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STATE OF THE ART REPORT

ON

CHARCOAL PRODUCTION IN BRAZIL

Prepared by

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FORWARD

This report was prepared for the U.S. Department of Agriculture, Forest Service, Bioenergy Systems and Technology Project under contract No. 53-319K-0-141.

The report was prepared by Florestal Acesita, S.A. which is a subsidiary of a steel company - Cia, de Acos Especiais Itabira S.A. (ACESITA) which produces some 600,000 tons of special steel per year.

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Florestal Acesita - (FLORASA) supplies the steel plant with approximately 1.8 million cubic meter (450,000 tons) of charcoal per year of which approximately 60% is supplied from its own forest plantations of *Eucalyptus spp.* FLORASA has a Research and Development Program which involves research in the silviculture area, from seed production to forest management and in developing carbonization processes including by-products recovery. FLORASA has planted some 142,000 ha with *Eucalyptus spp*, in three locations: Jequitinhonha and Rio Doce Valley, (with 80,000 and 54,000 ha respectively), in the state of Minas Gerais and an area of 8,000 ha located in the state of Espirito Santo, near the coast. The parent company, ACESITA is owned by Banco do Brasil S.A., a Brazilian government bank, and employs some 7 thousand employees.

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INTRODUCTION

Due to the rising oil price and a growing risk of continued disturbances in oil supply, wood and charcoal have become a more important source of industrial energy in Brazil. The planting of forests for energy purposes is becoming competitive with other sources, especially for those countries which lack fossil fuels. Equally important, forest planting and charcoal production can be done utilizing a wide range of technology levels (from totally manual to highly mechanized) suitable to the economy and employment conditions of a given country. For under-developed countries, charcoal production, from man-made forests or from the woody material recovered from forest clearing for agricultural and cattle raising purposes, can be of great help in creating employment in rural areas and for a low level of investment.

Brazil, for many decades, had produced charcoal for use in the iron and steel industry. About 5 million tons are produced per year from native and planted forests. Brazil has approximately 4 million hectares of manmade forests for use as firewood, charcoal, pulp and paper, and lumber. At the end of the 70's wood and charcoal became an important alternative for fuel, and many industries other than the steel industry, have been planning their substitution for fuel oil. This trend has been increasing in recent years. This paper on the Brazilian charcoal experience was prepared for the United States Department of Agriculture - Forest Service (USDA-FS) and the U.S. Agency for International Development (USAID), Office of Energy.

Chapter 1 introduces the reader to the general role of charcoal in Brazil primarily as a thermo-reductant in the iron and steel industry. Charcoal's role has become more prominent over the last decade due to rising coke prices. This trend has made charcoal more competitive for pig iron and steel production and increased its importance as a thermo-reductant.

An even more fundamental change has occurred as a result of the world-wide increase in petroleum prices which has had a large and damaging impact on Brazil's trade situation. Not only has higher cost of petroleum imports been primarily responsible for the large increase in Brazil foreign debt, it has also changed the nature of imports to Brazil. In 1972 petroleum accounted for less than 9% of total imports while capital goods accounted for 41%. The 1980 petroleum accounted for 41% and capital goods only 19%. Today the share of petroleum has risen to almost 50%.

Despite many initiatives in the energy sector, Brazil's policy of highly subsidized fuel oil prices effectively excluded charcoal and fuelwood from playing any significant role in substituting for imported oil. This subsidy was based primarily on the belief that industry would not respond to higher fuel oil prices by increasing the efficiency of energy use. In late 1979 and 1980 the government's policy changed and fuel oil prices were increased to approximately the world market level. This opened the perspective of economically viable substitution of fuel oil with fuelwood and charcoal and for which there has been considerable recent activity. As chapter 1

suggests this activity is likely to vary from region to region. The impetus towards fuel oil substitution is the crucial reason behind the elaboration of this work, though much of the technical and economic analysis is likely to be of interest to countries regardless of whether their goal is fuel oil substitution or not.

Chapter 2 traces the historical development of charcoal production, the resource base and projections of use during the next decade. Most charcoal is produced from and clearing of native forests for agriculture, and despite considerable reforestation, the use of wood from native forests will persist for some time. Very little, however, is known about the availability of this resource and its scale, but available evidence suggests that the government's target of about 120,000 barrel/day substitution of fuel oil by 1985/86 will not be constrained by the physical lack of supply. By the end of the decade charcoal (or fuelwood) from planted forest should begin to predominate. This, however, will depend on a favorable evolution of the rate of planting. The chapter ends with a brief discussion of methods of financing reforestation in Brazil.

Chapter 3 presents, in some detail, the technologies used to grow trees and to convert the wood to charcoal and to grow the wood. It begins with a description of the basic pyrolysis process, the characterization of the products and the issue of quality control before turning to current production techniques to grow the trees. Virtually all the charcoal produced in Brazil today, from either native or planted forest, uses some version of a brick beehive kiln.

Several designs and their operation are described. These kilns have an energy efficiency, of about 53% in terms of amount of wood into the kiln and the charcoal produced. In plantations, if we consider all the plantation wood produced per hectare (including material now left in the field), this efficiency falls to about 42%. Work in progress suggests that this could be increased to about 66% with relatively low cost adaptations to use some residues; measures to reduce contamination of fines with dirt, recuperation of insoluable tar; and the addition of a combustion chamber under the kiln. Efficiencies of up to 72% can be achieved by using continuous carbonization processes and by the recovery of methanol, acetic acid, soluble and insoluble tars along with use of forest residues and charcoal fines.

The section on reforestation techniques focuses on Eucalyptus, which is the only genus planted for charcoal production, and describes step by step the state-of-the-art of species selection, seed and seedling production, land clearing, planting, and plantation management. The discussion of denser spacings and fertilizer treatments is likely to be of special interest to readers. Reforestation technology in Brazil, is directed to increasing yields per hectare. It is estimated that the productivity of new plantations has been increasing by at least 5 to 6% per year over the past 7 or 8 years. A comparable rate of increase in productivity can, in principle, be maintained over the next decade.

Chapter 4 presents the economics of charcoal production with the state-of-the-art technology for both native and planted forests. For

plantations various topographies and levels of mechanization are evaluated. For the benefit of our readers from other countries, the analyses have been broken down systematically into terms of physical inputs (man-days, hours of equipment, time, etc.) for each operation. This hopefully will help translate the economic results to other countries where unit costs are different. However, it is still not possible to mechanically translate the results to other regions, since (for example) yields of wood per unit input may differ substantially.

Even if wood or charcoal costs are less per unit of energy to (produce and transport) compared to fuel oil, it is necessary to consider the relatively higher costs to the final consumer which are generally associated with their use. Chapter 5 adds this element to the analyses using the costs of delivered charcoal and wood taken from chapter 4. While there are a number of ways to substitute wood fuel for petroleum products in other industries, only two were analyzed. The first case involves various levels of charcoal substitution in the production of clinker for cement manufacturing. The second case assumes a choice between the installation of new, medium-sized boilers using oil, coal, charcoal and wood. Retrofitting of existing boilers for charcoal or fuelwood use, a potentially interesting analysis was not considered. The results of the analyses are generally favorable at today's fuel oil prices for both wood and charcoal. One interesting point is that nonsubsidized domestic coal is not cheaper than wood or charcoal from either the native or planted forests. This is due in part to the costs of transporting the coal over long distances. The results, it must be emphasized, are preliminary and only with more site specific analysis would it be possible to conclude whether a consumer should use wood instead of charcoal. It is clear however, that a program to substitute fuelwood or charcoal is qualitatively different in its competitiveness with oil prices than, say, the National Alcohol Program. While the former shows total costs approximately equal to or less than the derivatives being substituted, the cost of producing alcohol is at least 50% higher than the cost of gasoline which is substituted.

Chapter 6 provides a panoramic view of the Brazilian charcoal based iron and steel industry. Its organization and some of its fundamental technical characteristics are discussed. Included are some technical coefficients for different production levels. This is done to introduce the reader to charcoal based iron and steel economics, shown in Chapter 7. It is interesting to note that, among the alternatives to produce pig iron and steel, those using charcoal result in the lowest production costs in Brazil. Of course it is difficult to provide an economic analyses in general terms because of the wide variety of hypotheses, such as location, processes, selected technology, future-development forecasts, capital cost, etc. Brazil is a country which lacks good quality metallurgical coal which is the reason that 83% of the thermo-reductant is imported from other countries.

Chapter 8 looks at the social impact of charcoal development with concerntration on the issue of employment. Permanent direct employment per unit of output is estimated for production from native forests and for three levels of forest plantations. The investment required is also considered,

and for the plantation forest, the employment per hundred hectares is typical for areas of the cerrado, the savannah region in the interior of Brazil.

Employment and income generation in many rural areas are very important objectives in Brazil. As such it may be valid to shadow price labor at a price lower than the market, as the World Bank did for the northeast region in its appraisal of a loan for the Brazil alcohol program. The chapter carries out a calculation to roughly illustrate the impact which such a shadow price for labor can have on the economics of wood and charcoal relative to fuel oil, and also the impact it can have on the selection of technologies for fuelwood or charcoal production. Other factors which might be shadow-priced, such as foreign exchange, were not considered.

Considerable discussion arises when considering the environmental impact of reforestation projects and in terms of potential danger there are three basic criticisms: soil impoverishment by the exhaustion of nutrients, watertable depletion and impact on wildlife habitat. Chapter nine presents some results of research on these subjects, comparing Eucalyptus with other agriculture monocultures.

1. WOOD CHARCOAL IN BRAZIL

1.1 INTRODUCTION

The oil crisis has had an impact on the Brazilian economy, with its price increases from 1973 on, and difficulties, already serious during the industrial development period (1968-1973) became even worse. Brazil's economic growth, became more limited from 1974 on, as oil costs caused a negative balance in the Nation's foreign trade. From 1974 to 1977, Brazilian imports were kept at a US $12 - billion level, but the constant increase of oil prices caused a rapid decline of other items, such as primary materials and capital goods. Table 1.1 shows the impact on capital goods from 1971 to 1980. Prime materials decreased from 41% to 26% of total imports from 1974 to 1977. Capital-goods meanwhile, were kept at a constant 3.5 billion-dollar level, restricting growth in the secondary sector, which partially depends on the import of capital goods.

In an attempt to decrease oil imports measures were adopted in 1975 from the National Alcohol Plan to the "so-called risk contracts" to explore for oil in Brazilian territory. This met with limited success. From 1977 the alcohol program did result in a supply of ethanol to be mixed with gasoline.

As the foreign-trade balance worsened and there was greater instability in the supply and the price of oil, the pressure on demand increased after 1978-79, leading to a constant raising of prices. Gasoline, with its price increases were much higher than those of other oil derivitives, which were used to subsidize them.

In 1979 an attempt was made to establish an energy policy which would bring forth the potential of all available resources, including those previously undeveloped. The following basic guidelines were defined for the Nation's strategy in attempting to reach energy autonomy:

* an increase in national oil production.

* implementing a policy of energy conservation.

* maximum utilization of national energy sources to substitute for oil, with diversification, and minimum transportation usage.

Alternative sources then became part of the elaboration of our energy projections. High among such alternative sources was the utilization of charcoal which, thanks to the iron and steel industry, has always been used in Brazil. Historically charcoal use in Brazil went through the entire period when oil was cheap and even survived the competition of a modern coke-based steel complex. The charcoal-based steel industry updated itself, with its own technology, and charcoal has now become one of the accepted solutions to Brazil's energy crisis.

1.2 MAGNITUDE OF CHARCOAL USE IN BRAZIL'S STEEL INDUSTRY

Charcoal has a prominent place in the country's production of pig iron. The Brazilian steel industry was originally charcoal-based and gradually

TABLE 1.I - BRAZILIAN IMPORTS (FOB)

YEAR	TOTAL IMPORTS US$ MILLIONS	PETROLEUM % OF IMPORTS	CAPITAL GOODS MACHINERY AND EQUIPAMENTS % OF IMPORTS
1971	3247	8.6	-
1972	4232	8.7	41.0
1973	6192	10.4	34.1
1974	12641	21.1	24.6
1975	12210	22.9	32.2
1976	12383	28.1	28.7
1977	12023	30.4	25.6
1978	13683	29.9	26.0
1979	18084	34.7	20.9
1980	22961	40.8	19.1

SOURCE - SUMA ECONÔMICA, July 1981.

gave way to imported coal. Table 1.II shows the evolution of pig iro production in the 70's, using coke as well as charcoal. For such production, there was an annual consumption rate of charcoal as shown in Table 1.III.

In 1979 almost all charcoal (83%) was produced from the exploitation of native forests, most of which came from forest clearing operations for agriculture expansion. That can be seen on Table 1.III if one analyzes the difference between charcoal purchased and consumed by integrated steelworks, which approximates the charcoal coming from Eucalyptus forests. If one considers the average density of 250 kg of charcoal per cubic meter, than the Brazilian iron and steel industry consummed close to 3.9 millions tons in 1979.

1.3 THE POSITION OF CHARCOAL IN BRAZIL'S ENERGY PLAN

Table 1.IV shows an overall view of the evolution of the consumption of primary energy from 1969 to 1979. One thing that stands out is the trend towards oil and away from wood. By 1979, wood is no longer the main energy source, either for home use or for medium-size industries.

There has also been a trend towards a greater utilization of the country's hydro electric potential, although the ever-greater distances between sites of production and consumption requires more investments and thus restricts somewhat the applications of electric power.

As for charcoal, there has been a slight increase in its share of the market, brought about mainly by the expansion of the independent pig-iron complex until 1973 and, from then, by the expansion in integrated steelworks. The charcoal consumption curve swings downward again, after 1976, due to the rise of coke (80% of which is imported) in the nation's large coke-based iron and steel works.

Charcoal production in 1979 was equivalent to nearly 3 million tons of oil, or 59,000 barrels per day. The use of the product was concentrated in the state of Minas Gerais and this region the energy balance is substantially different from the national average; charcoal represented approximately 19% of the total consumption of primary energy (Table 1.V).

Table I.IV also shows the impact of local solutions to supply of primary energy. For the first time, the use of forests for energy purposes was recognized as being very relevant. Such recognition led to the creation of an Inter-Cabinet Task Force on Charcoal, a group which published a "Program for the Development and Rational Use of Wood and its By-products". Its recommendations are now being discussed by those in charge of elaborating the Federal Government's action plans.

TABLE 1.II - PIG IRON PRODUCTION (1) - X 1.000 t

Pig Iron	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Using Coke	2,327	2,499	2,759	2,827	2,639	3,423	4,141	5,537	6,199	7,282
Using Charcoal*	1,878	2,187	2,540	2,706	3,157	3,630	4,029	3,843	3,844	4,312
TOTAL	4,205	4,686	5,299	5,533	5,846	7,053	8,140	9,380	10,043	11,594
% Participation of charcoal	44.6	46.7	47.9	48.9	54.0	51.5	49.4	41.0	38.3	37.2

* Pig iron from eletric reduction furnace using charcoal included

SOURCE: IBS - Instituto Brasileiro de Siderurgia

TABLE 1.III- CHARCOAL CONSUMPTION (1) X 1.000 m^3

Year	IRON AND STEEL INDUSTRY *		Estimated Consumption From Independent Producers **
	Purchased in Domestic Market	Consumption	
1972	5,105	5,591	3,317
1973	5,385	5,802	3,688
1974	6,095	5,998	5,040
1975	6,297	7,001	6,192
1976	5,955	6,143	7,717
1977	5,834	6,785	6,772
1978	5,232	6,333	7,069
1979	6,173	7,430	7,988

* Only integrated steelworks, producing steel and/or cast tubs

** Companies producing only pig iron

SOURCE: IBS

TABLE 1.IV - BRAZILIAN ENERGY CONSUMPTION

YEARS	PETROLEUM		NATURAL GAS		ALCOHOL		OIL SHALE		HYDROELECTRICITY		COAL		WOOD		SUGAR CANE BAGASSE		CHARCOAL		NUCLEAR		TOTAL
	1.000 t	%	1.000 t	%	1.000 t	%	1.000 t	%	1.000t	%	1.000 t	%	1.000 t	%	1.000 t	%	1.000 t	%	1.000 t	%	1.000 t
1969	21.673	38,5	96	0,2	27	0,0	-	-	9.481	16,8	2.342	4,2	18.999	33,7	2.520	4,5	1.191	2,1	-	-	56.329
1970	22.814	37,8	104	0,2	155	0,3	-	-	11.494	19,1	2.391	4,0	18.809	31,2	3.030	5,0	1.484	2,4	-	-	60.281
1971	25.716	39,9	140	0,2	213	0,3	-	-	12.444	19,3	2.431	3,8	18.862	29,2	3.037	4,7	1.655	2,6	-	-	64.498
1972	28.206	40,9	166	0,2	328	0,5	-	-	14.632	21,2	2.491	3,6	17.661	[illegible]	3.542	5,1	1.978	2,9	-	-	69.000
1973	33.682	43,8	178	0,2	260	0,3	-	-	16.716	21,8	2.493	3,2	17.429	[illegible]	[illegible].993	5,2	2.091	2,8	-	-	[illegible]
1974	36.363	43,6	339	0,4	160	0,2	-	-	18.982	22,7	2.469	3,0	18.541	22,2	3.989	4,8	2.636	3,1	-	-	83.459
1975	38.603	43,5	369	0,4	136	0,2	-	-	20.898	23,3	2.850	3,2	19.328	21,8	3.597	4,1	2.897	3,3	-	-	88.[illegible]
1976	42.114	42,9	367	0,4	144	0,1	-	-	23.954	24,4	3.435	3,5	21.294	21,7	4.095	4,1	2.870	2,9	-	-	98.273
1977	42.705	41,3	492	0,5	537	0,5	-	-	26.997	26,1	4.106	4,0	20.885	20,2	5.157	5,0	2.561	2,4	-	-	103.440
1978	45.862	41,4	483	0,5	1.266	1,2	-	-	29.796	26,9	4.781	4,3	20.676	18,7	5.243	4,7	2.559	2,3	-	-	110.666
1979	47.975	40,7	498	0,4	1.876	1,6	-	-	33.379	28,3	5.123	4,3	20.469	17,4	5.489	4,7	2.976	2,6	-	-	117.785

NOTE: Figures are for tons of Petroleum Equivalent

SOURCE: Brazilian Energy Balance - Ministry of Mines and Energy

BEST AVAILABLE

TABLE 1.V - MINAS GERAIS - ENERGY BALANCE 1978

Petroleum	35,2 %
Eletric	24,6 %
Wood	11,5 %
Charcoal	18,9 %
Coal	9,8 %
Energy Consumption at Iron and Steel Industry	23,1 % of the total

SOURCE: CETEC - Fundação Tecnológica de Minas Gerais

2. CHARCOAL SOURCES IN BRAZIL

2.1 HISTORICAL ASPECTS

In pre-Columbian times (prior to the year 1500) the original inhabitants of the country lived in forest areas, on which most of them depended on to meet all their food and living needs; fruits, wood for heating and cooking, hunting and fishing, etc. Some other tribes developed agricultural activities, with the result that, little by little, forest destruction took place; land was cleared of trees with the use of wooden and stone tools and the remaining wood was burned. Because these tribes were made up of a small number of individuals, the woodland was not cleared on an impressive scale. Each piece of cleared land was cultivated for a period of four consecutive years, (as dictated by its soil fertility) after which the land was left to self-regeneration (1).

With the coming of European settlers to Brazil, the country's economic activity was to undergo deep changes which, in turn, would bring about a marked modification in the community-forest resource relationship. The distinct sets of activities affecting forest resources are readily identifiable:

- Forest harvesting activities for export purposes.

- Cattle raising and agricultural activities, creating demand for land.

As far as the harvesting activity was concerned, the extraction of "Pau-Brasil" (Caesalpinia echinata) for export purposes was the first historical example, on their their virtual extinction or, at least, their depletion as commercially valuable wood. "Pinho do Parana" (Araucaria angustifolia), "Jacaranda da Bahia" (Dalbergia nigra), and other species are examples for this century.

In terms of the agricultural and/or cattle raising activities, the forests have been regarded as an obstacle and not as an economically valuable resource deserving sustained exploitation. Forest areas are destroyed, wood of high commercial value is marketed, and the remaining woody material is disposed of by burning.

Considering the foregoing historical background, forestry activity as a systematic economic activity with a long-term perspective is really a development of this century. Depletion of the country's forest resources throughout the years was mainly for the enlargement of agricultural frontiers.

2.2 PRODUCTION OF CHARCOAL FOR THE IRON AND STEEL INDUSTRY

Charcoal production arises as a secondary activity to agriculture and/or livestock. As soon as the woody material is felled, the farmer is faced

with a delemma: either to burn it or sell it as charcoal for energy purposes. Most of the time they burn the wood because the decision to produce charcoal, even temporarily, involves investments and demands to meet the requirements of a forest code. An even more important deterrent is the fluctuation of an unstable charcoal market with which the farmers are not familiar.

It is a mistake to believe that the need for firewood and the manufacturing of charcoal for the steel industry has historically been the reason for the forest depletion that has occurred in Brazil. If one takes into account:

- All the charcoal production for the charcoal-based steel industry in Brazil since the end of the XVI century, is, roughly - 60 x 10^7 tons;

- An average production of charcoal per hectare is on the order of $70m^3$;

- An average consumption of $4m^3$ of charcoal per ton of pig iron, that is, the accumulated consumption of 240 x $10^6 m^3$ of charcoal;

- And, finally, disregarding the natural regeneration which would normally occur in essentially a forest activity.

It can be observed that the areas which have been deforested for use by the steel industry, 3,43 x 10^6 ha, would only amount to an area 5% of the size of the state of Minas Gerais.(2)

Of the present Brazilian pig iron production, 1[illegible] x 10^6 tons, 40% is based on charcoal and of that over 90% comes from the state of Minas Gerais. Anticipated Brazilian production of pig iron from charcoal for the next decade should evolve as shown in Table 2.I and is based on the following assumptions:

- The participation of charcoal to pig iron production relative to total domestic output remain at 40% based on the forecasted production growth for Minas Gerais, Mato Grosso do Sul and Para/Maranhao (Carajas Project);

- The new projects envisaged by the steel industry must be self-sufficient in charcoal from plantation forests.

- The existing iron and steel plants attain self-sufficiency in charcoal by 1990.

2.2.1 CHARCOAL PRODUCTION POTENTIAL FROM NATIVE FOREST - MINAS GERAIS

In the preparation of this report we have used estimates contained in a recent report on the potential for charcoal production in Minas Gerais (3). This report consists of forest inventories carried out in the State of Minas Gerais, based on aerial photographs made in 1964-66, and updated by field studies conducted in 1977-78. Some 336,196 km^2 of this state land has now been covered. The area not covered by the above-mentioned

TABLE 2.I - CHARCOAL BASED PIG IRON PRODUCTION - BRASIL - 1981 - 1990

YEAR	PIG IRON PRODUCTION 10^3t	CHARCOAL CONSUMPTION			
		NATIVE 10^3t	EUCALYPTUS 10^3t	TOTAL	
				10^3t	10^3PEt*
81	5.080	2.961	1.143	4.104	2.581
82	5.394	2.819	1.564	4.383	2.757
83	5.755	1.993	2.386	4.379	2.754
84	6.050	1.758	2.852	4.610	2.899
85	6.360	2.238	2.607	4.845	3.047
86	7.024	1.933	3.286	5.219	3.282
87	7.608	1.442	4.180	5.622	3.536
88	8.390	963	5.220	6.183	3.889
89	9.151	480	6.237	6.717	4.224
90	10.245	-	7.499	7.499	4.716

* PEt - PETROLEUM EQUIVALENT TON

SOURCE: ABRACAVE - CHARCOAL BRAZILIAN ASSOSSIATION - 1980

report (146,595 km^2) relates to those regions not producing charcoal (northern and southern regions and the western part of Minas Gerais, the so-called "Triangulo Mineiro"). In addition, of the charcoal-producing area 20% has been left out, that being the Jequitinhonha Valley, the Mucury Valley and the southern part of the Metallurgical Zone.

For the areas under observation, a characterization of vegetation types is important to the production of charcoal by providing an estimate of their average productivity and life cycle (Table 2.II). An analysis of aerial photographs made it possible to conduct a preliminary survey of the areas available for the production of charcoal. Field studies further updated the information previously obtained and helped to chart those areas effectively (Table 2.III). A more detailed survey is dependent on new aerial photo data. Based on the figures appearing in the tables, it was concluded that the State of Minas Gerais charcoal production potential for charcoal production, assuming a sustained management practice is 10×10^6 m^3/year equal to 1.57×10^6 tons of petroleum equivalent (TPE) per year (Table 2.IV).

2.2.2 CHARCOAL PRODUCTION FROM PLANTED FOREST

The establishment of man-made plantation forests has been intensified since 1967, when the federal government launched its fiscal incentive policy. Part of the planting is geared to the iron and steel sector, part to the pulp and paper industry and a third part oriented to the wood products industry. There are also other plantations with outputs suitable for various uses. For our purpose, we are solely concerned with those plantations geared to the iron and steel industry (Table 2.V) and particularly with those to be used in the production of charcoal.

It is only natural to expect, that after more than 25 years, the planting of forests should have resulted in very diverse practices, as far as spacing, planting techniques, amount of yield and so on are concerned. It is not possible to provide accurate information on such items as the extent of successful forest development to the present, percentage of dead trees and the like. These factors are likely to reduce the availability of wood below nominal estimates. On the other hand, some of the plantings not directly related to the iron and steel industry will have some other energy purpose.

The regional distribution of these plantation (Table 2.VI) shows the concentration of almost all the planting for charcoal in Minais Gerais. Planting explicitly designated for charcoal for the iron and steel sector accounts for only 19.9% of the total forest planting to date. The pulp and paper industry accounts for another 18.3% and the remaining 61.8% of the plantings are designated as being for "other purposes". The vast majority of this in fact has no explicit purpose. Some of these large areas may be available for fuelwood/charcoal production.

New forest plantations must be established, at a higher rate than in the past, if expansion of the charcoal-based iron and steel sector is to occur and if existing plants are to reach self-sufficiency by 1990 (Table 2.VII).

TABLE 2.II - WOOD PRODUCTION OF SOME BRAZILIAN VEGETAL FORMATIONS GROUPS.

VEGETAL FORMATION TYPE	MEAN PRODUCTIVITY st/ha	ROTATION (YEARS)
"Cerrado" Group:		
Small "Cerrado"	15	15
"Cerrado"	40	20
Big "Cerrado"	80	25
Forest Group		
Small "Capoeira"	50	15
"Capoeira"	110	20
Big "Capoeira"	130	25
Forest	250	25

SOURCE: CETEC - 1978

TABLE 2.III- AREAS OF DIFERENT VEGETAL FORMATION TYPES IN THE CARBONIZATION ZONE OF MINAS GERAIS - BRAZIL.

VEGETAL FORMATION TYPES	AREA, Km^2		
	1964	1976/78	Percentual variation
Small "cerrado"	38.196	32.844	- 14,00
"Cerrado"	28.562	26.073	- 8,72
Big "Cerrado"	23.803	19.023	- 20,10
Small "Capoeira"	32.967	26.402	- 19,91
"Capoeira"	13.532	13.849	+ 2,29
Big "Capoeira"	10.446	8.087	- 22,58
Native Forest	2.360	2.188	- 7,29
"Jaiba" Forest	4.180	3.880	- 7,18
Others	182.150	203.850	+ 10,65

SOURCE: CETEC - 1978

TABLE 2.IV- CHARCOAL PRODUCTION POTENTIAL OF MINAS GERAIS STATE - BRAZIL

VEGETAL FORMATION TYPER	AVAILABLE AREA FOR CHARCOAL (ha) (1)	ROTATION (YEARS)	ANNUAL CUTTING AREA(ha)	PRODUCTIVITY st/ha	WOOD ANNUAL PRODUCTION	CHARCOAL(2) ANNUAL PRODUCTION
Small"cerrado"	2.956.000	15	197.070	15	2.956	896
"cerrado"	2.216.200	20	110.810	40	4.432	1.343
Big "cerrado	1.617.000	25	64.680	80	5.174	1.725
Small "capoeira"	2.112.700	15	140.850	50	7.042	2.608
"capoeira"	1.107.900	20	55.390	110	6.094	2.257
Big "capoeira"	647.000	25	25.880	130	3.364	1.246
Native Forest	-	25	-	250	-	-
"Jaiba" Forest	-	25	-	200	-	-
Others	-	-	-	-	-	-
TOTAL	10.656.800	-	594.680	-	29.062	10.075

SOURCE: CETEC - 1978

NOTE (1) - Area indicated at table 4.III decreased by 15, 20 or 100% according to the vegetal formation type, for preservation.

NOTE (2) - Conversion wood/charcoal index variable: 2.7 - 3.0 and 3.3 st/m^3 according to the vegetal formation type.

TABLE 2.V - EUCALYPTUS FORESTS FOR CHARCOAL BRAZIL - 1980

YEAR	PLANTED AREAS PER YEAR 10^3 ha
until 1966	74.6
1967	7.7
1968	8.3
1969	18.5
1970	20.4
1971	21.8
1972	22.8
1973	29.1
1974	40.9
1975	53.9
1976	82.6
1977	99.8
1978	101.8
1979	72.0
1980	62.0
TOTAL	715.9

SOURCE: ABRACAVE - IBDF - M.A. - Diagnosis of the Forestal Production sub-system.

TABLE 2.VI -EUCALYPTUS FORESTS - BRAZIL 1978 - DISTRIBUTION

BRAZILIAN STATES	IRON & STEEL INDUSTRY		PULP AND PAPER		OTHERS		TOTAL AREA
	TOTAL	%	TOTAL	%	TOTAL	%	
Bahia	5,8	1,0			76.1	4.2	81.9
Federal District	-	-			15.4	0.9	15.4
Espirito Santo	11.6	2,0	97,9	18,3	20.3	1.1	129.8
Goiás	-	-			41.6	2.3	41.6
Mato Grosso do Sul	-	-			337.6	18.7	337.6
Minas Gerais	564.5	97.0	51.9	10.3	340.0	18.9	959.4
Paraná	-	-	123.4	23.0	317.5	17.6	440.9
Rio Grande do Sul	-	-	35.4	6,6	80.0	4.4	115.4
Rio de Janeiro	-	-	5.5	1.0	6.0	0.3	11.5
Santa Catarina	-	-	98.6	18.5	161.4	9.0	260.0
São Paulo	-	-	119.4	22.3	404.8	22.6	524.2
TOTAL	581,9	100.0	535.1	100.0	1800,7	100.0	2.917,7
	19.9	-	18,3	-	61.8	-	100,0

SOURCE: ANFPC, ABRACAVE/IBS - STI/MIC

TABLE 2.VII - EUCALYPTUS PLANTING PROGRAM FOR IRON & STEEL INDUSTRY 1981 - 1990

YEAR	AREA (1.000 ha)
1981	79
1982	72
1983	114
1984	171
1985	317
1986	260
1987	218
1988	254
1989	228
1990	59
TOTAL	1.772

SOURCE: ABRACAVE

2.3 REPLACING FUEL OIL WITH CHARCOAL

2.3.1 PRODUCTION OF CHARCOAL FROM NATIVE FORESTS - BRAZIL

Although a sustainable program of fuel oil substitution with wood or charcoal in Brazil must depend on an adequate level of planting, over the next few years any significant increase must come largely from native forest. This is particularly true for the existing targets established for 1985. Energy forests planted now will only begin to produce a substantial amount of fuelwood or charcoal later in the decade.

Estimating the impact of this substitution on overall wood demand and exploitation of native forest is complicated by:

a - the statistical difficulties, common to most countries with a large traditional fuelwood demand, in estimating overall demand;

b - difficulties in estimating the growth rates and standing biomass of native forests and the rate of harvest or clearing of these forests;

c - the tentativeness of any estimate to distinguish demand for direct use of fuelwood from charcoal use.

Present targets for fuel oil substitution in Brazil by 1985 are in the vicinity of 120,000 barrels per day. Estimates for five major consuming industries suggests that a total of 31 million tons (56 million cubic meters) of wood (dry basis) would be required to supply this level of substitution (Table 2.VIII). This is equivalent to about 17% of the total wood consumption estimated for 1985 (Table 2.IX - with industrial fuelwood added).

A crucial variable in the supply/demand balance is the extent to which fuelwood can be recovered from forest clearing as the pasture land and crop land expands. The current estimated rate of deforestation is almost 4 million hectares per year. Present wood supply estimates for Brazil outside of the northern (or Amazonian) region suggest that only 45.6 million cubic meters (4) are or can be used from this forest clearing, which is currently estimated to generate about 200 million cubic meters of wood each year. (Amazonia alone generates another 193 million cubic meters).

More complete use of wood from logging areas and sustainable management of existing native forest (as discussed earlier for Minas Gerais) may also contribute to supply, though probably on a smaller scale.

Any conclusions regarding the ability of native forest to supply the additional amounts of wood implied in the short-term by the targets of the governments (about 55 million cubic meters), must be tentative. It is clear that the physical capacity exists to produce this amount without increased deforestation. The problems however are economic, institutional and logistical. Projections today are still not strong and the literature

TABLE 2.VIII - ESTIMATE (1979 VINTAGE) OF OIL SUBSTITUTION POTENTIAL IN FIVE INDUSTRIES IN 1985

INDUSTRY	OIL CONSUMED	OIL ASSUMED TO BE SUBSTITUTED (1000 t)	CHARCOAL CONSUMED (1000 t)	WOOD EQUIV. OF CHARCOAL (1000 t)	DIRECT USE OF WOOD (1000 t)	TOTAL (1000 t)
Paper and Pulp	1,900	1,330	-	-	5,590	5,590
Cement	4,210	2,275	3,290	13,160	-	13,160
Ceramic	1,500	750	800	3,200	1,000	4,200
Food Processing	2,100	1,005	1,100	4,400	1,300	5,700
Textile	1,100	550	400	1,600	800	2,400
TOTAL	10,800	5.910	5,590	22,360	8,690	31,050

SOURCE: POOLE, Alan [4]

TABLE 2.IX - PROJECTION OF DEMAND FOR WOOD BY REGION AND PRODUCT
(MILLIONS OF CUBIC METERS OF ROUNDWOOD EQUIVALENT)

	NORTHEAST		SOUTHEAST		SOUTH		CENTRAL-WEST		BRAZIL	
	1980	1985	1980	1985	1980	1985	1980	1985	1980	1985
Firewood (traditional)	61.7	62.8	45.9	46.7	24.8	26.1	10.2	11.3	149.9	154.7
Charcoal	-	-	39.0	44.8	-	0.3	-	-	39.0	45.1
Sawnwood	2.4	3.3	12.5	17.3	3.6	5 1	0.9	1.3	19.9	27.6
Laminated Products	0.2	0.3	2.0	3.1	0.5	0.8	0.1	0.2	2.9	4.4
Particleboard	0.1	0.1	1.0	1.6	0.2	0.3	-	0.1	1.3	2.1
Fibreboard	0.1	0.1	0.7	1.1	0.2	0.3	-	0.1	1.1	1.6
Pulp-Short Fibre	0.4	0.5	3.1	4.6	0.8	1.1	0.2	0.3	4.4	6.7
Long Fibre	0.5	0.6	2.2	3.0	0.7	0.9	0.2	0.2	3.6	4.9
Newsprint	0.4	0.5	1.2	1.6	0.4	0.5	0.1	0.2	2.1	2.8
Writing Paper	0.4	0.5	2.8	4.0	0.7	1.0	0.2	0.2	4.0	6.0
Packaging	0.7	1.0	4.2	6.1	1.1	1.7	0.3	0.4	6.5	9.3
Industrial Paper	0.2	0.4	2.8	4.5	0.6	1.0	0.1	0.2	3.9	6.1
Other Industrial Wrap	0.5	0.7	3.3	4.8	0.9	1.3	0.2	0.3	5.1	7.3
Total	67.6	71.0	120.7	143.2	34.5	40.4	12.5	14.8	243.7	278.6
Subtotals										
Industrial Wood	5.9	8.2	35.8	51.7	9.7	14.0	2.3	3.5	54.8	78.8
Fuelwood	61.7	62.8	84.9	91.5	24.8	26.4	10.2	11.3	188.9	199.8

NOTE: Excludes wood for industrial fuel oil substitution which at 0.55 ton per m^3 is 56 million cubic meters.
SOURCE: POOLE, Alan [4]

indicates much contradiction. This uncertainty may in fact inhibit development of charcoal and fuelwood use in the industry, especially if an aggressive planting program is not followed. Beyond this point, however, it is probably of limited interest to other countries to dwell on complicated numerical speculations of the future which are in fact entirely specific to Brazil.

2.3.2 PLANTED FORESTS

An acceleration in planting explicitly for energy forests has been proposed by the Ministry of Agriculture (though it has not been implemented). The original proposal called for planting 300,000 ha in 1981 with a 10% increase each year thereafter. This would mean a production of about 9 million cubic meters of charcoal by 1990 (equivalent to about 30,000 b/d tons) from about 8 million tons (dry) of wood. The Ministry of Agriculture's plan is shown in Table 2.X.

In addition to this there are other resources from planted forests which may be available before the new plantationsreach harvest age. These includes residues from the harvest of roundwood in planted forest. These residues need not be restricted to Eucalyptus plantations for charcoal, but could include plantations in Pinus, etc. There is one estimate that the gross quantity of such residues would reach about 5 million tons (dry) of wood by 1985 (5). Use of such residues was not considered in the past because the charcoal produced was of too small a dimension to be used in blast furnaces. It is conceivable that wood residue recovery could also begin with small independent producers from native forest.

A final possible resource is the large area of existing plantations which do not have a specific market and are not as yet included as a potential resource for charcoal or fuelwood. Such plantations account for 62% of the area planted up to 1978. Their utilization will depend on market conditions for charcoal and other alternatives.

Considering various factors it seems likely that a considerable expansion of charcoal production can take place in the next few years. While this expansion may not reach the ambitious levels established by the government, this hardly detracts from the significance of the growth of this resource.

2.4 BRAZILIAN INCENTIVES POLICY FOR REFORESTATION

2.4.1 HISTORICAL BACKGROUND

The interest in forest products began just after 1500 when the first Portuguese settlers came to Brazil. At that time brazilwood (Pau Brazil) was extracted from native forests and exported as raw material for the dye industry. The "Brazilwood Regulation", passed in 1605, was the first attempt to curb predatory deforestation; since then there has been continuous government action geared to protection of natural forests and their rational and economic utilization. By 1934, all previous federal regulations were organized under the Brazilian Forest Code, which prevailed until 1965 when the enactment of law no 4.771 established a new and revised code.

TABLE 2.X - PROPOSAL FROM BRAZILIAN AGRICULTURE DEPARTMENT FOR EUCALYPTUS PLANTATIONS - 1981 - 1990

YEAR	AREA (10^3 ha)
1981	300
1982	330
1983	363
1984	399
1985	439
1986	481
1987	-
1988	-
1989	-
1990	-
TOTAL	2.312

After 1965 the federal government set up the Brazilian Institute of Forest Development (IBDF) and passed new laws enforcing wood and charcoal consumers to carry out reforestation programs. In addition to this regulation the government also established a tax incentive policy to stimulate the implementation of reforestation projects.

Most of the Brazilian man-made forests were planted as a result of this policy but, now, the government is partially substituting the tax-incentive policy by special credit lines. At the present stage of development, the forest activity in Brazil is believed to be sufficiently profitable to sustain its own expansion with less government intervention.

2.4.2 GOVERNMENT REGULATION AND CONTROL

Large natural forests in Brazil were depleted as a result of destruction by fires which wer set by farmers and cattle raisers in order to clear the ground to grow crops and expand their pasture lands. With the installation of charcoal based steel mills part of the woody material could be used as an important raw material in the steel making process.

To regulate and control the forest activity the Brazilian Forest Code and complementary legislation established procedures and obligations to be followed by consumers. The main features of these regulations are as follows:

- Since 1965 all charcoal consumers are obliged to plant eight trees for each m^3 of consumed charcoal and wood consumers must also plant four trees for each m^3 of consumed wood.

- All wood and charcoal consuming industries must be 50% self-sufficient by 1985 and 100% self-sufficient by 1995 in their supply of wood from man-made forests.

- In order to preserve the indigenous tree species and native vegetation, 20% of the original forest must be maintained and can not be cleared.

  One percent of a reforestation project must be planted with native tree species.

2.4.3 FISCAL INCENTIVES FOR REFORESTATION

The Government soon recognized that large amounts of investments would be required for the consuming industries to carry out the legal obligation of forest renewal. The solution to this question was provided by the tax-incentive policy which allowed any company to deduct part of its income tax to invest in reforestation projects. Thus, the investor (in fact, a tax-payer) may put his money into his own reforestation project or, if he is not engaged in the forest activity, he may choose any other project to invest in.

The financial resources from the income tax are managed by the Sectorial Investment Fund (FISET) which lays out the investors funds on the selected project. The investor can deduct the following figures from his income tax.

- 25% of the income tax to invest on projects to be implanted in the North and Northeast regions.

- 17.5% of the income tax to invest on projects to be implanted in other Brazilian regions.

In general, many investors take part in financing one project. However, the reforestation project with tax incentives must be managed and implemented by a forest company registered in the Brazilian Institute of Forest Development. This company is held responsible for managing the project during its whole production cycle, including the wood harvesting and selling; the profits will be distributed among the investors according to their share of the business.

The government in fact gives up part of the income tax resources, giving the tax-payer the opportunity of taking part in a business which should provide him profits and the return of his investment. But most investors are not directly involved in the forest activity and are not interested in taking risks; so, they prefer to have the guarantee of receiving their money back after a certain period of time of participating in the business. On the other hand, the company in charge of managing the project may be a charcoal or wood consuming industry interested in the wood utilization. In this case, a common practice is for the company to simply refund to the other investors after a fixed period of time, paying their original investments and the corresponding monetary correction with no return on investments. Of course, this is an inexpensive form of financing its project.

With present restrictions on the tax-incentive policy, however, wood and charcoal consuming companies will have to rely more on loans granted by federal and state development banks to finance their projects, at higher financial costs.

2.5 REFERENCES

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3. REFORESTATION AND CHARCOAL PRODUCTION IN BRAZIL

3.1 REFORESTATION

3.1.1 INTRODUCTION

The formation of man-made forest with exotic species began around 1900 in Brazil, with the pioneering work of Edmundo Navarro de Andrade. The first research projects were started with an attempt to identify rapid-growing native species which would yield a large volume of wood per hectare to supply the demand of the Sao Paulo State Railway Company, both for railroad ties as well as fueling the locomotives.

Frustrating experiments with native species led attention to exotic species - and from the start great attention was given to the Eucalyptus sps, originally from Australia and - to a lesser extent - from the Phillipines, Indonesia and New Guinea.

Its productive capacity, resistance to disease and to insects, and adaptability all have made Eucalyptus the main objective of the on-going reforestion program in Brazil. About 4 million hectares are presently reforested in Brazil, approximately half of it planted with Eucalyptus species and the rest with various Pinus species.

Fifteen years after the Forest Code was enacted, Brazil now benefits from great increase in its reforestation activity, mainly in large plantations, which reaches a yearly rate of 400,000 hectares.

Incentives in the form of tax (or fiscal) incentives were created in the 60's to benefit the forestry sector. Through such a mechanism, the Federal Government attempted to make the Brazilian businessman more conscious of the importance of forests to the Nation's economy. There was a rush to plant great forest stands. By the end of the 70's, a new process set in, with more emphasis to forestry research. New techniques of qualitative improvement began to be employed, as well as ecologically-stronger species with improved seeds; the system of forest management was changed; the harvesting cycle was reduced, etc. This chapter presents a panoramic view of Eucalyptus silviculture in Brazil.

3.1.2 FOREST ESTABLISHMENT

Forest establishment is a process consisting of a series of operational steps which ranges from the selection of land to the actual planting.

3.1.2.1 Choice of the Area

Ecological as well as economic zoning criteria have been established in Brazil. On the economic side, regions are grouped according to whether they meet certain conditions which will allow the formation of large forest

stands for future industrial use. Such areas are called Forest Districts. They must be served by a good road system, electric power, water, and so forth. On the ecological side, Brazil was divided into 26 bio-climatic regions, according to the types of climate, altitude, topography, vegetation, annual average temperature and rainfall, frosts and water deficiencies, types of soil, etc, (1).

This double-pronged economic and ecologic zoning is the basis for the selection of areas. The greater part of reforestation is located in the Southern-central region of Brazil.

3.1.2.2 Choice of Species

Most of the initial Eucalyptus planting involved basically two species, Eucalyptus grandis and Eucalyptus saligna. This was due to limited knowledge of other species and to the fact that these two species were easily manageable both in the nursery and in the field. In addition their seeds were readily available and they show marked adaptability and productivity. Other species were used to a lesser extent, such as Eucalyptus paniculata, Eucalyptus citriodora, Eucalyptus tereticomis, Eucalyptus microcorys, Eucalyptus alba (a Rio Claro hybrid), etc.

Research has led to the use of other species. This has been made possible by the introduction of new species and provenances to study specific technological characteristics for the utilization of wood as an energy source. The Project for Development and Forest Research (Projeto de Desenvolvimento e Pesquisa Florestal - PRODEPEF), a joint project between the Brazilian Government through its Brazilian Institute for Forest Development (Instituto Brasileiro de Desenvolvimento Florestal - IBDF) and FAO - Food and Agriculture Organization - made possible, during the period 1974-78 the introduction of new Eucalyptus species and provenances.

This PRODEPEF program had as its goal the testing of species and provenances, according to ecological zoning. Thus, 400 provenances of 45 species were introduced in the South-Central area of Brazil foremost among them being Eucalyptus grandis, Eucalyptus urophyl and Eucalyptus tereticornis. In the savanna regions, on the other hand, Eucalyptus camaldulensis, Eucalyptus propingua, Eucalyptus pilularis and Eucalyptus cloeziana were also planted (2).

