjustment of process equipment and procurement of civil and building materials.



The schedule and organization assumes the following procedure. After having secured the required fund NCSR will select a consulting company through bids. The consulting company shall conduct the field survey and proceed with the basic design and preparation of tender documents which then will be used for tender to select the contractor. The contractors could be civil and building constructors, plant manufacturers or even trading companies.

13.5.3 Route of equipment importation

The importation will be via Dar es Salaam, Tanzania. This route may not be efficient but would not pose any serious problem.

13.6 Construction Cost

The construction cost is estimated on the basis of unit prices of local materials and labor cost obtained during the field survey and estimated costs of process equipment, auxiliary equipment, plus transportation cost and other items as shown in Table 13-6-1. The base period is March 1986. This estimate includes the cost of spare parts for the process equipment for a period of five years.

Table 13-6-1 Construction Costs (Estimate)

As of March, 1986

	Details / Type of work	Machinery and material expenses		Machinery weight	Local construction expenses			Transport expenses	TOTAL		NOTES
		Foreign currency FOB(¥1000)	Local currency (Kwacha)	Ton	Foreign currency FOB(¥1000)	Local currency (Kwacha)	M^3	Foreign currency (¥1000)	Foreign currency (¥1000)	Local currency (Kwacha)	
Construction Work	1 Coal briquettes process equipment	423,000	-	185	Include in 9	65,000	490	41,700	464,700	65,000	
	2 Carbonization equipment	245,000	-	60	do	54,000	120	10,200	255,200	54,000	
	3 Clay stoves process equipment	34,000	-	20	do	32,400	50	4,300	38,300	32,400	
	4 Electrical facility	105,000	-	20	do	54,000	50	4,300	109,300	54,000	
	5 Supplemental equipment/ miscellaneous material	26,000	-	15	do	10,000	40	3,400	29,400	10,000	
	6 Spare parts	24,000	-	5	-	-	40	3,400	27,400	-	
	7 Civil & building works	128,000	2,590,000	200	Include in 11	1,950,000	500	30,000	158,000	1,540,000	Half of the imported materials are from neighbouring nations
	8 Transport system	32,400	-	45	-	-	260	21,600	54,000	-	
	9 S.V. for test-operation Adjustment/Installation	-	-	-	90,000	-	-	-	90,000	-	
	10 Temporary work expenses	20,000	510,000	10	Include in 11	400,000	50	4,300	24,300	910,000	Includes expenses for electricity, water, sewage
	11 Overhead	-	-	-	84,400	650,000	-	-	84,400	650,000	Includes local expenses
	Total construction cost	1,037,400	3,100,000	560	174,400	3,215,400	1,600	123,200	1,335,000	6,315,400	
Engineering	12 Field survey, design, Preparation of Tender documents	75,900							75,900		
	13 S.V. dispatch expenses	96,000							96,000		
	Total engineering costs	171,900							171,900		
	TOTAL	1,209,300	3,100,000	560	174,400	3,215,400	1,600	123,200	1,506,900	6,315,400	

14. TOTAL CAPITAL REQUIREMENT

14.1 General

This chapter describes the total capital requirement for this project. In this study, the total capital rquirement is defined as the accumlative amount of capital investment required until the commencement of plant operation, and includes the following items:

. Plant construction cost
. Pre-operation cost
. Initial working capital
. Interest during construction

14.2 Basic Premises

Calculation of total capital requirement is based on the following premises.

14.2.1 Price basis

The prices in March 1986 are used as calculation basis. As to the foreign currency portion, the escalation rates of the Japanese domestic wholesale and export price indexes are referred to, because this study assumes that major machinery and equipment will be procured in Japan. Table 14-2-1 shows that these price indexes have been quite stable from 1980 to 1984. Accordingly, fixed prices are adopted for the foreign currency portion.

Table 14-2-1 Price Index

	Domestic Wholesale Price Index	Export Price Index
1980	100.0	100.0
1981	101.4	101.2
1982	101.9	105.1
1983	101.2	98.8
1984	101.3	99.4
1985	100.5	98.0
Average (1980-84)	101.1	100.4

Source: Price Indexes Annual, Bank of Japan

As to the local currency portion, the escalation rate is set to be zero based on the discussion with NCSR.

14.2.2 Financing sources

The local currency portion is to be covered by NCSR's own fund and/or grants from the Zambian governmental organizations such as Ministry of Higher Education. The foreign currency portion is to be covered by the long term loan with appropriate conditions. In this study, a long term loan with an interest rate of 3.0% p.a. is applied for the purpose of financial evaluation (See 16-2).