A conclusion drawn from these experiments was that climatic factors were more decisive and relevant than the soil characteristics in species selection. Climate has a bearing on the plants' aptitude towards a certain ecologic condition, while soil influences mainly production. Thus, the results shown in Tables 3.I would be 2 or 3 times greater if they were from a woodland region.

The different behavior of species and provenances according to the edaphic-climatic characteristics, which are the result of the genotype-phenotype interaction shows the importance of a proper choice not only of species, but also the geographic origin of the seed.

TABLE 3.1 - PRODUCTIVITY OF 10 ESPECIES OF EUCALYPTUS IN "CERRADO" SOIL - AGE: 5 YEARS - JEQUITINHONHA VALLEY - BRAZIL

	SPECIE	HEIGHT (m)	DIAMETER (cm)	VOLUME (m^3/ha)
1	E. pilularis	15.25	13.72	187.92
2	E. grandis	16.01	12.87	173.60
3	E. pilularis	15.40	12.34	153.51
4	E. cloeziana	12.08	12.38	121.20
5	E. propinqua	13.55	11.52	110.38
6	E. saligna	12.85	10.33	89.76
7	E. exerta	10.81	10.97	85.16
8	E. tereticornis	11.11	10.37	78.21
9	E. exerta	9.97	10.83	76.55
10	E. urophylla	11.44	9.87	72.94

SOURCE: NASCIMENTO FILHO E MAGALHÃES [3]

Another factor determining selection of species is the proposed utilization of the material. Specifically regarding wood for charcoal production, an important characteristic is wood density, which varies among species, location, age, and growth rate. Wood density displays a high correlation to charcoal density as shown in item 3.2.3.3.

As regards species, some FLORASA studies have shown that species such as E. grandis and E. saligna, although among those most widely planted, are in the low-density group, between 0.4 and 0.5 gr/cm^3. Species such as E. robusta, E. tereticornis and E. camaldulensis are among the medium-density species. In the high density group we find E. citriodora, E. cloeziana, E. maculata, E. paniculata, etc., having a density of around 0.600 gr/cm^3.

Ecologi conditions greatly influence density, since there is a close correlation with growth rate. A faster growth rate is matched by lower densities, and so a species planted in two different locations will at the same given age, have two different density values. As an example, see Table 3.II. The age of a tree stand is another factor which influences density, in a given condition. Studies in a population of E. urophylla, E. grandis, and E. saligna (ages from 2 to 9 years) have shown that density has a linear relationship to age.

In summary species selection demands that all variables previously mentioned be taken into account, so as to take the best advantage, both qualitatively and quantitatively, of the soil.

3.1.2.3 Supply of Seeds

Brazilian silviculture faces as one of its great problems today the supply of quality-proven seeds. It is one of the problems accounting for low-yield plantations. The Nation's present capacity for producing Eucalyptus seeds only meets approximately 20% of the national demand. Imports, mostly from South Africa and Zimbabwe, round out the supply. Brazil will be self-sufficient in forest seeds within the next five years and, may then become an exporter.

The National Commission for Forest Seeds has been intensifying the granting of authorization to companies which already have tree stands to widen their operation into seed-producing areas. But these companies must show proven technical standards, so as to better insure quality control. Moreover, the Brazilian Institute for Forestry Development (IBDF) has granted special incentives to those companies making use of national seeds from production areas which are already officially registered and on file. Current national production of Eucalyptus seeds is shown in Table 3.III.

3.1.2.4 Production of Seedlings

Several factors interact in order that a tree plantation may show a good performance. Some of these factors are: species, fertilization, crop-tending, and so on. Individually, a single factor does not mean much; it is the interaction of all factors that is important. But even though

TABLE 3.II - WOOD SPECIFIC GRAVITY VARIATION WITH TWO DIFFERENT PLANTING LOCAL

SPECIES	LOCAL A	LOCAL B (*)
E. urophylla	0.528	0.546
E. saligna	0.454	0.545
E. grandis	0.490	0.527
E. propinqua	0.538	0.628

SOURCE: FERREIRA [4]

(*) Local with lower productivity

such interaction is dependant, its basic success rests with the nursery stage. Badly-formed seedlings result in non-productive plantations unresponsive to fertilization and to crop-tending. In other words, such seedlings may spell financial disaster.

When forestry started in Brazil, the production of seedlings was handled as in horticulture. Seeds were planted in spear-made holes in beds and, sometime after germination, were transplanted to containers. "Torrao Paulista" was long used for packing, which consisted of a mixture of clay and organic material.

The planting of large forest stands led to the creation of new nursery techniques. The stands' large dimensions called for new containers, new seeding methods, irrigation systems, management, etc. The most common seedling container used today is the polyethylene bag measuring: height = 15 cm; diameter = 11 cm; plastic thickness = 0.05 cm. Subsoil mixed with a certain amount of fertilizer (which varies from region to region) and is used in the container. Florestal Acesita does not presently mix fertilizer with the soil. Rather, fertilizer is applied through the irrigation water, and that allows for a better control of seedling growth, even to the point of hastening or delaying it, as called for by the planting schedule. A drawback in using plastic bags is that they must be totally removed for planting, otherwise the roots end up tangled.

In seeding, which generally occurs 120 days before planting, 3 or 4 seeds are placed in each polyethylene container. A special seeding device, holding from 100 to 150 grams of seeds, is used for species whose seeds are very small and are known as microsperms - such as E. grandis, E. saligna, E. tereticornis, E. cloeziana.

On the other hand, macrosperms such as E. citriodora, E. maculata, E. torelliana have such large seeds that two are placed directly in each container, with no need for the special seeding device.

After seeding, the seed is covered by a thin layer of earth and another of rice husks or grass clippings so that the surface may be protected against direct sunshine and moisture loss.

Nursery management comprises control of irrigation, disease, insects and weeds, thinning and selection. When the plants are approximately 4 cm tall, thinning takes place.

The most common disease is damping-off, caused by the cilindrocaldium, Rhizoctoma, Botritis, Pythium, and Fusarium fungi. Diseases and insects occur less often in temporary nurseries (1 to 3 years) than in permanent nurseries. As for insects, attention should be called to lagarta rosca (Agrothis ipsilon). Treatment for diseases is preventative, but for insects treatment occur when they are encountered. Quality criteria for seedling selection for planting is as follows:

TABLE 3.III - BRAZILIAN EUCALYPTUS SEEDS PRODUCTION CAPACITY - 1981

SPECIE	AREA (ha)	PRODUCTION(kg/year)
E. grandis	115,0	1457
E. saligna	183,6	1230
E. urophylla	36,4	265
E. citriodora	8,1	80
E. paniculata	10,4	80
E. viminalis	215,3	200
TOTAL	568,8	3322

SOURCE: MIC/STI [5]

a - Size = 20 to 25 cm.

b - Disease free appearance.

c - Normal nutritional appearance, which means that nutritionally-deficient seedlings are either left in the nursery or are eliminated.

d - A normal radicular root system, with no tendency towards root tangling.

e - No sign of bifurcation.

f - Sufficiently mature.

An alternative to the classic, seed-seedling process, is a new production technique recently introduced in Brazil. It consists of rooting leaf cuttings from selected trees. This results in excellent productivity since only superior trees are used.

This rooting technique is quite simple, but does require special conditions. Greenhouses which are built to avoid direct sunlight are screened structures erected to filter and evenly distribute sunlight. The screen also serves as protection against hail and heavy summer rainstorms, and to reduce the impact of both winds and temperature.

Such a technique has been successful along the Brazilian seacoast, where environmental conditions are extremely favorable. The ideal temperature is around 24°C and the relative humidity in the green-house has to be maintained at around 100°C. This demands installation of an automatic water mist system. The demand for these special conditions has hampered the expansion of this technique to other areas in Brazil, where the average winter temperature is low. To overcome such drawbacks, several experiments are now under way, in an attempt to arrive at a heating system coupled with biological stimulants that may improve the rate at which cuttings successfully root. In these difficult regions, the survival of rooted cuttings is around 40-50%; in the seacoast it reaches 70% without stimulants. Seedling fertilization, protection and selection all follow the same pattern as the traditional process.

3.1.2.5 Spacing

Up to the end of the past decade, the formation of man-made forests in Brazil followed traditional systems, with standard spacing. Until 1967, plantings with a company's own resources, specially those of iron and steel companies, had a 2.0 x 2.0 m spacing, with three cuttings at seven year intervals. Later, as fiscal incentives were granted and fertilizers were used, spacing was increased to 3.0 x 2.0 m. This system persisted until very recently, when a 3.0 x 1.5 m spacing was initiated. FLORASA experiments have shown that this latter spacing is superior to the former by some 25% (Table 3.IV).

Spacing, which has a direct influence on the rotation age, is decided by the eventual utilization of the wood. In denser plantings, a greater

competition for light and nutrients will set in sooner than in plantings with a wider spacing (less plants per-unit area), so that these trees may be harvested at an older age than the former.

On-going research for charcoal production shows that wood from younger, smaller size trees yield a product with better physical and mechanical characteristics.

In defining spacing, other factors must also be taken into account, such as species, edaphic-climatic characteristics, silvicultural practices, and so on.

Experimental work has shown that tree diameter is greatly influenced by spacing and ultimately, will be reflected in the total volume of wood per hectare.

Experiments have also shown, for instance, that species behavior differs, in terms of competition for water, light and nutrients. Such competition may reach such a level that, in a stand, the stronger trees at a certain age may eliminate others. Greater or lesser spacing determine when self-thinning begins and its level is important to genetic improvement. In the case of heterogeneous material, a number of dominant trees will eliminate the others during self-thinning (See Table 3.V).

As mentioned, the rotation age depends upon spacing. The greater the spacing, the more advanced the age for harvesting without any stagnation in volume. Figure 3.VI shows a decrease in the survival rate in E. grandis stand in a 2-to-10-year period with 2.80 x 2.80 m spacing.

On-going tests at FLORASA have demonstrated that, in addition to the area-per plant, the arrangement of the spacing is also fundamental to the development and survival at a given age. A test has been made in which 5 spacing models were established, ranging from a symmetric one where trees receive light evenly to a grouping of 2 and 4 trees in a row or alternated between rows.

At the age of 16 months (Table 3.VIII), it may be observed that survival has been influenced by area per plant, and that both survival and area/per plant increase. The results already observed are partial and will be altered because of age; nevertheless a model interaction of spacing vs. area/plant can already be seen.

A profound change has been taking place since 1980 in the technical parameters guiding the formation of short rotation forests, for the generation of energy wood, either used directly as firewood or as charcoal. Such change should bring about a reduction in rotation age and, consequently, of spacing. Within this framework, FLORASA had pilot-plantings done in 1980, in 2.0 x 1.0 m and 1.5 x 1.0 m spacings. This was done on flatland as well as in mountain country and data is being evaluated to decide the rotation cycle.

The increase in number of trees-per-hectare implies a higher cost for forest-stand establishment due to more fertilizer, more seedlings and more labor. On the other hand, the cutting cycle will be reduced from 7 to 3 or

TABLE 3.IV - PRODUCTION VARIATION OF E. SALIGNA WITH TREE SPACING "CERRADO" SOIL OF JEQUITINHONHA VALLEY - AGE: 64 MONTHS

SPACING (m)	HEIGHT (m)	DIAMETER (cm)	VOLUME (m^3/ha)	ANNUAL MEAN INCREMENT (m^3/ha/year)
3.0 x 1.5	14.17	11.1	129.28	24.94
3.0 x 2.0	13.50	11.6	103.23	19.36
2.5 x 2.5	13.12	10.9	84.70	15.88
3.0 x 2.5	13.02	12.2	86.95	16.30
3.0 x 2.8	13.33	12.6	82.97	15.56
3.0 x 3.0	12.60	12.4	72.91	13.68
3.0 x 3.5	12.40	12.2	61.34	11.50
3.0 x 4.0	12.48	12.6	57.14	10.71
4.0 x 4.0	11.94	13.2	43.99	8.71

SOURCE: NASCIMENTO FILHO E MAGALHÃES (6)

TABLE 3.V - PERCENTAGE OF DOMINATED TREES IN FUNCTION OF TREE SPACING AND AGE

SPACING (m)	AGE (YEARS)		
	4	6	9
3.0 x 1.5	31	45	57
3.0 x 2.0	31	37	43
3.0 x 2.5	13	22	38
3.0 x 3.75	21	25	35

SOURCE: BALLONI et alii (7)

TABLE 3.VI - VARIATION OF % OF DEAD TREES IN FUNCTION OF AGE. E. GRANDIS, TREE SPACING 2.8 x 2.8 m

AGE		DEAD TREES	VOLUME
YEARS	MONTHS	(%)	(m^3/ha)
2	3	1.9	4.4
2	9	1.9	8.1
4	4	2.6	22.7
5	5	3.6	39.9
6	6	5.6	57.2
7	16	13.4*	70.1
9	1	10.6	94.7
10	4	25.0	109.8

SOURCE: BALLONI et alii (7)

* During the seventh year the rainfall was exceptionally low.

5 years, and there will be more cuts - from 3 up to 4, 5 or 6. Another test is being conducted, with observations every 3 months, in an attempt to arrive at the optimum rotation age, as it relates to spacing. This is an experimental planting, and it is hoped that a productivity curve will be developed. Table 3.VII details this experiment and its results are summarized in Tables 3.VIII and 3.IX. Such results are from the first 18 months, and some tendencies can be detected in the behavior of E. grandis. This planting was made in low-fertility savanna soils, with 1,000 mm annual rainfall and an annual average temperature around 18°C.

Although results are preliminary, they do show that reduced harvesting ages correspond to greater plant-density per hectare. A decrease of current increment - a sure sign of stagnation - is already taking place in the 0.5 m x 0.5 m plantings. All spacing-related tests in the Company, show that short-rotation plantings (3 to 4 years) display an optimum area-per-plant of 2.0m^2 independently of spatial distribution, and that is equivalent to 5,000 plants per hectare.

What limits the adoption of short spacing in flat land is that it would hamper the utilization of machinery for cultivation and exploitation, both of which are manually done in hilly country. Among viable alternatives for reconciling spacing to short-rotation cycles, and maintaining mechanical upkeep and exploitation is that of aisle spacing, specifically the 3.0 x 1.0 x 1.0 variety, which may well catch on in the future. In this spacing, plants are found in two rows, 1 m and 3 m apart between each strip (aisle) of two rows, with a 5.000-plant-per-hectare population. Upkeeping takes place between the aisles, the same place through which the wood will be eventually harvested and removed.

In addition to this non-conventional spacing, FLORASA's commercial plantings in 1979 and 1980 were in 3.0 x 1.5 m spacing, with two seedlings per container. Such a system allows the number of plants per hectare to be doubled, at no additional cost and no need for replanting. In practice, not all holes have two trees, only about 70% of them.

3.1.2.6 Soil Preparation

Forest productivity results from an interaction of genotype and the environment. Possible changes in environment will be dealt with here, and refer to type of preparation, levels of and seasons for fertilization. Soil preparation ranges from forest-clearing to the digging of ditches and holes, and it varies according to local characteristics, that is, texture, topography, etc.

Forest Clearing

Land clearing, or the removal of vegetation, is done either manually or mechanically, according to topography and vegetation. This is necessary so that later operations may take place either that include removing existing wood, hole-digging, planting and, later, land cultivation.

When forest clearing is done through mechanical means, it is common for most companies to use an embanking process, that is, residues are pushed

TABLE 3.VII - FLORESTAL ACESITA SPACING TRIALS SPECIFICATION - E. GRANDIS, 18 MONTHS

	TREE SPACING (m)	Nº TREES/ha	FERTILIZATION g/SEEDLING	OBSERVATION
1	0.5 x 0.5	23,800	14	Bands of 3 m
2	1.0 x 1.0	10,000	33.4	
3	1.0 x 1.0	6,800	49	Bands of 3 m
4	1.5 x 1.0	6,667	50	
5	1.5 x 1.5	8,888	75	Two seedlings per bag
6	3.0 x 1.5	4,444	150	Two seedlings per bag

SOURCE: NASCIMENTO FILHO E MAGALHÃES (6)

NOTE: Fertilizer application per hectare was constant

TABLE 3.VIII - FIGURES UP TO 18th MONTH OF FLORESTAL ACESITA SPACING TRIALS, E.GRANDIS, JEQUITINHONHA VALLEY

AGE MONTHS	TREE SPACING ACCORDING TABLE 3.VII																	
	1			2			3			4			5			6		
	% DEAD TREES	HEIGHT (m)	DIAMETER (cm)	% DEAD TREES	HEIGHT (m)	DIAMETER (cm)	% DEAD TREES	HEIGHT (m)	DIAMETER (cm)	% DEAD TREES	HEIGHT (m)	DIAMETER (cm)	% DEAD TREES	HEIGHT (m)	DIAMETER (cm)	% DEAD TREES	HEIGHT (m)	DIAMETER (cm)
6	7.37	2.26	-	5.80	1.35	-	5.71	1.38	-	1.60	0.94	-	3.00	1.39	-	5.40	1.25	-
9	7.37	3.57	1.80	5.80	2.51	1.80	5.71	2.53	1.80	1.60	2.08	1.40	3.00	2.66	1.90	5.40	2.21	1.70
12	9.13	4.53	2.10	6.20	3.76	2.30	5.71	3.78	2.30	2.40	3.38	2.20	3.00	4.17	2.80	6.80	3.76	2.80
15	9.13	5.82	2.60	6.20	5.10	3.10	5.71	4.79	3.30	2.40	4.82	3.10	3.00	5.16	3.20	6.80	5.13	3.70
18	14.20	6.30	2.70	8.80	6.06	3.50	6.80	5.92	3.60	3.20	5.93	3.70	7.00	4.40	6.80	6.80	6.81	5.00

TABLE 3.IX - PRODUCTIVITY UP TO 18th MONTH OF FLORESTAL ACESITA SPACING TRIALS, E. GRANDIS, JEQUITINHONHA VALLEY

PRODUCTIVITY (m^3/ha)

TREE SPACING	9th MONTH	12th MONTH	15th MONTH	18th MONTH
1	20.06	33.89	65.21	71.53
2	6.22	14.67	37.08	52.90
3	4.22	10.08	26.44	38.83
4	2.25	8.35	24.15	41.14
5	3.39	11.07	26.65	46.32
6	0.99	4.46	15.92	28.02

aside in rows, allowed to dry and then burned. This is not, however, an advisable procedure and FLORASA has abandoned it, because of negative effects on the growth of stands. The cuase is an unbalance in the top layer of soil. Currently, after felling using large chains, all the woody material is cut and removed, and that eliminates the so-called ash-bed effect.

Plowing and Disking

The conventional operations in soil preparation for planting are: plowing, disking, and opening of furrows. Ongoing experiments show a positive interaction between tree growth and the extent of soil preparation. The positive effect of plowing and disking is tied to the efficiency of incorporating organic residues, since in almost all Brazilian soils (specially "cerrado") most nutrients and organic matter are found in the surface horizon.

Although experimental results so far are only partial, they do show the advantage of plowing the entire area followed by subsoiling, especially if there are layers of subsurface impediments. Given this characteristic, good results have been achieved in soil treatment through subsoiling, followed by disking with a special bedding harrow which aggregates the top soil.

3.1.2.7 Fertilization

Although fertilization is a factor in productivity, it was not introduced into Brazilian silviculture until 1960. The early and prevailing notion was that Eucalyptus demanded very little in terms of natural soil fertility, being sensitive only to the soil's physical and mechanical conditions. As availability of land and topography brought forestry to the new frontier of "cerrado" soil, the almost non-existence of natural fertility in had to be faced. From then on, problems did arise in connection with low stand productivity, resulting in part from the lack of nutrients, especially phosphorus.

Until recently, the mineral fertilization of Eucalyptus was based mainly on an almost standardized usage of NPK, the edapho-climatic conditions of each region notwithstanding. The growing number of fertilizers is forcing a change in experiments, since the level of fertilization which yields maximum production seldom is the same level which yields maximum economic savings. The most widely used NPK formula in Brazil is 10-28-6 + boron, zinc, and copper, at a rate of 80 to 100 grams per planting hole. Experiments have now led FLORASA to make use of the 5-30-10-+B formula.

Apart from whichever formula may be best and what fertilization levels may be called for, it can be said in general terms that the positive effects of fertilization are undeniable. Experiments have shown that fertilized areas are 50 to 70% more productive than non-fertilized areas. The first macro-element, in order of importance, is phosphorus (P). If it is

lacking, and even though nitrogen (N) and potassium (K) may be present, production is significantly reduced. Potassium ranks in second place and nitrogen third. Some results are shown in Table 3.X.

Phosphorus-based treatments showed no significant statistical differences among themselves. The P-80g level led to no increase in production, compared to P of 40 g. There is no significant evidence of the effect of N application. When growth is checked, in terms of height, it can be seen that the maximum level of N-32g had no influence. As for K, its behavior was slightly superior to N, but without any statistical significance.

Several trials have been made on fertilizer application, in an attempt to find the best season and location. No meaningful differences appear in terms of methods of application. Those most commonly used is application in the planting hole or furrow at the time of planting, or on the soil surface beside the seedling no later than 30 days after planting. Each company has its own system, some using equipment for ditch-digging and fertilization simultaneously, others distributing the fertilizer by hand, in which case the fertilizer is placed in each hole at planting or on the soil beside the seedling. Topography and/or climatic conditions may also lead to these variations. When planting takes place in the dry weather season with irrigation in each hole, fertilization occurs only after the plant has been thoroughly settled, so that no physiological changes may alter the newly-planted seedlings.

In addition to the macronutrients, 3 mironutrients are added, copper, boron and zinc. Recent experiments have led to a decreasing use of copper and zinc, leaving only boron. It has an important physiological function and its deficiency is associated with seedling die-back.

As a consequence of these experimental results it appears that the mineral element of foremost importance for Eucalyptus is phosphorus. The significance of this is increased by the nearly total lack of phosphorus in most Brazilian soils, especially the red-yellow latosoils in the "cerrado" regions. Tests have begun, at Florestal Acesita, on the use of natural sources of phosphate.

Because Eucalyptus culture differs substantially from farming crops and with its long-duration cycle and because phosphatic rocks are abundantly available in the state of Minas Gerais, testing has begun with phosphatic rock types in the state. These are listed below, along with their respective total P_2O_5 contents:

Sources of Phosphate	Total P_2O_5 content
Rock phosphate from Patos de Minas	24.16
Rock phosphate from Araxa	36.53
Rock phosphate from Tapira	77.14
Rock phosphate from Catalao	37.25

TABLE 3.X - WOOD VOLUME PER ha, E.SALIGNA, 52 MONTHS, "CERRADO" SOIL AT JEQUITINHONHA VALLEY, EXPERMENT ON FERTILIZATION

FERTILIZATION g/SEEDLING			m^3/ha	m^3/ha.year
N	P	K		
16	40	32	88.77	20.50
32	40	16	81.47	18.82
16	40	16	77.83	17.98
16	80	16	75.78	17.50
16	40	16	70.28	16.23
16	20	16	64.88	14.99
-	40	16	64.37	14.87
16	40	16	63.38	14.64
16	40	-	58.39	13.49
16	-	16	32.51	7.51
-	-	-	17.88	4.13

SOURCE: FLORESTAL ACESITA (8)

Among those natural sources of phosphorus, araxa phosphate has yielded the best results this far and FLORASA routinely applies 1,000 kg per hectare before planting, incorporating it to the soil during grading. In hilly regions, this application is made in the planting holes, at a rate of 200 gr per plant. So far, available results for "cerrado" soils on a commercial scale are positive, as shown in Table 3.XI.

Natural phosphates also serve as a source of calcium, as can be seen in Table 3.XII.

3.1.3 FOREST PROTECTION

Forest Protection comprises a wide set of activities, ranging from controlling diseases and insects (especially ants) to a clearing process which attempts to keep the land free of competitive vegetation, and to preventing fires.

3.1.3.1 Fighting and Controlling Insects

a) Ants

Eucalyptus in Brazil is plagued mainly by leaf-cutting ants such as Atta and Acrominex, popularly known in Brazil as "suava" and "quenquem" ants. There are 3 basic methods for fighting ants:

- Grain bait whose active principle is Dodecaclorum:

This is the method generally employed during the dry-weather season. Ten grams of the commercial product are used per square meter of ant-hill. Efficiency can be as high as 97%, however, its average centers around 70%.

It is an easy-to-apply method, at a low-cost-per-area unit, without any danger to humans. On the negative side, it cannot be used during the rainy season, its efficiency is decreased in areas of abundant undergrowth, and it may be harmful to wildlife.

- Thermonebulization

It is a mechanized system, whereby a heavy-spray machine pumps the chemical product directly into the ant-hill.

Lethal action begins 3 to 4 hours after application, stopping an activity almost instantly. Its efficiency reaches nearly 100% and it can be used year-round. The average dosage is 5 ml per square meter. Its advantages are:

- it may be used year-round;
- there is no need for previous ant-hill preparation;
- there is no need to calculate dosage;

TABLE 3.XI - SOIL PREPARATION WITH 1 t/ha OF NATURAL PHOSPHATE ROCK - "CERRADO", JEQUITINHONHA VALLEY

HEIGHT (m)	DIAMETER (cm)	MEAN ANNUAL INCREMENT (m^3/ha/year)	FERTILIZATION
10.50	8.70	20.59	NPK
10.89	8.80	24.23	NPK + Natural Phosphate rock

SOURCE: FLORASA

NOTE: The NPK level is the same in both tests. Thus the second test with natural phosphate rock has a higher total rate of phosphate application.

TABLE 3.XII - PARTIAL COMPOSITION OF PHOSPHATE ROCKS FROM DIFFERENT MINES

CALCIUM SOURCE	SOLUBLE CaO (%)	SOLUBLE MgO (%)
Araxá Phosphate	30.8	0.7
Patos Phosphate	21.3	0.2
Tapira Phosphate	45.0	0.3

- low consumption of formicide;

- low cost per square-meter;

Its disadvantages are:

- transportation is difficult for the operator (working-man) since it is a heavy machine.

- the operator must be familiar with the machine.

- special safety precautions must be taken.

- high operational cost in areas of low ant incidence.

- Methyl Bromide

It complements both previous methods, especially during the planting season due to its immediate lethal action. If properly used, it may be 100% effective. Its average dosage is 3 cubic centimeters per square meter, and it may be used in all seasons and during any kind of weather.

It has, however, serious drawbacks, chief among them is its high cost, the need for previous ant-hill preparation (which largely accounts for the high cost), and the special safety precautions that must be taken. Reaction to intoxication is irreversible.

Generally speaking, fighting and controlling ants follows these steps: Each group has a leader, in charge of distributing tools and products. He also gives the appropriate instructions and supervises the work, specifying in special forms, which are filled out monthly, the area of work and the time spent. Work procedure is as follows: soon after land clearing, grain baits are used and/or thermonebulization. This takes place in the dry season (June to August). After plowing, the same procedure is repeated. A third step occurs during planting, but only Methyl bromide is then used.

After planting, a permanent-watch system is set up in the area, and a work team checks the same area repeatedly during the forest cycle.

When sprouting takes places, usually 20 days after cut, care is intensified and the workers are constantly on the look-out, for the Acrominex ant.

(b) Leaf-Eating Insects

Other plagues have been identified, but their level of incidence and the degree of harm they cause is small. Lepidoptera should be mentioned. They have been exhaustively researched since 1975 and approximately 30 species have been found. The following have been identified: (9)

- o Autonieris sp
- o Catoria sp
- o Eupseudosoma imoluta
- o Euselasia euploea eucerus
- o Glena sp

- o Hylesia sp
- o Lanonia sp
- o Megolopyge sp
- o Mimalho amilia
- o Nystalea myseus
- o Olcedostera nina
- o Oxydia sp
- o Phoebtron sp
- o Sabuloides caberata
- o Sarsina violacens
- o Thyrinteina arnobia
- o Thyrinteina leucocera

No chemical products are used to fight them off, because they are in a state of balance with their natural enemies. Their highest levels of incidence occur in cold weather, but once the temperature begins to rise balance is restored.

(c) Termites

In Brazil denominated by "cupins" they may cause problems, mainly during forest establishment. These insects attack the young seedlings eating the bark at the soil level, causing death. The control is done using chemicals such as "Aldrin".

3.1.3.2 Diseases and/or Physiological Alterations

(a) Canker

Among diseases found in Eucalyptus stands, some mention should be made of the fungus Cryphonectria cubensis (Bruner fungus). It currently is of the greatest economic importance, and was discovered in 1965 (10).

It is geographically distributed from the southern state of Sao Paulo all the way up to the Amazon region. Critical areas are the Rio Doce Valley in the state of Minas Gerais and the seashore of Espirito Santo state, both due to their high relative humidity and temperature.

This disease attacks plantations ranging from the seedling stage to mature trees. The former undergo a yellowing process and die from drying up. In older plantations, the tree barks shows local depression, and death may also occur.

The only control over such disease is the planting of resistant species. Studies have pointed out E. maculata, E. saligna, E. alba (Rio Claro), E. grandis, E. propinqua and E. tereticornis, as susceptible to it. On the other hand, E. cloeziana, E. microcorys, E. paniculata, E. robusta, and E. citriodora are fairly resistant to the disease, and both E. torelliana as well as E. urophylla are highly resistant to it.

Harmful effects increase after the third year and that is why the rotation ages are between 3 and 4 years.

(b) Trunk Darkening ("pau-preto")

A resin flowing outside through cracks in branches and in the bark causes a darkening of the trunk. Some experts claim that the disease starts out with an attack by insects. It is also suggested that it is a defense mechanism on the plant's part against a fungus attack.

So far, there have been no detailed studies in Brazil concerning the disease. It occurs predominantly in *E. grandis*, reaching, in extreme cases, up to 40% of a tree stand.

(c) Die-Back

This physiological disturbance is a seasonal phenomenon, occuring during periods of heavy water deficit.

Its main characteristic is the death of the meristemic tissues, but recovery takes place through new ramification, oftentimes resulting in trunk bifurication.

Intensity of occurence is tied to local edaphic-climatic conditions. Thus, there is much variation among species and among provenances of a given species. Within this framework and considering the age variable, the occurrence is most common and most harmful in young stands, gradually tapering off until the third year.

(d) Rust Fungus

It is a disease caused by the fungus *Puccinia psidi*, attacking mainly *E. grandis*, although it has also been found in other species, such as *E. citriodora*, *E. cloeziana*, etc. Its origin can be traced to South Africa.

Studies are all recent and, the only scientific certainty is that there is variation in resistance, both inter and intra-species.

3.1.4 REGENERATION MANAGEMENT

Eucalyptus regenerates itself through coppicing, thus allowing clear cuts in short rotation. Most companies have traditionally adopted, until recently, the 7-year cutting cycle. There is now a tendency to reduce this cycle, due to smaller spacing, and consequently the number of cuts increases. As experimental results are preliminary in nature, there is, so far, no concrete data for the implication forthcoming from the increase of stand interference as related to nutritional cycles, soil compactation, reduction in sprouting vigor, reduction of volume between cuts, and so on.

The classic regeneration procedures used even today by most forest enterprises is limited to stemming through the selection of stronger sprouts; 2 to 3 of them are, on the average, left on each stump. Conclusions from carbonization research at FLORASA have shown that smaller-diameter wood produces less-friable charcoal. Those conclusions sparked a series of experiments with different species, attempting to verify regenerative behavior according to type of management. What has been observed so far is a natural-selection or self-thinning process in no-stemmed areas. At the 2-year mark, there is a volume superiority in favor to an area where stemming has taken place.

Because of the change to a reduction in harvest cycles, new experiments are beginning, attempting to determine fertilization levels, seasons and methods of application, and sources of elements such as natural phosphate.

In highly productive stands, an on-going experiment is interplanting. It attempts to correct, during cutting, planting flaws and other defects that may have occurred during maturation. Furthermore, there are defects due to sprouting after a cut, but whether they be due to genetic or environment factors, insects or injuries is not known. All this could theoretically bring back the stand's original density. This technique is limited by a series of factors, such as only taking place in the rainy season; it should not occur long after cutting, since sprouting displays an initial growth rate superior to that of interplanted seedlings; seedlings of the same species as in the original planting must be used, and so forth.

3.1.5 CLOSING REMARKS

The forest industry in Brazil started in the 60's and its initial activities were oriented towards only planting large areas with little regard to the quality of plantings. Only in the late 60's did changes begin to take place in the criteria guiding forest establishment. Federal-level research programs were started, and companies also set up their own research-and-experiment programs.

Eucalyptus and *Pinus* now cover a 3,618,859 hectare area of Brazil, with *Eucalyptus* accounting for 60%. Historically, three distinct periods can be seen, as shown in Table 3.XIII.

Production has positively evolved, mainly due to new technology related to methods of soil preparation, better and ecologically-adapted seeds, better use of fertilizers along with an improvement of their sources (the utilization of natural sources, such as natural phosphate) reduction in spacing, and so on. This evolution is shown in Table 3.XIV.

If these factors are coupled with the specific edaphic-climatic characteristics of each region, the figures on Table 3.XIV may be totally different. In the "cerrado" regions, for instance, where present yield in the 3.0 x 1.5 m spacing is around 30 st/ha/year, the 1.5 x 1.0 m spacing yield is increased to approximately 80 st/ha/year. In the seacoast of Espirito Santo (a state halfway down the Brazilian Atlantic coast),

productivity reaches close to 100 st/ha/year for stands with a spacing of 3.0 x 1.5 m. In the Rio Doce Valley (state of Minas Gerais), where average yield is around 25 st/ha/year, plantings with better seeds have reached up to 52 st/ha/year.

All these production figures show that yield limits have not been fully reached. An interaction of environment and genetic factors with fertilization and forest management may substantially influence the production process, both quantitatively as well as qualitatively. A good management and experimental operation must be continuously underway.

3.2 CHARCOAL PRODUCTION

Before starting to describe charcoal production in Brazil we will give an introduction to the carbonization processes, their products and by-products and a review of charcoal properties.

3.2.1 PROCESSES

Pyrolysis, also known as carbonization or dry distillation is a process by which wood or any other vegetable material is decomposed under controlled atmosphere and at a given temperature, resulting in charcoal (a solid product), and volatile matters which, in turn, may be further partially condensed. The following by-product are thus obtained:

* Pyroligneous Liquid, encompassing two phases:

** Pyroligneous acid, a brown acquous solution presenting several components such as: acetic acid, methanol, soluble tar (Tar B) and less important constituents.

** Insoluble tar (Tar A), a black, denser and viscous combustible product which is separated from the previous by gravity.

** Non-condensable gases (NCG), a combustible gas consisting basically of CO_2, CO, N_2, and C_nH_n.

The carbonization process can be broken into 4 distinct phases:

* Drying Phase - Evaporation of the water contained in the wood:

  - Hygroscopic, in wood pores (up to 110°C)
  - Absorbed through cell walls (110°C to 150°C)
  - Chemically bound (150° to 200°C)

* Pre-Carbonization Phase - Endothermic period of the process in which a fraction of pyroligneous liquid and a small amount of NCG are obtained. Temperature ranges from 180 - 200 to 250 - 300°C.

* Carbonization Phase - A period characterized by an exothermic and violent reaction. Most of the light tar and pyroligneous acid are produced during this phase. Temperature ranges from 250°C to 300°C.

TABLE 3.XIII - EVOLUTION OF EUCALYPTUS PLANTATIONS IN BRAZIL

PERIOD	PLANTED AREA (ha)	%	PRODUCTIVITY ESTIMATIVE st/ha.year
1967 - 1972	482.838	21	22
1973 - 1975	572.185	25	25
1976 - 1980	1.246.627	54	34

SOURCE: Adapted from IBDF

TABLE 3.XIV - COMPARISON BETWEEN TRADITIONAL AND NON-CONVENTIONAL EUCALYPTUS PLANTATIONS

TREE SPACING (m)	Nº OF TREES PER HA	PRODUCTIVITY (st/ha/year)	CYCLE YEARS	Nº OF CUTTINGS	OBSERVATIONS
3.0 x 2.0	1.667	25	7	3	Traditional
3.0 x 1.5	2.223	34	7	3	Traditional
3.0 x 1.5	2.223	42	6	3	Improved seeds Natural phosphate Rock reformulated Fertilization
2.0 x 1.0	5.000	55	4	5	Improved seeds Natural phosphate Rock reformulated Fertilization
1.5 x 1.0	6.667	60	3	6	Improved seeds Natural phosphate Rock reformulated Fertilization

* Final Phase of Carbonization - Following the previous phase, due to a rise in temperature (over 300°C), there follows a period characterized by an increase in charcoal carbon content and, consequently, a decrease of volatile materials, producing important amounts of tar. The higher the temperature in this phase, the higher the carbon-content.

Table 3.XV shows, the evolution of carbonization products as related to temperature.

The wood carbonization process is an old one and can be carried out in several different ways. If we are able to control the amount of oxygen contained in the process chamber, we will manage to obtain charcoal in much the same way it was produced in primitive kilns, where firewood was simply covered with earth (earthen kilns).

Depending on the source of heat, to overcome the endothermic phases inherent in the process, the carbonization systems can be divided into two large groups:

* Internal Heat Source - A fraction of charged wood is burned, in a controlled way, in order to generate heat for carbonization. Included here are the very primitive kilns, pit or earthen kilns, as well as the beehive-type kilns used in Brazil and portable kilns.

* External Heat Source - The required heat is generated outside the carbonization chamber, in a combustion chamber designed to burn wood, residues, NCG, and other combustible materials. The hot gases then provide the necessary heat for the carbonization process. The heat transfer to the wood can be accomplished by two different systems:

** Indirect heating: Hot gases have no contact with the wood to be carbonized. The combustion chamber has no contact whatever with the carbonization chamber. This system presents positive as well as negative aspects. Favoring this kind of system is a higher purity of the by-products. Since the carbonization chamber is separated, no oxygen takes part in the process. Recovery of the by-products in the systems is simpler, particularly in smaller plants, because the volatiles generally do not condense in the form of a mest.

A considerable disadvantage is the loss of heat due to the indirect heat exchange. Since wood is a poor heat-conducting medium, the exchange area and the residence time of the heated gas must both be large, which makes costs excessively high. The wood has to be in direct contact with the walls of the carbonization chamber (it facilitates heat exchange), and that calls for high-quality steel materials, (otherwise, the heated volatiles would corrode the chamber walls), and makes costs much higher.

** Direct Heating: Hot gases pass through the charge, in direct contact with it, in the carbonization chamber. This principle was adopted many years ago for the drying of firewood for the Lambiotte plants in Belgium and France. The Reichert process (Germany, 1935) was the first application of such a principle on an industrial basis. In brick kilns we

TABLE 3.XV - WOOD DRY DISTILATION EVOLUTION

Carbonization phase	Water evolution	Oxygenated gases evolution	Start of hidrocarbon evolution	Hidrocarbons Phase	Dissociation	Hydrogen Phase
Temperature(°C)	150-200	200-280	280-380	380-500	500-700	700-900
Carbon Content % in weight	60	68	78	84	89	91
Non Condensable gases(%)						
- CO_2	68.0	66.5	35.5	31.5	12.2	0.5
- CO	30.0	30.0	20.5	12.3	24.6	9.7
- H_2	0.0	0.2	6.5	7.5	42.7	80.9
- Hidrocarbons	2.0	3.3	37.5	48.7	20.5	8.9
Gas calorific Power kcal/m^3	1.100	1.210	3.920	4.780	3.630	3.160
Volatiles Condensable constituents	Water vapour	Water vapour + Acetic acid	Acetic Acid + Methanol + Ligth tar	Heavy tar	Tar	Small Condensation
Volatiles amount	Very Small	Small	Important	Important	Small	Very Small

Source: DOAT and PETROFF (1975).(11)

can mention the Schwartz furnace, which consists of a wood carbonization chamber and a combustion chamber (below the first one) where firewood is burned. The heated gases are then fed into the carbonization chamber, thus resulting in wood pyrolysis. In Brazil, a similar system is now being developed (the brick beehive kiln, with a combustion chamber) the operation of which will be discussed later.

The above examples refer to furnaces using direct heating and discontinuous carbonizing. Where the carbonization zone is always charged with wood the result is a continuous carbonizing furnace, the best example of which is the processes developed by Lambiotte.

The most important problem to be considered when producing charcoal is selecting the most suitable system to meet the following requirements:

- Characteristics and type of forest exploitation.

- Availability of financial resources.

- Cost and availability of labor.

- Environmental constraints.

In Brazil where the exploitation of native and man-made forests for the production of charcoal is common practice, two different approaches to carbonization can be observed. The exploitation of native forests results to a large extent from the utilization of the wood obtained through the felling of trees to clear land for cattle raising and agricultural purposes. Charcoal production is basically a nomadic activity. The moment the forest resource is used up, the carbonizing activity comes to an end, the whole process lasting from 1 to 2 years on the same site.

Under such circumstances, it is necessary to make use of systems favoring low investment costs and this is made possible through the use, of independent charcoal producers, with low capacity furnaces (12 to 20 stere charge capacity) of the brick beehive type.

As for the exploitation of planted forest, the production of charcoal is a more permanent activity, the average cycle for a plantation being 20 years in Brazil. Therefore, more permanent systems can be adopted, resulting in increased productivity per equipment, larger production units, larger investments, and more efficient labor use. Movable metal kilns would be a solution for small areas or for areas having a limited production cycle, were it not for their high cost and relatively short useful life as compared to brick kilns, at least as far as Brazil is concerned.

The most sophisticated systems, such as the continuous one, demand high investment costs. In Brazil, the continuous carbonization system is 40 times more costly, per unit of output when compared to the traditional brick beehive kilns. The former shows such advantages as:

- higher yields:

- possibility to act on the carbonization to vary the physical and chemical characteristics of the charcoal;

- clean process: practically all of the by-products are recoverable;

- long useful life, between 20 and 30 years.

The use of these continuous systems is also dependent on the utilization of the by-products generated in order to render the process economical.

In Brazil, only brick beehive kilns are presently used, varying a little in size and type of construction. More complex systems are simultaneously being envisaged, aimed at taking better advantage of man-made forests.

3.2.2 PRODUCTS AND BY-PRODUCTS

As mentioned, the carbonization process yields a solid product (charcoal), a liquid product (pyroligneous liquor), and a gaseous product (non-condensable gas - NCG). The contents and quality of each product in proportion to the oxygen content in the reaction zone as well as to the rate of carbonization. Table 3.XVI shows the effects of wood heating rates up to the limit of carbonization temperature (400°C) as well as the reaction zone pressure by individual product.

As can be seen, the higher the heating rate the higher the yield of tar. In vacuum pyrolysis, the volatile products and the water are immediately removed from the reaction zone, thus causing an increase in tar yield and a decrease of charcoal. This can be seen in Table 3.XVII which shows the yields of pyrolysis products from dry distillation of beechwood.

In Brazil, as no recovery is made of by-products from wood carbonization no industrial data are available.

In keeping with a program for the implementation of a continuous carbonization process, Florestal Acesita, in close cooperation with Fundacao Centro Tecnologico de Minas Gerais, carried out laboratory experiments on Eucalyptus, the results of which are shown in Table 3.XVIII. Laboratory experiments carried out by the ESALQ-USP'S Silviculture Department, on 67 native species obtained yield values as shown in Table 3.XIX.

In Europe, during the past century, wood was a major source of Chemical products such as methanol, acetic acid, acetones, and low-boiling point solvents. Charcoal was then an important reducing agent in the iron and steel industry. Later on, with the emergence of organic synthesis, cheaper products began to appear on the market, thus rendering the chemical industry based on wood nonviable.

The charcoal used to feed blast-furnaces for the production of pig-iron was, in the more developed countries, replaced with mineral coke Brazil, whose iron and steel industry was at its inception 100 percent charcoal-based was also to switch to coke (60%). It is believed that the charcoal-based steel industry in Brazil is still alive due to the small availability of good-quality metallurgical coal and the availability, in the short term, of wood from deforestation.

TABLE 3.XVI - DRY DISTILLATION OF BIRCHWOOD (MAXIMUM TEMPERATURE 400°C) (2)
YIELDS IN WEIGHT PERCENT OF DRY WOOD ON ASH-FREE BASIS

Products	High Vacuum 5 hr Heating	Low Vacuum 5mm Hg 5 hr	Atmospheric Pressure			
			3 hr heating	8 hr heating	16 hr heating	14 days heating
Charcoal	19,38	19,54	25,51	30,85	33,18	39,[illegible]4
Tar	43,66	37,18	18,00	16,94	10,10	1,80
Acetic Acid	7,05	7,05	6,50	6,77	6,58	6,48
Formic Acid	2,40	2,30	0,71	0,61	0,55	0,33
Methyl Alcohol	-	1,20	1,49	1,47	1,50	1,41

SOURCE: KLASON, P. Apud : WENZL (12)

TABLE 3.XVII - YIELDS OF PYROLYSIS PRODUCTS FROM DRY DISTILLATION OF BEECHWOOD

	Yields Based on 100 kg dry wood
Charcoal	34.3
Water	25.4
Gases	20.8
Acetic Acid	6.7
Methanol and Alcohols	2.3
Tar	10.5

SOURCE: Pohl, W. Apud : WENZL (12)

TABLE 3.XVIII-DRY DISTILLATION PRODUCTS OF EUCALYPTUS GRANDIS CARBONIZATION TEMPERATURE - 500°C

Products		Weight % in relation to bone-dry wood
- Charcoal (86% Fixed Carbon)		33.0
- Pyroligneous acid		35.5
Constituents:		
- Acetic acid	5.0	
- Methanol	2.0	
- Soluble Tar	5.0	
- Water + minor constituents	23.5	
- Insoluble Tar		6.5
- Non Condensable Gas (NCG)		25.0
		100.0

Source: CETEC [13]

TABLE 3.XIX-DRY DISTILLATION PRODUCTS OF 67 NATIVE SPECIES FROM STATE OF MARANHÃO-BRAZIL (5) - CARBONIZATION TEMPERATURE - 450°C

Products		Weight % in relation to bone-dry wood
- Charcoal (71% Fixed Carbon)		34.5
- Pyroligneous acid		29.5
Constituents:		
- Acids	3.0	
- Methanol	1.0	
- Water + minor constituents	25.5	
- Insoluble Tar		15.6
- Non Condensable Gas (NCG)		21.0
		100.0

Source: BRITO, J.O. [14]

Brazil did not avail itself of the by-products derived from wood carbonization. Products such as acetic acid, methanol, and others are obtained from the oil industry.

Increased oil prices coupled with the effort towards curbing oil imports have made wood a very important source of energy, be it used directly or as charcoal or by-products. Presently, in addition to developing continuous carbonization systems, the steel companies producing their own charcoal from Eucalyptus forests are developing ways to recover the tar resulting from carbonization in brick beehive kilns.

Florestal Acesita, as will be shown, is presently developing its own system, aiming at supplying the ACESITA steel plant with wood tar, which will be used to power heating furnaces to replace fuel oil. Insoluble tar (Type A) appears in Brazil as the first by-product from carbonization to be used on an industrial basis. Other products are expected to come on stage and the chemical industry of wood is likely to grow.

3.2.3 CHARCOAL PROPERTIES/QUALITY CONTROL

If we take into account the large influence of charcoal on the production cost of pig iron (more than 60%) and its increasing utilization as energy input to industry, it is necessary to optimize the production processes as well as the utilization process aiming to decrease the impact of its cost on the final products.

So, it is of great importance to know the charcoal properties, how they vary with the carbonization parameters and how these properties influence the performance of the utilization process.

Unfortunately the characteristics of charcoal are not well known. Normally, the procedures used to evaluate its quality, utilized by the few industries which produce and utilize charcoal are not yet, standardized. As the charcoal is almost totally utilized, in Brazil, by the pig iron makers and more than half by small industries, they do not practice quality control of charcoal.

Now up for discussion is what is the best charcoal for blast furnace or other process of utilization, in terms of fixed carbon, volatile matters, density, reactivity, etc. Little has been done to define these characteristics. Difficulties arise because there are no established standard which take into account the real conditions to which charcoal is submitted during utilization. The tests studied in Brazil are cold tests, realized in an atmosphere different from that to which charcoal is used. It is also difficult to correlate the tests results with the operational parameters of the utilization process.

The tumbling test, for instance, shows more about the ability for charcoal to generate fines (charcoal powder) during handling and transportation than its performance as a reducer for pig iron production. The same occurs with the utilization of charcoal as an energy source for combustible gas production or other sources of energy. It is time to study the influence

of charcoal characteristics, such as fixed carbon, volatile matter, reactivity and others on the energy characteristic of the gas produced. Data about the burning kinetics of pulverized charcoal is lacking for the study of the performance of such processes.

But something has been done to learn more about charcoal. The "Associacao Brasileira de Normas Tecnicas" (ABNT), the Brazilian standards association, created a group of people from industries, research institutions and others, to study and formulate standards and procedures for quality tests of charcoal. These procedures have the advantage of standardizing tests on a national scale. To date, the following standards have been issued:

- MB-1375-Part I - Charcoal Size Measurements
- MB-1375-Part II - Tumbling Test
- MB-1375-Part III - Charcoal Bulk Density
- MB-1375-Part IV - Shatter Test
- 1/2.1/01 - Charcoal Sapling
- 1/21.1/001/81 - Charcoal Chemical Analysis

Among the major properties of charcoal as far as its utilization is concerned are:

- Chemical Composition
- Reactivity
- Density
- Mechanical Strength

3.2.3.1 Chemical Composition

Charcoal can be considered as being made up of three components in terms of chemical analysis: fixed carbon, volatiles and ash. Of the parameters determining the content of each component during the carbonization process, temperature is the principal one.

Early studies on the subject can be seen in Table 3.XX, which depicts the elementary composition as a function of temperature. It can also be seen that temperature has an effect on charcoal yield, causing yield to decrease while the carbon content increases.

Table 3.XXI shows similar results for *Eucalyptus grandis* (Minas Gerais, Brazil). An additional column showing yields of fixed carbon as a function of temperature is also included.

From the two tables it can be seen that the increase of fixed carbon, above 700°C, is very small and therefore, no additional energy should be expended to go beyond this temperature. A constant yield of fixed carbon is also observed from 500°C, and this fact has important implication for the utilization of charcoal, particularly in blast furnaces, where we can work with higher carbon contents and still obtain the same yield.

In present-day carbonization technology with brick kilns, controlling the carbonization temperature may prove to be a difficult task. To produce a high-content of fixed carbon is to risk burning the charcoal. Temperature

TABLE 3.XX-ELEMENTARY COMPOSITION AND YIELD OF CHARCOAL IN RELATION TO THE CARBONIZATION TEMPERATURE

Carbonization Temperature °C	Elementary Composition (%) C	H	O	Charcoal Yield % D.B
200	52.3	6.3	41.4	91.8
300	73.2	4.9	21.9	51.4
400	82.7	3.8	13.5	37.8
500	89.6	3.1	6.7	33.0
600	92.6	2.6	5.2	31.0
800	95.8	1.0	3.3	26.7
1000	96.6	0.5	2.9	26.5

SOURCE: Pohl, W - Apud : WENZL (12)

TABLE 3.XXI-COMPOSITION AND YIELDING IN FUNCTION OF CARBONIZATION TEMPERATURE *Eucalyptus grandis*

Carbonization Temperature °C	Chemical Analysis Fixed Carbon (% D.B)	Volatile Matter (% D.B)	Charcoal Yield % D.B	Fixed Carbon Yield % D.B
300	68	31	42	29
500	86	13	33	28
700	92	7	30	28
900	94	5	29	27

* obtained by = Charcoal yield x % of Fixed Carbon ÷ 100

Source: Cetec (15)

measurements from brick kilns show that its distribution is rather variable from one point to another.

Variation in charcoal composition is observable between the top and the bottom of the kiln.

Top - 81% fixed carbon
Middle - 80% fixed carbon
Bottom - 76% fixed carbon

These kilns operate at a maximum temperature of 450°C.

3.2.3.2 Reactivity

Reactivity is the charcoal's capacity to react with a given substance. For its use as a reductant an important reaction must take place: that of charcoal with CO_2, resulting in CO - one of the most important reactions to take place inside the reduction furnace. In gasification, for the production of fuel gas, the reactivity to oxygen, $C + O_2 = CO_2$ is most important, but the former reaction ($CO_2 + C = 2\ CO$) is also important, since it increases the gas calorific power.

Wood charcoal, compared with other combustibles or reductors, is one of the most reactive, as can be seen in Fig. 3.1 where Eucalyptus charcoal is compared with coke, coal, and babacu charcoal. In this figure, for a given temperature, the higher the content of CO in the gas produced by the reaction the more intense the reactivity. That is to say that the more the curve moves to the left, the greater the reactivity of the compound.

The charcoal reactivity follows the fixed carbon content as shown in Table 3.XXII.

3.2.3.3 Charcoal Density

There are several kinds of charcoal density:

Bulk Density - The weight of a given volume of grained charcoal.

Apparent Density - The density of isolated pieces of charcoal.

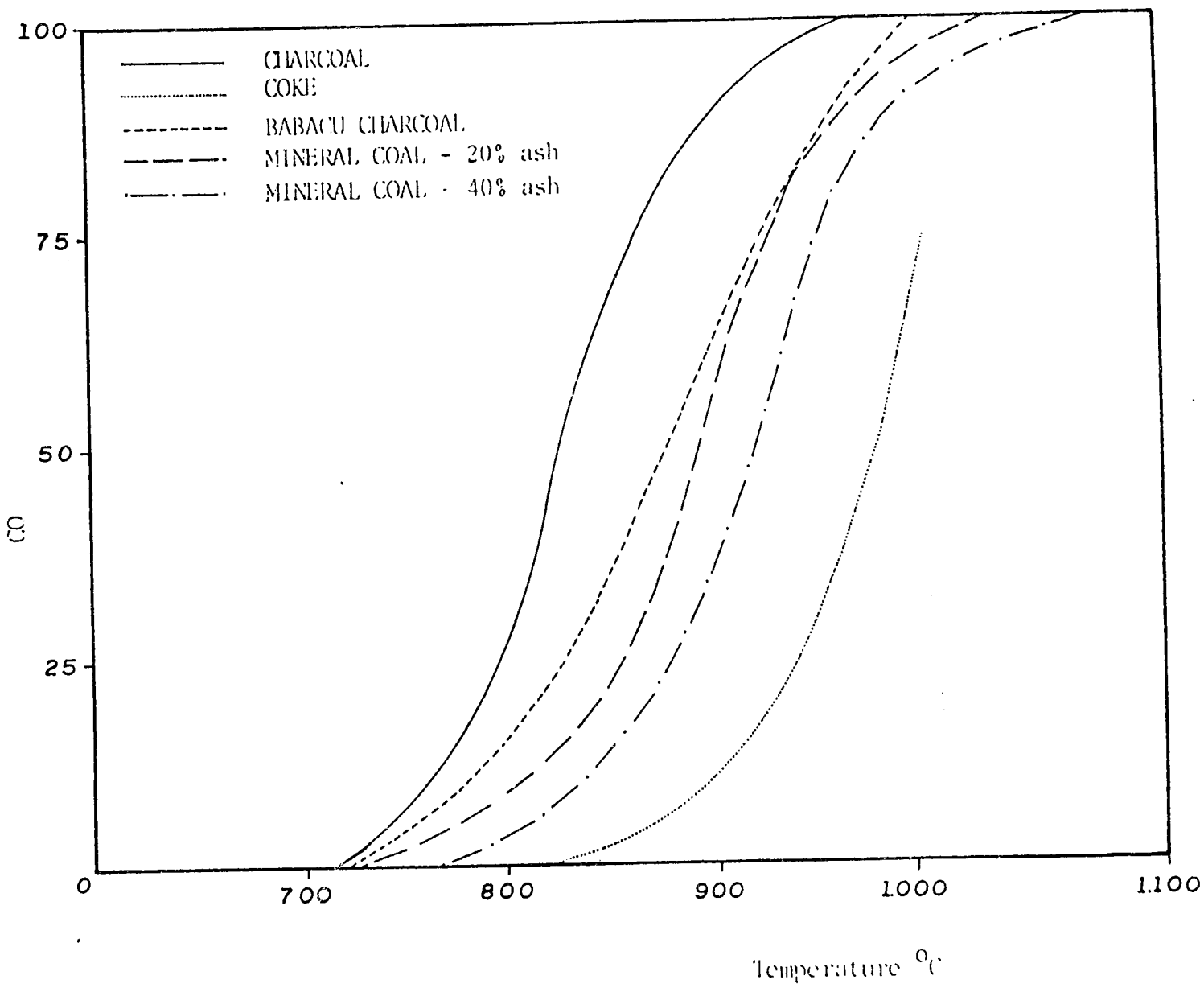
True Density - The density of the substance making up the charcoal, not including its internal porosity.

By relating the true density to the apparent density we can obtain the porosity. In practical terms, bulk density determines charcoal quality. The remaining two densities providing excellent data for scientific studies on charcoal characteristics for carbonization purposes.

Charcoal density is about half that of coke, therefore its specific energy content ($kcal/m^3$) is much lower.

Charcoal has a very high porosity, 70% to 80%, which renders it an excellent material for the manufacture of activitated charcoal. For energy

FIG. 3.1 - REACTIVITY CURVES (CO_2) FOR SOME MATERIALS



SOURCE: MATOS, M et alii [16]

TABLE 3.XXII - CHARCOAL REACTIVITY AS A FUNCTION OF CARBONIZATION TEMPERATURE

Carbonization Temperature °C	Fixed Carbon Content % (Dry Basis)	Reactivity % of increase in relation to 300°C
300°C	68	-
500°C	85	14 %
700°C	92	19 %

SOURCE: CETEC [15]

purposes it would be advisable to work with the most dense charcoal possible, and the major parameter influencing this density is the density of the wood used. The greater the wood density the more dense the charcoal, as can be seen on Table 3.XXIII.

Of course, other parameters related to wood density also play an important part in determining charcoal density, for example, age and diameter. The carbonization temperature has much less influence on charcoal density than does the wood density.

Generally, the bulk density varies between 200 to 300 kg/m^3 for the charcoal produced in Brazil.

3.2.3.4 Mechanical Strength

The mechanical strength of charcoal may be defined in several different ways.

The tumbling test subjects the charcoal to a combined abrasive action. This test provides an indication of charcoal friability, which is defined as the capacity to generate fines under mechanical stresses during the handling and transport of the product. It envolves placing charcoal of a given grain size, in a cylindrical drum and revolving it at a given rpm.

The shatter test subjects a certain amount of charcoal to a certain number of free falls from a given height, thereby obtaining its friability ratio.

To verify the charcoal resistance to static loads the compression test is applied. It consists of applying successive loads to a test specimen to assess its maximum strength before destruction.

As mentioned before, all tests devised till the present for charcoal, are not easily correlated with the parameters for its use, since they are cold tests always carried out in a different atmosphere from that in which charcoal is actually used. In Brazil, the tumbling tests as used, is believed to be most representative of the actual handling of charcoal.

The compression test is not justified as a routine quality control test, as it involves rigorous preparation of the test samples in addition to requiring a large a number of samples per cubic meter of tested material. On the other hand, it is an excellent laboratory tool to check the charcoal strength against carbonization parameters.

Laboratory tests carried out by Fundacao Centro Tecnologico de Minas Gerais - CETEC, have shown that the moisture content of wood to be carbonized has a very large influence on the friability of the charcoal at least as far as the tumbling test is concerned (see Table 3.XXIV).

Higher wood moisture content makes charcoal more susceptible to internal cracking. These cracks, due to the action of mechanical forces during the tumbling testing, develop further fractioning of the material, thereby increasing the production of fines.

TABLE 3.XXIII - CHARCOAL DENSITY IN FUNCTION OF WOOD DENSITY. *Eucalyptus* OF SEVERAL VARIETIES CARBONIZED BY FLORESTAL ACESITA

Wood Density Interval g/cm^3	Charcoal Density g/cm^3
0.530 to 0.579	0.265
0.580 to 0.629	0.277
0.630 to 0.679	0.299
0.680 to 0.729	0.365
0.730 to 0.780	0.366

SOURCE: FLORESTAL ACESITA

Experiments carried out by Florestal Acesita S/A also point to the same effect on an industrial scale, as can be seen in Table 3.XXV. Wood length has a smaller influence than wood moisture content as can be verified from the industry-wide data shown in Table 3.XXVI.

It is known that wood diameters has a considerable effect on the formation of cracks during the carbonization process. The older the tree the greater the wood diameter and the larger the heartwood volume. The heartwood is rather impervious since the pits in the fiber walls are no longer active. When a wood is placed in a carbonization furnace, the sapwood dries more rapidly than the heartwood. Under such conditions, water vapor or other substances begin to build-up inside the fibers causing the appearance of cracks. These cracks will eventually lead to further brittleness of charcoal and consequently, to increased fine production.

Studies developed by CETEC have shown that the carbonization temperature greatly influences the charcoal resistance to compression. The maximum rupture stress range as related to the carbonization temperature was obtained through studies on Eucalyptus grandis (8 years of age), as seen on Table 3.XXVII. Fig. 3.2 shows the curve of such data. It can be observed that the charcoal strength (compression) dropped from 300°C to 500°C, and rose significantly from 500°C to 900°C. This drop in strength must be related to the decomposition of the wood constitutents.

A drop in charcoal strength in relation to wood strength within the 100°C to 600°C range, is usually verified. Collaborators studying the dynamic modulus of elasticity of hardwood (birch), carbonized at different temperatures (200° to 700°C) have observed a modulus decrease with carbonization temperatures of up to 500° - 600°C, and an increase at temperatures above this range. It was shown that for the wood in question (birch), most of the loss in mass in relation to the original dry wood occurs between 400° and 500°C. The thermogravimetric curve for Eucalyptus alba, Fig. 3.3 confirms this finding.

The increase in strength from 500°C upward may well be related to several facts:

- decrease of volume following carbonization, even above 500°C;
- changes in the size and form of porosity, at high temperatures (500° - 600°C);
- possible structural re-arrangement of residual carbon, resulting in a highly resistant structure.

3.2.4 CHARCOAL TECHNOLOGY

3.2.4.1 Introduction

As mentioned, all charcoal produced in Brazil is based on the use of brick beehive kilns which differ somewhat in size and shape depending on whether the charcoal production activity is geared to native or man-made forest. It should be recalled that 80% of production is from native forest

TABLE 3.XXIV - CHARCOAL TUMBLING TEST IN FUNCTION OF WOOD MOISTURE CONTENT LABORATORY TESTS

Wood moisture content (%)	Fines % below 12 mm generated on tumbling Tests*
below 20	11.2
20 to 30	13.5
above 30	15.9

Source: CETEC [15]

* Results obtained using a 30 cm diameter and 25 cm length drum, 35 r.p.m, 500 rotations. Charcoal sized between 23 to 38 mm.

TABLE 3.XXV - CHARCOAL TUMBLING TEST IN FUNCTION OF WOOD MOISTURE CONTENT *Eucalyptus grandis* - INDUSTRIAL TESTS

Wood moisture content (%)	Fines % below 10 mm generated on tumbling Tests*
47	27.4
41	23.7
33	20.9
25	20.8
22	19.0

Source: FLORESTAL ACESITA [17]

* Results obtained using a 100 cm diameter and 100 cm length drum, 25 r.p.m, 70 rotations - ABNT MB 1375 PART II.

stands. Therefore, two approaches could be considered as far as wood carbonization in brick kilns is concerned:

Native Forests: small-sized kilns with a capacity less than 20 steres of wood, grouped in batteries of 4 kilns and located at the cutting site.

Plantation Forests: large-sized kilns, more than 20 steres, grouped in batteries of 7-9 kilns making up more or less centralized charcoal plants of up to 10-11 batteries (70 to 100 kilns).

Native-wood charcoal making is to a large extent derived from a nomadic practice, involving the utilization of woody material generated from the clearing of land for agricultural and cattle-raising operations. Hence it is important to highlight some characteristic features of the activity performed by the owners of rural estates:

* The utilization of woody material is a by-product of agricultural and stock raising activity.

* In areas where the woody material is not put to any practical use, burning of the whole vegetation is common practice among rural populations.

* In Brazil, the practice of systematic and controlled regeneration of native stocks, which could otherwise be implemented on a large scale, is very limited.

* The depletion of natural resources due to the clearing of vast woodlands for agricultural use has brought about successive increases in transportation costs, as the charcoal producing front is forced to move further away from the consuming centers. Some years ago, the mean radius of transportation was about 150 km, today it is about 500 km.

This "always-on-the-move" characteristic of the charcoal making sites leads to the setting-up of small charcoal making systems, at low investment costs, and limited life span (1 to 2 years), following along the deforestation route.

Generally, the makers of charcoal from native forests are grouped into three categories, depending on their monthly output:

Small charcoal makers - up to 200 m^3/month
Medium charcoal makers - from 200 to 500 m^3/month
Large Charcoal makers - above 600 m^3/month.

As a rule, below the 600 m^3 production level, work is practically non-mechanized; felling operations are carried out with axes, and the wood is transported in oxen-drawn carts over distances varying from 500 to 1000m. The carbonization process is carried out in brick kilns. Two types of kilns are distinguished:

- brick beehive kiln - "hot tail" type
- slope type brick beehive kiln.

TABLE 3.XXVI - CHARCOAL TUMBLING TEST IN FUNCTION OF WOOD LENGTH - *Eucalyptus grandis* - INDUSTRIAL TESTS

Wood Lenght (m)	Fines % below 12 mm generated on tumbling tests
0.5	21.3
1.0	22.6
1.5	25,0
2.0	26,0

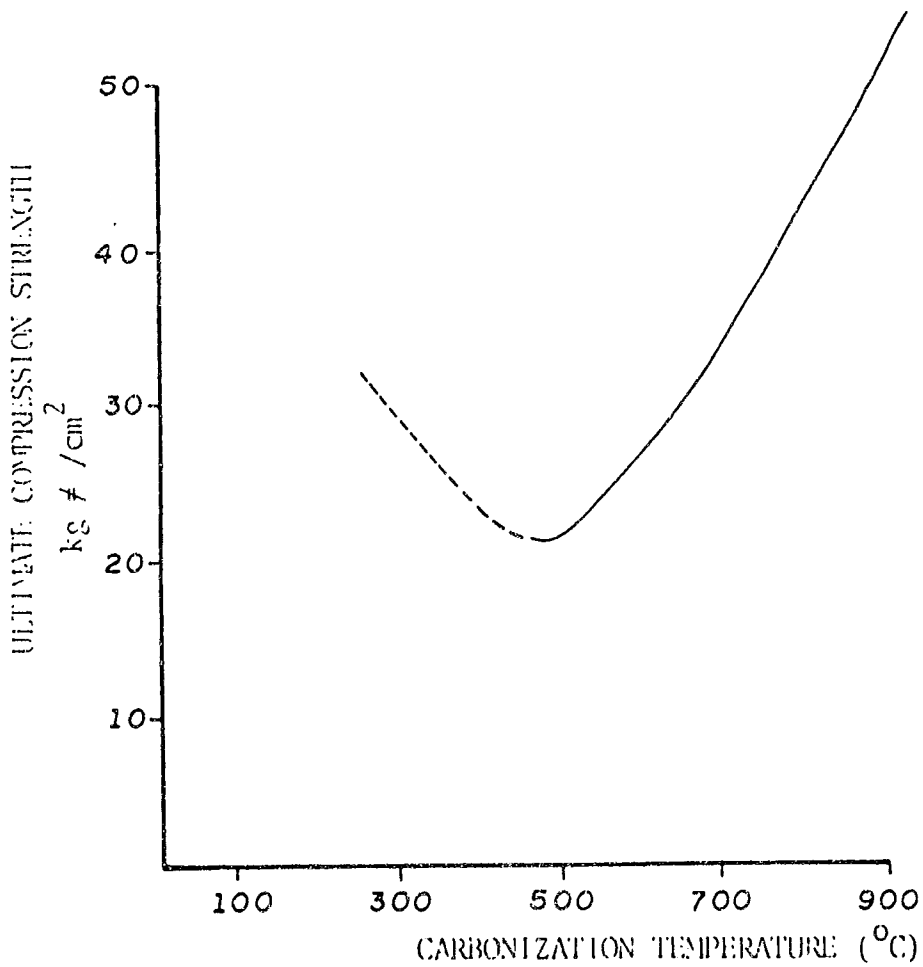
SOURCE: FLORESTAL ACESITA[18]

TABLE 3.XXVII - COMPRESSION STRENGTH IN FUNCTION OF CARBONIZATION TEMPERATURE

Carbonization Temperature ^{o}C	Compression Strength kgf/cm^2
300	28.6 ± 2.3
500	20.9 ± 2.4
700	34.3 ± 5.9
900	51.3 ± 13.1

SOURCE: CETEC [15]

FIG. 3.2 - INFLUENCE OF THE CARBONIZATION TEMPERATURE ON THE COMPRESSION STRENGTH



SOURCE: CETEC [15]

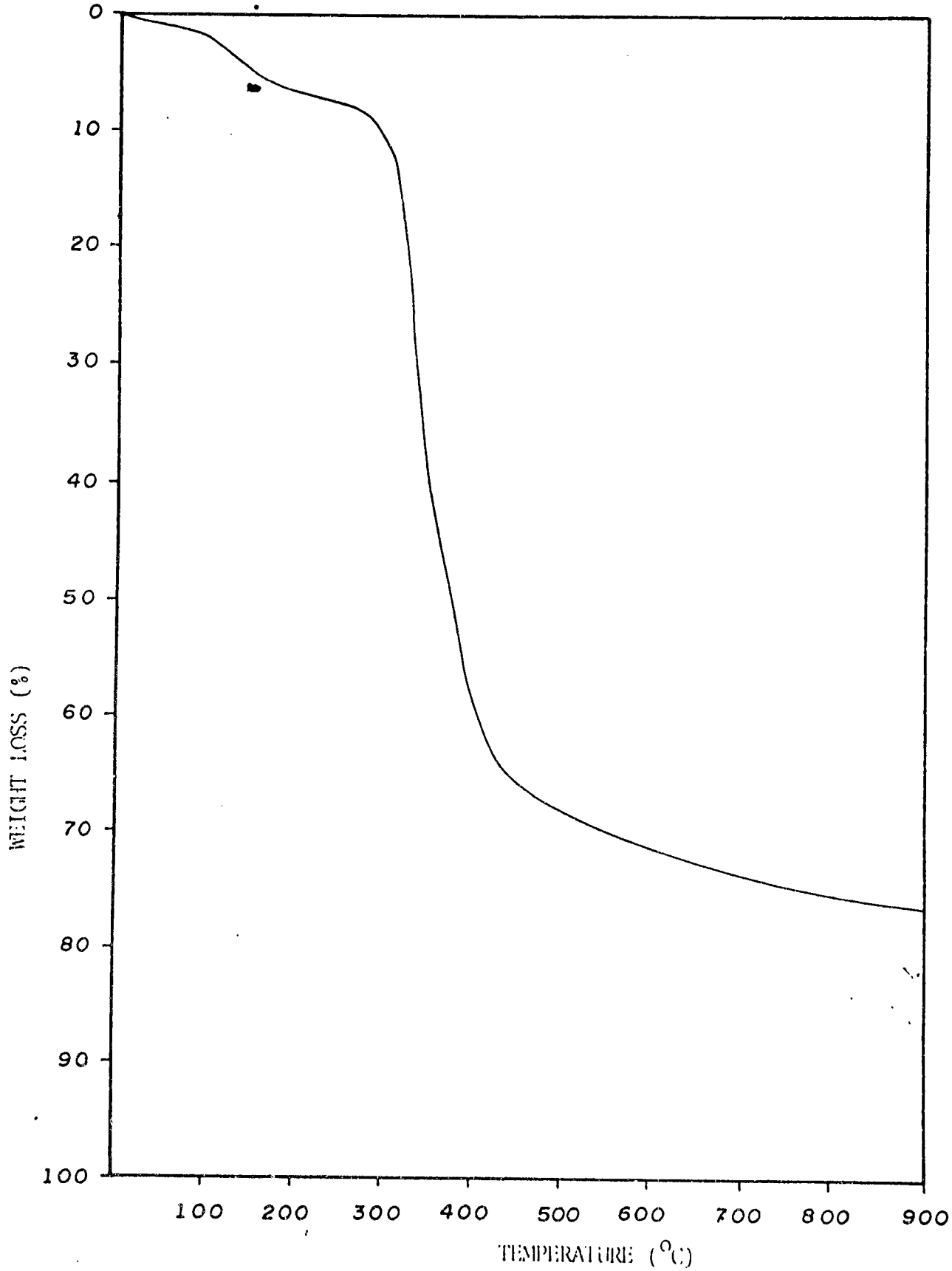


FIG. 3.3 - THERMOGRAVIMETRIC CURVE FOR EUCALYPTUS ALBA

SOURCE: CETEC[15]

The former is a circular, low capacity (12 st) kiln, usually grouped in 4-unit batteries, and operated by one man.

The slope type is a circular brick kiln, built into a slope or hill, and has the advantage of using fewer bricks. Its capacity is a little over 19 st of wood (See fig. 3.4 and 3.5).

The average yield of wood from native forests is on the order of 3.0 cubic meters of wood per cubic meter of charcoal.

The carbonization process, encompassing charging, carbonizing, cooling, and discharging, takes about 5 to 8 days, the life span of such kilns is no longer than 24 months, which accounts for the nomadic character of the operation.

Five meter diameter kilns, with a capacity of 36 to 40 st of wood, for the carbonization of wood from man-made forests, are usually used by the Brazilian charcoal makers of the integrated iron and steel industry. Most of the companies favor the 36-108 kiln battery system. These companies, because they require large amounts of wood, need a mechanized handling system to handle the wood at the batteries and to load the trucks. This system presents the following advantages:

* concentration of the necessary infrastructure, such as, services in general, labor housing, etc.

* better control of production and quality.

* night-time control of carbonization is facilitated, as only one operator can take care of more than one kiln at a time.

* greater possibility of mechanization at the charcoal producing site.

It is worth noting that charcoal making in Brazil comprises a series of systems and kilns depending not only on the quality of the forest but also on the amount of investment capital available.

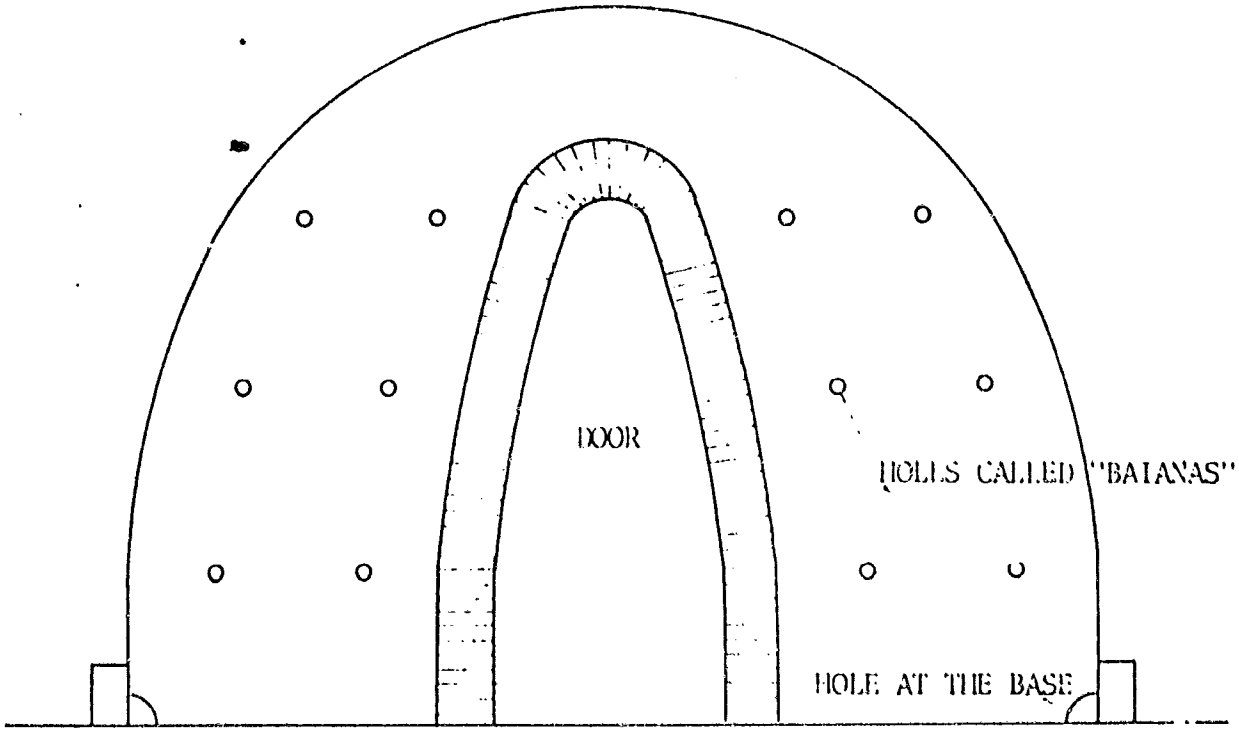
3.2.4.2 The Manufacture of Charcoal

This item deals with the carbonization of *Eucalyptus* trees in standard brick beehive kilns (5 meters in diameter).

These kilns are built of ordinary fire bricks, 25 cm long x 10 cm wide x 5 cm high. On the average, 8,000 bricks are used for the construction of a 5-m diameter kiln, as shown in Fig. 3.6. To lay the bricks, a mixture of clay slurry, fine sand, and water is used. Generally, the mixture is made of three to four parts of slurry and one part of sand and water, enough to obtain a sound mixture.

Charging of the kiln is usually done by two men, one placing the wood at the door and the other piling it inside the kiln. The wood is at first

FIG. 3.4 - BRICK BEEHIVE KILN - "HOT TAIL" TYPE



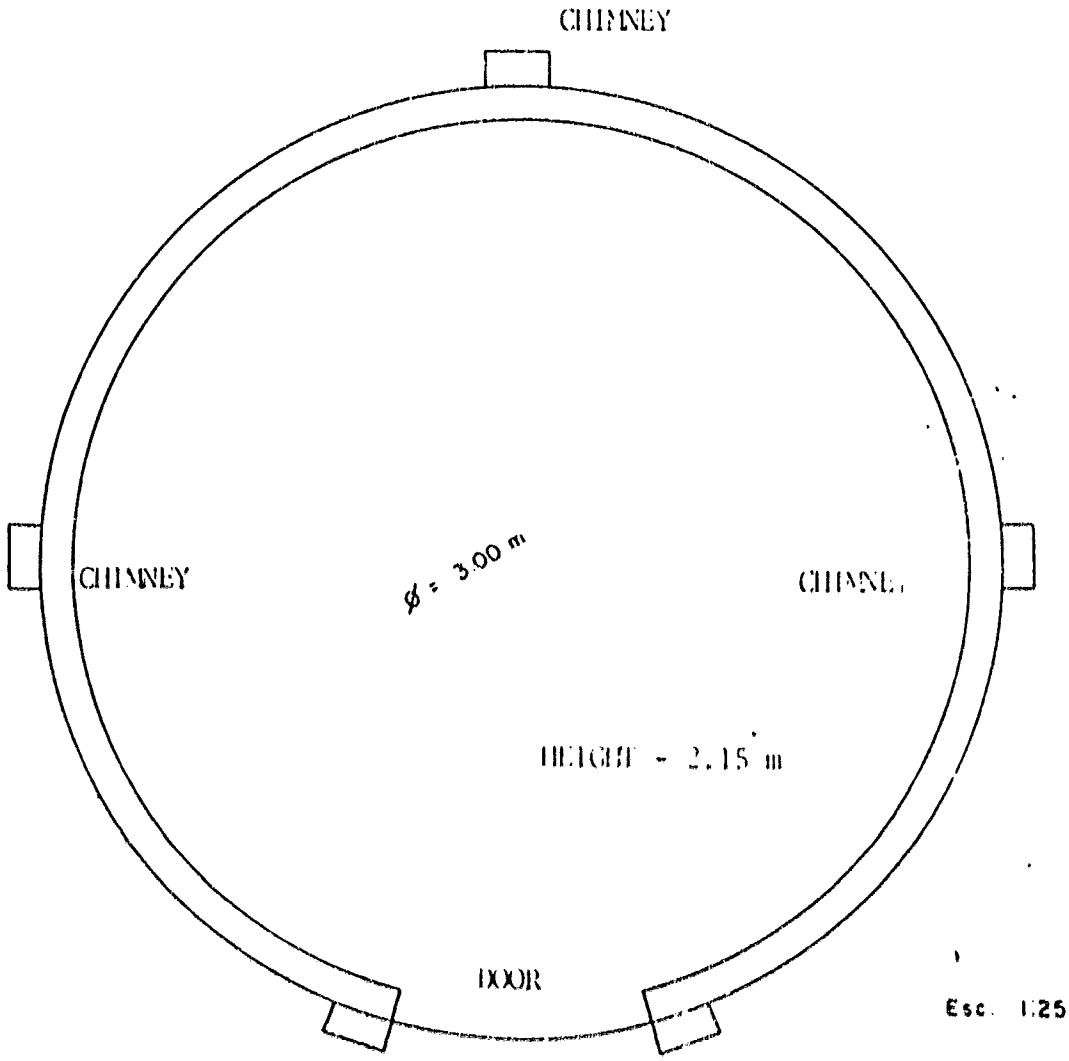
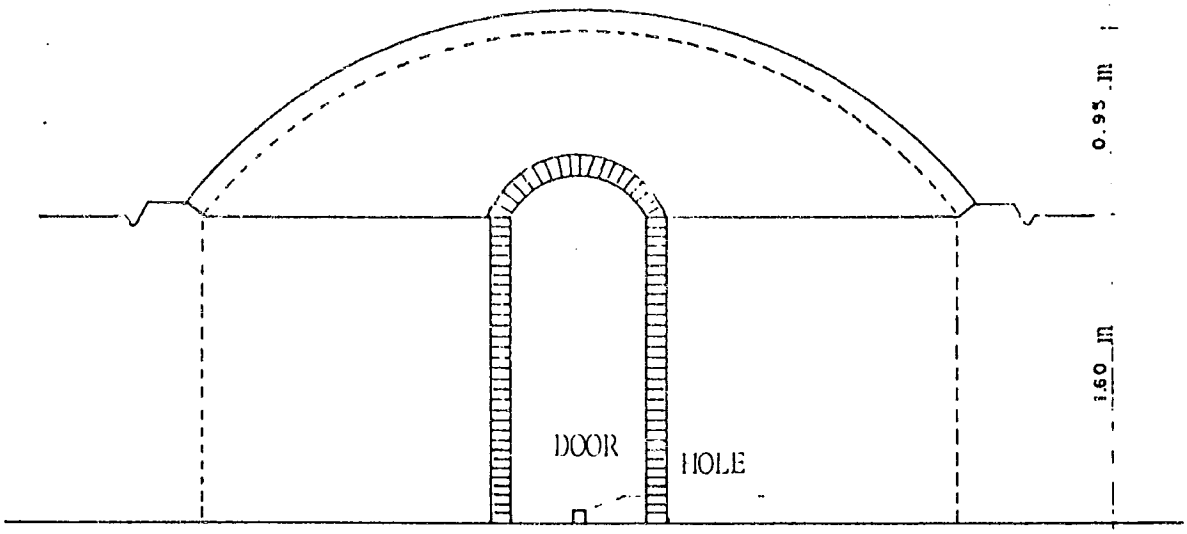
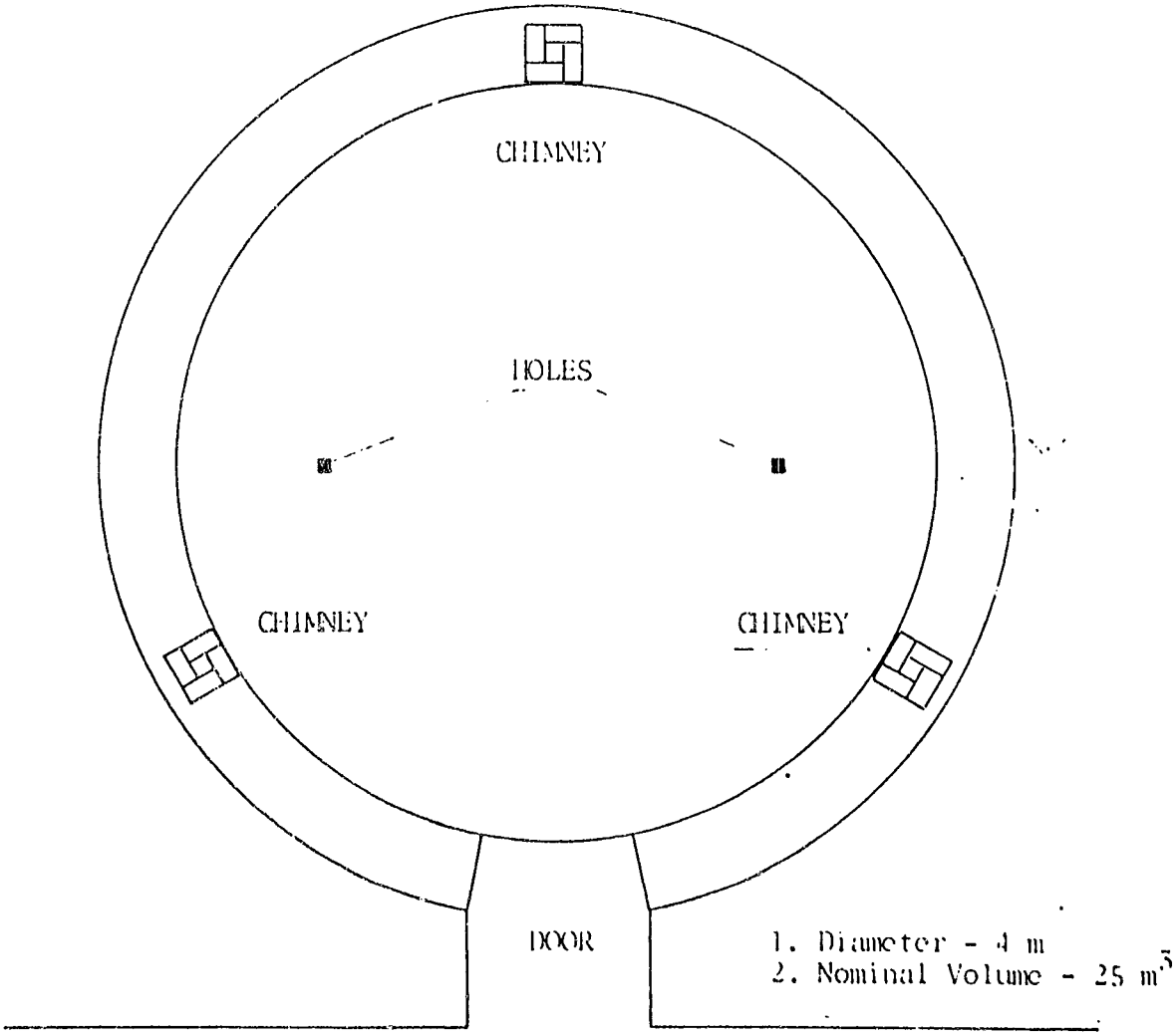


FIG. 3.5 - SLOP TYPE BRICK BEEHIVE KILN





placed in a vertical position, covering the cylindric portion of the kiln and in such a way as to avoid gaps between the logs. Next, the thinner pieces of wood are laid horizontally, filling the entire dome. After charging, the doors are sealed with piled-up bricks, with no mortar. These are plastered by hand with a mortar made of 1 part of slurry and 1 part of sieved sand and water.

Ignition of the kiln is done by pouring a shovelful of ember into the central opening of the kiln dome (wood bark may be added to facilitate ignition).

The state of the combustion period is indicated by observation of the combustion gases, a thick white smoke issuing from the ignition opening and dome portholes. When the smoke begins to get dark (more or less 15 minutes), the opening is closed with bricks. Carbonization proceeds from top to bottom and also horizontally. After the ignition opening is closed, smoke begins to issue from the dome outlet portholes, initially colored. As soon as the smoke becomes dark, the dome portholes are closed one after another. This procedure extends down to the base of the kiln. The next step is to control the carbonization by observation of the smoke issuing from the chimneys. The moment the smoke color turns to bluish, all the chimneys must by closed - this begins the cooling period. At this stage, the kiln is already sealed to prevent any oxygen entering the chamber.

After the cooling period, which the operator controls by simply putting his hand on the door wall and feeling the temperature, the kiln is opened and the charcoal is discharged. The kiln must not be unloaded as long as the charcoal temperature inside the kiln is above 60°C, otherwise fire may start again spontaneously. Discharging is usually done by two men with a special fork and a basket. The charcoal is removed from the kiln and heaped in a covered place in front. About a week later, the charcoal is ready to be transported by truck to the consuming centers.

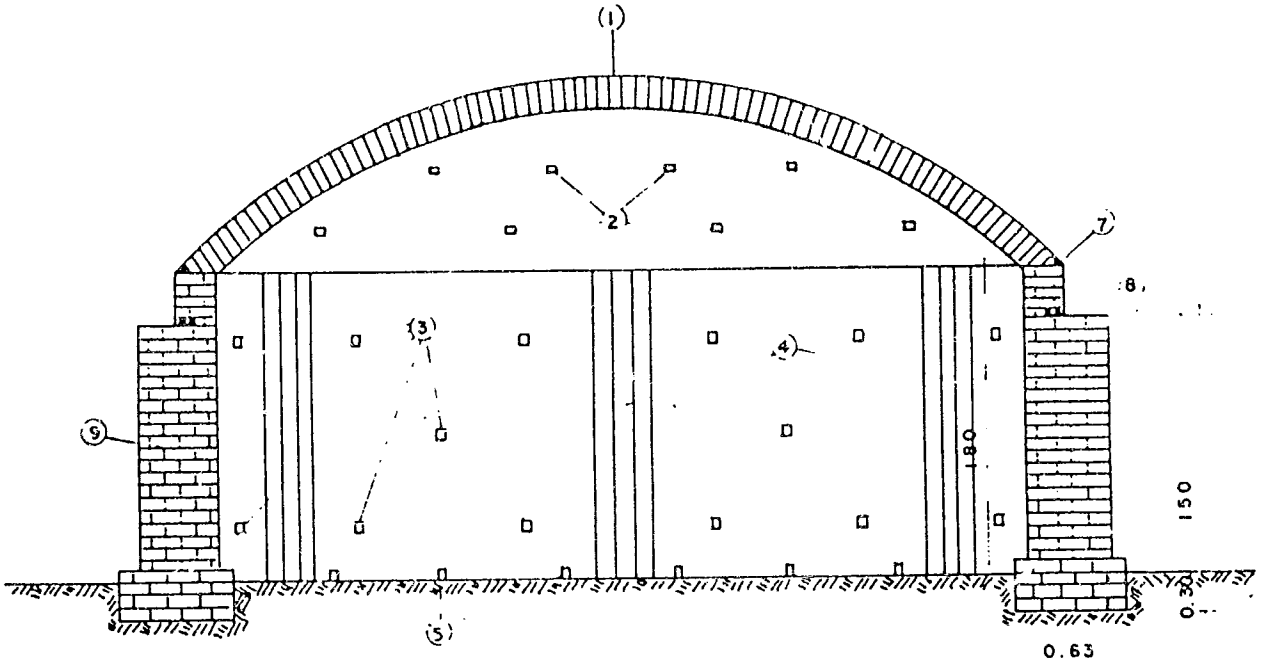
The present charcoal manufacturing system in brick beehive kilns, with no recovery of by-products and leaving wood residues (leaves and limbs below 15 mm in diameter) at the cutting site, is shown in a schematic way in Fig. 3.7.

In terms of utilization of the energy potential of total above ground available biomass, considering the recovery of 50% of fines (as steel industries do, for sinter production), this system is somewhere around 42% efficient considering the heating value (enthalpy) of charcoal (as produced) and firewood (25% moisture) as 7.000 kcal/kg and 3.000 kcal/kg, respectively.