14.3 Summary of Total Capital Requirement

The total capital requirement for the case where the above financing sources are applied is summaried in Table 14-3-1.

Table 14-3-1 Total Capital Requirement

Items	Foreign Currency (Million Yen)	Local Currency (1000 Kwachas)
Plant Construction Cost	1506.9	6315.4
1. Land Aquistion	0.0	0.0
2. Machinery & Equipment	889.4	0.0
3. Material for Building	148.0	0.0
4. Transportation & Insurance	123.2	0.0
5. Engineering	171.9	0.0
6. Civil & Building	84.4	6100.0
7. Erection	0.0	215.4
8. Supervision	75.0	0.0
9. Commissioning	15.0	0.0
Pre-operation Expense	0.0	9.4
Initial Working Capital	0.0	5.0
Interest during Construction	15.9	0.0
Total	1522.8	6329.8

14.4 Plant Construction Cost

The plant construction cost consists of the following items.

(1) Land cost

The site in Namununga is assumed to be obtainable free of charge in exchange of the site in George Town which NCSR has already taken possession of.

(2) Machinery and equipment cost

Table 14-4-1 shows the cost of machinery and equipment for coal briquettes, clay stoves and auxiliary facilities. The price of machinery and equipment are calculated based on the assumption that they are procured entirely in Japan.

Table 14-4-1 Summary of Machinery & Equipment Expense

(Unit: Million Yen)

Type of Equipment	Machinery & Equipment Expense*
1. Coal Briquettes Process	423.0
2. Carbonization Process	245.0
3. Clay Stove Process	34.0
4. Electrical Facility	105.0
5. Transport System (Trucks)	32.4
6. Supplemental Equipment	26.0
7. Spare Parts	24.0
Total	889.4

* FOB Japan

(3) Material of building

The cost of imported material for building is allocated for this cost.

(4) Ocean freight and insurance

This cost covers the ocean freight and insurance cost for the above machinery, equipment and materials to be transported from Japan to the plant site via Dar es Salaam of Tanzania.

(5) Engineering fee

This is the cost for local survey works and plant design.

(6) Civil and building

This is the cost necessary for land preparation, foundation and concrete works.

(7) Plant erection

This is the cost for erection and assembly of plant equipment and facilities.

(8) Construction supervision fee

The supervisory works by the foreign engineers are necessary for plant construction. This cost is estimated to be 75 million yen (30 man-month).

(9) Comminssioning Fee

Commissioning fee is the expense that is required for the initiation and performance guarantee operation on the entire equipment when the plant is transferred to the plant owner after the mechanical completion of the plant by the contractor. The amount of 15 million yen of supervisiory cost (6 man-month) is estimated as the commissioning fee.

14.5 Pre-operation Cost

Pre-operation cost is the cost required until the commercial operation starts. The following costs required for the trial operation (1 month, 50% running rate) is counted as pre-operation cost.

. Labor cost for plant operation: 5,000K (6 man-month)
. Raw material and utility: 4,410K

14.6 Initial Working Capital

The initial working capital means the funds prepared for the continuation of daily operation on completion of plant, and usually includes the costs of spare-parts and raw materials. However, since the cost of spare-parts is included in the plant construction cost and the procurement of the raw materials is easy, the cash equivalent to one month's direct labor cost 5,000k is counted as initial working capital.

14.7 Interest During Construction

The interest during the plant construction is estimated based on the disbursment schedule. This study assumes, for the purpose of financial analysis, that 20% of the plant construction cost is paid 3 months after the award of contract, 30% 9 months after the contract, and the remaining 50% on completion of the plant construction (15 months).

Table 14-7-1 Expenditure Schedule of Total Capital Requirement

	1st time		2nd time		3rd time		Total	
	Foreign *	Local **	Foreign *	Local **	Foreign *	Local **	Foreign *	Local **
Plant Construction Cost	301.4	1263.1	452.1	1984.6	753.5	3157.7	1506.9	6315.4
Pre-operation Expense	0.0	0.0	0.0	0.0	0.0	9.4	0.0	9.4
Initial Working Capital	0.0	0.0	0.0	0.0	0.0	5.0	0.0	5.0
Interest during Construction	0.0	0.0	4.5	0.0	11.4	0.0	15.9	0.0
Total	301.4	1263.1	456.6	1984.6	764.8	3172.1	1522.8	6329.4

* Million Yen
** Thousand Kwachas

15. OPERATING EXPENSE

15.1 General

This chapter describes the costs and expenses necessary for the production of coal briquettes and clay stoves. The operating expense is divided into variable expense and fixed expense. The former covers the raw material costs (coal slurry, bagasse, molasses, clay and others) and utility costs (electricity and water). The latter is the cost which is not relating to the operating rate of plant, and it covers direct labor cost, maintenance cost, insurance cost and miscellaneous cost.