The process as such (in a 5 meter diameter brick kiln) presents the following technical data:

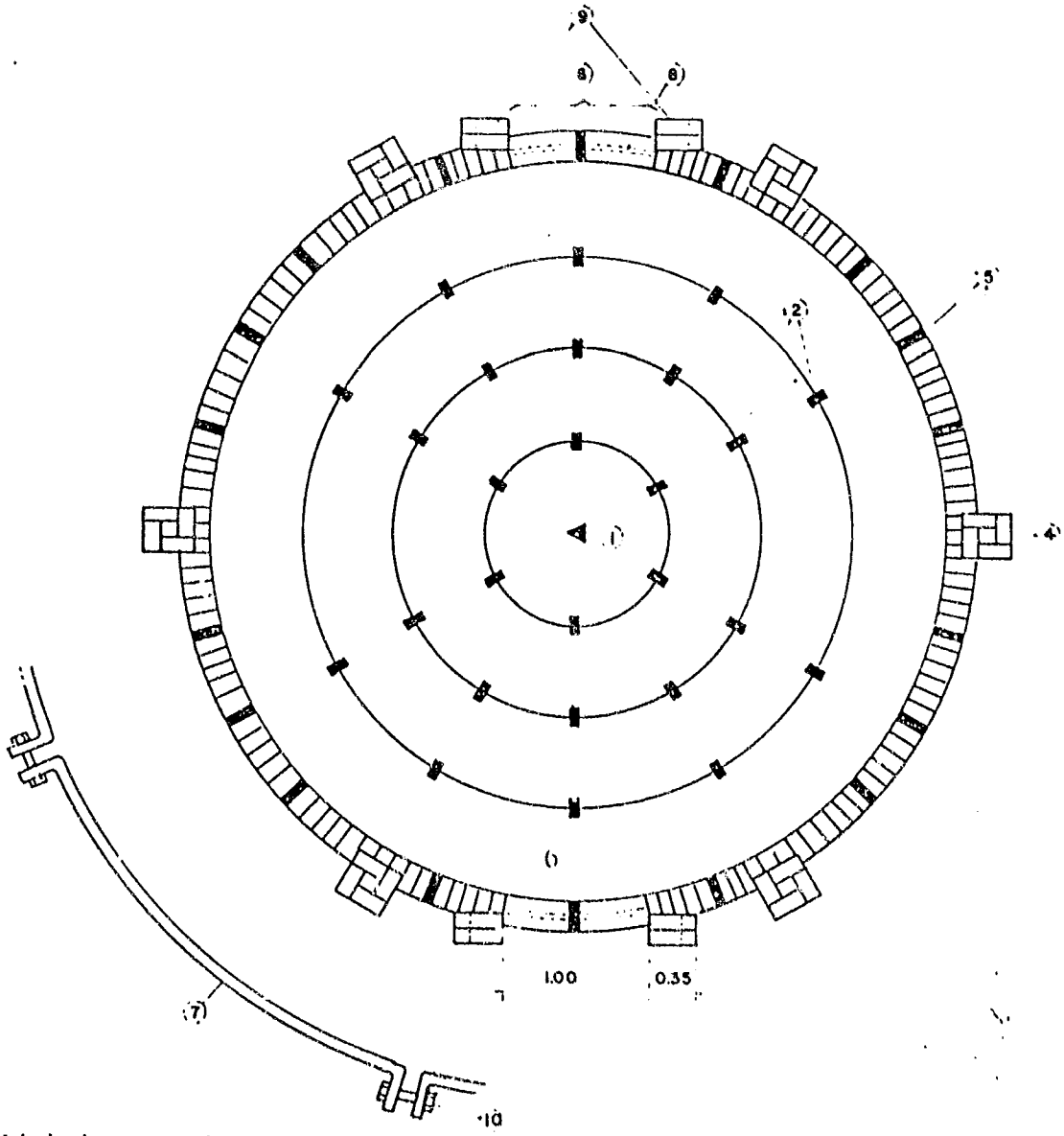
- volume of wood 37 steres per charge
- operating cycle:
  - . charging - 4 hours (2 men)
  - . carbonization - 96 hours
  - . cooling - 96 hours
  - . discharging - 5 hours (2 men)
  - Total 201 hours

FIG. 3.6 - BRICK BEEHIVE KILN - UTILIZED BY INTEGRATED STEEL INDUSTRY



NOTE: See next page

FIG. 3.6 - BRICK BEEHIVE KILN UTILIZED BY INTEGRATED STEEL INDUSTRY



1. Lighting opening
2. Air control holes at the dome called "BAIANAS"
3. Air control holes at the cylindrical surface
4. Chymney
5. Air control holes at the botton of the cylindrical surface called "TATUS"
6. Door. There are two doors, one to charge with wood and one, in front of the others, to discharge charcoal
7. Steel belt located at the top of the cylindrical surface of the kiln
8. Steel door structure
9. Protection door column
10. Screw of steel belt

A - Diameter 5 m
B - Nominal Volume - 49 m^3
C - Number of "Tatus" - 18
D - Number of Chymney - 6
E - Number of "Baianas" - 26
F - Number of Surface holes-28
H - Number of Bricks - 8,500

Yields

- Charcoal yield (dry base) = 33% by weight
- Fixed carbon yield (dry base) = 26 to 27% by weight
- Conversion index = 1.8 to 2.0 stere per m^3 of charcoal. (a stere is a stacked cubic meter of wood).

Production

- Charcoal per batch = 18 to 20 m3
- Productivity ratio = 9.95×10^{-2} m^3/hour
- Assuming 250 kg/m^3 charcoal density: productivity ratio = 2.49×10^{-2} t/h

This productivity ratio varies with the size of the kiln: the larger the kilns the greater the productivity.

If we take into account only the carbonization process we have an energy efficiency of 53%. The difference between this figure and the former one (42%) is due to the fact that forest residues produced during harvesting are left in the field. These residues represent an important potential resources for energy production because they represent about 20% of total forest biomass in a plantation. In the calculations we assumed that only 50% of the fines produced during carbonization and charcoal handling are used. This assumption is based on the constraints imposed by the use of the charcoal for metallurgical purposes (blast furnaces charcoal minimum size is 10 mm). For fuel oil substitution all the fines can be used, specially if care is taken not to contaminate them with dirt during truck loading, transport and handling. In this case, the process energy efficiency will increase to 59%.

3.2.4.3 Charcoal Production in Brazil

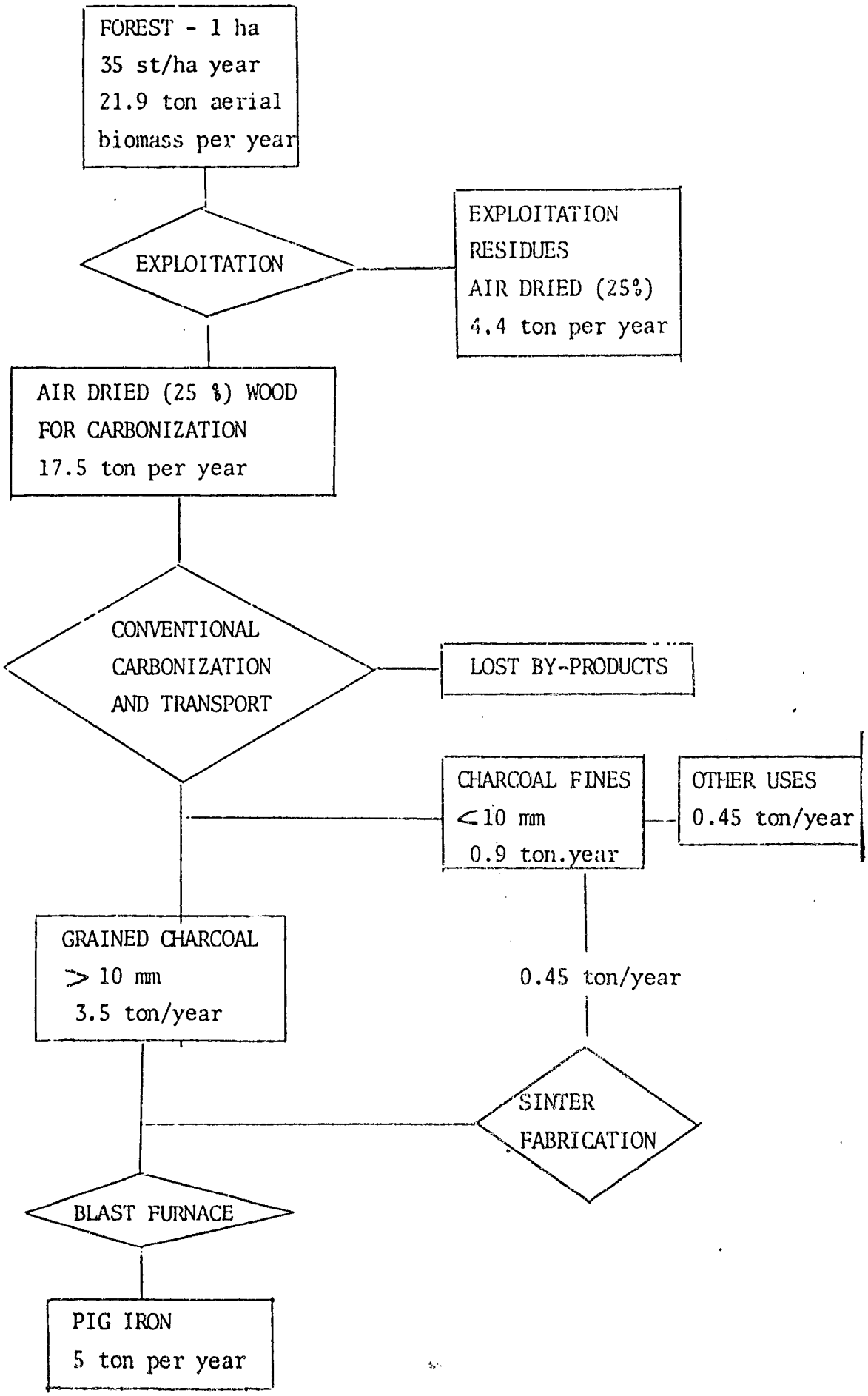
Over the past few years, increasing attention has been given to charcoal production technology in Brazil, involving not only the carbonization process as such but also silviculture as previously mentioned (item 3.1).

The work in the field of carbonization aims basically at increasing the yield of energy from the total available biomass in the planted forest. To achieve this result the following measures have been envisaged:

* Increase of charcoal yield obtained from carbonization in brick beehive kilns.
* Partial recovery and utilization of by-products from carbonization in brick beehive kilns.
* Development of higher technology with higher charcoal yields and recovery of by-products.

Several studies have been made which aim at better characterization of the carbonization process in brick beehive kilns. The results obtained so far point to:

FIGURE 3.7


FOREST - 1 ha
35 st/ha year
21.9 ton aerial
biomass per year
EXPLOITATION
EXPLOITATION
RESIDUES
AIR DRIED (25%)
4.4 ton per year
AIR DRIED (25 %) WOOD
FOR CARBONIZATION
17.5 ton per year
CONVENTIONAL
CARBONIZATION
AND TRANSPORT
LOST BY-PRODUCTS
CHARCOAL FINES
<10 mm
0.9 ton.year
OTHER USES
0.45 ton/year
GRAINED CHARCOAL
> 10 mm
3.5 ton/year
0.45 ton/year
SINTER
FABRICATION
BLAST FURNACE
PIG IRON
5 ton per year

* The importance of proper drying time for harvested wood.

* Increase of yield by a better control of air inside the kiln.

* Recovery of the tar obtained from carbonization.

* Importance of proper training of operating personnel.

In addition to these measures, some Brazilian companies are presently seeking to take advantages of wood residues for energy purposes resulting from forest harvesting. Basically, these are the objectives which Florestal Acesita S/A and other Brazilian companies have been pursuing for the past two years.

Carbonization at Florestal Acesita is performed with wood having a moisture content below 30% (wet base). In this case, drying time takes about 90 to 120 days depending on the season. In the rainy season Eucalyptus wood (1.3 to 2 m long) takes 120 days to decrease moisture below 30%.

Table 3.XXVIII shows the ffect of wood moisture content on carbonization yields both in weight and in volume (st/m^3).

As we said before, carbonization in Brazilian brick beehive kilns was done by controlling some 56 portholes which permits air intake to support partial combustion of the wood and to give heat to the process. This is difficult to control and normally we burn more wood than necessary. With the objective to decrease the number of holes to be controlled, Florestal Acesita is testing a carbonization chamber to be fitted to the 5 meter diameter brick kiln which has yielded promising results. It consists, basically, in transfering the firewood burning process, which normally takes place inside the kiln, to a combustion chamber located under the kiln floor (Fig. 3.8), this eliminates the air inlet portholes and allowes control of the process by means of a butterfly valve coupled to the feed door of the combustion chamber. As a result the whole carbonization prices can be better controlled and high temperatures (700° to 900°C) inside the carbonization chamber can be avoided (Figs. 3.9 and 3.10).

The kiln at the experimental battery of Florestal Acesita has the following characteristics:

Wood volume - 37 steres, the same as in the conventional kiln.

. Production per batch - 25m^3 of charcoal.

Carbonization cycle - similar to the conventional kiln.

Yields

. charcoal yield (dry base = 36% by weight
. conversion index = 1.65 steres of wood/m^3 of charcoal.

The results so far obtained show an excellent prospect for the utilization of the carbonization process, for the following reasons:

- higher yields.

- easier operation, since the new kiln eliminates the need for air inlet portholes in its surface.

- longer useful life of the kiln due to the absence of higher temperatures.

- low installation costs: less than US $400.00 (combustion chamber).

- the process is less dependant on external conditions (wind direction, for example).

Florestal Acesita S/A is already assessing the first results obtained from 50 kilns scattered over its charcoal production areas.

Not long ago, a few integrated steel makers, through their subsidiary forest companies, started to develop a new process to recover the tar generated in brick beehive kilns. A new manufacturing process is now being developed by Florestal Acesita in which the volatile gases from carbonization are collected in the central part of the kiln and pass through a washing tower cyclones and filters. (Fig. 3.11).

The tar obtained from carbonization is, for the Brazilian integrated steel industry, an excellent substitute for fuel oils, having the following advantages:

- It can be produced by the company making use of it.

- Large availability.

- Optimum fluidity for use in burners; low preheating temperature - 40°C to 50°.

- Clean fuel, practically free from ashes and sulphur.

- It is a liquid fuel.

- High heating value: 5,500 to 6,500 kcal/kg (about 60% of that of fuel oil).

The system being implemented by Florestal Acesita S/A allows, as average, recovery of tar in the order of 4.0% of the dry weight of wood. This, in terms of the wood used by the company, means an average of 120 kg of tar per ton of charcoal produced.

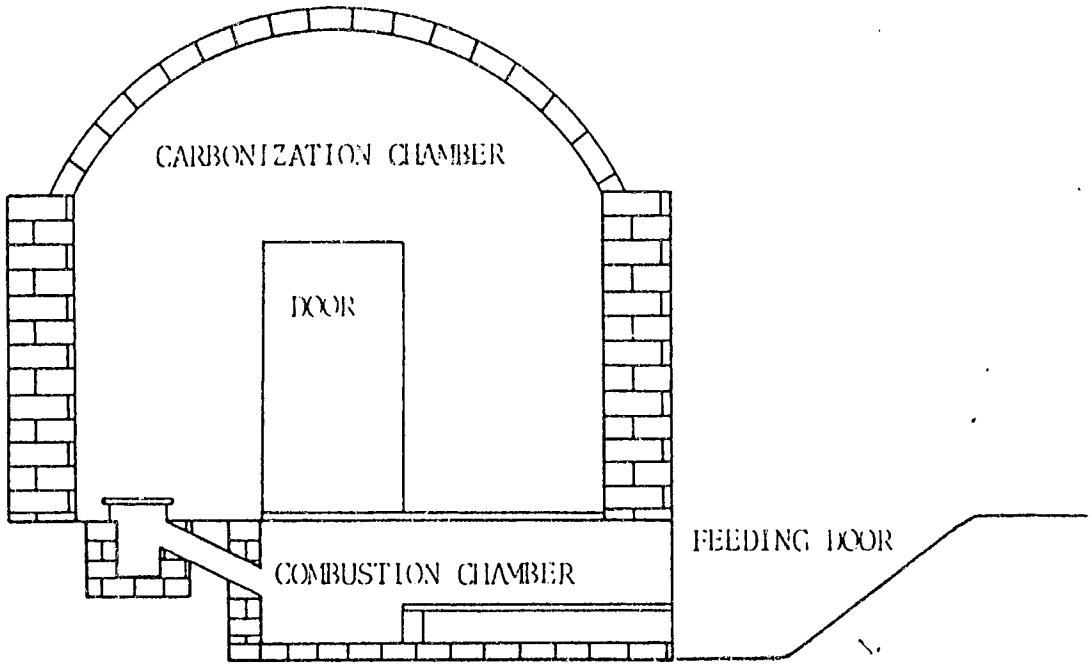
Considering the company's monthly production of 20,000 tons of charcoal, there is a recovery potential of 2.400 t/month of tar, that is, 60% of the ACESITA steel plant requirements for fuel oils can be expected by 1983. Within a few years, in addition to supplying all the charcoal for the steel plant, Florestal will also be able to produce enough tar to meet the plant's fuel requirements for its heating furnaces, that is, the equivalent to its total fuel oil consumption.

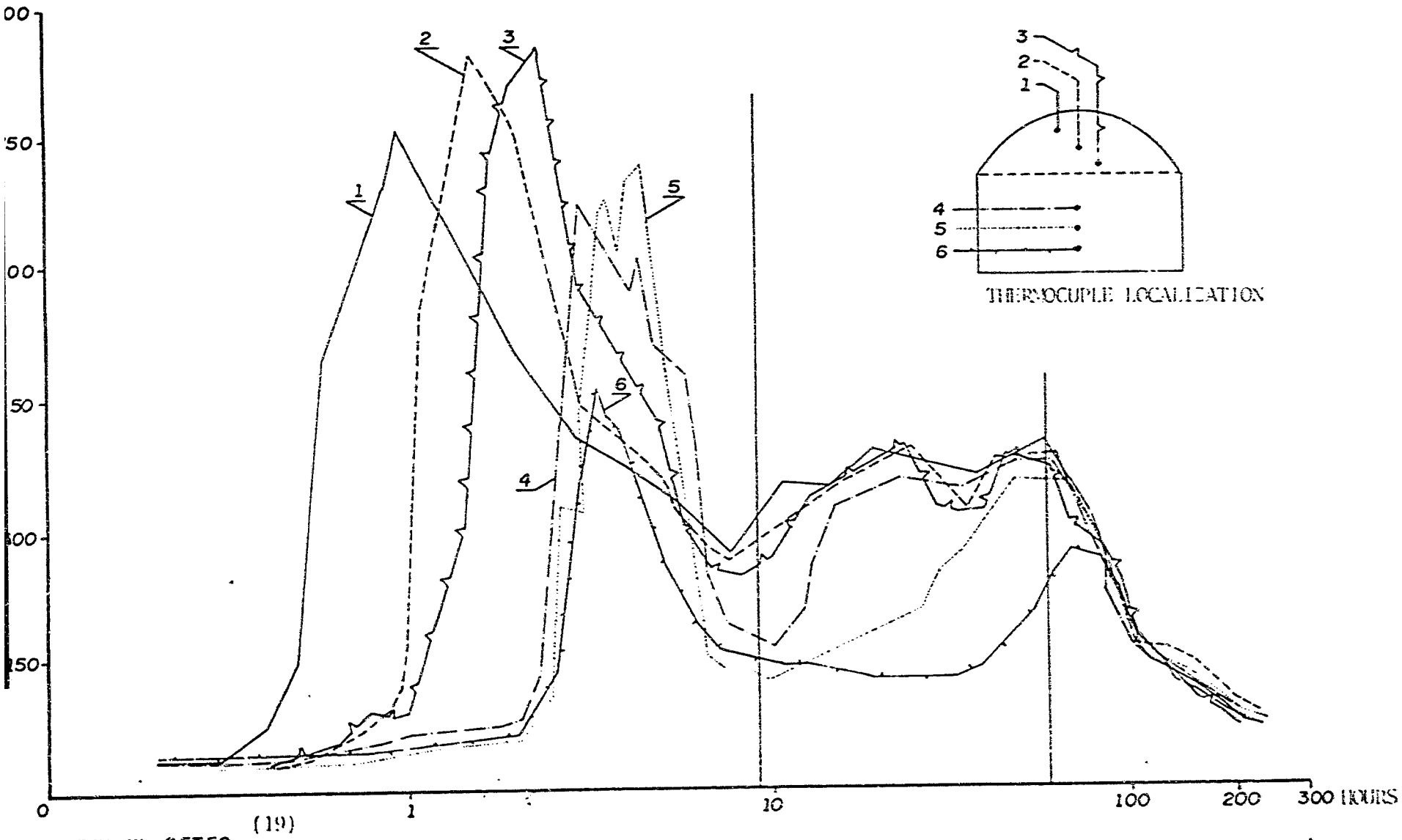
TABLE 3.XXVIII - EFFECT OF WOOD MOISTURE CONTENT ON CARBONIZATION YIELD FOR BRICK BEEHIVE KILN - (5 m of diameter). Eucalyptus grandis- 5 YEARS OLD

DRYING TIME (days)	MOISTURE CONTENT (%)	CARBONIZATION YIELD	
		% Of Dry Wood	Steres of Wood/m^3 of charcoal
10	47	21	2,51
30	41	27	2,16
60	33	31	1,76
90	25	33	1,51
120	22	33	1,51

SOURCE: FLORESTAL ACESITA ( )

FIG. 3.8 - BRICK BEEHIVE KILN WITH COMBUSTION CHAMBER

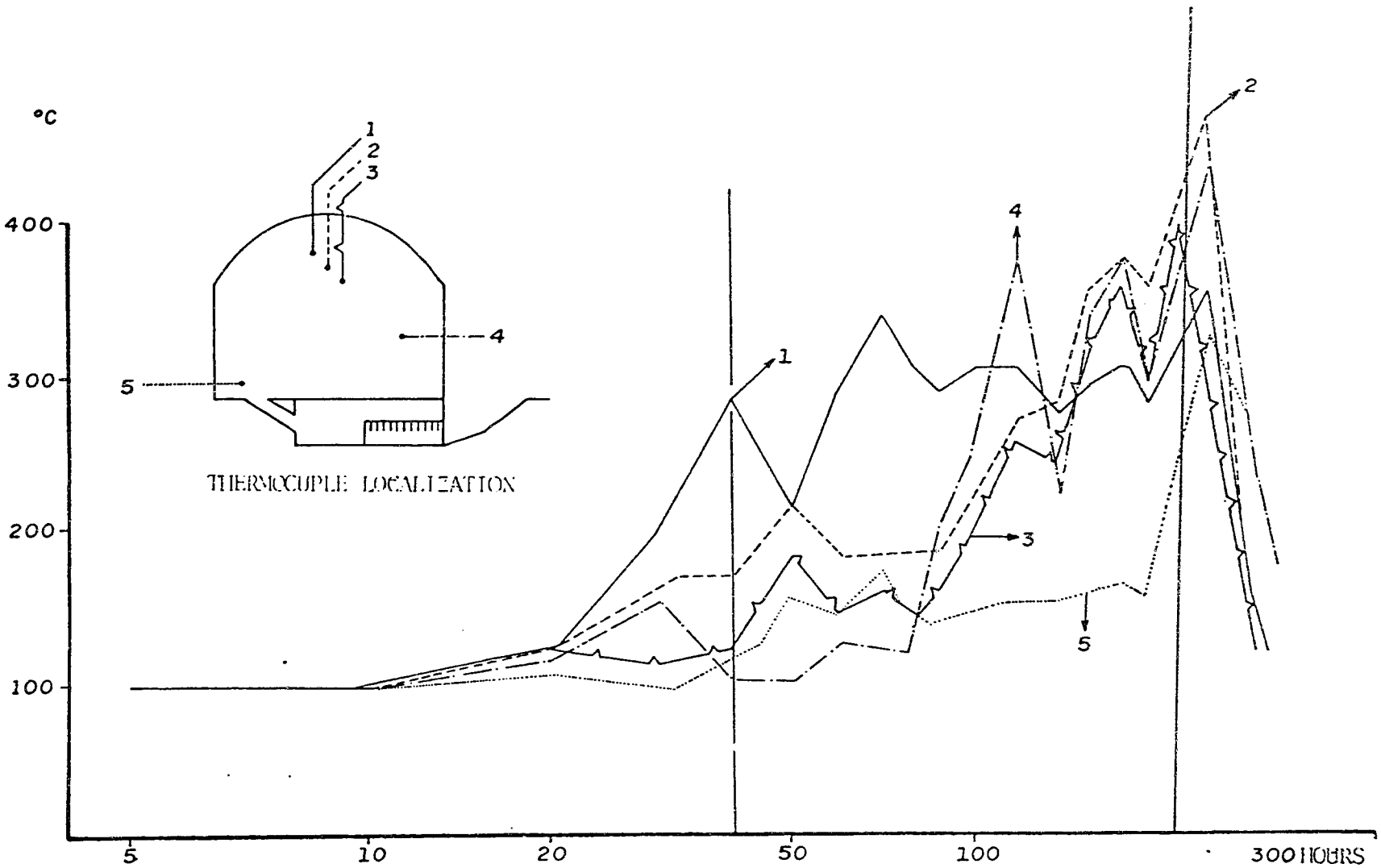




(19)

SOURCE : CETEC

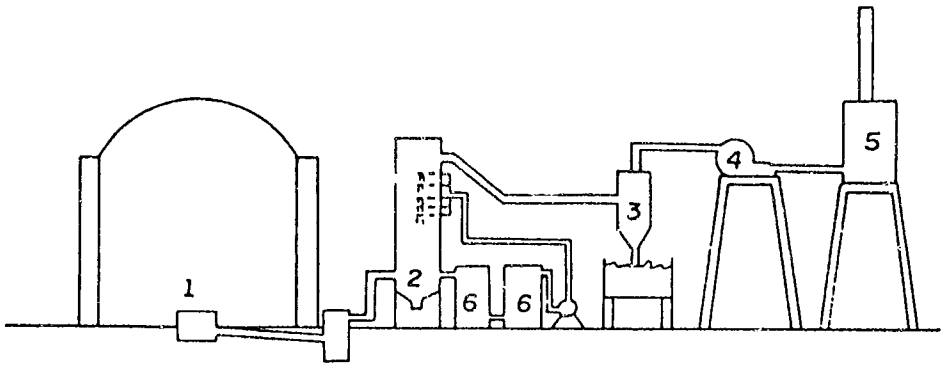
FIG. 3.9 - BRICK BUILT KILN INTERNAL TEMPERATURE DISTRIBUTION

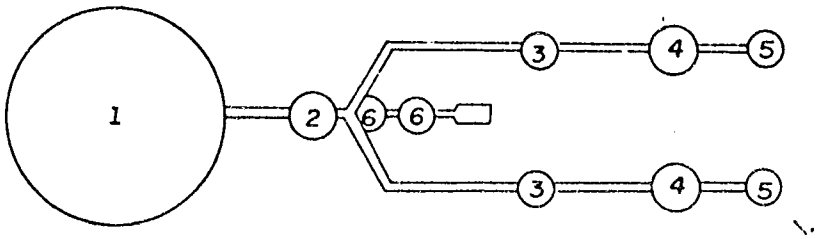


SOURCE: FLORESTAL ACESITA

FIG. 3.10 - INTERNAL TEMPERATURE DISTRIBUTION OF BRICK BEEHIVE KILN WITH COMBUSTION CHAMBER

FIG.3.11 EQUIPAMENT FOR TAR RECOVERY FROM BRICK BEEHIVE KILNS VOLATILES





1 - KILN

2 - WASHING TOWER

3 - CYCLONE

4 - FRIN

5 - FILTER

6 - COLLECTING DRUMS

Twenty such units, with a monthly production capacity of 3.6 t each, are to be installed in the current year. The objectives of these units are:

- production of tar for adaptation in burning systems in replacement for petroleum derivitives.

- development of transportation and storage systems for charcoal.

- setting-up of personnel training centers aimed at developing operation techniques for charcoal making and tar recovery.

- development of systems of quality control and reliability aimed at its commercialization.

At the same time, further developments of the system will be devised to increase the rate of tar recovery and bring down costs.

Fig. 3.12 shows, in a schematic form, the utilization of forest biomass, with a tar recovery. In terms of utilization of the energy potential of the total biomass we have 47%. In terms of the energy yield of the process as such the efficiency is 59%.

A marked interest in continuous carbonization processes is gradually emerging in our country. These systems, besides allowing higher yields makes possible the recovery of almost all the carbonization by-products, either for the manufacture of chemical products or for use as a medium heating power fuel.

In this particular area, Florestal Acesita S/A has been experimenting with a new retort for the production of 10 tons of charcoal per day. This retort, to be installed in the Rio Doce Valley, is scheduled to start operating by 1983.

As observed earlier the utilization of forest residues left in the field during harvesting operations represents an important potential energy resource. The following uses are being developed now in Brazil:

* Direct use in boilers for industrial heat.

* Electricity production.

* Conversion to low heating value gas.

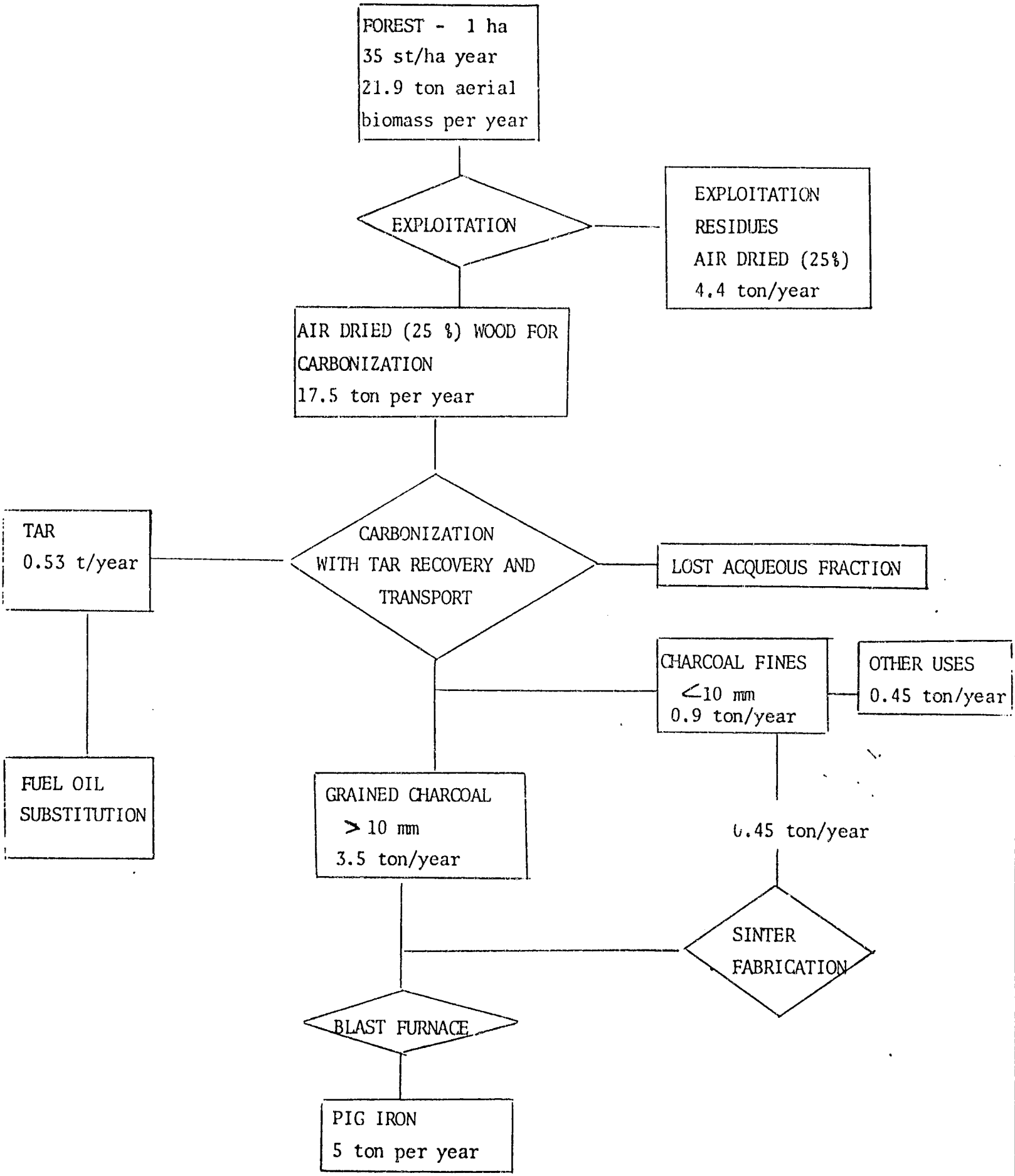
* Densification for the same above use to minimize transportation costs.

* Conversion to charcoal for general uses (not for blast furnaces).

* Hydrolyses for the production of alcohol and high quality lignin coke.

The first alternative, which has been adopted by a few pulp and paper companies is a rather attractive one, mainly for those industrial units located close to their forest areas and within short transportation distances.

FIGURE 3.12


FOREST - 1 ha
35 st/ha year
21.9 ton aerial
biomass per year
EXPLOITATION
EXPLOITATION
RESIDUES
AIR DRIED (25%)
4.4 ton/year
AIR DRIED (25 %) WOOD FOR
CARBONIZATION
17.5 ton per year
TAR
0.53 t/year
CARBONIZATION
WITH TAR RECOVERY AND
TRANSPORT
LOST ACQUEOUS FRACTION
CHARCOAL FINES
<10 mm
0.9 ton/year
OTHER USES
0.45 ton/year
FUEL OIL
SUBSTITUTION
GRAINED CHARCOAL
> 10 mm
3.5 ton/year
0.45 ton/year
SINTER
FABRICATION
BLAST FURNACE
PIG IRON
5 ton per year

As a source of electric power, the residue may be profitably used in rural areas lacking in electricity. Although efficient and reliable technologies for small power plants have been developed in various countries, no plants have as yet been built in Brazil.

Gasifier development is very active in Brazil for utilization of wood or charcoal. This development is not explicitly directed to the use of residues although it can be done easily. Through densification, the making of briquettes from crushed wood residues, a denser and more homogeneous material can be obtained, thus rendering it more suitable to utilize the existing gasifier technology and to decrease the transportation costs.

An alternative way to produce a more transportable product from residues is to convert them to charcoal. Until recently this option was not developed because the charcoal produced was not suitable for use in blast furnaces.

However it is suitable for oil substitution. Existing kiln technology is being adapted to produce charcoal from residues. Although the trade-off between densification and charcoal have not yet been adequately analyzed, it appears that charcoal conversion technology is more adapted to the dispersed nature of this resource.

Acid hydrolysis of wood and residues is being developed in Brazil to produce ethanol and lignin coke. Current technology yields 150 liters of alcohol and 350 kg of lignin (175 kg of coke) per ton of Eucalyptus forest residues processed. For every ton of wood processes approximately one ton is needed to generate steam for the plant, as a consequence the overall energy efficiency is low (between 20 and 25%).

3.2.4.4 Final Considerations

The effort to increase the energy production from a given amount of available forest biomass can have a very large effect. Table 3.XXIX summarizes the impact which various changes discussed above can have upon this measure of efficiency, both singly and when combined. It is noteworthy that a combination of relatively low cost and low technology modifications (option E in the Table) can increase the energy output from available biomass in the forest by almost 60% compared to the standard procedure today.

We have not yet taken into account the limit of economic viability of each technology, but this is currently being done. Several of the low investment options are likely to be viable.

TABLE 3.XXIX - IMPACT OF DIFFERENTE TECHNOLOGY COMBINATIONS ON CONVERSION EFFICIENCY

LEVEL OF TECHNOLOGY	PROCESS EFFICIENCY (%)	FOREST UTILIZATION EFFICIENCY (%)	INVESTMENT per ton.year of charcoal installed
A. Standard Procedure: brick beehive kilns, no by-products recovery, no forest residue on 50% fines recovery	53	42	US$ 6 Included only brick beehive kilns
B. Standard Procedure with increase charcoal yield-brick beehive kilns with wood combustion chamber	58	46	US$ 7 Included brick beehive kilns with combustion chamber
C. Standard Procedure with tar recovery	59	47	US$ 24 Included brick beehive kilns with one tar recovery equipment for 2 kilns
D. Brick beehive kilns with combustion chamber, tar recovery, no forest residue use, 100% fines recovery	71	56	US$ 24 Included brick beehive kilns with combustion chamber with one tar recovery equipment for 2 kilns
E. Case D plus small brick beehive kilns to convert 80% residue to charcoal	-	66	US$ 24
F. Advanced continuous carbonization retort with tar recovery only, without residue use, 100% fines recovery	78	62	US$ 280 Included only continuous carbonization with tar recovery furnace
G. Advanced continuous carbonization retort with by-products recovery as methanol, acetic acid and solube tar, plus small brick beehive kilns to convert 80% residues to charcoal, 100% fines recovery	78	72	US$ 428 Included continuous carbonization furnace with tar, acetic acidand methanol recovery
H. Advanced continuous carbonization retort with by-product recovery 100% fines recovery plus production of Ethanol and lignine coke by acid hydrolysis	-	66	

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4. BRAZILIAN WOOD CHARCOAL ECONOMICS

4.1 INTRODUCTION

Charcoal is a major raw material for producing pig iron accounting for more than 60% of the final product cost.

For the steel mills the commercial price of charcoal from native forests is the most significant cost component of consumed charcoal. In 1980 the charcoal based pig iron and steel industry consumed 19 million cubic meters of charcoal, of which 80% was estimated to have been produced from wood of natural forests. Small pig iron makers, accounting for 60% of total consumption, still depend entirely on charcoal from native forests.

On the other hand, the integrated steel mills are already using their man-made forests to manufacture part of the consumed charcoal; some companies have already reached a 50% self-sufficiency. An intensive program of eucalypt forest plantation is being implemented, with a goal of complete self-sufficiency by 1995.

Therefore, it is of great importance to analyze the economics of charcoal production from both native and man-made forests. This is further accentuated by the growing use of charcoal to substitute for fuel oil in the industry.

The following stages of charcoal production will be considered:

CHARCOAL PRODUCTION

REFORESTATION	CHARCOAL MAKING	TRANSPORTATION

4.2 REFORESTATION

This stage begins with site preparation and planting and continues with silvicultural treatments throughout the forest production cycle.

The most used silvicultural regime in Brazil is a twenty year forest cycle with three cuttings at intervals of six or seven years; spacings are of 6 to 4.5 m^2 per stem, equivalent to 1,667/2,223 stems per ha.

ROTATION	ITEMS	PERIOD
1st	Stand Establishment	1st Year
	Maintenance	From the 2nd to the 7th year
	Cutting	7 years after planting
2nd	Regeneration	8th year
	Maintenance	From the 8th to the 13th year
	Cutting	6 years after the first cutting
3rd	Regeneration	14th year
	Maintenance	From the 15th to the 20th year
	Cutting	6 years after the 2nd cutting

Recently, however, an aiming at maximizing wood production for energy purposes, the concept of intensive stand management, based on close spacing and short rotations, was introduced; plantings with less than 3 m^2 per stem and cutting of stands less than three years of age was initiated.

4.2.1 STAND ESTABLISHMENT

The first eucalypt plantations for charcoal production were established on steep areas located near the steel mills. Subsequently, due to a rise in land prices and increasing labor costs the flat areas in the state of Minas Gerais became desirable, in spite of great distances from the steel plants.

What follows is a detailed study of plantation establishment and management in flat areas which are believed to be the most representative of present Brazilian silvicultural practices. Figure 4.1 shows an operation flow for establishment of forests in flat areas and Table 4.1 shows the direct costs for stand establishment.

4.2.1.1 Site Clearing and Preparation

Clearing of the terrain depends on the kind of vegetation cover. It is much easier, for example, in the brush wood regions of the states of Sao Paulo and Minas Gerais than in the coastal forests in the state of Espirito Santo.

Two caterpillar bulldozers, dragging a steel chain between them, are used to clear the land of its vegetation cover. The stumps are removed and piled by a caterpillar equipped with scraper blades. The trunks are cross cut with chain saws and used for charcoal making. Table 4.1 shows the direct costs for site clearing in brush land regions.

In open areas, with no significant vegetation cover, the residues are simply piled by caterpillar tractors and later burned.

In general, forestation areas are divided into tracts of approximately 50 ha each to facilitate equipment handling within the area and also to prevent risks of fire.

Plowing, harrowing and opening the furrow complete the site preparation. These operations are performed with a 105 HP wheeled tractor at a cost as shown in Table 4.I. Usually, the ground is prepared for planting at the beginning of the year through September, before the start of the rainy season (October to March).

4.2.1.2 Growing of Seedlings

Use of seedlings produced from seeds has been the most common technique in Brazil. We have recently introduced vegetative propagation from rooted cuttings, which although very promising, is still used on only a small scale.

The nursery is established on a terrace made by scraper blade machines; the irrigation system consists of pumps, piping and sprinklers. The seeds are planted in transparent plastic bags filled with a mixture of soil, fertilizer, and lime. The containers are treated with fungicides after sowing and with insecticides when needed. The seedlings are thinned, selected, and after maturation they are dispatched in plastic boxes for planting. The length of the seedling growth period is approximately 100 days. Table 4.I shows the direct costs for seedlings.

4.2.1.3 Planting and Replanting

Planting can be mechanized to some degree. There are planting machines, pulled by a wheeled tractor that can perform the simultaneous operations of opening the furrow, fertilization, and seedling planting in the required spacing; however, the operation of opening the plastic bags and planting are performed manually. Twelve workers with this equipment can plant up to 16,000 seedlings per day.

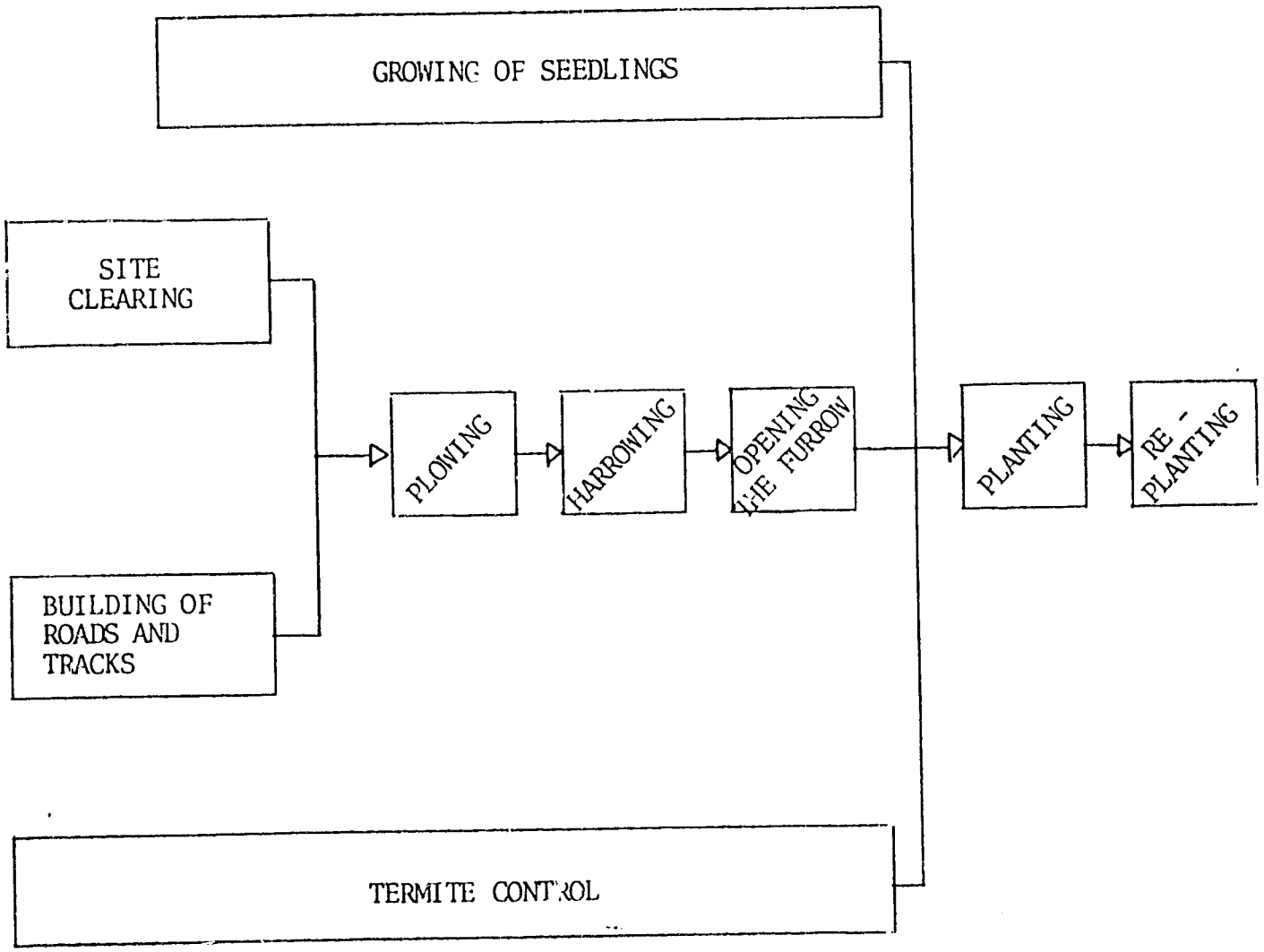
Although several experiments have been carried out, no suitable equipment for mechanized seedling planting has yet been developed. The use of plastic bags makes planting mechanization difficult and tests with other containers have not been successful. For this reason, once the mechanized opening of the furrow has been done wheeled tractors with carts, or even trucks, are usually used for planting and fertilizer distribution. The operations of staking-out, digging holes, fertilizating, and finally planting are performed manually. In sandy soils like those of the coastland of the state of Espirito Santo where the operation of opening the furrow is not common practice, a machine pulled by a wheeled tractor is employed for digging the holes and planting seedlings. Table 4.I shows direct costs of planting in a manual system.

TABLE 4.I - DIRECT COSTS FOR STAND ESTABLISHMENT

OPERATION	INPUTS			QUANTITY OF UNIT PER HA	COST US$/ha
	ITEM	UNIT.	US$/UNIT		
BUILDING OF ROADS AND TRACKS	CATERPILLAR	Eh	16.58	0.52	8.62
	MOTO-SCRAPER	Eh	20.50	0.31	6.33
	LOADER	Eh	8.67	0.36	3.12
	DUMP-TRUCK	Eh	5.58	0.36	2.00
	SUB-TOTAL				20.07
SITE CLEARING	CATERPILLAR	Eh	16.58	3.00	49.74
	CHAIN-SAW	Eh	3.27	4.00	13.08
	TRUCK	Eh	5.58	4.70	26.23
	LABOR	Mh	0.95	38.00	36.10
	SUB-TOTAL				125.15
TERMITE CONTROL	EQUIPMENT FOR FORMICIDE APLICATION	Eh	2.04	2.00	4.08
	FORMICIDE (MIXTURE)	-	-	-	2.69
	LABOR	Mh	.95	6.00	5.70
	SUB-TOTAL				12.47
PLOWING	TRACTOR WITH PLOW	Eh	9.90	2.50	24.75
HARROWING	TRACTOR WITH HARROW	Eh	9.68	1.50	14.52
OPENING THE FURROW	TRACTOR WITH IMPLEMENT	Eh	9.24	1.80	16.63
SEEDLING GROWING	SEEDS	kg	109.89	.67	73.63
	LABOR	Mh	.95	39.98	37.98
	OTHERS	-	-	-	19.39
	SUB-TOTAL				131.00
PLANTING	TRUCK	Eh	5.58	1.50	8.37
	TRACTOR WITH CART	Eh	9.67	4.50	43.52
	FERTILIZER	t	439.56	.23	101.09
	LABOR	Mh	.95	30.00	28.50
	SUB-TOTAL				181.48
IRRIGATION	WATER-TRUCK	Eh	5.58	.50	2.79
	TRACTOR WITH WATER CART	Eh	9.78	1.50	14.67
	LABOR	Mh	.95	8.00	7.60
	SUB-TOTAL				25.06
REPLANTING	TRUCK	Eh	5.58	0.70	3.91
	TRACTOR WITH CART	Eh	9.78	0.70	6.85
	LABOR	Mh	.95	4.00	3.80
	SUB-TOTAL				14.56

NOTE: ALL FIGURES ARE EXPRESSED IN TERMS OF HECTARE OF EFFECTIVE PLANTING

FIG.4.1 OPERATION FLOW FOR ESTABLISHMENT OF FORESTS IN FLAT AREAS



The replanting operation is completed within 50 days after initial planting and it is always performed manually.

Both planting and replanting operations are usually performed in the rainy season, from October to March, preferably after the rains. On sunny days the planting must be complemented by irrigation using equipment consisting of one water-truck with three water cart-equipped wheeled tractors.

In regions presenting a more even yearly distribution of rainfall as in the coastland, seedling establishment and planting are performed uniformly through the year.

4.2.1.4 Summary of Direct Costs for Stand Establishment

The cost for forest establishment varies according to the topographic features of the terrain, type of existing vegetation cover, level of mechanization, level of technology applied, type of spacing, etc.

Following is a summary of the costs, shown in Table 4.II for establishing a plantation that we consider typical of traditional Brazilian silviculture, having the following characteristics:

- topography: flat
- vegetation cover: brushwood
- fertilization: 100 gr of NPK per stem
- spacing: 3m x 1.5m

4.2.2 FOREST MAINTENANCE

Termites are the hazard causing the most threat and damage to plantations in Brazil. In the period of stand establishment an intensive control of termites must be done and continued without interruption, during the entire forest cycle, even when the eucalypt trees have reached maturity.

During the forest maintenance period one to four weedings a year are performed, depending on the extent of the undergrowth. In flat areas weeding is mechanized, requiring 1.5 hours of wheeled tractor time per ha. This work, however, must be complemented with manual weeding among trees in the same row. Table 4.III shows the cost of maintenance in the first year, in flat areas. In steep areas the work is entirely manual and may take up to 60 hours per ha. Maintenance costs in subsequent years are lower, as Eucalyptus trees grow and achieve stand closure thereby diminishing the intensity of undergrowth.

4.2.3 REGENERATION

Regeneration is a one-year period following each cutting. In addition to the operation of controlling termites, there is also the selection and cutting of the best sprouts, which is performed six months after harvesting.

TABLE 4.II - SUMMARY OF DIRECT COST FOR STAND ESTABLISHMENT

OPERATIONS	US$/HA
Building of roads and tracks	20.07
Site Clearing	125.15
Termite Control	12.47
Plowing	24.75
Harrowing	14.52
Opening the Furrow	16.63
Seedling Production (2223 seedlings per ha)	131.00
Planting	181.48
Irrigation	25.06
Replanting	14.56
TOTAL	565.69

NOTE: Labor cost was based on the country's minimum salary plus 20% and an additional 43% for social taxes.

TABLE 4.III - DIRECT COST FOR MAINTENANCE - 1st YEAR FOR FLAT AREAS

INPUTS			QUANTITY OF	COST
ITEM	UNIT	US$/UNIT	UNITS/HA	US$/HA
Wheeled tractor with harrow	Eh	7.44	1.80	13.39
Labor	Mh	0.95	15.20	14.44
Others	-	-	-	2.34
TOTAL	-	-	-	30.17

NOTE: Included under heading "others" is the formicide costs and the hourly cost of the device for applying it.

4.2.4 FINAL COSTS FOR FOREST ESTABLISHMENT

The direct costs analyzed this far are composed of inputs (equipment, labor and materials) that are specific for each operation.

Indirect costs are also an integral part of the operating cost and can be divided into two distinct groups of expenses:

- expenses generally related to the number of workers, such as: personnel transportation, clerical services, supervision, and social benefits (food and housing subsidies, medical and social care, safety, etc).

- general expenses such as: rents, taxes, amortizations, miscellaneous materials, survey services, etc.

In addition to these indirect costs there is "overhead" for the general expenses of main office, technical services, research, etc., which are more centralized and typical of larger firms. Table 4.IV shows the cost composition for 1.000 ha plantation.

4.2.5 STUMPAGE COSTS

In brief, the costs for establishing a typical plantation, under the conditions set forth previously and considering a 20 year forest cycle with 3 cuttings at 6 to 7 year intervals, are as follows:

ROTATION	ITEM	PERIOD	US$/HA/YEAR
1st	Stand Establishment	1st	690.28
	Maintenance (1st year)	2nd year	37.20
	Maintenance (following years)	From the 3rd to the 7th year	16.83
2nd	Regeneration	8th year	42.07
	Maintenance	From the 9th to the 13th year	16.83
3rd	Regeneration	14th year	42.07
	Maintenance	From the 15th to the 20th year	16.83

Besides the investment in the forest itself, the cost of the land must also be considered. The value in US $100/ha will be taken as representative of a "cerrado" land located within a radius of 400 km from the major steel plants in the state of Minas Gerais; a 3% interest rate will be assumed to calculate a return on land investment.

Considering the latest yields attained in Brazil in a 3 x 1.5 m spacings; the following harvests can be estimated:

- 1st cutting: 34 st/ha/year x 7 years = 238 st/ha
- 2nd cutting: 30 st/ha/year x 6 years = 180 st/ha
- 3rd cutting: 30 st/ha/year x 6 years = 180 st/ha

TABLE 4.IV - COMPOSITION OF TOTAL COSTS TO ESTABLISH 1,000 HA OF EFFECTIVE PLANTATION US$/1,000 HA

ITEM	STAND ESTABLISHMENT	MAINTENANCE 1st YEARS	MAINTENANCE FOLLOWING YEARS	REGENERATION
1. Direct Cost	565,690	30,170	13,490	34,540
2. Indirect Cost	85,520	4,920	2,390	5,150
3. Overhead (6% of 1+2)	39,073	2,105	953	2,381
4. TOTAL COST	690,283	37,195	16,833	42,071

NOTE: 1000 ha of effective plantation (area actually planted in trees) has associated with it additional areas for tracks, roads, firebreaks and preservation areas whose costs are included in the calculations.

TABLE 4.V - STUMPAGE COSTS FOR DIFFERENT DISCOUNT RATES

ITEM		US$/st	US$/t (*)
DISCOUNT RATE	10% a year	4.54	9.08
	8% a year	3.83	7.66
	1% a year	1.98	3.96

(*) It has been assumed that one stere has 500 kg at 25% moisture.

TABLE 4.VI - MANPOWER AND EQUIPMENT FOR ESTABLISHMENT OF 1.000 HA

ITEM	UNIT	STAND ESTABLISMENT	MAINTENANCE 1st YEAR	MAINTENANCE FOLLOWING YEARS	REGENERATION
PERSONNEL					
. Laborers	Qty.	85	8	3	15
. Fore men	Per	4	1	1	1
. Clerical Workers	1,000 ha	5	1	1	1
TOTAL		94	10	5	17
EQUIPMENT					
. Caterpillar (88HP)	Qty.	2	-	-	-
. Wheeled Tractor (105HP)	Per	7	0,5	0,5	0,5
. Truck (130 HP)	1,000 ha	4	0,5	0,5	0,5
INVESTMENTS					
. Caterpillar		133,450	-	-	-
. Wheeled Tractor		135,457	9,676	9,676	9,676
. Truck		118,036	14,755	14,755	14,755
. Implements (Plow, Harrow, etc.)	US$ Per	68,000	797	510	797
. Other Equipment (Scraper, Front Lorder, Chain-Saw, etc)	1,000 ha	46,662	-	-	-
. Buildings, Mantenance Shop, etc.		54,900	4,300	4,300	4.300
TOTAL		556,505	29,528	29,241	29,528

TABLE 4.VII - ANNUAL INVESTMENT FOR 7.000 HA

YEAR	ITEM	US$/ha
0	110,000	110,00
1	110,00 + 690,280	800,280
2	110,000 + 690,280 + 37,200	837,480
3	110,000 + 690,280 + 37,200 + 16,830	854,310
4	110,000 + 690,280 + 37,200 + 2 x 16,830	371,140
5	110,000 + 690,280 + 37,200 + 3 x 16,830	887,970
6	110,000 + 690,280 + 37,200 + 4 x 16,830	904,800
7	- 690,280 + 37,200 + 5 x 16,830	811,630
TOTAL		6,077,610

NOTE: The value of US$ 110,000 refers to annual investments on land purchasing which amounts to a total area of 7.000 ha.

4.2.6 PERSONNEL AND INVESTMENT REQUIREMENTS

The silviculture operations are not performed uniformly during the year. Site preparation should be done before the rainy season and planting limited to the last months of the year. Consequently, equipment and manpower are unevenly distributed during the year. For the sake of simplification Table 4.VI shows the average manpower and equipment and the average investments required for the establishment of 1,000 ha of a forest plantation. The investments shown in this table refer to equipment and installations. A forest plantation should have an area of 7,000 ha in order to sustain annual cuttings in 1,000 ha; assuming a 200 st/ha yield after seven years of age, this forest would attain a 200,000 st annual capacity.

The required investments to implement such a project would accrue each year to the time of the first harvest, at 7 years of age, as shown in Table 4.VII. The present worth of these investments is US $4,199,927 at a discount rate of 8% per year. Considering an annual production of 200,000 st the required investment would be US $21.00/st per year capacity.

4.2.7 COSTS OF FOREST ESTABLISHMENT ON STEEP AREAS

On steep areas, where mechanization is not feasible, site preparation and planting are carried out manually and at higher costs. In the following chart the establishment costs of a forest having the following features are shown:

- condition of the terrain: steep area
- spacing: 3.0 m x 1.5 m (2,223 stems per ha)
- fertilization: 100 gr of NPK per stem.

ROTATION	ITEM	PERIOD	US$/HA/YEAR
1st	Stand Establishment	1st	1,246.37
	Maintenance (1st year)	2nd year	92.60
	Maintenance (following years)	From the 3rd to the 7th year	38.46
2nd	Regeneration	8th year	76.92
	Maintenance	From the 9th to the 13th year	38.46
3rd	Regeneration	14th year	76.92
	Maintenance	From the 15th to the 20th year	38.46

Costs of forest exploitation on steep areas are higher than those on flat areas. Nevertheless, in cases of availability of land in the vicinity of a consumer plant, the low costs of transport can offset the high prices of land, especially if the final product is wood and not charcoal.

4.2.8 ECONOMIC IMPACT OF TECHNOLOGICAL CHANGES

So far we have analyzed stumpage costs of a plantation established according to conventional silviculture. Recent interest in using forests as an alternative energy source, however, has led foresters to review former management concepts, which generally aimed at wood production for non-energy purposes. Intensive forest management aims at maximizing the use of soil and the inputs applied to the forest to attain the highest wood volume per ha.

Intensive use of land requires higher investment per unit of area. From the economic viewpoint, intensive management will be profitable when the increase in productivity is higher than the additional investment applied. Table 4.VIII summarizes a comparison among the costs of some management regimes. In spite of the small stumpage cost reduction or the shorter spacings, an appreciable reduction in the planting area is attained at the same level of production. This aspect is still more relevant in places where land availability is less and land costs are higher.

4.2.9 STUMPAGE COSTS OF NATIVE FORESTS

Unlike man-made eucalypt plantations, the native forest, that it is natural, requires no investment for its the growth. As previously stated, the charcoal market in Brazil is today dominated by commercialization of charcoal from native forests.

Deforestation in Brazil has been stimulated basically by the expansion of cattle raising and agricultural boundaries. Charcoal making is a by-product and constitutes a marginal and subsidiary activity in this case. Due to the fast pace of deforestation for pasture and agricultural purposes the supply of stumpage has overrun consumer needs, causing a very low quotation for the price of stumpage. However, it is true that this situation has changed somewhat since the exhaustion of native forest reserves and has enhanced the value of the remaining forest closer to the consumer centers.

The market value of stumpage for native forests varies from US $0.30/st to US $0.80/st depending on the location. There are no major differences of quality between the two kinds of charcoal, hence we may conclude that the market price for native wood is today very much less than the stumpage cost for established eucalypt forests.

For the future, however, the following occurrences must determine a price balance for the two kinds of wood:

1 - exhaustion of native forest reserves leading to an increase in wood price
2 - reduction in costs of man-made forests due to gains in productivity

4.3 CHARCOAL MAKING

This stage of production comprises the entire wood transformation from the standing tree to the final product (charcoal) at the kiln yard. Fig. 4.2 shows a simplified operation flow for charcoal making.

TABLE 4.VIII - COMPARISON BETWEEN SOME MANAGEMENT REGIMES

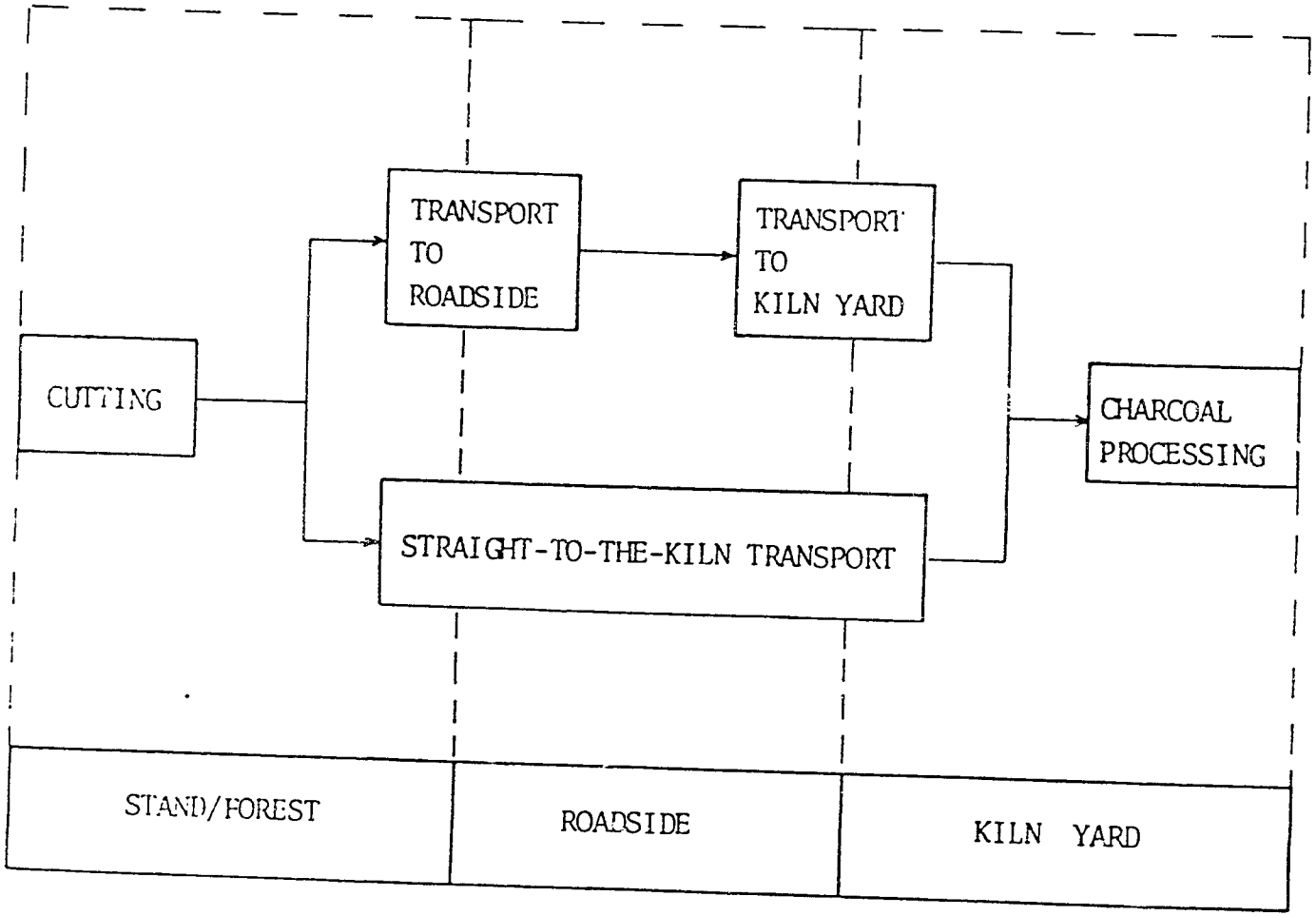
SPACING TYPE (m)	NUMBER OF TREES PER HA	USED TECHNOLOGY (1)		YIELD st/ha YEARS	1st YEAR ESTABLISHMENT COST US$/ha	STUMPAGE COST US$/st	AREA (3) HA
		PHOSPHATE	CUTTING AGE				
3.00 x 2.00	1,667	N.A.(2)	7 y.s.	24	613.67	5.32	9.600
3.00 x 1.50	2,223	N.A.(2)	6/7 y.s.	34	690.28	3.83	6.800
3.00 x 1.50	2,223	1 t/ha	6/7 y.s.	42	783.13	3.46	5.500
2.00 x 1.00	5,000	1 t/ha	4 y.s.	55	1,165.77	3.37	4.200
1.50 x 1.50	6,667	1 t/ha	3 y.s.	60	1,395.31	3.28	3.800

NOTE: 1) It was also assumed that in the cases of the three last types of spacing (3 x 1.5, 2 x 1.5, and 1.5 x 1.00) an improvement in selected seeds and site preparation has been accomplished.

2) N.A. = not applied.

3) Required area for an annual production of 100,000 m^3 of charcoal.

FIG. 4.2 - SIMPLIFIED FLOW OF OPERATIONS FOR CHARCOAL MAKING



To dry the wood it must be stored, for at least, ninety days. The stocks can be maintained in three different places:

- In the stand/forest

The wood is cut, gathered and, following the period of drying, taken to the kilns. This method can only be applied to native forests where regeneration is not desirable and no special care is required. This method is also suitable for eucalypt plantations, when removal of logs can be done by mule-drawn carts or other equipment not causing damage to the emerging sprouts.

- At the roadside

The logs must be removed from the stand to the roadside within 20 days so as not to damage the emerging sprouts. After drying for a period of 70 days, the logs are transported to the kilns.

- At the kiln yard

The logs can be transported straight from the stand to the kiln yard. After drying, they are moved to the entrance of the kiln.

Drying wood in the forest, has the advantage of eliminating one handling operation and hence reducing costs.

4.3.1 COMMONLY USED EQUIPMENT

Charcoal making operations can be performed by various types of equipment, depending on the topographic conditions and whether the wood is from native forests or from man-made eucalypt plantations. The most important equipment and operations will now be described.

4.3.1.1 Cutting Operations

Axes and chainsaws are used for felling, delimbing, and cutting the trees into logs. Axes are recommended for young and small diameter trees. One man equipped with only an axe is able to fell and cut into logs an average of 7 st of wood per day or 25 st per day when using a chainsaw.

4.3.1.2 Transportation

Mules and oxen are the most used methods for hauling wood and can be employed on both flat and steep land. Oxen can pull drays or carts loaded with logs, or they can simply drag the trees along. Mules can pull a cart or carry logs in baskets. These animals are more suitable for hauling to the roadside or directly-to-the-kiln transport over short distances. Accordingly, the productivity varies from 7 to 20 st per day.

Trucks, or tractors, equipped with carts can be used to transport the logs, however they can only work on flat areas or roads. Where loading and unloading is done manually this equipment can transport from 50 to 80 st per day.

Hauling on flat areas may be done by forwarders attaining a productivity of 230 st per day. This is a common practice in the pulp and paper industry

Another device for hauling entire tree trunks over flat areas, is the "mini-skidder", which proved unsuccessful.

In steep areas the hauling of tree trunks can be done by winches. There is a diesel-powered drum winch that can haul 35 st/per day. Another type is fitted to a wheeled tractor and can haul 60 st per day.

4.3.1.3 Loading and Unloading the Wood

A wheeled tractor fitted with a grapple is used for loading and unloading logs. A set of equipment consisting of two loaders and three tractors with carts, or trucks can transport 450 st per day.

4.3.1.4 Loading of Charcoal

Charcoal loading can be done manually using baskets or by a loader fitted with a special bucket. This equipment can load a truck with 45 m3 of charcoal in less than one hour.

4.3.1.5 Other Equipment Types

Experiments with more sophisticated equipment such as feller-bunchers, skidders and heavy loading machines have not been successful. Investment and operating costs of this equipment are too high under present Brazilian economic situation. In the case of the feller-buncher there is the additional risk of the eucalypt stumps being damaged by shearing.

4.3.2 CHARCOAL PROCESSING

Wood is carbonized in beehive kilns built of ordinary bricks. The kilns may be installed separately or grouped in a set or battery. The usual method is to group the kilns in a "battery" in which the production is geared to the work of two men (one operator or burner, and one helper).

There are many types of kilns for charcoal processing, but the most frequently used are as follows:

- a brick beehive kiln five meters in diameter, with 6 chimneys
- a sloped type brick beehive kiln, four meters in diameter.
- a brick beehive kiln, three meters in diameter with no chimneys (hot tail)

The five meter diameter kiln is the largest of the three and has the longest life span. The chimneys allow a better control of the carbonization process. It is suitable for more centralized and permanent production centers.

The three meter diameter kiln is easy to build and the investment is low. Due to its short life span, it is more suitable for scattered and mobile units used for making charcoal from native forests. The four meter diameter kiln, requires fewer bricks for construction and must be installed, on sloping land.

The wood is cut into logs of 1.0 to 2.0 m in length, depending on the size of the kiln. Loading is done manually with the logs placed in an upright position. To cool the kiln it must be brushed over several times with clay slurry.

The total production cycle of the kiln comprises wood carbonization and charcoal cooling and lasts seven days for the three meter diameter kilns and ten days for the five meter diameter kilns. The total time depends very much on the wood moisture content.

Generally, two steres of wood with 30% moisture content are required to make one cubic meter of charcoal. Native wood, however, mainly from the brush woods, due to its irregular shape, does not even fill out the usable space of the kiln. Because of this 2.7 steres of wood are required to make one cubic meter of charcoal.

After complete cooling, the kiln is opened and the charcoal is removed manually by means of forks and baskets. Due to the risk of charcoal catching fire spontaneously when in contact with the oxygen in the air, it is necessary to keep it in an open area in the kiln yard for a period of at least 24 hours. Another major care is to protect the charcoal from eventual rains through the construction of ordinary roofings or covering the charcoal with a plastic canvas.

4.3.3 PRODUCTION ORGANIZATION

Production may be organized into small autonomous units or centralized into larger units. The small unit concept is more frequently used for making charcoal from natural forests. The kilns are scattered over the working areas and the wood is transported directly from the stumps by animals. The owners of these units are farmers, or small contractors whose main activity is charcoal making. Small production units have the advantage of appreciably reducing the wood handling distance to the kiln and hence are more suitable for transportation with animals. In small units, installed in eucalypt plantations, the wood may be kept in the stand for drying and then removed by animals, thus eliminating one handling operation.

Centralized production areas are more common in charcoal making from eucalypt forests, which are generally harvested by large companies. This kind of organization is associated with a higher level of mechanization due to the scale of work required.

Another major aspect is related to work organization: in macro-units work is organized by functions, with specialized crews for cutting, transportation and charcoal processing. In micro-units, on the contrary, tasks are more diversified with little specialization. The concept of the "micro-unit", as applied by Florestal Acesita to most of its production, will be analyzed later in this section.

4.3.4 TYPICAL SYSTEMS OF CHARCOAL MAKING

There are many systems that can be used for charcoal making. What follows is an analysis of those systems considered to be the most representative of the present Brazilian reality, as shown in Table 4.IX. Figures 4.3, 4, 5, 6, 7, 8, and 4.9 illustrate the typical systems.

4.3.5 DIRECT COSTS OF CHARCOAL MAKING

Table 4.X shows a summary of the direct costs of charcoal operations according to the systems previously mentioned.

The manual system, used in native forest wood based charcoal making has the lowest cost of all, in spite of adverse working conditions, the low yield of the kilns and the low operational productivity. The major reason is the low labor cost of the small farmers, who generally, subcontract the charcoal making service. Whole families are employed and paid according to production, assuring the maintenance and economic stability of their family members. The system of sub-contracting charcoal activities simplifies the administrative task and reduces its cost.

On the other hand, charcoal from plantation grown eucalypt wood is manufactured by well-organized companies that offer higher wages to their employees as well as benefits and services enforced by law. The costs here presented are based on the current minimum salary plus 20%. Some companies, such as Florestal Acesita, pay even higher salaries.

Among the charcoal making systems from eucalypt wood, the semi-mechanzied system in steep areas has the highest cost of all as shown in Table 4.XI. In this case, the wood must be handled twice, thereby increasing its cost. Moreover, the transport to the roadside is done by mules on very steep slopes.

The manual system of making charcoal from eucalypt wood presents higher indirect costs because of some expenses directly related to the quantity of workers employed, such as costs of personnel, transportation, supervision, and social benefits. On the other hand, financial costs are lower due to the lower level of investment applied.

The mechanized system shows higher financial costs and its indirect cost is affected by some expenses related to supporting services, such as, warehouse, maintenance shop, specialized services, etc.

Table 4.XII gives a more detailed breakdown of the costs of charcoal making including coefficients for labor and equipment inputs. The manual system for native forests and the semi-mechanized for plantation eucalyptus wood have been selected as examples. These costs show, contrary to commonly-held opinion, that there are no significant differences among the various charcoal making systems in flat areas. This economic evidence further strengthens the social argument in favor of manual systems.

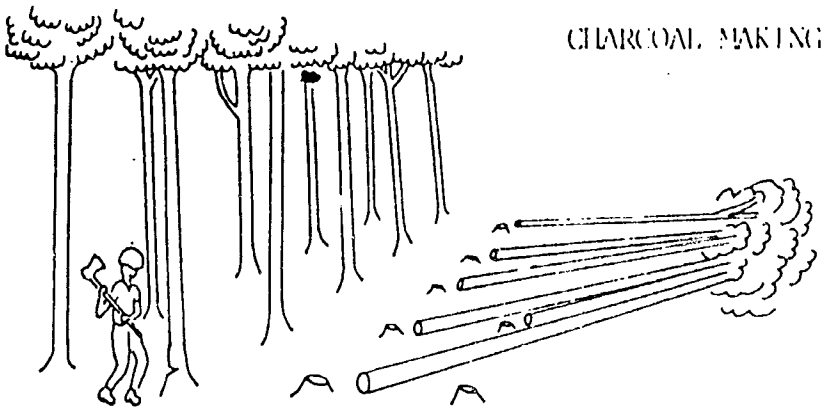
TABLE 4.IX - TYPICAL SYSTEMS OF CHARCOAL MAKING

TYPE OF WOOD	GROUND CONDITION	SYSTEM	DESCRIPTION
EUCALYPTUS	FLAT AREA	MANUAL	. Felling the trees with axes . Straight-to-the-kiln transport by mules . Manual charcoal loading
		SEMI MECHANIZED	. Felling the trees with axes . Straight-to-the-kiln transport by trucks . Manual charcoal loading
		MECHANIZED	. Felling the trees with chain-saws . Transport to the roadside with tractor and mechanic loader . Transport to the kiln yard with truck and mechanic loader . Charcoal loading with mechanic loader
	STEEP AREA	SEMI MECHANIZED	. Felling the trees with chainsaw . Transport to the roadside by mules . Transport to the kilns by truck . Charcoal loading with mechanic loader
NATIVE	FLAT AREA	MANUAL	. Felling the trees with axes . Straight-to-the-kiln transport by oxen . Manual charcoal loading

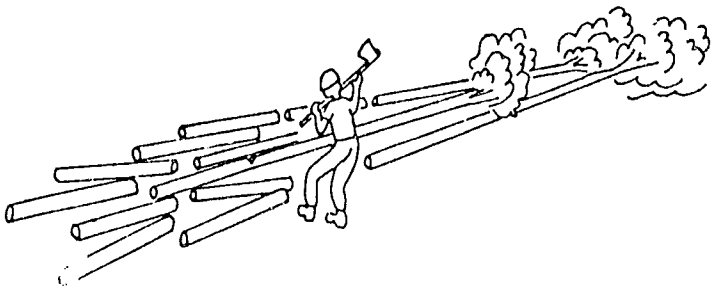
FIG. 4.3

CHARCOAL MAKING FROM EUCALYPT WOOD IN FLAT AREAS

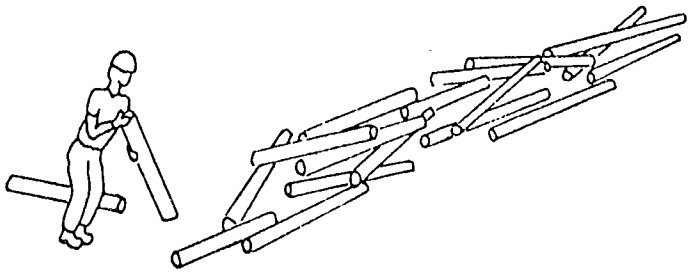
MANUAL SYSTEM



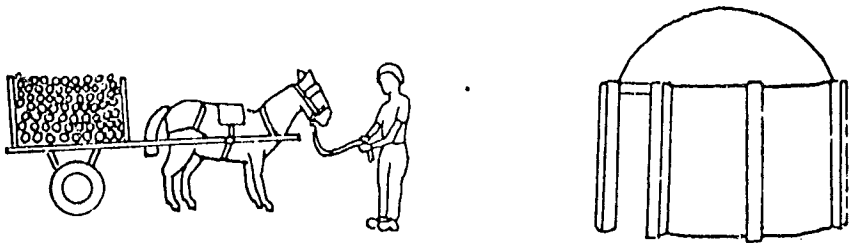
1 - FELLING WITH AXES



2 - CUTTING INTO LOGS AND DELIMBING WITH AXES



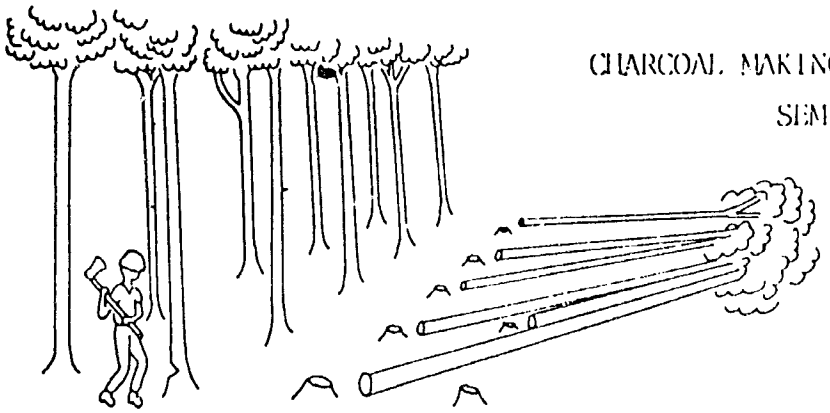
3 - MANUAL BUNCHING



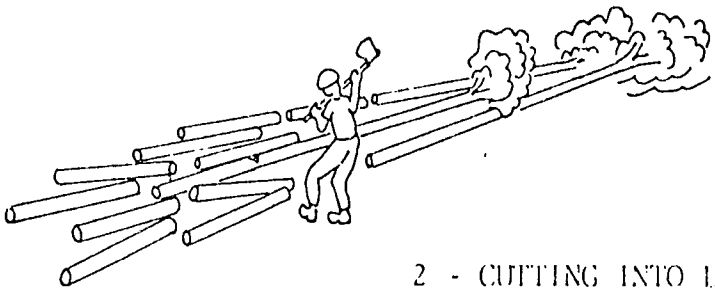
4 - STRAIGHT-TO-THE-KILN TRANSPORT

FIG. 4.4

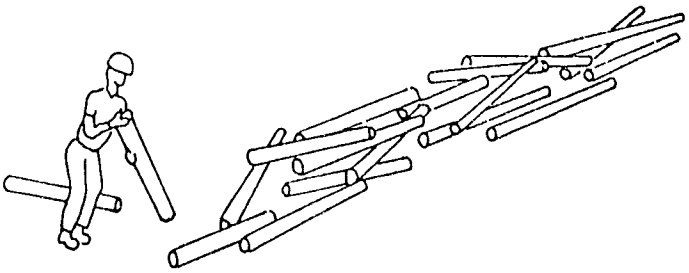
CHARCOAL MAKING FROM EUCALYPT WOOD IN FLAT AREAS
SEMI-MECHANIZED SYSTEM



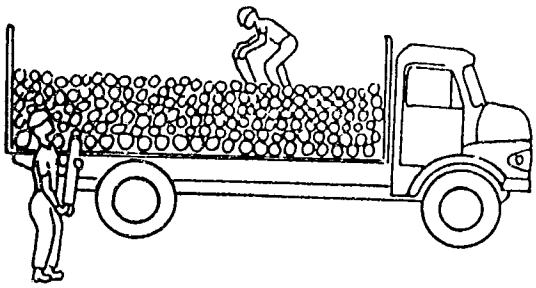
1 - FELLING WITH AXES

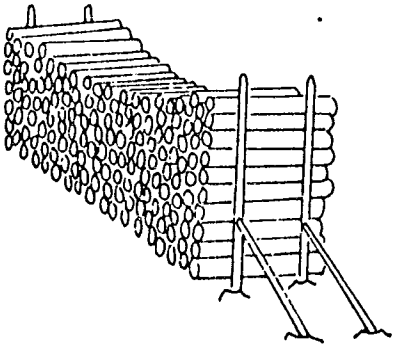


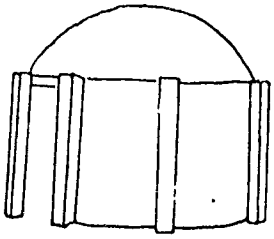
2 - CUTTING INTO LOGS AND DELIMBING WITH AXES



3 - MANUAL BUNCHING





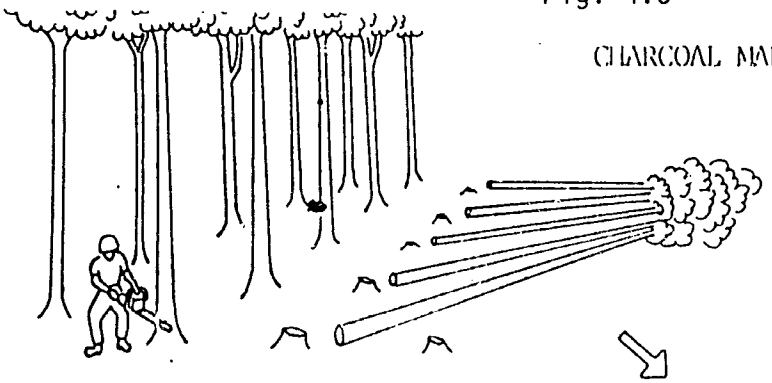


4 - STRAIGHT-TO-THE-KILN TRANSPORT

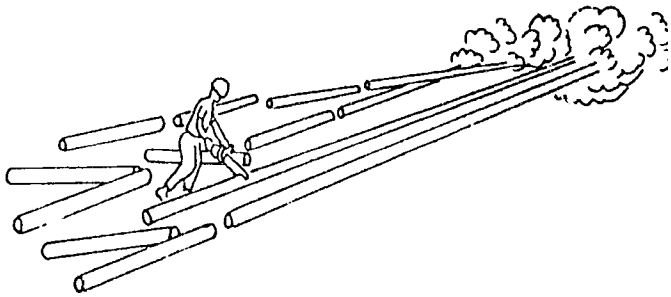
Fig. 4.5

CHARCOAL MAKING FROM EUCALYPT WOOD IN FLAT AREAS

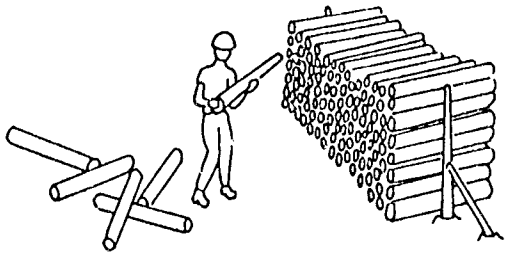
MECHANIZED SYSTEM



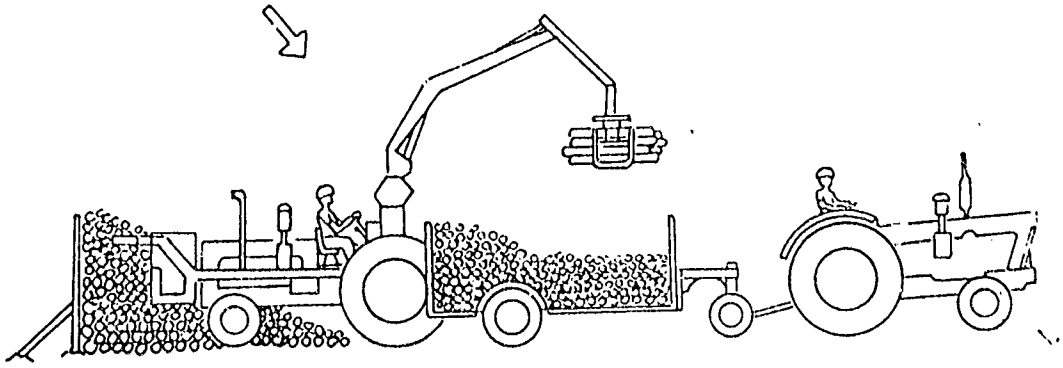
1 - FELLING WITH CHAINSAWS



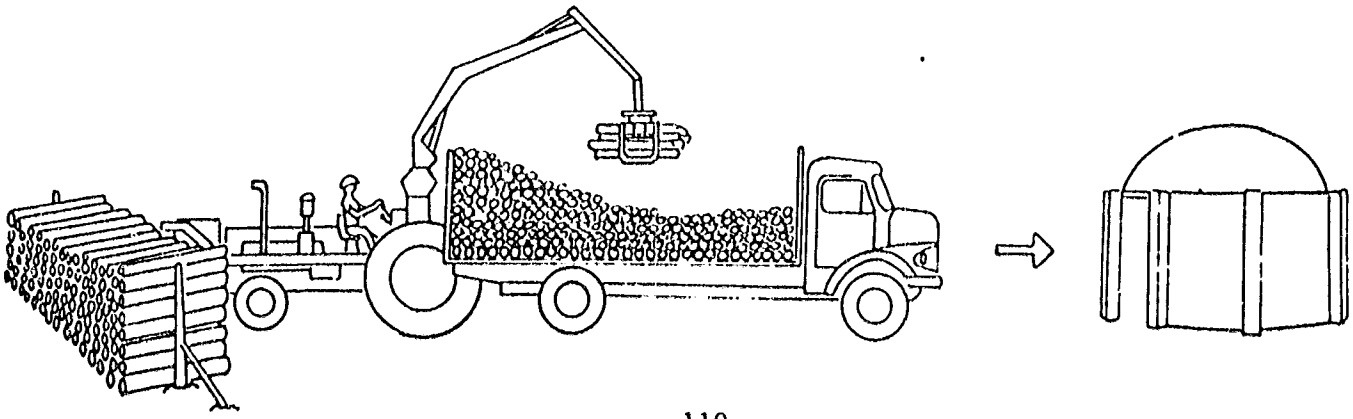
2 - CUTTING INTO LOGS AND DELIMBING WITH CHAINSAWS



3 - MANUAL PILING



4 - MECHANIZED TRANSPORT TO ROADSIDE



5 - MECHANIZED TRANSPORT TO KILNS

Fig. 4.6

CHARCOAL PRODUCTION FROM EUCALYPT WOOD IN STEEP AREAS
SEMI-MECHANIZED SYSTEM

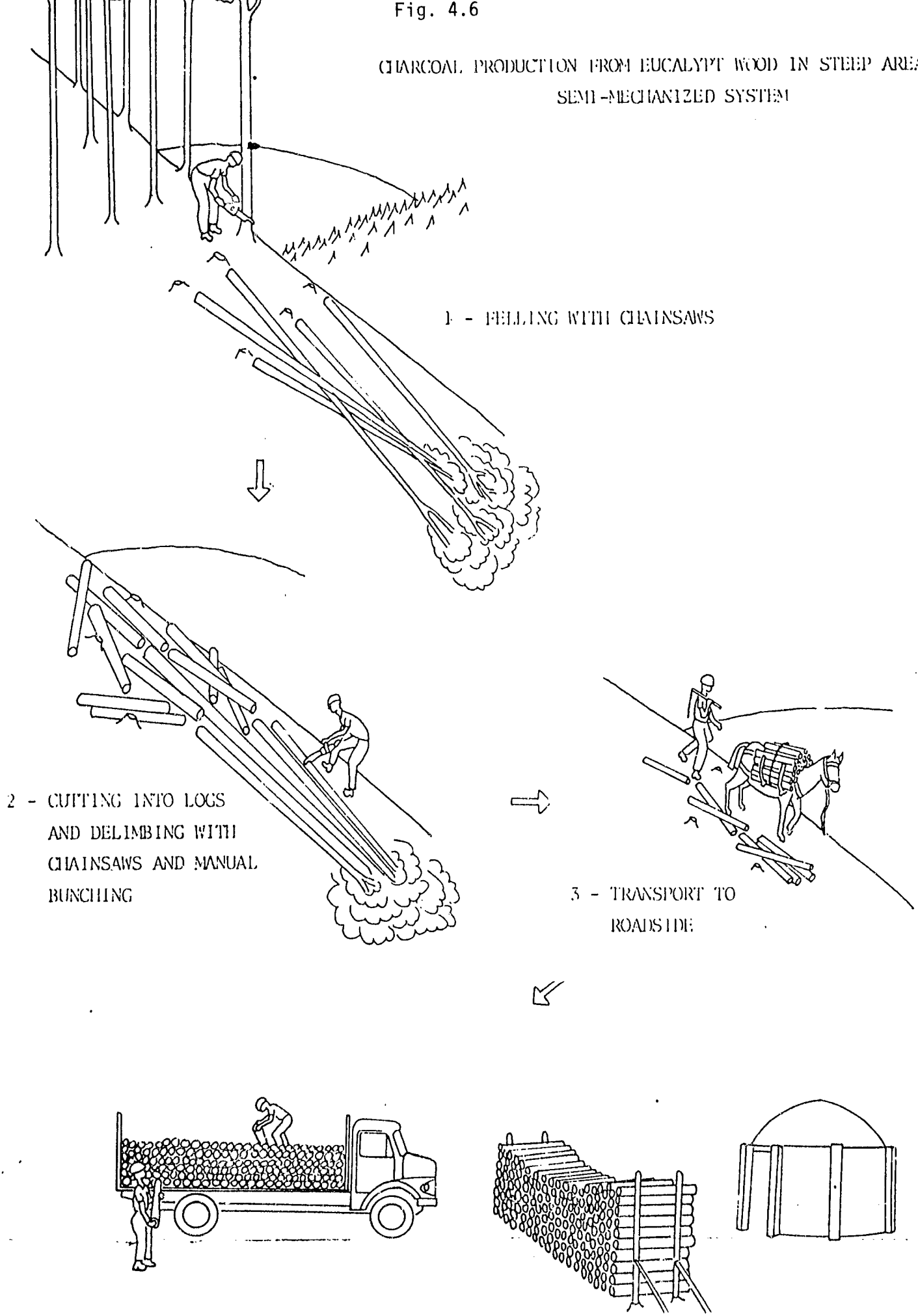
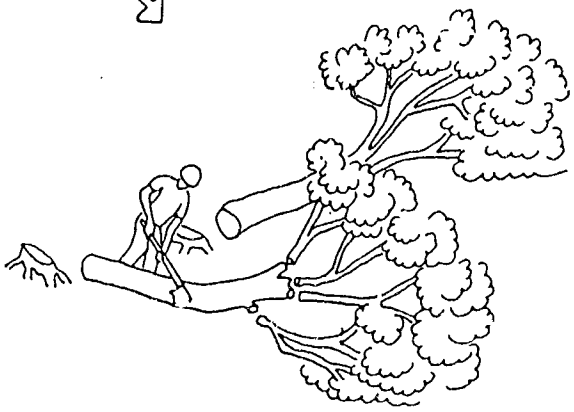