15.2 Variable Operating Expense

The variable operating expenses for the production of coal briquettes and clay stoves are summarized in Table 15-2-1. The annual raw material and utility costs are calculated on the assumption that annual production volume of coal briquettes and clay stoves are 1,000 tons and 4,000 pieces, respectively. The raw material costs such as coal slurry and bagasse are estimated on the basis of the transportation by trucks.

Table 15-2-1 Summary of Variable Operating Expenses

(Unit: Kwachas/year)

	Coal Briquett	Clay Stove
Coal Slurry	49,171	-
Bagasse	18,266	-
Molasses	6,143	-
Slaked Lime	12,337	-
Clay	-	1,562
Grog	-	4
Plaster	-	400
Electricity	19,086	3,875
Water	855	285
Total	105,858	6,126

15.2.1 Coal slurry

This project uses the coal slurry at the Maamba Collieries as principal raw material. The coal slurry is an unused waste resource and will be supplied at zero price at the Maamba Collieries. Accordingly, the price of coal slurry at the plant site is equal to the transportation cost including loading and unloading. At the standard condition the coal slurry required and its transportation cost are 1,214 tons and 49,171 K, respectively, to produce 1,000 tons of coal briquettes.

15.2.2 Bagasse

The excess bagasse piled at Nakambala Sugar Estate will be supplied at zero price. The price of bagasse at the plant site is also decided by the transportation cost. The bagasse required is 940 tons/year; and the transportation cost of bagasse from Nakambala to the plant site is 18,266 k/year as mentioned in Chapter 6.

15.2.3 Molasses

Molasses, which is used as binder of coal briquette, will be supplied by Nakambala Sugar Estate. At present, they sell molasses at a price of 40 k/ton and will supply to this project at the same price. The price of molasses at the plant site is calculated by adding the transportation cost to the above price. The following is the summary of cost for molasses:

. Unit price at Nakambara:	40 k/ton
. Annual consumption:	123 tons/year
. Purchase cost:	4,920 k/year
. Transportaion cost:	1,223 k/year
Total cost	6,143 k/year

15.2.4 Slaked lime

Slaked lime is an additive to coal briquettes to fix sulfur dioxide and is available in Lusaka at a price of 11k/25kg. The slaked lime required for the production of coal briquettes is 28 tons/year, and the transportation cost is 16.5 k/year. Accordingly, the annual cost is calculated to be 12,337 k/year.

15.2.5 Clay

The clay used as the principal raw material for clay stoves is available in Lusaka in sufficient amount at a price of 30 k/ton. The unit pirce of clay at the plant site is calculated to be 30.5 k/ton by adding the transportation cost, 0.5 k/ton, to the above price. The consumption of clay to produce the 4,000 pieces of clay stoves is estimated to be 51.2 tons.

15.2.6 Brick powder (Grog)

Grog, or powdered waste firebrick, is blended with clay to a ratio of 20 to 80 on dry basis. Waste firebricks are obtainable at zero price from cement plants or oil refinery or other factories at the time of turnarounds of their furnaces.

Accordingly, the cost of grog is the transportation cost which is assumed to be equal to that of clay. The grog required for the production of 4,000 pieces of clay stoves is 8 tons.

15.2.7 Plaster

Plaster used for making mould is available at a price of 2,500 k/ton. The required amount of plaster to make 4,000 pieces of clay stoves is estimated to be 160 kg.

15.2.8 Electricity

The electricity is supplied by Zambia Electric Supply Corporation (ZESCO) at a price of 0.0287 k/Kwh. The electricity required to produce 1,000 tons of coal briquettes and 4,000 pieces of clay stoves are 665,000 Kwh and 135,000 Kwh, respectively.

15.2.9 Water

The water consumption to produce 1,000 tons of coal briquettes and 4,000 pieces of clay stoves are 2,250 tons and 750 tons. The price of industrial water, as shown below, changes depending upon the consumption volume.

. less than 36 t/month	11.00 Kwachas/month
. 36 - 135 t/month	0.34 Kwachas/t
. 136 - 235 t/month	0.36 Kwachas/t
. 236 - 335 t/month	0.38 Kwachas/t
. 336 - 435 t/month	0.40 Kwachas/t
. more than 436 t/month	0.42 Kwachas/t