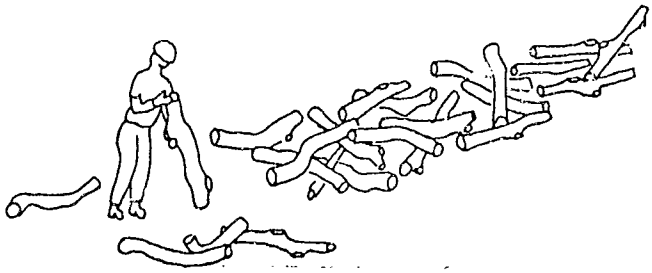
FIG. 4.7

CHARCOAL MAKING FROM NATIVE WOOD IN FLAT AREAS
MANUAL SYSTEM

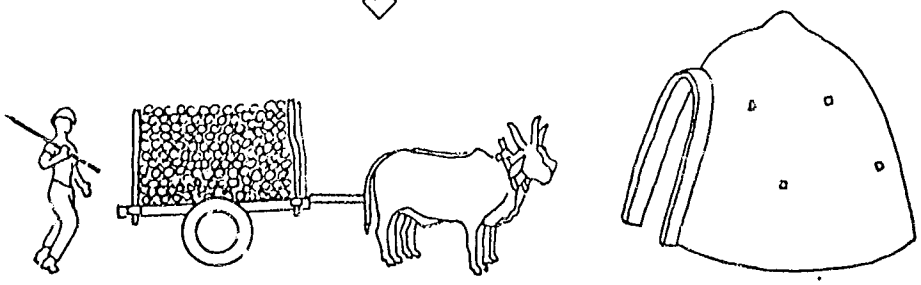
1 - FELLING WITH AXES



2 - CUTTING INTO LOGS AND DEVIMBING WITH AXES



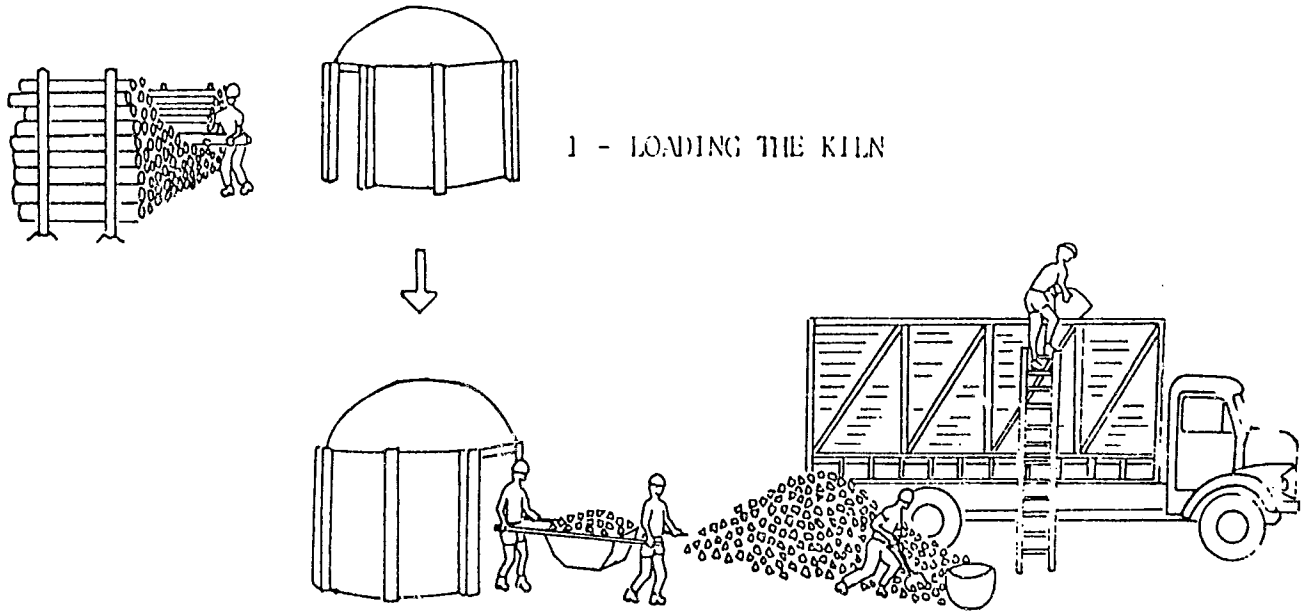
3 - MANUAL BUNCHING



4 - STRAIGHT-TO-THE-KILN TRANSPORT

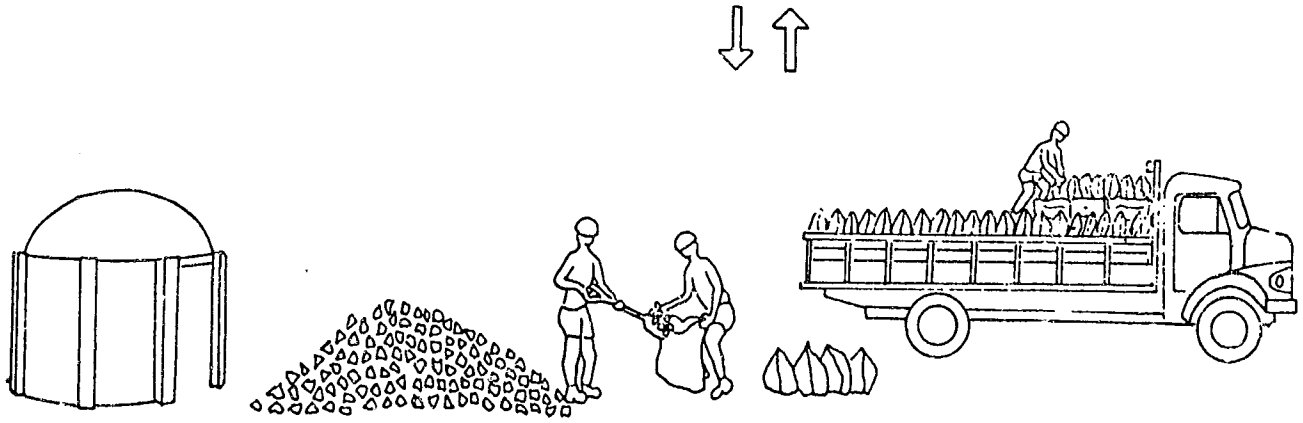
FIG. 4.8

CHARCOAL PROCESSING AND MANUAL LOADING



1 - LOADING THE KILN

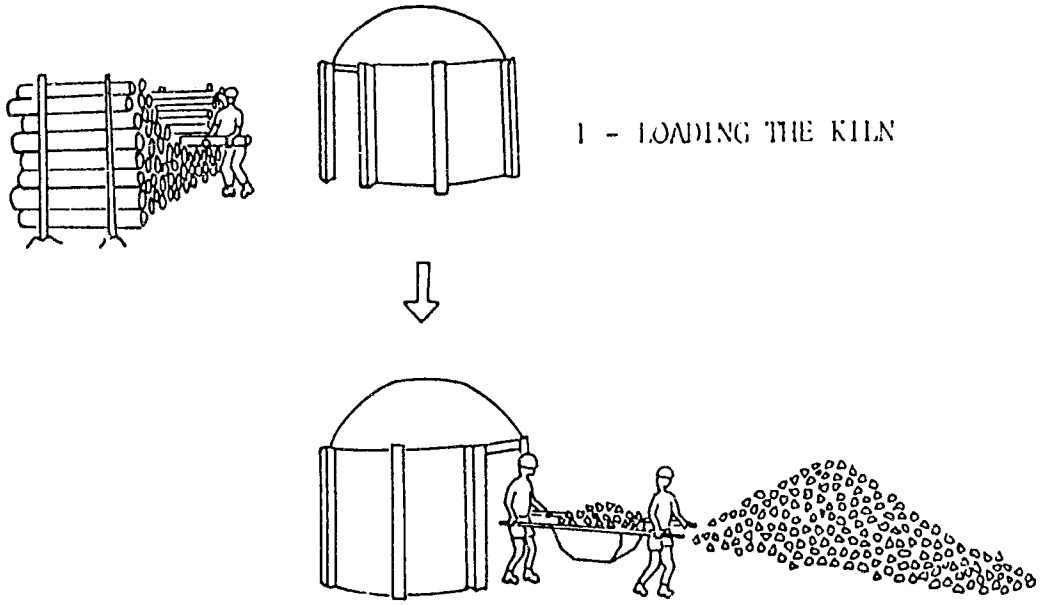
2 - UNLOADING THE KILN AND LOADING THE TRUCK WITH BASKETS



3 - LOADING THE TRUCK WITH BURLAP BAGS

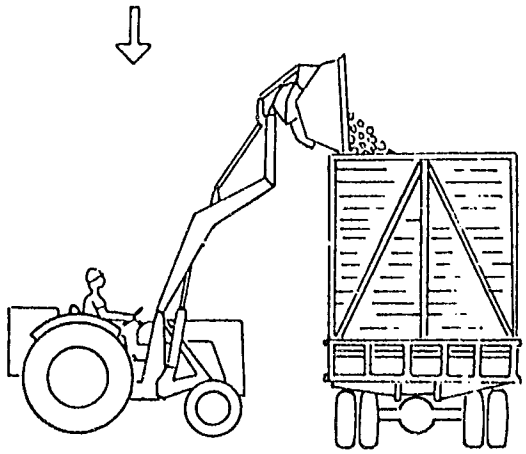
FIG. 4.9

CHARCOAL PROCESSING AND MECHANIZED LOADING



1 - LOADING THE KILN

2 - UNLOADING THE KILN



3 - LOADING THE TRUCK WITH A HYDRAULIC LOADER

TABLE 4.X - CHARCOAL MAKING DIRECT COSTS (US$ per m^3 of charcoal)

ITEM	EUCALYPT WOOD				NATIVE WOOD
	FLAT AREA			STEEP AREA	FLAT AREA
	MANUAL	SEMI MECHANIZED	MECHANIZED	SEMI MECHANIZED	MANUAL
. Clearing the Underbrush	0.23	0.23	0.23	0.32	0.43
. Felling	2.19	2.19	1.89	3.01	2.46
. Piling	-	-	0.87	-	-
. Straight-to-the-kiln transport	2.64	2.64	-	-	1.35
. Transport to the Roadside	-	-	2.02	3.17	-
. Transport to the kilns	-	-	1.34	1.68	-
. Charcoal Manufacture	3.25	3.25	2.85	2.85	2.83
TOTAL DIRECT COST	8.31	8.11	9.20	11.03	7.07

NOTE: The operation "clearing the underbrush" is done manually and carried out ten days before cutting.

The "piling " operation makes subsequent operation of mechanic loading easier.

A conversion rate of 2.3 steres per m^3 was assumed for eucalypt wood and 2.7 stere per m^3 of charcoal for native wood.

4.3.6 PERSONNEL AND INVESTMENT REQUIRED

Table 4.XIII shows personnel and fixed investments in equipment and buildings required to install a 1,000 m^3 capacity charcoal operation per month (or 12,000 m^3/year).

Assuming an average fixed investment of US $70,000 and a working capital for a two month's operation, the total investment can be calculated as follows:

- investment on fixed capital - US $70,000
- investment on working capital - US $24,000
- Total Investment - US $94,000

Under these conditions, the required investment is US $7.83/$m^3$/year (US $94,000 - 12,000 m^3/year). Assuming charcoal with a bulk density of 250 kg/m^3 the investment cost can be expressed as US $31.32/t/year of installed capacity.

4.3.7 FLORESTAL ACESITA'S PHILOSOPHY

Florestal Acesita's philosophy rests obviously not only with economic parameters but, also on the belief that the final objective of a business should be directed towards man and the community. First, there is a Brazilian reality that should be considered and that is typical of a developing country. The following facts characterize our economic and social situation:

- Labor surplus:
  - high level of unemployment and underemployment
  - low wage levels.
  - very poor regions, such as the Jequitinhonha Valley.

- Deficit in energy balance:
  - lack of fossil fuels.
  - increasing costs of oil and its by-products.

- High costs of machines and equipment which, directly or indirectly depends on imports.

Under these conditions there is good reason for the use of manual systems which offer employment for a larger number of people, utilize domestic inputs, and also save energy.

In the Jequitinhonha Valley region, most of the charcoal production of 30,000 m^3 per month is being accomplished with very simple equipment: axes and about 400 mules for straight-to-the-kiln-transport of wood. In the hilly regions of the Rio Doce Valley there are more than 500 mules and 200 oxen employed in the transport of wood.

TABLE 4.XI - TOTAL COSTS OF CHARCOAL MAKING (US$ PER m^3 OF CHARCOAL

ITEM	EUCALYPT WOOD				NATIVE WOOD
	FLAT AREA			STEEP AREA	FLAT AREA
	MANUAL	SEMI MECHANIZED	MECHANIZED	SEMI MECHANIZED	MANUAL
1. Direct Cost	8.31	8.11	9.20	11.03	7.07
2. Indirect Cost	2.40	2.08	1.45	2.08	0.52
3. Overhead (6% of 1+2)	0.64	0.61	0.64	0.79	-
4. Financial Cost	0.76	0.84	1.19	1.32	0.49
5. TOTAL COST	12.11	11.64	12.48	15.22	8.08

NOTE: Financial cost includes financial charges for investments and working capital in section 4.3.6.

TABLE 4.XII - DIRECT COSTS FOR CHARCOAL MAKING

A - CHARCOAL MAKING FROM NATIVE WOOD IN FLAT AREAS/MANUAL SYSTEM

A-1 - WOOD HANDLING

OPERATION	INPUTS			QUANTITY OF UNIT	COST US$/st
	ITEM	UNIT	US$/UNIT		
Clearing The Underbrush	Labor	Mh	.65	.25	.16
Felling	Labor	Mh	.65	1.40	.91
Straight-to-the-kiln Transport	Ox with Cart	Eh	1.25	.40	.50

NOTE: A 2.7 yield of wood to charcoal was assumed for all operations

A-2 - CHARCOAL MANUFACTURE (CARBONIZATION AND CHARCOAL LOADING)

OPERATION	INPUTS			QUANTITY OF UNITY	COST US$/$m^3$ OF CHARCOAL
	ITEM	UNIT	US$/UNIT		
Charcoal Manufacture	Labor(Burner)	Mh	1.35	1.22	1.65
	Labor(Helper)	Mh	.65	.70	.46
	Others	-	-	-	.72
	Sub-Total				2.83

NOTE: Under the Heading "Others" the followings expenses are included: kiln depreciation, water consumption, canvas, hand-cart, baskets, etc.

B - CHARCOAL MAKING FROM EUCALYPT WOOD IN FLAT AREAS/SEMI-MECHANIZED SYSTEM

B-1 - WOOD HANDLING

OPERATION	INPUTS			QUANTITY OF UNIT PER st	COST US$/st
	ITEM	UNIT	US$/UNIT		
Clearing the Underbrush	Labor	Mh	.95	1.10	.10
Feeling	Labor	Mh	.95	1.00	.95
Straight-to-the-kiln	Truck	Eh	5.58	.14	.78
Transport	Labor	Mh	.95	.56	.54
	Sub-Total				1.32

NOTE: A 2.3 yield of wood to charcoal was assumed for the operations of clearing the underbrush and felling. Firewood is transported to the kiln after being dried in the stand during a period of 90 days. Due to the volume loss caused by the drying process a 2.0 yield of wood to charcoal wal considered for the operation of transport to the kiln.

B-2 - CHARCOAL MANUFACTURE

OPERATION	INPUTS			QUANTITY OF UNIT m^3 OF CHARCOAL	COST US$/$m^3$ OF CHARCOAL
	ITEM	UNIT	US$/UNIT		
Charcoal	Labor (Burner)	Mh	1.30	1.00	1.30
Manufacture	Labor (Helper)	Mh	.95	1.00	.95
	Others				1.00
	Sub-Total				3.25

TABLE 4.XIII- PERSONNEL AND INVESTMENT FOR 1.000 m^3 CHARCOAL/MONTH

ITEM	EUCALIPT WOOD				NATIVE WOOD
	FLAT AREAS			STEEP AREAS	FLAT AREAS
	MANUAL	SEMI MECHANIZED	MECHANIZED	SEMI MECHANIZED	MANUAL
PERSONNEL (For a Production of 1.000 m^3 of Charcoal per Month)					
. Laborers	40	33	20	33	53
. Foremen	2	2	1	2	1
. Clerical workers	2	1	1	1	1
TOTAL	44	36	22	36	55
INVESTMENT (US$ per 1.000 m^3 of Charcoal per Month)					
. Chainsaw	-	-	3,066	4,371	-
. Pasture (Mules)	13,200	-	-	13,200	-
. Mule With Cart	13,600	-	-	13,600	-
. Ox With Cart	-	-	-	-	15,600
. Truck	-	36,000	13,505	24,535	-
. Tractor With Cart	-	-	13,628	-	-
. Mechanic Loader For Wood	-	-	28,000	-	-
. Mechanic Loader For Charcoal	-	-	4,505	4,505	-
. Kilns and Infrastructure	22,000	22,000	22,000	22,000	18,000
. Others	1,000	2,000	6,000	5,000	1,000
TOTAL	49,000	60,000	90,704	87,211	34,600

Axes presently used in cutting operations substitute for about 430 chainsaws and save 960,000 liters of gasoline annually, 336,000 liters of oil for the mixture, and 480,000 liters of lubricating oil, accounting for a total value of US $1,370,000. In the Jequitinhonha Valley transportation alone by mules is estimated to save 540,000 liters of diesel oil annually, and accounts for a savings of US $221,400.

The manual systems are also consistent with the company's philosophy of decentralization. The objective is to make decisions as close to the place of action as possible and even more important to provide for participation and integration of workers in the decision-making process.

In the Jequitinhonha Valley, for instance, Florestal Acesita has developed a type of organization, called "micro-horto", having the following features:

- Area: An autonomous production unit occupying a 50 ha forest stand

- Installations: at the center of the unit a beehive brick kiln is installed with a capacity of 50 m^3 of charcoal per month

- Working Team: 2 workers with simple, totally indigenous equipment: 2 axes and one mule-drawn cart. These two workers accomplish all the needed operations for making charcoal: felling the trees, cutting them into logs, transporting and carbonizing the wood. And more important: organize their own work and determine their own progress.

There are also some what larger units, "mini-hortos", working with teams of 5 or 10 workers, in which the same essential principles of organizing "mirco-hortos" is applied.

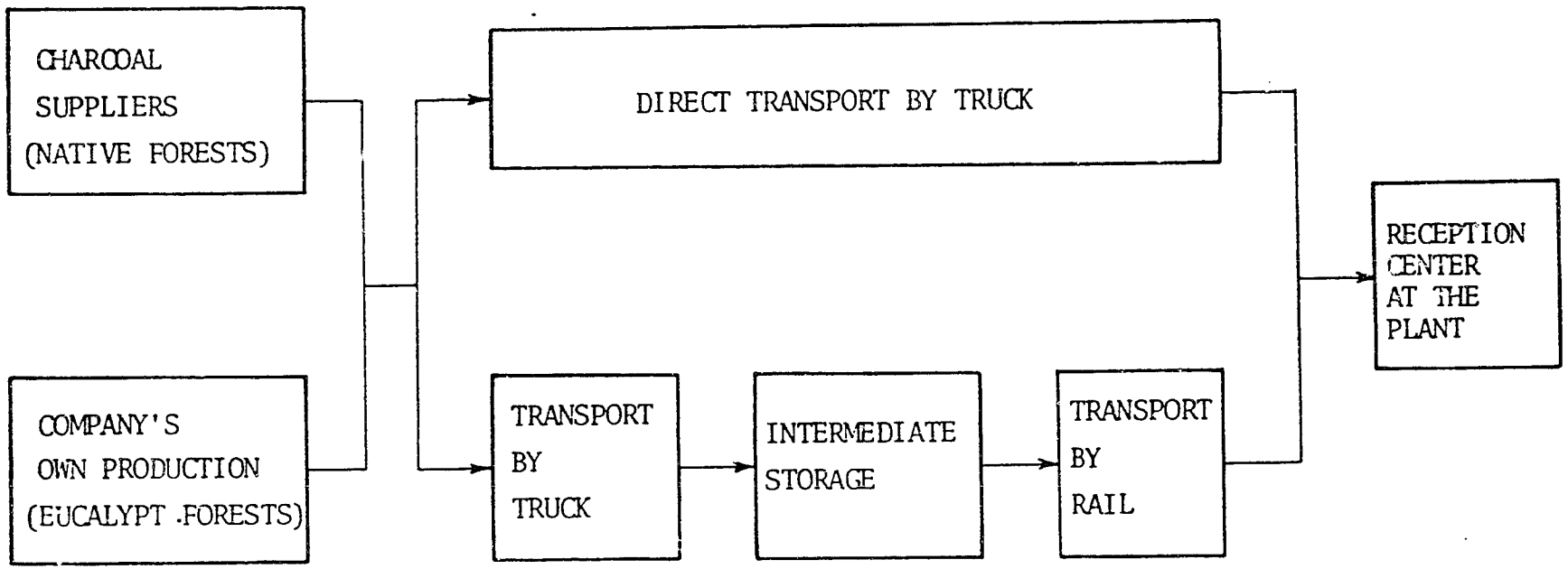
4.4 CHARCOAL TRANSPORTATION

The third and last stage of charcoal production deals with charcoal handling from production centers to the reception at the plant. Figure 4.10 shows a typical flow of charcoal transportation. Charcoal transportation can be done by roads, by rail, or by water, the latter very seldom used.

Most of the charcoal produced in Brazil is transported by trucks with loads ranging from 40 to 80 m^3. Trucks can carry charcoal in burlap bags or in lump form within a cage-like structure fitted to the truck-body. The use of burlap bags allows the trucks to carry other merchandise on the return journey. Charcoal loading can be done by a machine or manually with the help of baskets. Transport by rail over long distances is cheaper, but, is limited to areas accessible to the railway network.

Small ironmakers generally purchase all their required charcoal from independant suppliers. In these cases, charcoal is delivered directly to the plant, which operates with a minimum level of stock.

FIG.4.10 - TYPICAL FLOW OF CHARCOAL TRANSPORTATION



The integrated steel mills, however, generally install several intermediate storage depots to receive charcoal in strategic locations near the main roads. These depots are intended to store buffer stocks to insure charcoal supply during the rainy season or during periods of product shortage in the market. In the intermediate depots, charcoal is placed in separated sections and covered by plastic canvas. Some depots are connected to a railnet making it possible to remove charcoal from trucks to railway cars.

At the reception centers (see Figure 4.10) the volume of charcoal is measured and samples are collected for quality control analysis (fixed carbon, density and grain size distribution). Charcoal handling operations within the depots are generally done by loader machines and dump-trucks.

4.4.1 COSTS OF CHARCOAL TRANSPORTATION

In Brazil, charcoal is always expressed in terms of volume. A reduction of volume occurs when charcoal is removed from the production center to the reception center at the plant. This reduction is caused by two factors: first, a volume loss due to the generation of fines caused by handling operations within the battery or depot; secondly, loose charcoal "settles" during transport filling the empty spaces, which also diminishes the initial volume.

On the average, total volume loss, from the battery yard to the reception center, may reach the following percentages:

- loss due to handling operations	-2%
- loss due to "charcoal settling" during transport	-5%
Total Loss	7%

Charcoal storage in an intermediate depot may cause an additional 8% volume loss.

One should note that these reductions in quantity are important only when charcoal measurement is expressed in terms of volume. Obviously, gravimetric measures would not show the same level of charcoal "loss".

Truck transportation of native wood produced charcoal can be done by independant truckers or by the charcoal makers themselves. Integrated steel mills generally own and maintain a fleet of trucks to transport only part of their required charcoal.

Freight's cost for truck transportation varies according to the distance, as follows:

DISTANCE (KM)	US$/m^3 OF CHARCOAL
200	2.75
400	4.80
600	6.90
800	8.96

4.5 COST OF CHARCOAL CIF STEEL PLANT

The cost of charcoal delivered at the steel plant can be summarized as shown in Table 4.XIV. These data show that native wood based charcoal cost is 63% of plantation grown eucalypt wood based charcoal cost. The difference in costs can be explained by the following facts:

- commercial prices for native wood are very low due to its relative abundance as a by-product of deforestation for pasture and agricultural purposes;

- costs for plantation grown eucalypt wood based charcoal are higher because the former is made by well-organized companies incurring higher social costs;

- present prices of native wood based charcoal are very low because there is an excess at the market.

Native wood based charcoal in Brazil is ruled by supply and demand. The market follows a cyclic evolution, with interchanging periods of shortage and surplus. Sometimes a shortage is caused by a combination of events such as: excessive rainfall, which makes charcoal production and transportation difficult, increase of pig iron export; low storage level of integrated steel mills; etc. Charcoal shortage is accompanied by sharp price rises, with price increases as much as 300% in a one-year period. To cope with market demand old producers expend their activities while new ones are attracted by the prospects of high profitability.

The opposite takes place in times of surplus; prices go down, reducing or eliminating producer's profit. The market is down at present; producer's profit has been reduced and many of those who worked in less favorable conditions have given up the activity with losses.

In the long-run, depletion of native reserves and improvement in productivity of man-made forests, on the one hand, and the exhaustion of non-renewable sources of energy, such as petroleum, on the other, will establish a balance between the price of native wood based charcoal and the cost of plantation grown eucalypt wood for charcoal production.

TABLE 4.XIV - CHARCOAL COST DELIVERED TO STEEL PLANT

ITEM	CHARCOAL			
	EUCALYPT WOOD BASED		NATIVE WOOD BASED	
	US$/m^3	US$/ton	US$/m^3	US$/ton
1. Stumpage	8.81	35.24	1.35	5.40
2. Charcoal Making	12.00	48.00	8.08	32.32
3. Transport	6.45	25.80	7.76	31.04
4. TOTAL	27.26	109.04	17.19	68.76

NOTE: . The yield of wood to charcoal wars assumed to be 2.3 for eucalypt wood based charcoal and 2.7 for [illegible]ive wood based charcoal.

. Assumed distances from production centers to the steel plant: 400 km for eucalypt wood based charcoal and 600 km for native wood based charcoal.

. Transportation costs include freight, a volume loss of 7.0% and intermediate storage costs.

. Charcoal bulk density is 0,25 t/m^3.

5. CHARCOAL FOR ENERGY USES - A CASE STUDY

5.1 INTRODUCTION

Tables 5.I, 5.II and 5.III show the industrial fuel-oil consumption in the state of Minas Gerais, for the year 1979. Out of a 1,822,477-ton total consumption, the most important items are, the processing and heating ovens and the generation of steam. The furnace's contribution amounts to 1,390,312 t, equivalent to 76% of overall consumption. Steam-generation's share is 387,552 or 21% of the consumption.

The cement industry is the state's largest consumer, accounting for 34% of total industrial demand. This situation is further aggravated by the fact that cement production falls short of market demand. Expansion of production units is programmed, as shown in Table 5.IV.

The situation being similar in the other Brazilian states, the Ministry of Industry and Commerce and the Ministry of Mines and Energy have developed studies that showed it is possible to replace oil with charcoal in a 5-year period. Table 5.V shows the schedule of this substitution process, with the first phase now completed.

Two case studies are now presented:

1 - a cement company which has been making use of charcoal in its furnaces;

2 - the cost of steam generation, based on different fuels.

5.2 CASE STUDY 1 - THE CEMENT FACTORY

5.2.1 PRODUCTION UNIT OF CLINKER

* UNIT CHARACTERIZATION

Location of Factory: In the Brazilian state of Minas Gerais

* Types of Cement Produced: The unit produces clinker. Part of the total production is sent to another unit, which purchases blast-furnace slag, dries such slag and produces blast furnace-type cement. The rest of the clinker remains in the production unit itself, where common portland cement and blast furnace-type portland cement are produced. To produce the blast furnace-type cement, the clinker factory receives from the other unit dried slag.

* Annual Production: 460,000 tones of clinker.

* Fuel Consumption: Unit operation was previously 100% based on heavy-type fuel oil, with a specific consumption of 100 kg oil/ton of clinker. This amounts to an annual consumption of 46,000 tons of oil. It should be mentioned that, using 100% fuel oil, the factory's total output was half a million tons of clinker per year.

TABLE 5.I - PETROLEUM DERIVATES INDUSTRIAL CONSUMPTION IN MINAS GERAIS - HEAVY FUEL OIL (BPF)

(TONS)

INDUSTRY	NUMBER OF ENTERPRISES	STEAM GENERATION	FURNACES	OTHERS	TOTAL
CEMENT	12	8.423	477.524	5.048	490.995
GLASS	1	-	1.888	-	1.888
CERAMIC	34	82	50.040	4.929	55.051
NON METALS	66	4.564	143.946	8.990	157.500
METALLURGY	22	109.279	191.884	2.671	303.834
MECHANICAL	-	-	-	-	-
ELECTRICAL/ELECTRONICAL	2	2.145	1.051	-	3.196
TRANSPORT	1	7.155	-	-	7.155
WOOD	1	-	-	2.077	2.077
PULP & PAPER	8	85.431	8.111	2.642	96.184
RUBBER	1	580	-	-	580
CHEMICAL/PETROCHEMICAL	4	14.017	1.156	2.276	17.449
PHARMACEUTICS	1	573	-	-	-
PARFUM	-	-	-	-	-
PLASTIC	1	575	-	-	575
TEXTIL	35	45.205	-	5.173	50.378
CLOTHES	-	-	-	-	-
LEATHER	3	3.171	-	-	3.171
FOOD	56	65.789	-	7.681	73.470
BEVERASE	8	19.467	-	-	19.467
TOBACCO	2	4.002	-	-	4.002
OTHERS	15	6.195	71.988	96	78.279
TOTAL	273	376.653	947.588	41.583	1.365.824

SOURCE: CONSELHO NACIONAL DE PETRÓLEO - INSTITUTO DE DESENVOLVIMENTO INDUSTRIAL DE MINAS GERAIS

TABLE 5.II - PETROLEUM DERIVATES INDUSTRIAL CONSUMPTION IN MINAS GERAIS - 1979 - LOW SULPHUR OIL (BTE)

(TONS)

INDUSTRY	NUMBER OF ENTERPRISES	STEAM GENERATION	FURNACES	OTHERS	TOTAL
CEMENT	4	1.241	121.884	1.666	124.791
GLASS	-	-	-	-	-
CERAMIC	5	879	14.645	1.020	16.544
NON METALS	3	940	29.909	-	30.849
METALLURGY	11	3.638	271.504	-	275.142
MECHANICAL	-	-	-	-	-
ELECTRICAL/ELECTRONICAL	-	-	-	-	-
TRANSPORT	1	2.845	-	-	2.845
WOOD	-	-	-	-	-
PULP & PAPER	-	-	-	-	-
RUBBER	-	-	-	-	-
CHEMICAL/PETROCHEMICAL	1	-	1.410	-	1.410
PHARMACEUTICS	-	-	-	-	-
PARFUM	-	-	-	-	-
PLASTIC	-	-	-	-	-
TEXTIL	1	1.151	-	203	1.354
CLOTHES	-	-	-	-	-
LEATHER	-	-	-	-	-
FOOD	-	-	-	-	-
BEVERAGE	-	-	-	-	-
TOBACCO	-	-	-	-	-
OTHERS	1	-	796	-	796
TOTAL	27	10.694	440.148	2.889	453.731

SOURCE: CONSELHO NACIONAL DE PETRÓLEO - INSTITUTO DE DESENVOLVIMENTO INDUSTRIAL DE MINAS GERAIS

TABLE 5.III - PETROLEUM DERIVATES INDUSTRIAL CONSUMPTION IN MINAS GERAIS - 1979 - LIGHT FUEL OIL (OC-4)

(TONS)

INDUSTRY	NUMBER OF ENTERPRISES	STEAM GENERATION	FURNACES	OTHERS	TOTAL
CEMENT	-	-	-	-	-
GLASS	-	-	-	-	-
CERAMIC	1	8	97	36	141
NON METALS	2	-	386	39	325
METALLURGY	7	20	1.371	4	1.395
MECHANICAL	-	-	-	-	-
ELECTRICAL/ELECTRONICAL	-	-	-	-	-
TRANSPORT	-	-	-	-	-
WOOD	-	-	-	-	-
PULP & PAPER	-	-	-	-	-
RUBBER	-	-	-	-	-
CHEMICAL/PETROCHEMICAL	1	-	22	-	22
PHARMACEUTICS	-	-	-	-	-
PARFUM	-	-	-	-	-
PLASTIC	-	-	-	-	-
TEXTIL	1	-	-	32	32
CLOTHES	-	-	-	-	-
LEATHER	-	-	-	-	-
FOOD	2	177	-	-	177
BEVERAGE	-	-	-	-	-
TOBACCO	-	-	-	-	-
OTHERS	1	-	800	-	800
TOTAL	15	205	2.576	111	2.892

SOURCE: CONSELHO NACIONAL DE PETRÓLEO - INSTITUTO DE DESENVOLVIMENTO INDUSTRIAL DE MINAS GERAIS

TABLE 5.IV - CEMENT INDUSTRIES INSTALLED CAPACITY - MINAS GERAIS

YEAR	AMOUNT (10^3t)
1979	7,260
1980	7,260
1981	7,260
1982	8,470
1983	9,767
1984	10,767
1985	10,767

SOURCE: ACP/BDMG

TABLE 5.V - SCHEDULE OF THE FUEL OIL SUBSTITUTION BY CHARCOAL CEMENT INDUSTRIES

PHASE	SUBSTITUTION	PROCESS PHASE	SCHEDULE	
			TERM (MONTHS)	FINAL DATE
1[a]	Until 30%	pre-heating (dry process) paste (wet process)	6/12	Dez, 1980
2[a]	Plus 50%	principal blowtorch dry and wet process	24/[illegible]	Dez, 1982
3[a]	Plus 20%	principal blow torch dry and wet process	60	Dez. 1984

SOURCE: CDI/MIC

* Replacement with Charcoal

Clinker production basically takes place as raw materials are mixed and heated under high temperatures. At the end, a rotary furnace, with a blowtorch attached, is used. The raw material thus flows counter-current to the flow of heat. Gases leaving the rotary furnace preheat the material before these enter the furnace - and that is done through a cyclone battery. The first attempt at charcoal utilization was made in the cyclone tower, where non-ground charcoal was introduced; also, the high, burning temperature at the place of entry contributed to the preheating of the material, thus diminishing oil consumption in the rotary furnace's blowtorch.

Presently, charcoal is screened, prior to injection into the cyclones, and fractions under 3 mm are crushed and injected into the blowtorch. The charcoal injection system and the carbon-feeding flowchart can be seen in Figs. 5.1 and 5.2.

A substitution of fuel oil on the order of 38% is thus possible, with the pre-heater accounting for 18% and the remaining 20% being saved in the blowtorch. A 100% substitution is being targeted, but that demands additional equipment. Specific charcoal consumption is in the order of 170 kg charcoal/ton of clinker.

* Investments

Up to US $1,2000,000 was spent in this initial stage (the 38% fuel-oil substitution). In the 100% substitution, an expansion in clinker production is also planned, from 460,000 to 1,240,000 tons per year. Additional investment, as charcoal replaces oil, will be over US $10,000,000. The system's useful life is estimated to be 20 years.

* Rate of Return on Investment (as of July '81)

Figures are based as of July 1981 and only three elements were taken into account, money invested, additional revenue due to the cost difference bebetween oil and charcoal, and the decreasing profit relative to the reduction in clinker production from 500,000 to 460,000 tones per year. According to the factory itself, the increase in personnel needed to handle charcoal is not representative and both operational and maintenance costs are the same as the system using 100% fuel oil.

Two return-rate values will be presented:

A - Taking present factory condition into account, with the market price of charcoal relative to native-forest charcoal.

B - taking into account the price of plantation grown eucalyptus charcoal, as presented in Chapter 4.

Figures will be presented for both situations in terms of the 38% substitution and the proposed 100% substitution.

CIF price of heavy-type fuel oil - US $0.21/kg (CIF Mill, as of July '81).

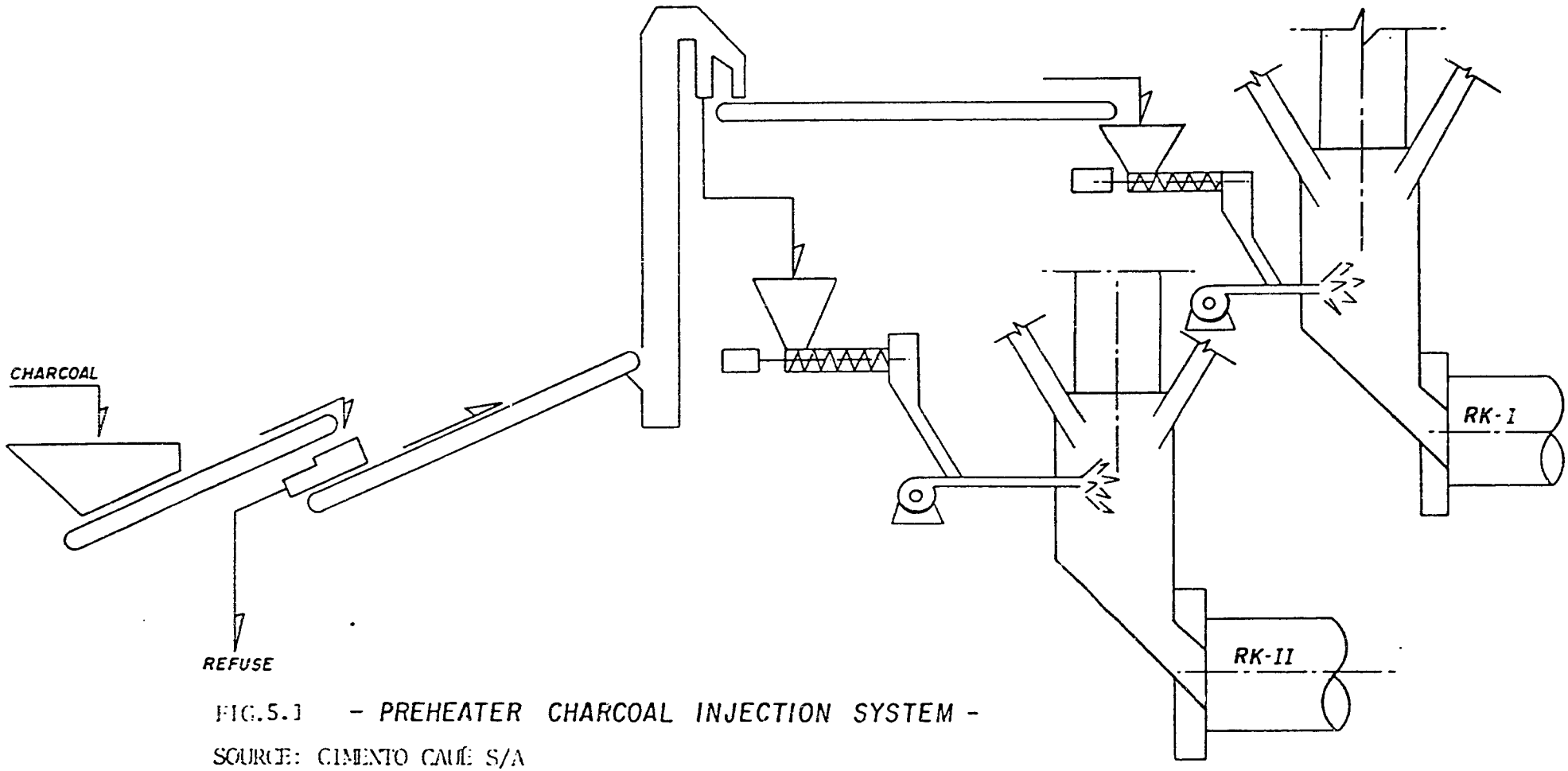


FIG.5.1 - PREHEATER CHARCOAL INJECTION SYSTEM -

SOURCE: CIMENTO CAUÊ S/A

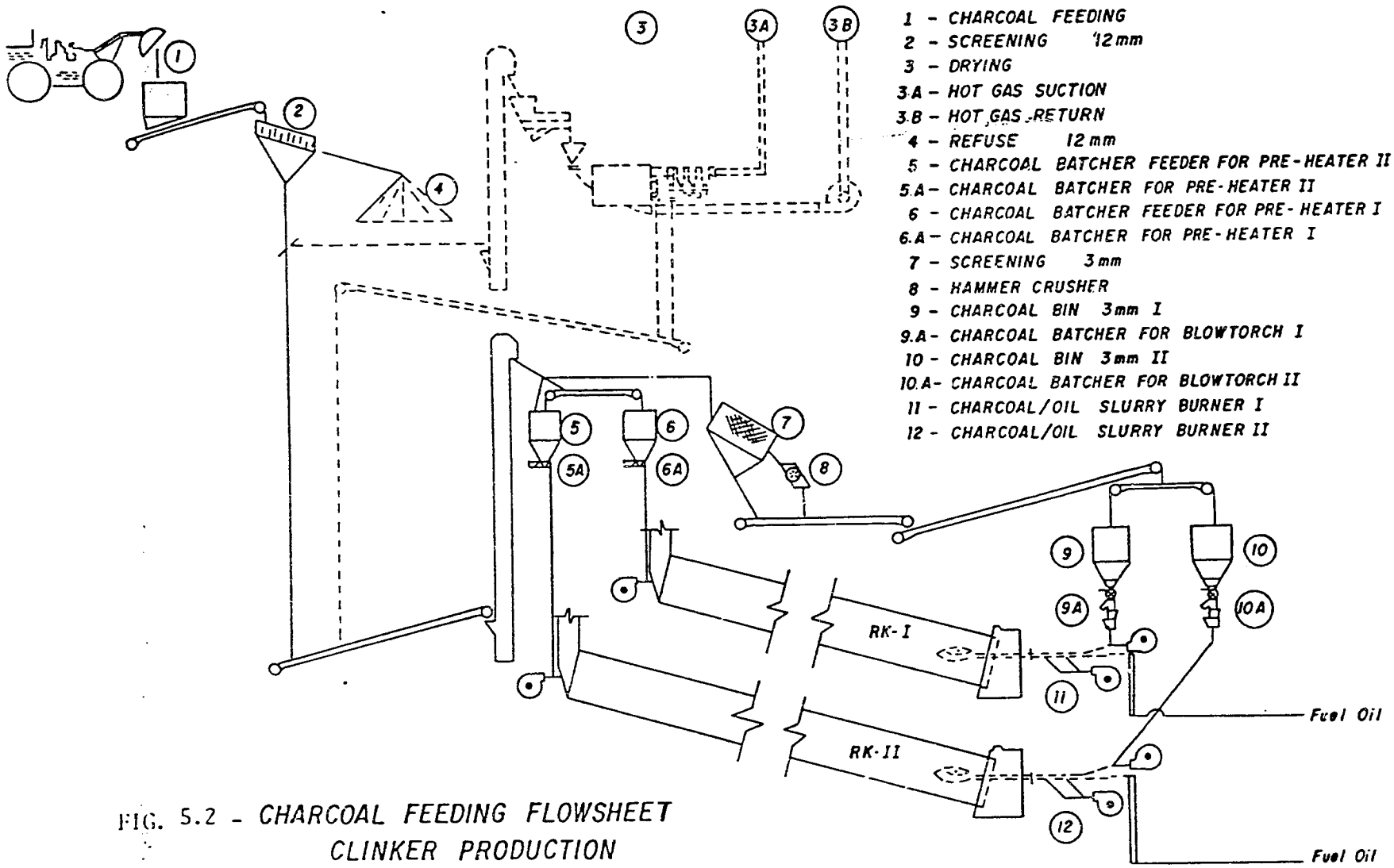


FIG. 5.2 - CHARCOAL FEEDING FLOWSHEET
CLINKER PRODUCTION

SOURCE: CIMENTO CAUÊ S/A

A - Market price for native charcoal = US $12.89/m^3 (CIF-Mill, as of July '81 average transportation = 200 km)

A.1 - Figures for the 38% substitution = a 100% utilization of oil annual consumption = 460,000 tons per year x 100 kg oil/ton clinker = 46,000 ton/year oil

Annual cost = 46,000 ton/year x US $210/ton = US $9,666,000, 38% being substituted by charcoal = 46,000 ton/year x 0.38 = 17,480 ton oil/year.

Since specific charcoal consumption is 1.7 times that of oil, this = 29,716 ton/year of charcoal.

Since average charcoal density is 250 kg/m^3, consumption is on the order of 118,864 m^3/year.

Annual Cost = 118,864 m^3/year x US $12.89/m^3 = US 1,532,157.

Additional Revenue

38% cost of Fuel Oil = US $9,666,000 x 0.38 = US $3,670,800
Corresponding Cost of charcoal = US $1,532,157 additional revenue = US $3,670,800 - US $1,532,157 = US $2,138,643.

Reduction in Production

As 38% of oil was substituted by charcoal, there was a reduction in clinker production, from 500,000 tons per year to 460,000 tons per year.

This 40,000 ton per year difference in clinker is equivalent to 46,500 ton per year of cement.

At a US $74-per-ton price of cement, there is a gross revenue reduction = 46,500 ton/year x US $74,000/ton = US $3,441,000/year.

Since 15% correspond to net profit, there is then a net-revenue reduction of US $516,150.

Table 5.VI shows the cash flow for this case.

Based on such a table, the rate of return on investment is calculated as 135% per year.

A.2 - Figures for the 100% substitution = Investment = US $10,000,000 + US $1,200,000 = US $11,200,00.

Production = 1,240,000 ton/year of clinker.

Fuel-oil consumption (if used) = 1,240,000 ton/year of clinker x 100 kg oil/ton of clinker = 124,000 ton/year.

TABLE 5.VI - 38% SUBSTITUTUION OF FUEL OIL BY CHARCOAL FROM NATIVE FORESTS - CASH FLOW

YEAR	0	1	2		20
Investment	(1,200,000)	-	-		-
Production decrease	-	(516,150)	(516,150)		(516,150)
Additional income	-	2,138,643	2,138,643		2,138,643
Liquid	(1,200,000)	1,622,493	1,622,493		1,622,493

Annual cost = 124,000 ton/year x US $210/ton = US $26,040,000.

Charcoal consumption = 124,000 ton/year of oil x 1.7 = 210,000 ton/year of charcoal or 843,200 m^3/year.

Annual Cost = 843,200 m^3/year x US $12.89/$m^3$ = US $10,868,848.

Additional Revenue from charcoal use = US $26,040,000 - US $10,868,848 = US $15,171,152.

Decrease in Production = Given the same 8% decrease in production as in the present system, in the case of the fuel-oil operation, production would be in the order of 1,347,836 ton/year of clinker. These additional 107,826 ton/year of clinker amount to 125,348 ton/year of cement. Given a cement price of US $74 per ton and a 15% net profit, there is a net-revenue reduction, due to charcoal use, of US $1,391,363/year.

Table 5.VII shows the cash flow for this case, which gives a return rate of 125% per year.

B - Price of plantation grown Eucalyptus charcoal, as calculated in Item 8

Charcoal Price = US $25.13/$m^3$
(average transportation of 200 km)

B.1 - Figures for the 38% substitution = Annual cost of oil = US $3,670,800.

Annual Cost of charcoal = 118,864 m^3/year x US $25.13/$m^3$ = US $2,987,052.

Additional Revenue = US $3,670,800 - US $2,987,052 = US $683,748.

Based on Table 5.VIII, one can arrive at a 13% per year rate of return on investment.

B.2 - Figures for the 100% substitution = Annual cost of oil = US $26,040,000.

Annual cost of charcoal = US $843,200 m^3/year x US $25.13/$m^3$ = US $21,189,616.

Additional revenue from the use of charcoal = US $26,040,000 - US $21,189,616 = US $4,850,384.

Reduction in Production = US $1,391,363 per year.

From Table 5.IX we can deduct a return rate of 31% per year.

5.2.2 UNIT PRODUCING BLAST FURNACE - TYPE PORTLAND CEMENT

* Factory Location = state of Minas Gerais, in Brazil.

* Type of Cement Produced = Blast-Furnace Portland, type AF 320, according to ABNT's EB 208 (ABNT = Brazilian Association of Technical Standards).

TABLE 5.VII - 100% SUBSTITUTION OF FUEL OIL BY NATIVE CHARCOAL - CASH FLOW

YEAR	0	1	2		20
Investment	(11,200,000)	-	-		-
Production decrease	-	(1,391,363)	(1,391,363)		(1,391,363)
Additional income	-	15,171,152	15,171,152		15,171,152
Liquid	(11,200,000)	13,779,789	13,779,789		13,779,789

TABLE 5.VIII - 38% SUBSTITUTION OF FUEL OIL BY CHARCOAL FROM MAN-MADE-FORESTS - CASH FLOW

YEAR	0	1	2		20
Investment	(1,200,000)	-	-		-
Production decrease	-	(516,150)	(516,150)		(516,150)
Additional income	-	683,748	683,748		683,748
Liquid	(1,200,000)	167,598	167,598		167,598

TABLE 5.IX - 100% SUBSTITUTION OF FUEL OIL BY CHARCOAL FROM MAN-MADE FORESTS - CASH FLOW

YEAR	0	1	2		20
Investment	(11,200,000)	-	-		-
Production decrease	-	(1,391,363)	(1,391,363)		(1,391,363)
Additional income	-	(4,850,384)	4,840,384		4,850,384
Liquid	(11,200,00)	3,459,021	3,459,021		3,459,021

* Monthly Output = 43,000 tons.

* General Description = This unit produces blast furnace-type cement, and does it by mixing clinker with blast-furnace slag. The clinker arrives ready at this unit, and the slag is purchased from a neighboring iron industry.

Since this slag has 15% humidity on arrival, it is dried down to a 0.2% moisture content.

The final mixture involves = 60% of dry slag; 4% of plaster; 36% of clinker.

* Fuel-Oil Consumption

The slag was dried with low sulfur-type fuel oil, and required 9 kg of oil per ton.

General unit consumption was 315,000 kg/month of oil is used for drying 35,000 ton/month of slag. Since all of the slag is not used at the unit, the remainder is sent to the clinker-producing unit, which also produces blast furnace-type Portland Cement.

* Oil Substituted by Charcoal

The slag dryer is now totally charcoal-powered, using a fluidized bed, as shown in Figure 5.3. Fuel consumption in the bed is from 18 to 20 kg of charcoal per ton of dry slag, which is equivalent to of 700 tons of charcoal/month, or 2,500 m^3/month.

The unit consumes 9 to 19 mm grain charcoal, with a 280 kg/m^3 density.

Investment on the charcoal-powered drying system was in the amount of US $153,846 with a 20-year useful life.

* Return Rate on Investment (as of July '81)

Only the charcoal-for-oil substitution investment is considered here, since the operating personnel is the same as in the previous unit, and maintenance will have roughly the same cost. The useful life of both units is also the same at 20 years.

Low sulfur content-oil cost = US $0.27/kg (CIF MILL)

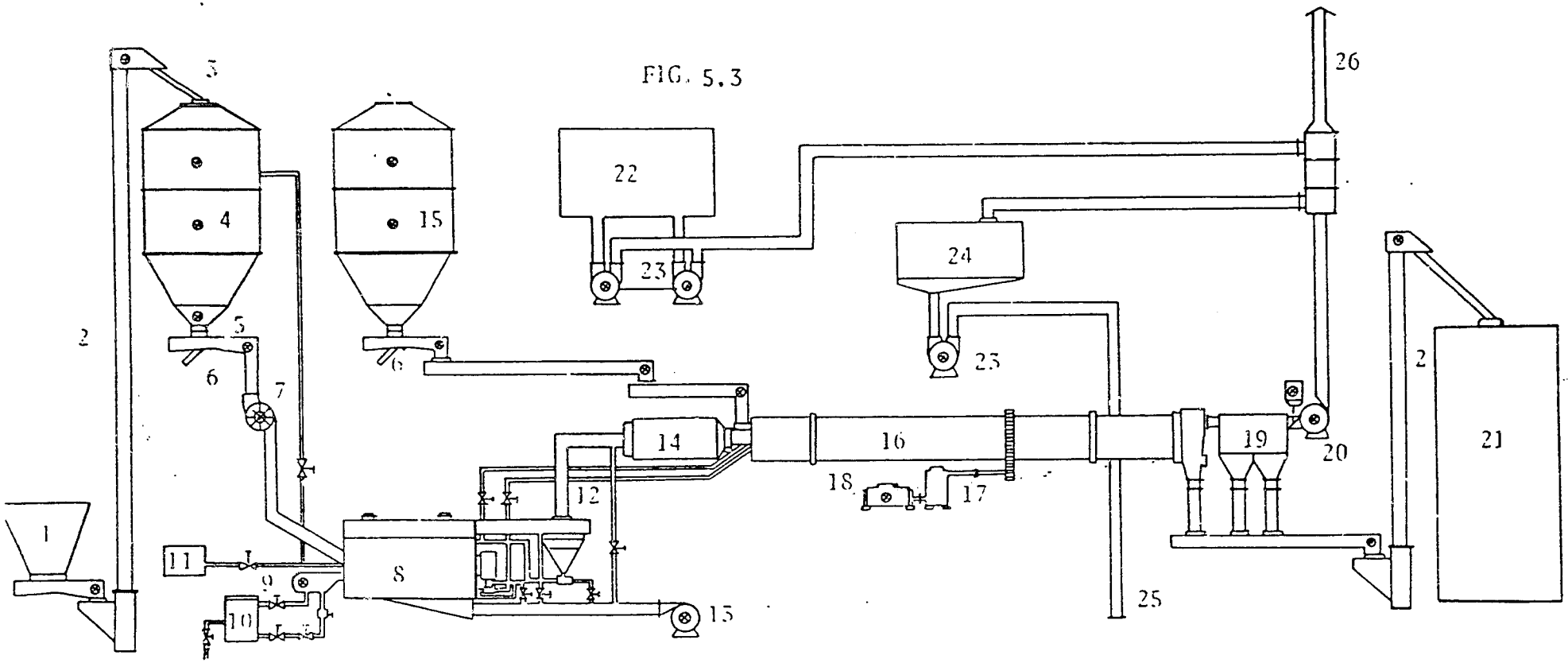
Monthly cost = 315,000 kg/month x US $0.27/kg = US $85,050

Charcoal cost = US $12.89/$m^3$ (CIF-Mill) Price of native-forest charcoal, with average transportation distance of 200 km.

Monthly cost = 2,500 m^3/month x US $12.89/$m^3$ = US $32,225/year.

Monthly additional revenue = Cost of oil - cost of charcoal US $85,050 - US $32,225 = US $52,825.

FIG. 5.3



1 - Feeder
2 - Lifter Feeder
3 - Flow Directioning
4 - Charcoal Bin
5 - Vibrating Cone
6 - Vibrating Feeder
7 - Rotary Valve
8 - Combustion Chamber
9 - Burner
10 - Fuel Oil
11 - Inert Gas
12 - Ciclone
13 - Blower
14 - Combustion Chamber
15 - Wet slag bin
16 - Drying Kiln
17 - Spped Regulating Gears
18 - Motor
19 - Ciclone
20 - Exaustion
21 - Dry Slag Bin
22 - Water Reservoir
23 - Pumps
24 - Decanter
25 - Discharge
26 - Stack

Annual additional revenue = US $633,900.

5.3 CASE STUDY II - THE COST OF STEAM GENERATION BASED ON DIFFERENT FUELS

5.3.1 PARAMETERS USED

For comparison, a boiler was chosen with the following characteristics:

- steam production: 12,000 kg/h
- operating pressure: 10,5 kg/cm^2
- steam temperature: saturated
- useful life: 10 years

Fuels studied were:

- heavy-type oil
- mineral coal
- charcoal from native and man-made forests
- wood from native and man-made forests

CIF Mill prices were used for all these fuels, and an average hauling distance (transportation) of 200 km was considered. For mineral vapor coal, there were three considerations: subsidized price (that in warehouses) and non-subsidized price. Transportation was chosen only for the purpose of comparison. As for wood and charcoal, it should be kept in mind that the greater the hauling distance, the more economic charcoal transportation becomes as compared to wood.

5.3.2 FUELS

* Heavy-type oil - US $0.21/kg

* Mineral coal: CV 35 from the southern state of Santa Catarina was chosen, considering the prices from Resolution 290/81 of the National Oil Council (Conselho Nacional de Petroleo) Producer price: US $51.04 (FOB mine) 1 ton. Selling price in warehouses (subsidized) = US $35.74/ton.

Subsidized Mineral Coal: To the base selling price in warehouses was added a 200 km railway transport charge.

For 200 km = US $6.42/t (Source: Rede Ferroviaria Federal S/A). Price of mineral coal: CIF Mill = US $35.74 + US $6.42 = US $42.16/ton.

Non-Subsidized Mineral Coal: Santa Catarina coal was used and an average distance of 100 km considered (roughly from the Criciuma region to the Port of Imbituba). Transportation would have been by railway. Maritime transportation was considered, from Imbituba to the seaport of Vitoria, the

state capital of Espirito Santo, since it was the cheapest means of transport. An average of 600 km distance by rail, from Vitoria to the state of Minas Gerais was considered. Table 5.X shows the breakdown of the transportation cost. This gives a cost of a ton of coal equal to US $79.93/ton.

Coal - CIF Mill:

Producer price	= US $51.04/ton
Transportation	= US $28.89/ton
Total	= US $79.93/ton

* Charcoal

** From native forests

	US $/m^3 of charcoal
Wood	1.35
Production	8.08
Losses	0.71
Transport	2.75
Total	US $12.89/m^3 or US $51.56/ton

** From man-made forests

	US $/m^3 of charcoal
Wood	8.81
Production	12.00
Losses	1.57
Transport	2.75
Total	US $25.13/m^3 or US $100.52/ton

* Wood

** From native forests

	US $/st
Wood on the side road	0.50 (market price)
Transport (200 km)	6.80
Total	US $7.30/st or US $14.60/ton

** From man-made forests

	US $/st
Stumped cost	3.83 (*)
Felling	0.92 (*)
Hauling	1.26 (*)
Transport	6.80
Total	US $12.81/st or US $25.62/ton

(*) These prices are taken from chapter 4. This Table gives the wood price for each cubic/meters of charcoal produced. The conversion rate is 2.3 st of wood per m^3 of charcoal.

TABLE 5.X - TRANSPORTATION PRICES - COAL

INTERVAL	TRANSPORTATION	DISTANCE	TARIFF(US$/ton)	SOURCE
Criciuma mine-Imbituba	Railway	100 km	4,22	Rede Ferroviária Federal S/A
Imbituba - Vitória	Maritime	853 milhas	9,91	Transporte Moderno Magazine. Aug. 1981
Vitória - Minas Gerais	Railway	600 km	14,76	Rede Ferroviária Federal S/A
TOTAL			28.89	

5.3.3 EQUIPMENT

The following costs (in US dollars) were given by CBC - Industrias Pesadas S/A for the same-size boilers previously specified:

	EQUIPMENT	INSTALLATION	MISCELLANEOUS	TOTAL
Heavy-type oil	483,516	164,835	87,912	736,263
Charcoal	956,044	296,703	131,868	1,384,615
Mineral Coal	956,044	296,703	131,868	1,384,615
Wood	956,044	296,703	131,868	1,384,615

5.3.4 DEPRECIATION

In a 10-year useful life, considering 80% of this operation time: 10 year x 365 days/year x 24 h/day x 0.8 = 70.080 hour.

Oil-fueled boiler: US $736,263 70,080 = US $10.51/hour. Mineral coal, charcoal and wood fueled boilers: US $1,384,615 + 70,080 = US $19.76/hour.

5.3.5 LABOR

Three persons are usually needed to operate solid-fuel boilers, an operator and two helpers. One person is enough to operate oil-fueled boilers.

The hourly wage was: Operator = US $1.90/hour; Helper = US $.95/hour. These wages include social benefits and contributions.

Labor Cost:

Oil fueled boiler: US $1.90/hour
Solid-fuel boilers:
One operator: US $1.90/hour
Two helpers: 2 x US $.95/hour = US $1.90/hour

5.3.6 MAINTENANCE

Not considered because it is the same cost as fuel-oil and solid-fuel boilers. All figures are as of July '81.

The costs of steam generation from different fuels is shown in Table 5.XI

CONSIDERATIONS

- The calorific power used in Table 5.XI for all the solid fuel is lower than that used in other parts of this paper, because quality control on boiler fuels is not as severe and the humidity and ash content are generally higher.

- Table 5.XI shows a specific situation. In the market there are other choices such as gasification and other kinds of boilers. It is even possible to make changes in the available boilers. These situations would have different costs. The costs presented are for new boilers.

- There are doubts in this analysis because the information was obtained from the boiler producer and some items like charcoal handling may vary. We are also not sure that the costs of a wood boiler and a charcoal or coal boiler are the same.

- These boilers are in use for a short time, therefore, we can expect a changing of costs by optimizing each boiler with its specific fuel.

- According to the actual wood market the transportation distances may not be the real ones.

TABLE 5.XI - STEAM GENERATION COSTS FOR DIFFERENT FUELS (JULY 81)

FUEL						EQUIPMENT					LABOR (US$/h)	TOTAL COSTS (US$/h)	STEAM PRODUCTION (kg/h)	STEAM COST (US$/1.000 kg)
TYPE	CALORIFIC POWER (Kcal/kg)	EFFICIENCY (%)	CONSUMPTION (kg/h)	COST (US$/kg)	TOTAL COST (US$/h)	BOILER (US$)	INSTALLATION (US$)	OTHERS (US$)	TOTAL (US$)	DEPRECIATION (US$/h)				
HEAVY TYPE FUEL OIL (BPF)	9,800	90.0	795	0.2100	166.95	483,516	164,835	87,912	736,263	10.51	1.90	179.36	12,000	14.9
SUBSIDIZED COAL	4,015	81.5	2,180	0.0422	92.00	956,044	296,703	131,868	1,384,615	19.76	3.80	115.56	12,000	9.6
NON SUBSIDIZED COAL	4,015	81.5	2,180	0.0799	174.18	956,044	296,703	131,868	1,384,615	19.76	3.80	197.74	12,000	16.5
NATIVE CHARCOAL	6,070	83.5	1,426	0.0516	73.53	956,044	296,703	131,868	1,384,615	19.76	3.80	97.14	12,000	8.1
EUCALYPTUS CHARCOAL	6,070	83.5	1,426	0.1005	143.31	956,044	296,703	131,868	1,384,615	19.76	3.80	166.87	12,000	13.9
WOOD FROM NATIVE FOREST	2,408	82.0	3,488	0.0146	50.92	956,044	296,703	131,868	1,384,615	19.76	3.80	74.48	12,000	6.2
WOOD FROM EUCALYPTUS FOREST	2,408	82.0	3,488	0.0256	89.20	956,044	296,703	131,868	1,384,615	19.76	3.80	112.85	12,000	9.4

SOURCE: FLORESTAL ACESITA AND CBC INDÚSTRIAS PESADAS S.A.

6. THE BRAZILIAN CHARCOAL BASED IRON AND STEEL INDUSTRY

6.1 ORGANIZATION

The Brazilian Charcoal Based Iron and Steel Industry is made up of three groups:

- integrated steel makers;
- non-integrated pig iron makers
- integrated pig iron makers, with manufacture of steel pipes and/or cast pieces.

6.1.1 INTEGRATED CHARCOAL BASED STEEL MAKERS

There were ten steel companies set up between 1920 and 1950: eight private companies and two government-controlled companies, all of which are joint-stock companies.

The annual steel production capacity ranges from 50,000 tons up to 800,000 tons. Outstanding among these companies are Acesita Belgo Mineira, and Mannesmann, whose production plans are gradually expanding to attain an output in the range of 1,000,000 ton/year.

Large companies develop their own reforestation schemes through their subsidiaries, whereas the smaller firms contract for the services of forest companies specialized in forest development. The former operate on the basis of incentives granted by the Brazilian Government.

The larger steel making firms manufacture their own charcoal to meet part of their requirements. The remaining charcol needs are purchased from independent producers or from contractors working under the supervision of the consuming company. There is a trend toward increasing production of charcoal through subsidiaries, aiming at controlling charcoal prices, production, and quality.

The larger companies have their own iron mines and operate them through their subsidiaries. The smaller firms either mine their own resources directly or purchase the iron are from independant producers.

The integrated pig iron production companies have, on occasion, not been large enough for the corresponding steel production, and in such cases the deficit in pig iron is offset by supplies from non-integrated pig-iron makers and to a lesser extent, by scraps. Most steel makers have been increasing their own pig iron production capacity in order to achieve pig iron self-sufficiency.

The steel is produced in small capacity (20-60 t) Siemens-Martin furnaces, LD Converters (20-45 t), and in electric arch furnaces (20-40 t).

The steel makers are planning increases in their production capacities in compliance with the guidelines set forth in the "Master Plan for the Steel Industry" worked out by CONSIDER - The National Council of Metallurgy.

These plans aim to increase pig iron production and to achieve self-sufficiency in charcoal supply.

Concomitantly, several studies have been carried out for the purpose of:

* improving charcoal processes and production.

* improving blast furnace performance and productivity.

* installing new equipment to be fitted to existing blast furnaces, or new high-capacity blast furnaces.

* making use of direct reduction processes, utilizing charcoal fines as the reducing agent.

6.1.2 NON-INTEGRATED CHARCOAL BASED PIG IRON MAKERS

There are 60 private companies with stock capital below US $300,000. The daily production capacity of pig iron blast furnace of these companies varies from 30 tons to 200 tons: however, 30% of these companies have a production capacity below 80 tons/day.

The non-integrated pig iron makers have consistently replanted forest areas compatible with their own charcoal consumptions, availing themselves of fiscal incentives granted by the Federal Government. Reforestation programs currently forecast 50% self-sufficiency by 1985.

Most of the charcoal used by the companies is supplied by independant producers, however, some of these companies either produce part of the charcoal to meet their requirements or are planning to do so in the future. Almost all the charcoal used by these companies is now transported by trucks over distances ranging from 100 km to 400 km.

The quality of charcoal varies considerably among the large number of producers and is due, mainly to lack of know-how. Progress in this area has been slow, and only sporadic and slow-paced developments have been observed.

Fifteen to twenty percent of fines, resulting from screening of the charcoal before charging it into the blast furnace, is used for different purposes.

The iron ore is purchased from some 30 small to medium mining companies, whose ore outputs vary between 1000 tons and 1,500 ton per month. It is transported by trucks over distances ranging from 10 km to 100 km.

Most of these pig iron makers supply the Brazilian foundaries, except for Usina Esperanca, which produces its own liquid pig iron, and three other producers of cast iron pipes. The state-owned captive foundaries are self-sufficient in coke pig iron. This group also supplies about 500,000 ton/year of pig iron for the integrated charcoal based industries whose output is still insufficient for technical reasons.

For countries undergoing an expansion in the industrial sector, as is the case in Brazil, it is estimated that the demand for cast iron and steel

as some 10% of the annual output of liquid steel. These data take into account the consumption of cast iron by the iron and steel industries themselves.

The Brazilian scrap based steel makers (electric-arch and Siemens-Martin furnaces), with a large potential for steel making, are sometimes faced with serious shortages of scrap. In times of increased domestic demand these exports are drastically reduced: on other occasions, due to the very nature of the international steel industry, foreign pig iron demand in highly industrialized countries is substantially reduced.

Notwithstanding these fluctuations, the experience accumulated during the past years has shown that it is quite feasible to export 600,000 to 800,000 tons per year of charcoal-based pig iron. Such a fact makes it possible for us to forecast a pig iron demand on the order of 2.5 million tons in 1981, and to be increased to 3.0 million tons by 1983.

6.1.3 INTEGRATED PIG IRON MAKERS (WITH MANUFACTURE OF CAST IRON AND CASTINGS)

Included in this group are two companies specializing in the manufacture of cast iron pipes and one manufacturer of castings. Cast iron pipes are widely used by utility companies installing water supply and sewage disposal systems in large and small towns. In addition to manufacturing cast iron pipes the companies also make the accompanying parts necessary to the systems, such as fittings, valves, etc. The foundaries also produce motor-blocks for the auto industry, and plates and sheets, etc., for the steel industry.

In the past few years, there has been an increase in the production of modular iron pipes, which display a greater strength and ductibility than the ordinary gray iron. Part of the pipe production is designed for export to both North and South America.

6.2 TECHNICAL AND FUNDAMENTAL ASPECTS

6.2.1 INTRODUCTION

The production of crude steel for the manufacturing of several finished products such as plates, wire, light or heavy profiles starts, in most processes, with the production of pig iron from iron ore. For the production of pig iron a number of pieces of equipment are used such as blast furnace and electric reduction furnace. As for the reductant, either charcoal or coal can be used.

Figs. 6.1 and 6.2 shows the pig iron production flow charts with the use of metallurgical coal/charcoal based electric reduction and blast furnaces. The illustration also shows the various raw materials used for the manufacture of pig iron and iron ore.

The blast furnace is utilized to remove the oxygen found in combination with the iron ore, by means of a series of chemical reactions between the iron oxides and the reducing agents resulting from the combustion of the

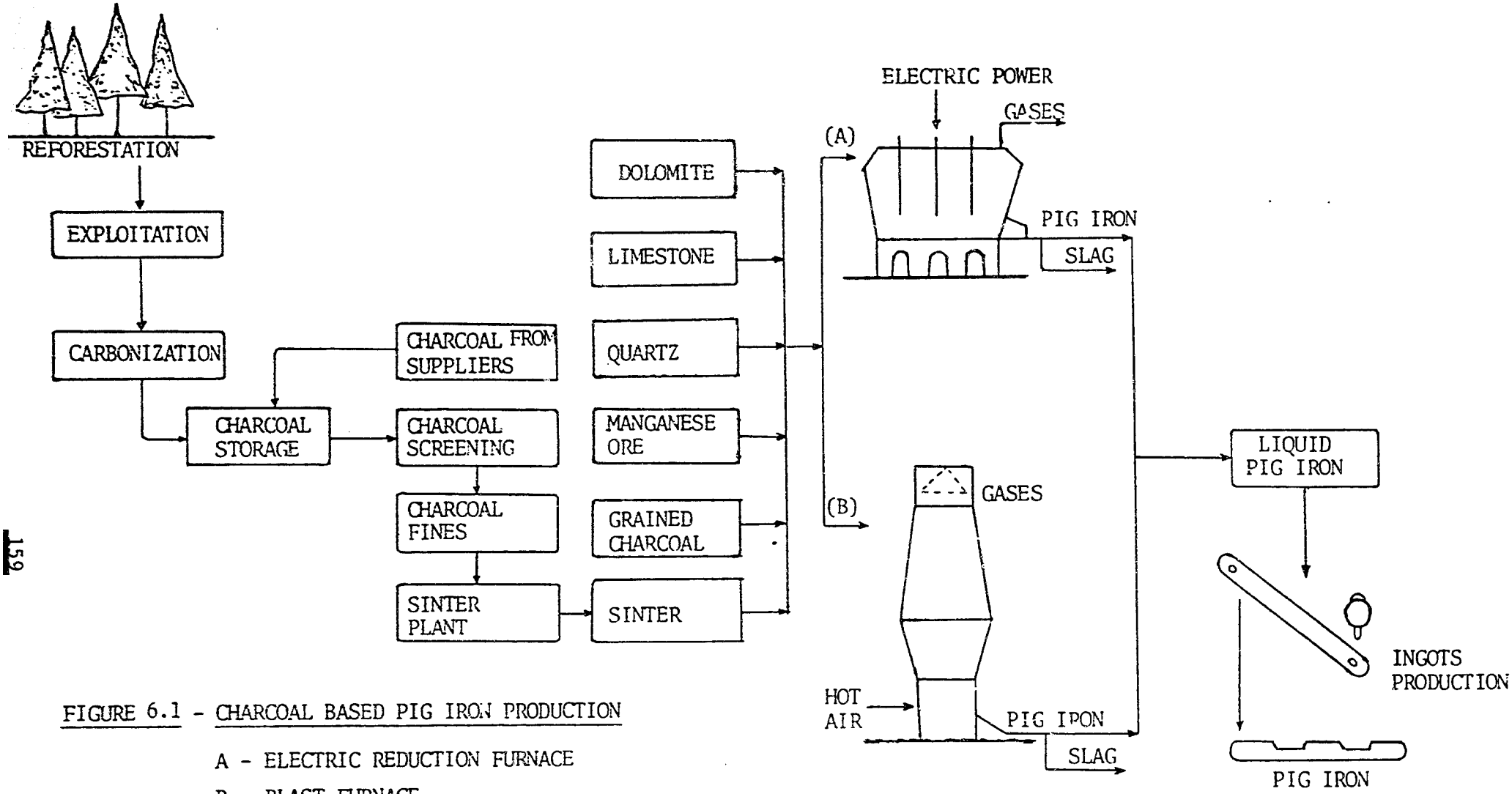


FIGURE 6.1 - CHARCOAL BASED PIG IRON PRODUCTION

A - ELECTRIC REDUCTION FURNACE

B - BLAST FURNACE

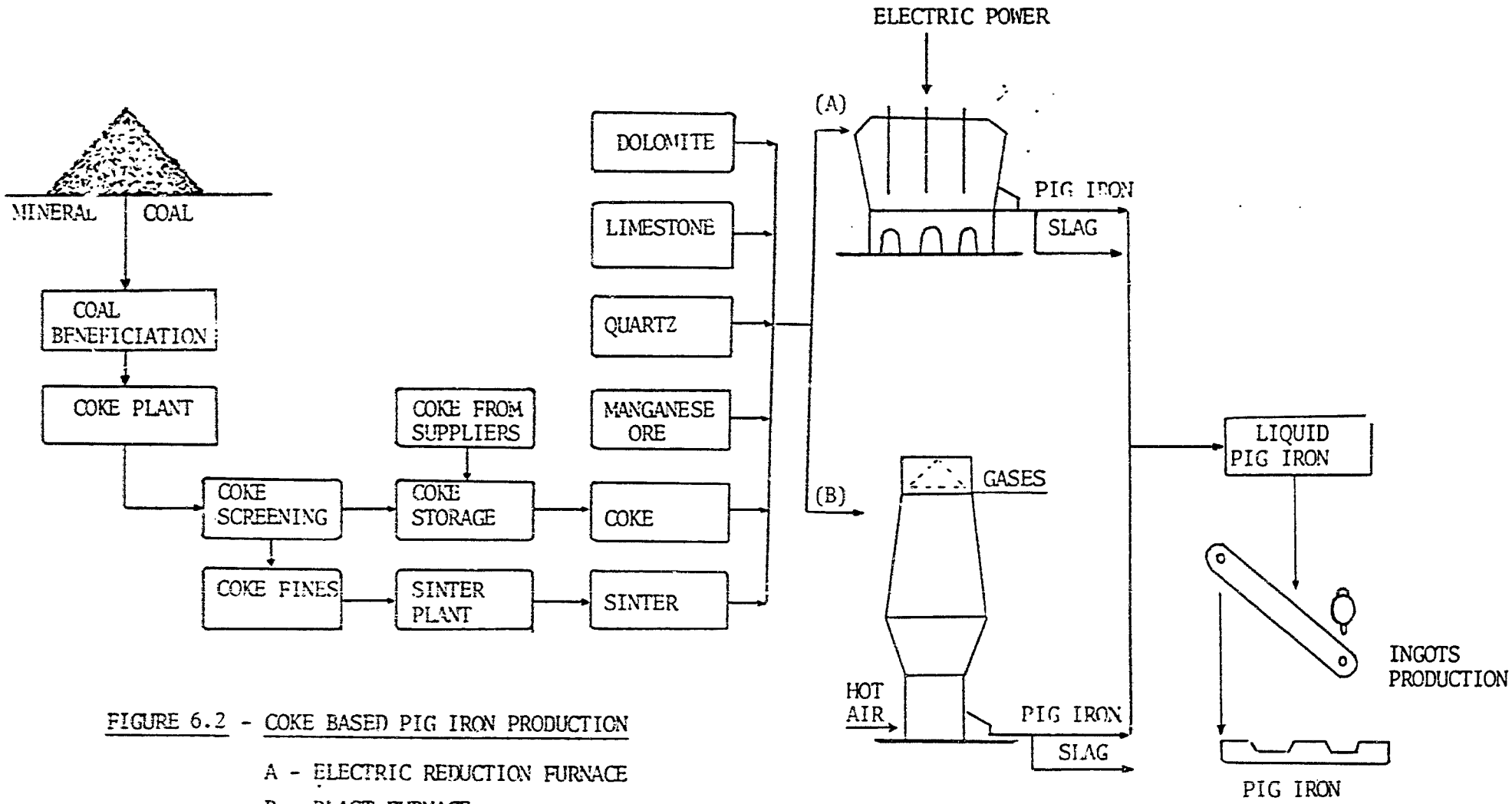


FIGURE 6.2 - COKE BASED PIG IRON PRODUCTION

A - ELECTRIC REDUCTION FURNACE

B - BLAST FURNACE

reductant. The combustion of the reductant also provides the necessary heat to melt the material resulting from the chemical reactions taking place inside the furnace. The metal must be separated from the non-metallic ingredients contained in the ore, fuel ashes, etc. through the formation of a slag.

These functions apply to a blast furnace using charcoal or coke, except that both reductants present different chemical and physical characteristics. These differences will influence both the design and operation of charcoal based blast furnaces.

In the case of the electric reduction furnace the basic carbon function is to reduce the ore to metallic iron, and most of the heat require to melt the burden is provided by electric power.

6.2.2 RAW MATERIALS USED FOR PIG IRON MANUFACTURE

The raw material used in pig iron making are: iron ore, sinter, manganese ore or maganese iron slags, limestone, dolomite, quartz, blast furnace slag, and charcoal or coke. The physical characteristics of these materials are quite similar:

- narrow size range, (depending on the component)
- high resistance to size degradation (in terms of abrasion and shatter test)
- high electric resistance as far as electric furnace is concerned.

Table 6.I shows the size ranges of several types of raw material used in electric reduction furnace and in blast furnace.

Most charcoal-based furnaces in Brazil make use of high Fe_2O_3 content hematite, an ore from the iron-rich region of Minas Gerais. The average chemical composition can be exressed as:

Fe	64% - 69%
SiO_2	0.5% - 2%
A_2O_3	0.7% - 2%
P	Less than 0.1%

Smaller blast furnaces make use of other types of hematite known as "Itabirites" made up of little plates with a smaller structure. "Canga" is another ore used for economic reasons. It is hydrated hematite with 55% - 60% Fe, 4% - 6% A_2O_3, and high phosphorus content (0.15% - 0.30%). It is partially used in the burden, usually up to 30%.

In iron ore mining, part of the ore presents a smaller grain size than that used for blast furnaces, and a few integrated mills sinterize these fines, and use the sinter in blast furnace. The sintering process is a way of making

TABLE 6.I - GRAIN SIZE OF RAW MATERIALS USED IN BLAST FURNACES AND ELECTRICAL REDUCTION FURNACES

COMPONENT	BLAST FURNACE mm	E. REDUCTION FURNACE mm
Iron ore	12-19	19-38
Manganese ore	12-19	19-38
Limestone	12-19	12-19
Dolomite	12-19	12-19
Quartz	12-19	12-19
Slag	15-45	15-45
Charcoal	10-75	6-30
Coke	25-75	6-19

use of both these ore fines and the charcoal fines generated by screening of the reductant. It presents some advantages in terms of blast furnace operation, such as productivity and charcoal consumption.

In order to remove undesirable burden materials and incorporate them in the slag, its basicity ratio $\frac{CaO}{SiO_2}$ must range from 0.7 to 0.9. To do so, it is necessary to add limestone to the burden. The limestone must have low melting temperature and high calcination speed.

Due to the high purity of our iron ores the addition of quartz is necessary to obtain a sufficient slag volume. It is added in the form of sand and gravel with silica content in excess of 95% and low amounts of alumina (below 0.5%).

Dolomite, which is calcium-magnesium carbonate, is used alone or in combination with limestone. It is used to make the slag more fluid, thus facilitating its removal from the reactor. Manganese is added to the burden to incorporate into the pig iron the maganese content required.

6.2.3 TECHNICAL COEFFICIENTS AND PRODUCTION LEVELS

The technical coefficients vary according to the scale of production, type of raw material used, and the product which is being manufactured. The following tables show the technical coefficients for different types of pig iron for different blast furnace/electric reduction furnace capacities.

TABLE 6.II - TECHNICAL COEFFICIENTS - PIG IRON PRODUCTION

BLAST FURNACE: CHARCOAL

PER TON OF PIG IRON

ITEMS	UNITY	% OF SILICON					
		0.5 - 1.0			1.0 - 1.5		
		CAPACITY t/d			CAPACITY t/d		
		200	400	800	200	400	800
1. Labor - Direct	hh	5,24	5,23	1,99	5,76	3,55	2,19
2. Labor - Indirect	hh	1,46	0,89	0,55	1,61	0,98	0,61
3. Raw materials							
iron ore	kg	1410	1410	1410	1410	1410	1410
manganese ore	kg	30	30	30	30	30	30
limestone	kg	40	40	40	40	40	40
dolomite	kg	70	70	70	70	70	70
quartz	kg	50	50	50	70	70	70
charcoal/ccke	kg	665	640	620	745	720	700
slag	kg	-	-	-	-	-	-
4. Other materials							
electrodes	kg	-	-	-	-	-	-
steel plate	kg	-	-	-	-	-	-
rod bar steel	kg	1,0	0,5	0,25	0,9	0,45	0,22
fire brick	kg	2,00	1,20	0,70	2,2	1,44	0,77
electric power	kwh	90	53,5	31,8	99	58,8	35,0
water	m^3	8	6,5	5,2	8,8	7,1	5,7
oxygen	Nm^3	1,0	0,5	0,25	0,9	0,45	0,22
5. Annual production	t	70000.	14000	280000	63000	126000	252000
6. gas credit	Nm^3	1530	1480	1430	1530	1480	1430

TABLE 6.III - TECHNICAL COEFFICIENTS - PIG IRON PRODUCTION

BLAST FURNACE: COKE

PER TON OF PIG IRON

ITEMS	UNITY	% OF SILICON					
		0.5 - 1.0			1.0 - 1.5		
		CAPACITY t/d			CAPACITY t/d		
		200	400	800	200	400	800
1. Labor - Direct	hh	4,76	2,94	1,81	5,24	3,23	1,99
2. Labor - Indirect	hh	1,33	0,81	0,50	1,46	0,89	0,55
3. Raw Materials							
iron ore	kg	1410	1410	1410	1410	1410	1410
manganese ore	kg	30	30	30	30	30	30
limestone	kg	50	50	50	50	50	50
dolomite	kg	70	70	70	70	70	70
quartz	kg	-	-	-	-	-	-
charcoal/coke	kg	595	595	550	655	645	610
slag							
4. Other materials							
electrodes	kg	-	-	-	-	-	-
steel plate	kg	-	-	-	-	-	-
rod bar steel	kg	1,0	1,0	1,0	1,0	1,0	1,0
fire brick	kg	1,82	1,10	0,63	2,0	1,3	0,7
electric power	kwh	81,8	48,6	28,9	90	53,5	31,8
water	m^3	7,3	5 9	4,7	8	6,5	5,2
oxygen	Nm^3	1,0	1,0	1,0	1,0	1,0	1,0
5. Annual production	t	77000	154000	308000	69300	138600	277200
6. gas credit	Nm^3	1530	1480	1430	1530	1480	1430

TABLE 6.IV - TECHNICAL COEFFICIENTS - PIG IRON PRODUCTION
ELECTRIC REDUCTION FURNACE: CHARCOAL

PER TON OF PIG IRON

ITEMS	UNITY	% OF SILICON					
		0.5 - 1.0			1.0 - 1.5		
		CAPACITY t/d			CAPACITY t/d		
		200	400	800	200	400	800
1. Labor-Direct	hh	5,24	3,23	2,75	5,45	3,36	2,86
2. Labor - Indirect	hh	1,46	0,89	0,76	1,52	0,93	0,79
3. Raw materials							
iron ore	kg	1405	1405	1405	1405	1405	1405
manganese ore	kg	30	30	30	30	30	39
limestone	kg	280	280	280	280	280	280
dolomite	kg	110	110	110	110	110	110
quartz	kg	150	150	150	170	170	170
charcoal/coke	kg	497	497	497	510	510	510
slag	kg	100	100	100	100	100	100
4. Other materials							
electrodes	kg	6	6	6	6,2	6,2	6,2
steel plate	kg	2	2	2	2,1	2,1	2,1
rod bar steel	kg	1,0	1,0	1,0	1,0	1,0	1,0
fire brick	kg	1,0	0,6	0,6	1,0	0,6	0,6
electric power	kwh	2000	1950	1950	2080	2080	2080
water	m^3	5,5	4,5	4,5	5,7	4,7	4,7
oxygen	Nm^3	1,0	1,0	1,0	1,0	1,0	1,0
5. Annual Production	t	70000	140000	280000	67300	134600	269200
6. gas credit	Nm^3	650	650	650	650	650	650

TABLE 6.V - TECHNICAL COEFFICIENTS - PIG IRON PRODUCTION
ELECTRIC REDUCTION FURNACE: COKE

PER TON OF PIG IRON

ITEMS	UNITY	% OF SILICON					
		0.5 - 1.0			1.0 - 1.5		
		CAPACITY t/d			CAPACITY t/d		
		200	400	800	200	400	800
1. Labor - Direct	hh	7,26	4,47	3,81	7,55	4,65	3,96
2. Labor-Indirect	hh	2,02	1,23	1,05	2,11	1,29	1,09
3. Raw materials							
iron ore	kg	1380	1380	1380	1380	1380	1380
manganese ore	kg	30	30	30	30	30	30
limestone	kg	280	280	280	280	280	280
dolomite	kg	110	110	110	110	110	110
quartz	kg	100	100	100	120	120	120
charcoal/coke	kg	450	450	450	460	460	460
slag	kg	360	360	360	360	360	360
4. Other materials							
electrodes	kg	8,3	8,3	8,3	8,6	8,6	8,6
steel plate	kg	2,8	2,8	2,8	2,9	2,9	2,9
rod bar steel	kg	1,0	1,0	1,0	1,0	1,0	1,0
fire brick	kg	1,4	0,8	0,8	1,4	0,8	0,8
electric power	kwh	2300	2240	2240	2380	2320	2320
water	m^3	7,6	6,2	6,2	7,9	6,5	6,5
oxygen	Nm^3	1,0	1,0	1,0	1,0	1,0	1,0
5. Annual Production	t	50400	100800	201600	48590	97180	194360
6. gas credit	Nm^3	650	650	650	650	650	650

7. CHARCOAL BASED IRON AND STEEL ECONOMICS

7.1 INTRODUCTION

The iron and steel industry is responsible for a large share of the country's total energy consumption. Eighty-three percent of the country's total domestic requirement for metallurgical coal - a major reductant in steel making - is met by imports. The expansion plans now being enviraged by the Brazilian steelworks make it possible to anticipate growing imports of this raw material for years to come.

Presently, plans are being developed by the government aimed at rapidly increasing the production and use of coal reserves in the south of the country, albeit contrary to the opinion of some who still dispute the quality of the southern coal, its profitability, and the current level of performance of our mining technology. At the same time, similar studies are being made on the feasibility of substantially increasing the use of charcoal, because no limiting factors exist regarding the Brazilian steel makers' capacity to produce charcoal-based pig iron. Current literature regarding the charcoal versus coal issue is abundant, and practically all of the studies emphasize the importance of charcoal as a viable answer to the energy problem faced by tropical countries.

The upward trend of international coal prices, the gloomy presence of our almost total dependence on coal imports, and the rapid development of charcoal technology may substantially alter the Brazilian iron and steel industry scenario.

In this chapter, we intend to show some comparative cost data regarding steel and pig iron production in Brazil.

7.2 ALTERNATIVES FOR CHARCOAL PRODUCTION

Steel making technology is rich in alternatives; foremost among them is the one making use of coke blast furnaces coupled with LD (oxygen) converters. For countries rich in high-quality, low cost coking coal resources, or for those countries lacking in alternatives to coking coal, the utilization of coke blast furnaces with LD converter is undoubtedly the most practical solution.

In Brazil, other solutions must be looked into if a reduction, or an equilibrium, in coal imports for coke production is to be achieved.

In the present study the following alternatives will be brought into focus:

1 - coke, blast furnace/LD converter
2 - charcoal blast furnace/LD
3 - coke electric reduction furnace/LD
4 - charcoal electric reduction furnace/LD
5 - direct reduction by coal reducing gas/electric arc furnace

The basic difficulty which arises when comparing these alternative processes is to establish the actual CIF prices for the raw reductant since it involves computing such intangibles as: government incentives, transportation distances, plant size, etc.

To overcome this difficulty, the unit price of each reductant necessary to an output of 300,000 t/year of steel, was calculated for each alternative presented; a 200 km transportation distance from the delivery point was assumed for Santa Catarina coal, at subsidized prices; as for the charcoal, a distance of 400 km from the production center was adopted.

7.3 UNIT COST OF REDUCTANT

7.3.1 COST OF CHARCOAL

On the basis of chapter 4, the CIF-Plant cost of one cubic meter of charcoal is assumed to be US $27.26 (no loss of fines will occur become the fines will be used as a solid fuel to be fed into the blast furnace tuyeres). To this cost must also be added cost related to unloading, storing, processing, quality and reception control, equipment maintenance, etc., which total US $4.33. Therefore, the cost at the blast furnace bin would amount to US $31.59 per cubic meter.

Charcoal self-sufficiency for any plant aiming at producing 280,000 t/yr of pig iron, with a specific consumption of 3 m^3 of charcoal per ton of pig iron, would be attained through an investment on the order of US $51,483,000 broken down as follows:

- silviculture - US $40,572,000.
- charcoal manufacture - US $ 6,577,000.
- transport to the plant - US $ 4,334,000.

7.3.2 COST OF COKE

It is assumed that no investments are made in coal mines and that the basic mixture to be coked is made up of domestically produced coal, imported coal (high, medium, and low volatiles), and petroleum coke.

The coking plant is designed to produce 180,000 t/yr of coke, and requires an over-all investment of US $39,240,000 to cover the following items: coal yards, coke ovens, gas-treatment facilities, by-product plants, anti-pollution equipment.

Table 7.I shows the cost of one ton of metallurgical coke. Under "services and general expenditures" are included the services at the coal yard, transport, gas cleaning, administration, etc.

Under "maintenance" are the following items: materials, labor, third party services, fire bricks, and provision for repairs.

7.3.3 PRODUCTION COST OF 1000 Nm^3 REDUCING GAS

Cost calculations will be for a plant with an annual production of 390.7 x 10^6 Nm^3 coal based gas. No investment in coal mining is assumed.

TABLE 7.1 - COST OF A TON OF COKE FOR 180.000 TON ANNUAL PRODUCTION

COST COMPONENTS		UNIT	US$/UNIT	COKE	
				INPUT U/TON	COST US$/TON
1. Labor		Mh	2.17	1,00	2.17
2. Raw Materials -	National Coal	ton	80.00	0.169	13.52
	Imported Coal	ton	80.00	1.070	85.60
	Petroleum Coke	ton	80.000	0.068	5.44
	Coke Plant Gas	Nm^3	0.04	72.0	2.88
	Blast Furnace Gas	Nm^3	0.01	605.0	6.05
	Others (Steam,Power Water, etc.)				1.12
3. Services and general expenses					17.43
4. Maintenance					6.85
5. Capital Costs					32.70
6. Credits -	Coke plant gas	Nm^3	0.04	390.0	-15.60
	Coke ovem gas by products	ton	60.00	0.050	- 3.00
7. Processing and Quality Control	Storage bin blast Furnace/SINTER				4.46
TOTAL					159.52

SOURCE: SILVEIRA, R.C.

Under this assumption the investment for installing a gasification plant, including coal treatment, is US $46,918,000. Table 7.II shows the production cost for 1000NM^3 of gas.

7.4 PRODUCTION COST OF A TON OF STEEL, CONSIDERING DIFFERENT ALTERNATIVES

The following alternates will be considered in determining the production cost of 1 ton of steel for an annual output of 300,000 tons:

- coke blast furnace and LD converter;
- coke electric reduction furnace and LD converter;
- charcoal blast furnace and LD converter;
- charcoal electric furnace and LD converter;
- direct reduction and electric-arc furnace.

7.4.1 COKE BLAST FURNACE & LD CONVERTER

As shown in Table 7.I, the cost of a ton of coke at the plant is US $159.62. This coke is to be processed in order to bring its grain size to specified ranges (20 mm - 70 mm or 25 mm - 75 mm). As a result, an appreciable amount of fines, below the limit range acceptable for blast furnace use, is expected to be generated. Fines can be used either as a fuel in sinter plants, as is usually the case, or as an inert material in the mixture to be coked, the latter alternative showing likely disadvantages as far as productivity is concerned. Assuming no use could be made of the fines thus generated, or should they be marketed at a lower sale price, an unwelcome accrual in coke prices would then ensure, thereby causing the cost in Table 7.I to be increased.

In order that the original coke price can be maintained the alternative favoring full utilization of the fines for sintering purposes has been selected.

The following cost calculations are shown for: sinter (Table 7.III), pig iron (Table 7.IV), and steel (Table 7.V).

The following values for fixed investments were taken into account:

- sintering US $19.8 x 10^6
- blast Furnace US $33.4 x 10^6
- LD converter US $53.8 x 10^6
- desulfurizing equipment US $0,27 x 10^6

7.4.2 CHARCOAL BASED BLAST FURNACE & LD CONVERTER

Pig iron and steel costs are shown in Table 7.VI and 7.VII, respectively. Investments in charcoal based blast furnace for a 280,000 t/yr output are about US $40.4 x 10^6, including charcoal fines injection installations.

TABLE 7.II - PRODUCTION COST OF 1000 Nm^3 OF REDUCING GAS BY KOPPER TOTZEK PROCESS

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/1000 Nm^3	COST US$/1000 Nm^3
1. Direct Labor	Mh	3.19	0.60	1.91
2. Indirect Laobr	Mh	3.27	0.36	1.18
3. Raw Materials				
. Steam Coal	ton	43.50	0.848	86.89
. Eletric Power	Kwh	0.024	475	11.40
. Cooling Water	m^3	0.04	3	0.12
. Water for Steam	m^3	0.06	1.5	0.09
4. Maintenance				0.85
5. Capital Cost				21.21
TOTAL COST				

SOURCE: SILVEIRA, R.C.

TABLE 7.III - COST OF A TON OF SINTER FOR 450.000 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COST US$/TON
1. Labor	Mh	2.17	1.0	2.17
2. Raw Materials				
. Iron ore fines	ton	6.00	0.646	3.88
. Iron ore	ton	7.00	0.045	0.32
. Bedding	ton	7.00	0.127	0.89
. Scales	ton	2.00	0.033	0.07
. Returned Sinter	ton	2.00	0.480	0.96
. Quartz	ton	3.20	0.004	0.01
. Lime	ton	30.00	0.030	0.90
. Limestone	ton	3.50	0.105	0.37
. coke	ton	159.62	0.050	7.98
. water	m^3	0.04	90	3.60
. Eletric Power	Kwh	0.024	58	1.39
3. Maintenance				0.19
4. Capital Costs				6.61
				29.34

SOURCE: SILVEIRA, R.C.

TABLE 7.IV - COST OF A TON OF A COKE BASED BLAST FURNACE PIG IRON. 280.000 TON ANNUAL PRODUCTION (LOW SILICON - 0.4 to 0.7 %)

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	2.3	4.99
2. Raw Materials				
. Sinter	ton	29.20	1.570	45.84
. Mn ore	ton	45.00	0.030	1.35
. Fluxes	ton	3.20	0.020	0.06
. Coke	ton	159.62	0.500	79.81
. Steel rod bars	ton	290.00	0.001	0.29
. Fired brick	ton	160.00	0.0006	0.10
. Eletric Power	Kwh	0.024	70	1.68
. Water	m^3	0.04	5	0.20
. Oxygen	Nm^3	0.06	0.8	0.05
3. Maintenance				1.00
4. Capital Costs				17.88
5. Desulfuration				5.38
6. Gas Credit	Nm^3	0.008	1430	-11.44
TOTAL COST				147.19

SOURCE: SILVEIRA, R.C.

TABLE 7.V - COST OF A TON OF COKE BASED LD STEEL. 300.000 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	2.4	5.21
2. Raw Materials				
. Liquid pig iron	ton	147.19	0.930	136.89
. Scrap	ton	120.00	0.157	18.84
. Fluorspat	ton	120.00	0.002	0.24
. Lime	ton	30.00	0.060	1.80
. Oxygen	Nm^3	0.06	60	3.60
. Fe - Mn	ton	600.00	0.007	4.20
. Fe - Si 75%	ton	750.00	0.005	3.75
. Aluminum	ton	1.620.00	0.0003	0.49
. Fire brick	ton	770.00	0.005	3.85
. Eletric Power	Kwh	0.024	30	0.72
. Water	m^3	0.04	8	0.32
3. Maintenance				1.37
4. Capital Cost				26.92
TOTAL COST				208.20

SOURCE: SILVEIRA, R.C.

TABLE 7.VI - COST OF A TON OF CHARCOAL BASED BLAST FURNACE PIG IRON 280.000 TON ANNUAL PRODUCTION (LOW SILICON 0.4 to 0.7 %)

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	2.3	4.99
2. Raw Materials				
. Iron ore	ton	8.00	1.410	11.28
. Manganese ore	ton	45.00	0.030	1.35
. Dolomite	ton	8.00	0.040	0.32
. Limestone	ton	3.50	0.070	0.25
. Quartz	ton	3.20	0.050	0.16
. Charcoal	ton	126.36	0.545	68.87
. Charcoal fines	ton	126.36	0.150	18.95
. Steel	ton	290.00	0.001	0.29
. Fire Brick	ton	160.00	0.0006	0.10
. Eletric Energy	Kwh	0.024	70	1.68
. Water	m^3	0.04	5	0.20
. Oxygen	Nm^3	0.06	0.8	0.05
3. Maintenance				1.00
4. Capital Costs				17.88
5. Gas Credit	Nm^3	0.008	1430	-11.44
TOTAL COST				115.93

SOURCE: SILVEIRA, R.C.

TABLE 7.VII - COST OF A TON OF CHARCOAL BASED LD STEEL. 300.00 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	2.4	5.21
2. Raw Materials				
. Liquid pig iron	ton	115.93	0.930	107.81
. Scrap	ton	120.00	0.157	18.84
. Fluorspat	ton	120.00	0.002	0.24
. Lime	ton	30.00	0.060	1.80
. Oxygen	Nm^3	0.06	60	3.60
. Fe - Mn	ton	600.00	0.007	4.20
. Fe - Si 75%	ton	750.00	0.005	3.75
. Aluminum	ton	1.620.00	0.0003	0.49
. Fire Brick	ton	770.00	0.005	3.85
. Eletric Power	Kwh	0.024	30	0.72
. Water	m^3	0.04	8	0.32
3. Maintenance				1.37
4. Capital Costs				26.92
TOTAL COSTS				179.12

SOURCE: SILVEIRA, R.C.

TABLE 7.VIII - COST OF COAL GAS PRE-REDUCED IRON. 15.000 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	3.27	0.8	2.62
2. Raw Materials				
. Pellets	ton	32.00	1.410	45.12
. Eletric Power	Kwh	0.024	110	2.64
. Coal	ton	43.50	0.157	6.83
. Reducing gas	1000 Nm^3	73.65	1.050	77.33
. Cooling water	m^3	0.04	3.00	0.12
. Steam water	m^3	0.06	0.5	0.03
3. Maintenance				1.33
4. Capital Costs				
TOTAL COSTS				159.09

SOURCE: SILVEIRA, R.C.

TABLE 7.IX - COST OF A TON OF ELETRIC FURNACE STEEL FROM SPONGE IRON 300.000 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	3.0	6.51
2. Raw Materials				
. Sponge iron	ton	159.09	1.052	167.36
. Scrap	ton	120.00	0.133	15.96
. Fluorspat	ton	120.00	0.002	0.24
. Lime	ton	30.00	0.060	1.80
. Oxygen	Nm^3	0.06	15	0.90
. Fe - Mn	ton	600.00	0.007	4.20
. Fe - Si 75%	ton	750.00	0.005	3.75
. Aluminum	ton	1.620.00	0.003	0.49
. Fire Brick	ton	770.00	0.015	11.55
. Eletric Power	Kwh	0.024	650	15.60
. Water	m^3	0.04	10	0.40
. Electrodes	ton	1.380.00	0.006	8.28
3. Maintenance				0.90
4. Capital Costs				17.50
TOTAL COST				255.44

SOURCE: SILVEIRA, R.C.

7.4.3 DIRECT REDUCTION & ELECTRIC-ARC FURNACE

The cost of the reducing gas has previously been studied (Table 7.II). Tables 7.VIII and 7.IX show the costs calculated for both the sponge iron and the steel from electric-arc furnace, respectively. Investment costs are as follows:

- Direct Reduction US $48.4 x 10^6
- Electric-arc furnace US $35.0 x 10^6

7.4.4 ELECTRIC REDUCTION FURNACE

In order to assess the role played by electric reduction furnaces in the Brazilian steel industry, the production cost of a ton of pig iron was calculated. Coke (Table 7.X), or charcoal (7.XI), being considered as the reducing agent.

It was assumed that the fines either from charcoal or coke would be available for sale, without taking into consideration the respective credits. The investment costs considered are as follows:

- coke based electric reduction furnace US $35.9 x 10^6
- charcoal based electric reduction furnace US $29.1 x 10^6

The difference in investment costs for the same production results from the lower productivity when coke is used, which leads to the need for a larger unit.

Since the electric reduction furnace requires less charcoal than the blast furnace, the investments in charcoal supply will be smaller for the electric process (US $36.26 x 10^6).

The cost of steel from LD converters using an electric reduction pig iron furnace was obtained by taking the pig iron costs from Tables 7.X and 7.XI to Tables 7.V and 7.VII, respectively.

Briefly, Table 7.XII shows the pig iron and steel costs as well as the investments required for each alternative.

7.5 ANALYSING THE ALTERNATIVES

It must be initially emphasized that it is difficult to offer a technical-economic opinion on the question of charcoal-based steel mills versus coke based mill or direct reduction. There is such a wide variety of hypotheses, involving location, processes, chosen technology, future-development forecasts, production increases, strategic questions, availability of financial resources, capital costs, cost-appropriation systems, etc., that all these hypotheses require extreme care when comparisons are made.

The subsidizing of coal in Brazil makes prices artificial in coke-based steelmaking and, if the subsidies are removed, the cost of production may no longer be feasible. In addition to that, calculations were made for seashore plants, where coal-transportation cost is low. Charcoal alternatives are better than coal alternatives, whether for blast furnaces or for electric reduction furnace.

The conclusion that charcoal-operated plants have a superior performance is strengthened by these considerations:

- wood production per hectare is increasing (forest yield greatly affects investments.)

- the recovery of carbonization by-products has not been taken into account. Such recovery is already taking place in Brazil with tar on an industrial scale.

- a consumption of 2.3 steres of green wood per cubic meter of charcoal was considered, and present carbonization rates are close to 2.0 - 2.1 per cubic meter.

7.6 ADDITIONAL ADVANTAGES FOR CHARCOAL-BASED STEELMAKING

Assuming, as has been shown above, that investments in charcoal will decrease considerably in the next few years, and considering the twin advantages of low production costs of both pig-iron and steel, the following additional advantages for the charcoal-based steelmaking industry should be mentioned:

. by generating its own reducing fuel for blast furnaces, Brazil, which lacks quality coal, will no longer be dependant on the other nations for its supply. Foreign exchange, so important to the Nation's economy, will be saved.

. Brazil has no control over the price of imported coal, and these prices are often increased for political or strategic reasons rather than for lack of supply. The company that plants its own forests can estimate the final cost of the reducing fuel, plan its own production, control the finished product price; and in short, have a firm grip on all parameters of the process;

- Brazil has the technological know-how to produce and utilize charcoal;

- a flexibility of output allows for economically-reasonable pig iron production in 40-1000-t/d, or larger furnaces;

- social welfare is served by the many unskilled labor jobs that are created in the poor regions of the nation. Side results are quickly felt, such as road development, generation of direct and indirect jobs, specialized training for rural workers and their families, a strengthening of the local health education and so on.

TABLE 7.X - COST OF A TON OF COAL ELETRIC REDUCTION FURNACE PIG IRON 280.000 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	3.5	7.50
2. Raw Materials				
. Iron ore	ton	8.00	1.380	11.04
. Manganese ore	ton	45.00	0.030	1.35
. Dolomite	ton	8.00	0.110	0.88
. Limestone	ton	3.50	0.280	0.98
. Quartz	ton	3.20	0.100	0.32
. Coke	ton	159.62	0.450	71.83
. Steel plate	ton	280.00	0.003	0.84
. Steel rod bar	ton	290.00	0.001	0.29
. Fire brick	ton	770.00	0.0008	0.62
. Eletric power	Kwh	0.024	2.240	53.76
. Water	m^3	0.04	6	0.24
. Oxygen	Nm^3	0.06	1	0.06
. Slag	ton	1.20	0.100	0.12
. Electrodes	ton	500.00	0.008	4.00
3. Maintenance				0.86
4. Capital Costs				16.61
5. Desulfuration				5.38
6. Gas credit				-13.77
TOTAL COST				163.01

SOURCE: SILVEIRA, R.C.

TABLE 7.XI - COST OF A TON OF CHARCOAL ELETRIC REDUCTION FURNACE PIG IRON 280.000 TON ANNUAL PRODUCTION

COST COMPONENTS	UNIT	US$/UNIT	INPUT UNIT/TON	COSTS US$/TON
1. Labor	Mh	2.17	3.5	7.60
2. Raw Materials				
. Iron ore	ton	8.00	1.405	11.24
. Manganese ore	ton	45.00	0.030	1.35
. Dolomite	ton	8.00	0.110	0.88
. Limestone	ton	3.50	0.280	0.98
. Quartz	ton	3.20	0.150	0.48
. Charcoal	ton	126.36	0.490	61.92
. Steel plate	ton	280.00	0.003	0.84
. Steel rod bar	ton	290.00	0.001	0.29
. Fire brick	ton	770.00	0.0008	0.62
. Eletric power	Kwh	0.024	1950	46.80
. Water	m^3	0.04	6	0.24
. Oxygen	Nm^3	0.06	1	0.06
. Slag	ton	1.20	0.100	0.12
. Electrodes	ton	500.00	0.008	4.00
3. Maintenance				0.86
4. Capital costs				16.61
5. Gas credit				- 13.77
TOTAL COST				141.12

SOURCE: SILVEIRA, R.C.

TABLE 7.XII - FINAL PRODUCTION COSTS SUMMARY AND INVESTMENTS FOR 300.000 TON STEEL PRODUCTION PER YEAR

ALTERNATIVE	COSTS		
	PIG IRON US$/TON	STEEL US$/TON	INVESTMENTS US$/$10^6$
I. Coke Blast Furnace + L.D.	147.19	208.20	146.51
II. Charcoal Blast Furnace + L.D.	115.93	179.12	145.68
III . Direct Reduction + Electric Reduction Furnace	(Pre-Reduced) 159.09	255.44	130.32
IV. Coke Electric Reduction Furnace + L.D.	163.01	222.00	120.93
V. Charcoal Electric Reduction Furnace + L.D.	141.12	201.21	119.16

8. SOCIAL IMPACT

8.1 JOB GENERATION - MAN-MADE FORESTS

The forest/charcoal activity is labor-intensive in the rural areas. In the Brazilian situation such characteristic is a definitive advantage, as part of a strategy devised to provide employment opportunities for the rural population in rural areas or small urban communities.

Today the large urban centers in Brazil are overcrowded with many people, living in precarious conditions since the creation of urban employment is not occuring at an adequate rate to absorb the labor which is migrating to the cities.

The problems of urban employment are exacerbated by the level and types of skill which are increasingly required. Forestry is much more compatible with the life experience of rural people who can adapt more rapidly to the needs of employment.

According to data found in chapter 4, job generation follows the parameters in Table 8.I. If the whole forest cycle is taken into account on a year-to-year basis, employment is as shown in Table 8.II, where the impact of different technology levels in the processes of forest harvest and charcoal production are considered.

The figures thus show much lack of continuity in the yearly supply of jobs; the same lack of continuity is shown in charcoal production. This is due to the fact that planting 1,000 ha is only one module, which must be repeated over again, in the same number of years throughout the forest cycle. That is done so there is always a unit being harvested, allowing for continuity of production and less job fluctuation year after year.

Table 8.III presents data related to the generation of jobs in a 7,000 ha project with annual planting and exploitation of 1,000 ha.

EXPLANATIONS TO UNDERSTAND TABLE 8.II

Table 8.II was calculated under the following assumptions:

Column 1 - utilizes figures from table 8.I.

Column 2, 3, and 4 - for forest harvest harvest and charcoal production were done with the following considerations:

* First harvest with production of 34 st/ha. year, a 7-year cycle, total of 238 st/ha. If a 2.3 conversion index (st/m^3 of charcoal) is used, production is then 103,478 m^3 of charcoal per 1,000 hectares. For 12,000 m^3 per year, there are, respectively, as shown in table 8.I, 44,36 and 22 jobs. From these data we can calculate the figures of colume 2, 3, and 4, respectively 379,310 and 190, which refer to 103,478 m^3 production of charcoal.

TABLE 8.I - GENERATION OF JOBS - EUCALYPTUS SILVICULTURE/CHARCOAL PRODUCTION - PARAMETERS

PHASE	SILVICULTURE ACTIVITIES	FOREST HARVEST AND CHARCOAL PRODUCTION ACTIVITIES			UNIT
		MANUAL SYSTEM	SEMI MECHANIZED SYSTEM	MECHANIZED SYSTEM	
Stand establishment - 1st year	94				Jobs per 1,000 ha/year
1st Forest Maintenance - 2nd year	10				Jobs per 1,000 ha/year
Forest Maintenances - After the 2nd year	5				Jobs per 1,000 ha/year
Regenerations 8th and 14th years	17				Jobs per 1,000 ha/year
Forest Exploitation/Charcoal Production 8th, 14th and 20th years		44	36	22	Jobs per 12,000 m^3 of Charcoal/year
Charcoal transport 8th, 14th and 20th years			2,4		Jobs per 12,000 m^3 of Charcoal/year

TABLE 8.II - GENERATION OF JOBS - EUCALYPTUS SILVICULTURE/CHARCOAL PRODUCTION FOR 1.000 HA - THE WHOLE CYCLE

YEAR	SILVICULTURE ACTIVITIES (1)	FOREST HARVEST AND CHARCOAL PRODUCTION			CHARCOAL TRANSPORT (5)	TOTAL			MEAN VALUE
		MANUAL SYSTEM (2)	SEMI MECHANIZED SYSTEM (3)	MECHANIZED SYSTEM (4)		MANUAL (1)+(2)+(5)	SEMI MECHANIZED (1)+(3)+(5)	MECHANIZED (1)+(4)+(5)	
1	94					94	94	94	94
2	10					10	10	10	10
3	5					5	5	5	5
4	5					5	5	5	5
5	5					5	5	5	5
6	5					5	5	5	5
7	5					5	5	5	5
8	17	379	310	190	21	417	348	228	331
9	5					5	5	5	5
10	5					5	5	5	5
11	5					5	5	5	5
12	5					5	5	5	5
13	5					5	5	5	5
14	17	287	235	143	16	320	268	176	255
15	5					5	5	5	5
16	5					5	5	5	5
17	5					5	5	5	5
18	5					5	5	5	5
19	5					5	5	5	5
20	-	28	235	143	16	320	268	176	255

TE: See observations on the next page.

TABLE 8.III - GENERATION OF JOBS - EUCALYPTUS SILVICULTURE/CHARCOAL PRODUCTION FOR 7.000 HA - ANNUAL PLANTING OF 1.000 HA

YEAR	SILVICULTURE ACTIVITIES								FOREST HARVEST AND CHARCOAL PRODUCTION				TOTAL			ANNUAL MEAN VALUES
	1st year	2nd	3rd	4th	5th	6th	7th	TOTAL (1)	MANNUAL (2)	S. MECHANIZED (3)	MECHANIZED (4)	ANNUAL MEAN VALUES (5)	MANNUAL (1) + (2) = (6)	S. MECHANIZED (1) + (3) = (7)	MECHANIZED (1) + (4) = (8)	
1	94							94					94	94	94	94
2	10	94						104					104	104	104	104
3	5	10	94					109					109	109	109	109
4	5	5	10	94				114					114	114	114	114
5	5	5	5	10	94			119					119	119	119	119
6	5	5	5	5	10	94		124					124	124	124	124
7	5	5	5	5	5	10	94	129					129	129	129	129
8	17	5	5	5	5	5	10	52	400	331	211	314	452	383	263	366
9	5	17	5	5	5	5	5	47	400	331	211	314	447	378	258	361
10	5	5	17	5	5	5	5	47	400	331	211	314	447	378	258	361
11	5	5	5	17	5	5	5	47	400	331	211	314	447	378	258	361
12	5	5	5	5	17	5	5	47	400	331	211	314	447	378	258	361
13	5	5	5	5	5	17	5	47	400	331	211	314	447	378	258	361
14	17	5	5	5	5	5	17	59	703	582	370	552	762	641	429	611
15	5	17	5	5	5	5	5	47	303	251	159	238	350	298	206	285
16	5	5	17	5	5	5	5	47	303	251	159	238	350	298	206	285
17	5	5	5	17	5	5	5	47	303	251	159	238	350	298	206	285
18	5	5	5	5	17	5	5	47	303	251	159	238	350	298	206	285
19	5	5	5	5	5	17	5	47	303	251	159	238	350	298	206	285
20	-	5	5	5	5	5	17	42	606	502	318	475	648	544	360	517
MEAN VALUES								71	402	333	212	316	332	287	208	276

NOTES: The Mean Values of Columns (2), (3), (4) and (5) refer to a 13 year's period

* Second and third harvest follow the same process as above, taking into account a 30 st/ha./year increment and a 6-year cycle.

Column 5 - takes into account that one man can transport 4,950 m^3 of charcoal per year. So, it will require 21 men to cope with a production of 103,478 m^3 of charcoal.

From the eighth year on, a new level of employment is reached, with an average of 360 jobs, 50 of them in strictly forest activities and 310 in harvesting, as well as in charcoal carbonization and transport.

The second and third cuts, from the 14th to the 20th year, are presented along with cuts of other stands, due to the adopted harvesting cycle.

Since different technologies are being considered, the general average is only slightly indicative assuming the simultaneous use of several systems, each one in the same proportion. In summary, permanent jobs are created, as shown in Table 8.IV.

The number of jobs generated is a function of the technology being used and this varies significantly. For each job created in the mechanized system, there are 1.9 jobs in the manual system.

The harvesting and charcoal production activity is considerably more efficient in terms of job generation than the other forest activities, in a 4.4-to-1 proportion.

8.2 JOB GENERATION: NATIVE-WOOD BASED CHARCOAL

Native wood based charcoal is produced from existing woody material. The stages of forest establishment are, therefore, not considered. As far as charcoal production is concerned, the operations are similar to that from man-made forests in which the manual system was adopted.

According to data in chapter 4, it is estimated that:

a - number of jobs generated by production = 55 per 3.000 ton of charcoal per year.

b - number of jobs generated by charcoal transport = 2.4/3,000 ton year.

c - total number of jobs = 57.4/3,000 ton year.

8.3 RELATIONSHIP BETWEEN INVESTMENT AND PERMANENT JOBS

Tables 8.V, 8.VI and 8.VII show the relationship between investment and permanent jobs.

The forest investments mentioned in chapter 4 were calculated for 1,000 ha/year of forest or 21,800 ton/year of charcoal. Investments for charcoal production refer to 1,000 cubic meters of charcoal a month or 3,000 ton/year.

TABLE 8.IV - GENERATION OF PERMANENT JOBS FOR A CHARCOAL PRODUCTION OF 3,000 t/yr (ESTIMATES FOR THE WHOLE PERIOD)

ACTIVITIES 1st to 20th YEAR	TECHNOLOGY LEVEL			MEAN VALUES
	MECHANIZED	S.MECHANIZED	MANNUAL	
Silviculture (1)	9.8	9.8	9.8	9.8
Charcoal Production and Transport (*)	29.2	45.8	55.3	43.5
Mean Values - 20 Years (3)	28.6	39.5	45.7	38.0

NOTES:

(1) According to Table 8.III the annual average number of jobs is 71 (total of column 1 divided by 20 years). However, this figure refers to a forest of 7,000 ha with an estimated production of 21,800 ton/year (200,000 st/ha/year ÷ 2,3 x 0,25 ton/m^3 of charcoal). Hence, for a 3,000 ton/year production the permanent number of jobs will be 9.8 (71 ÷ 21,800 x 3,000)

(2) The mean values refer to the last 13 years period in which the activities of charcoal production and transport take place.

(3) The mean values refer to both "silviculture" and "charcoal production and transport" activities considering the whole period of 20 years.

TABLE 8.V - INVESTMENT PER PERMANENT JOB - SILVICULTURE - (3,000 t/yr)

INVESTMENT US$	AVERAGE NUMBER OF JOBS	INVESTMENT/JOB US$
578.000	9.8	58.980

TABLE 8.VI - INVESTMENT PER PERMANENT JOB - CHARCOAL PRODUCTION (3,000 t/yr)

CHARCOAL PRODUCTION SYSTEM	INVESTMENT US$	AVERAGE NUMBER OF JOBS	INVESTMENT/ JOB US$
Manual	135.700	55.3	2.450
Semi-Mechanized	145.900	45.8	3.180
Mechanized	176.000	29.2	6.050
Mean Values	155.900	43.5	3.580
Native Charcoal	112.500	57.4	1.960

TABLE 8.VII - INVESTMENT PER JOB - ALL ACTIVITIES TOGETHER (3,000 t/yr)

SYSTEM	INVESTMENT US$	AVERAGE NUMBER OF JOBS	INVESTMENT PER JOB US$
Silviculture Charcoal Production: Mannual	713.700	45.7	15.620
Silviculture Charcoal Production: Semi-Mechanized	723.900	39.5	18.330
Silviculture Charcoal Production: Mechanized	754.600	28.6	26.380
Mean Values	733.900	38.0	19.300
Native Charcoal	112.500	57.4	1.960

NOTE: Number of jobs based on mean 20 year values in Table 8.IV

The tables mentioned above show all investments and figures relative to jobs for a charcoal production of 3,000 ton/year.

It can be noted that jobs generated by forest activities demand, on the average, an investment 16 times greater than that generated by charcoal production.

If only charcoal production is analysed and different technology levels are taken into account, it becomes clear that a job in the mechanized system demands an investment 2.5 times superior to that in the manual system.

If the average of several systems is considered, a job demands a US $19,300 investment. But a job generated by native charcoal production demands an investment of only US $1,960.

This is extremely important for those countries having native vegetation which can be used for energy purposes, specifically if they adopt a production system based on an intensive use of labor and a low application of capital. For instance, a production system based on native and man-made forests in a 50/50 proportion could lower the investment/job down to US $9,000.

For the sake of comparison, Table 8.VIII displays information on investments/job in the state of Minas Gerais.

8.4 TECHNOLOGY AND EMPLOYMENT

The selection of an adequate technology level for a productive sector, taking into account the different aspects related to the social and economic conditions of a country, is an important factor in a development strategy. Two important aspects of such conditions are how job supply relates to demand and the availability of financial resources. In most Brazilian regions today, the social pressure for jobs is overwhelming, mainly for jobs demanding skills equivalent to those in rural activities. As for the financial resources, besides being scarce, they are also dependent on foreign financial market; and present interest rates are very high. Thus, the selection of the technology level must be geared towards an intensive use of labor and reducing the amount of investment per job.

Charcoal production is a simple technology, well known and long mastered by the average Brazilian peasant. Thus, from a managerial viewpoint, its adaptation creates conditions to install production models in a smaller scale, applicable to the small family-owned rural properties.

Within such a context, managers could be more autonomous in their own territories, being less dependant on a central administration. In the forest charcoal activity, which by its very nature involves widespread areas, the prospect of such greater managerial autonomy has a far-reaching economic significance, for the following reasons:

a) the decisions can be made more promptly

TABLE 8.VIII - INVESTMENT PER JOB - MINAS GERAIS - 1980 - COMPARISONS BETWEEN SECTORS

SETOR	INVESTMENT/JOB - US$
Agriculture	12.000
Cattle raising	23.200
Agro-Industries	44.200
Chemical Industries and non-metals	76.300
Minas and Metallurgy	102.700
Micro-Industries	13.400
Mean Value	55.100
Eucalyptus Silviculture	19.300

SOURCE: BDMG - Activity Repport - 1980

b) the quality of decisions are improved due to a deeper knowledge of local conditions

c) the qualifications of personnel are improved as they are called on more often to make their own decisions and be held responsible for them.

Any country should make its own analyses to determine the level of labor utilization in its projects. This consideration should also be done by any company due to its social responsibilities or managerial convenience, such as:

a) a lesser dependance on inputs subjected to foreign decisions, which are not necessarily controllable by businessmen or even by the Government itself;

b) more controllable and less variable production costs;

c) demanded skills which are more realistically compatible with available human resources;

d) less absorption of financial resources and as a consequence less immobilization of these resources;

e) a lesser concentration of forests, thus reducing local pressure on the land market and ecological impacts;

f) more flexibility towards market conditions, both from a locational point of view as well as in terms of production volume.

As national employment policies prevail and programs to employ more labor get underway, the present situation will obviously change. When that happens, priority will be shifted to a more capital intensive technology. Precisely to make adaptation viable, even if profound changes come about within the country, every company should concentrate some efforts and some resources in the development of technological alternatives to meet different challenges and situations.

8.5 REGIONAL AND NATIONAL SIGNIFICANCE OF INVESTMENTS

The estimated cost of charcoal is an important parameter in the economic appraisal of any undertaking.

But when different forest enterprises, with different technology levels are analyzed, the profile of production cost components can be just as important, or even more so, as the decision-influencing element. This is especially true in countries such as Brazil, which are lacking in financial resources, in low cost fossil fuels and in employment.

The Axe Versus the Chain Saw

For the same volume of production, the use of axes create twice as many jobs as chain-saws and a higher fraction of costs go to salaries. On the

other hand, investments in axes are smaller, as compared to chain saws, in a 14-to-1 proportion. Fuel consumption (US $10 a day) is saved, and maintenance as well as spare-part stocking are not needed.

Thus, use of the axe allows more resources to remain in the region. The resources designed to purchase chain saws, spare parts and fuel, are spent on imports, so they are applied in other regions or even in other countries. Table 8.IX shows a comparison between chain saw and axe for the same level of production.

Equipment Versus Animals

The same arguments as above remain valid. The purchasing of animals, the upkeeping of pastures, the payment of salaries, all inject money into the region. On the other hand, the buying of machines means more imports.

Transport costs are approximately the same as long as the distances for animal transport are shortened. Such reduction allows greater spacial distribution of kilns and the installation of batteries with fewer kilns, so that a smaller territory can supply all the woody material. Thus, the argument in favor of smaller units is strengthened.

*"Town" in this context refers to an administrative unit ("municipia" in Portuguese) which includes urban and rural areas.

8.6 LOCAL IMPACT

Once money has been injected into a region, conditions are created for a local consumer's market. Even if new demands are met by simply importing products, opportunities are still created for small commercial business establishment. Replacing imports in the medium-run will also eventually create other opportunities food production and some consumer goods. Reforestation projects are established in some of the poorest and most backward regions of Brazil. These regions are subject to process, which, if left to itself, would have never altered the lives of people for these regions for the better.

As an example of that, the impacts data from the Jequitinhonha Valley - where Acesita has been present since 1975 - are shown in Tables 8.X and 8.XI. If the four towns where Florestal Acesita has been present are compared to the others in the Valley, it can be seen that:

a) urban - population growth in all four were significantly larger than in the others (111% versus 34%);

b) all four towns accounted for 5.9% of the Valley's population in 1970, and now (1980) that figure has risen to 9.0%;

c) rural population in the Valley suffered an absolute reduction between 1970 and 1980;

TABLE 8.IX - COMPARISON BETWEEN CHAIN-SAW AND AXE COSTS PER HOUR POR EQUAL PRODUCTION

ITENS	CUTTING WITH CHAIN-SAW	CUTTING WITH AXES
Labor	55,74	99,41
Depreciation	5,39	0,48
Insurance	0,50	-
Capital Return	0,86	0,06
Fuel	19,43	-
Lubrificant Oil	7,91	-
Spare parts	12,17	0,05
TOTAL	100,00	100,00

NOTE: Total costs per unit of output of the two systems are approximately the same as discussed in chapter 4.

TABLE 8.X - JEQUITINHONHA VALLEY - POPULATION INCREMENT - 1970/1980

CITIES	1970			1980			URBAN POPULATION INCREMENT 1980 1970 =100
	URBAN AREA	RURAL AREA	TOTAL AREA	URBAN AREA	RURAL AREA	TOTAL AREA	
Capelinha	4.432	15.214	19.646	10.541	13.203	23.744	238
Itamarandiba	3.799	23.223	27.022	8.243	20.770	29.013	217
Minas Novas	2.552	22.518	25.070	4.433	23.092	27.525	174
Turmalina	2.639	13.838	16.477	5.122	12.228	17.350	194
S.Total (4 towns)	13.422	74.793	88.215	28.339	69.293	97.632	211
48 others Towns	212.579	598.187	810.766	285.940	538.858	824.798	134
TOTAL JEQUITINHONHA	226.001	672.980	898.981	314.279	608.151	922.430	139

SOURCE: IBGE. Censo Demográfico

d) however the decrease in (c) was less intensive in the four towns than in the rest of the valley, since their share of rural population increased from 11.1% (1970) to 11.4% (1980).

As for income, since there are no recent regional studies, only the evolution of salaries of Acesita personnel is shown in Table 8.XII.

8.7 CLOSING REMARKS

For countries like Brazil which need to create jobs at a low investment cost, mainly in the rural areas, and need to decrease the impact of importing energy for its industrial development, charcoal making is an attractive possibility, creating many benefits. One way to capture these benefits in an economic analysis is to use "shadow prices" which are distinct from those prevailing in the market. In order to illustrate in a preliminary way the impact of such considerations, a calculation of economic costs was made assuming a shadow price for labor. The calculation was done taking from chapter 4 the labor costs involved in each activity and reducing them by 30%. This follows what the World Bank did for the northeast of Brazil in its appraisal of a loan for the alcohol program.

The calculation was carried out only for a flat area which is believed to be the most representative of present Brazilian silviculture. The following costs were arrived at to establish a typical Eucalyptus forest plantation:

ROTATION	ITEM	PERIOD	US$/HA/YEAR
1st	Stand Establishment	1st	631.62
	Maintenance (1st year)	2nd year	30.90
	Maintenance (following years)	From the 3rd to the 7th year	13.82
2nd	Regeneration	8th year	35.04
	Maintenance	From the 9th to the 13th year	14.02
3rd	Regeneration	14th year	35.04
	Maintenance	From the 15th to the 20th year	14.02

Considering the same indirect costs as does table 4.IV, the same productiveties as shown in chapter 4 and assuming a discount rate of 8% a year we get a stumpage cost of

US $3.25 per one stere of wood

This is 15% lower than that calculated in chapter 4 (US $3.83).

For charcoal making we assumed a semi-mechanized system which gave (Table 4.X) a direct cost of US $8.11 per m^3 of charcoal. If we decrease the labor costs (30%) for all activities, taking into account the physical inputs figures of table 4.XII part B we get:

TABLE 8.XI - JEQUITINHONHA VALLEY - POPULATION INCREMENT - 1970/1980
% DISTRIBUTION

	1970			1980		
	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL
4 tons(Florestal Acesita)	5.9	11.1	9.8	9.0	11.4	10.6
48 towns - Others	94.1	88.9	90.2	91.0	88.6	89.4
Total in the Valley	100,0	100,0	100,0	100,0	100,0	100,0

TABLE 8.XII - FLORESTAL ACESITA - PERSONNEL AND SALARY EVOLUTION
1974/1981

MONTH/YEAR	Nº OF PERSONNEL INDEX	MINIMUM SALARY; FLORESTAL ACESITA/BRAZIL	% OF PEOPLE WITH MINIMUM SALARY	FLORESTAL ACESITA MEAN SALARY/MINIMUM BRAZILIAN SALARY
July/1974	100	1,00	81.9	1.57
July/1981	380	1,36	5.0	2.92

Direct costs for charcoal making (flat area, semi-mechanized system)

	US/m^3 of charcoal
* Clearing the underbrush	0.16
* Felling	1.54
* Straight-to-the-kiln transport of wood	2.30
* Carbonization	2.58
TOTAL	6.58

Which is a value 19% lower than the former one.

Adding the indirect, over head and financial costs with the same rates as Table 4.XI for the semi-mechanized column we get a shadowed cost for charcoal making of:

US $9.61 per cubic meter of charcoal

For charcoal transportation we utilize the same values stated at section 4.4.1, Chapter 4.

The charcoal shadowed cost delivered to steel plant will be:

- stumpage - 7.48
- charcoal making - 9.61
- transport - 6.45

US $23.45 per cubic meter, or US $93.80 per ton of charcoal

This is 14% lower than the cost calculated for table 4.XIV.

Between all the phases of charcoal production forest establishment (including maintenance and regeneration), charcoal making and transportation, the second, charcoal making, is more labor intensive than the other in terms of the level of mechanization utilized.

To compare this shadowed cost with fuel oil, we perform, again, the calculation of the steam generation cost for charcoal from man-made forest as shown in Table 5.XI, Chapter 5.

If we make the same assumption as before (section 5.3.2) the charcoal costs will be:

	US $
Wood	7.48
Production	9.61
Losses	1.32
Transport	2.75
Total	$21.16 or US $84.64 per ton of charcoal

Utilizing the same parameters as shown in Table 5.XI the steam cost with this new value will be:

	kg/h Consump.	US$/kg Cost	US$/hour Total Cost	US$/h Deprecia.	US$/h Labor	US$/Ton Steam Cost
Eucalyptus Charcoal	1,426	0.0846	120.64	19.76	3.80	12.02

Which is 20% lower than the steam cost using heavy type fuel oil instead of the 7% before (Table 5.XI).

The impact will be greater if we consider a total manual system for charcoal making such as the one for native forest. A more complete social cost-benefit analysis consider all factors of production would probably also result in a greater reduction of charcoal cost relative to fuel oil.

9. ENVIRONMENTAL IMPACTS

9.1 INTRODUCTION

The formation of widespread man-made forest stands, like any other agricultural monoculture, obviously bring about changes in existing eco-systems. The levels of such changes vary in intensity according to the technology used in the several stages of the production process.

Strong criticisms are made of forest projects; and in terms of environmental damages there are basically three: soil is impoverished, watertables dry up and wildlife is not preserved. Crops such as sugar cane, coffee, soybeans, cotton and others, which are also exotic species (and often not even fundamental to the nutrition of the country), are spared many criticisms, probably because people are unaccustomed to the concept of systematically planting and harvesting trees on a significant scale.

9.2 SOIL IMPOVERISHMENT

The most serious criticism of man-made forests is undoubtedly the exhaustion of soil nutrients. Although not scientifically warranted, it nevertheless contributes to harmful prejudices.

Several studies made in Brazil have made it clear that man-made forests are more than just consumers (absorbers) of mineral elements. Quite the contrary, they set in motion a cycling of nutrients, bringing them up to the soil surface. This is an intense phenomenon, as shown in POGGIANI[1] in 6-year old E. saligna stands, where an accumulation of leaves and branches took place at a rate of 5.5/t/ha/year. Once such organic matter was analysed, the following data were found = 51 kg of nitrogen, 3 kg of phosphorus, 11 kg of potassium, 57 kg of calcium, and 8 kg of magnesium. These data show no significant difference if compared to those from the Amazonian forests, which presented a total volume of 6.4/t/ha/year[1].

Florestal Acesita has found that, in the Jequitinhonha River Valley, stands in red-yellow latosols leave, when cut, approximately 20% of the above ground tree weight on the soil in the form of residues such as leaves and small branches. Total residue per hectare varies according to species; the average is about 11,000 to 15,000 kg per hectare for a 1667-tree-per-hectare stand, when cutting takes place between 5 and 6 years. If one adds to that the accumulation of residues which accompanies the stand's growth, it will be seen that the physical and chemical conditions of the soil are, in fact, improved.

About 50% of the mineral elements in a tree are found in its leaves and branches as RESENDE[2] shows in Table 9.I. POGGIANI[1], analysing only NPK, arrived at similar results, in terms of element distribution in a 4-year-old E. grandis stand. (Table 9.II). Such results demonstrate that, popular opinion notwithstanding, the formation of man-made forest of Eucalyptus has an important and positive role in the recovery of spoiled areas.

The utilization of areas previously covered by Eucalyptus forests for farming and cattle-raising purposes has also met with very positive

TABLE 9.I - NUTRIENTS DISTRIBUTION IN E.GRANDIS, 3 YEARS OLD, SPACING 1,5 x 1,0 m

ELEMENTS	LEAVES kg/ha	%	BRANCHES kg/ha	%	TRUNCK kg/ha	%	TOTAL TREE kg/ha	FOREST FLOOR
N	124,56	51,6	28,20	11,70	88,59	36,70	242,35	196,63
P	6,79	30,0	2,62	11,60	13,19	58,40	22,61	3,58
K	41,07	19,9	22,40	10,80	142,62	69,30	206,10	103,93
Mg	13,[illegible]	46,6	2,39	8,60	12,56	44,80	28,01	14,0[illegible]
Ca	37,03	35,4	15,59	14,90	52,14	49,70	104,76	75,08
Fe	2,21	38,8	0,59	10,40	2,89	50,80	5,69	-
Cu	0,02	23,0	0,02	15,40	0,06	61,60	0,10	-
Mn	5,91	31,0	2,20	11,60	10,93	57,40	19,04	-
Zn	0,08	18,2	0,03	7,30	0,31	74,50	0,42	-

Source: Resende [2]

TABLE 9.II - NUTRIENTS DISTRIBUTION IN E. GRANDIS, 4 YEAR OLD

	N	P	K
Trunk	60 kg/ha	6 kg/ha	16 kg/ha
Residues	90 kg/ha	10 kg/ha	39 kg/ha

Source: POGGIANI

results. Florestal Acesita has reserved areas where E. citriodora and E. paniculata had been cultivated during 22 years for the planting of corn, beans and rice; and production has been superior (many times over) to that in the areas reserved exclusively for such crops. In areas where the forest cycle has reached its end, mixed agricultural/forest plantings are possible at the start of the new forest cycle. In the first six months of the new forest, corn and/or beans are also grown. When the new forest is more fully grown, the stand having reached an average height of 3 meters, the areas are opened for cattle grazing. The animals contribute to undergrowth control; in most reforested areas, such undergrowth is mainly made up of the panicum maximum type of grass. Such rational and integrated use of the land (known as the agro-silvo-pastoral system) not only reduces costs but also show that Eucalyptus forests do not harm the soil.

More detailed studies only reinforce what has been stated above. HOMEM[3] analysed the influence of Eucalyptus upon the soil and concluded that the soil was actually improved. A 6 hectare area has been exhausted due to many years of crop growing Eucalyptus tereticornis was then planted and, following a 37-year cycle, the soil was available for the planting of coffee. Five years later, soil samples from three distinct situations gave the results shown in Table 9.III. The figures above show that Eucalyptus improved the soil. The area samples are continuous and the original characteristics are therefore the same. It must be added that the coffee area was fertilized for five years with an annual application of approximately 400- grams of nitrogen, 300 grams of phosphorus (P_2O_5) and 500 grams of potassium (K_2O).

A study transcribed by CANDIDO[4] mentions that production of 3,000 kg of "red bourbon" coffee. Such coffee was planted in an area previously covered, during 33 years, by E. Saligna. If such plantations is compared to normal ones which have yields on the order of 1,200 kg/1,000 trees, the former clearly comes out ahead.

All this should be enough to demonstrate that Eucalyptus improves both the physical and the chemical conditions of the soil. It is also known that nearly all Eucalyptus species demand little natural fertility. They are therefore suited for soils which, due to physical, chemical and topographical conditions, are weak or inadequate for crops, Forests, therefore, need never compete with food production.

9.3 CHANGES IN SOILWATER LEVELS

Forest species, as a rule, demand much water. Eucalyptus, however, is always singled out, and accusations are made that Eucalyptus species are such heavy water consummers that they even end up drying some small water aquifiers.

In fact, the available technical studies so far have shown that some native or agricultural forest species demand more water per hectare than Eucalyptus does. Obviously, most Eucalyptus species have a deep radicular

TABLE 9.III - SOIL ANALYSES AFTER 37 YEARS OF EUCALYPTUS GROWTH 5 YEARS OF COFFE CULTIVATION

	AREA WITH EUCALYPTUS 42 YEARS - %	AREA WITH COFFE 5 YEARS %	AREA WITH OTHER CROPS (5 YEARS) %
Organic Material	5,20	4,80	2,00
Nitrogen	0,26	0,24	0,10
Phosphour	0,18	0,62	0,23
Calcium	16,70	15,60	3,80
Potassium	0,28	0,25	0,05
PH	6,50	6,35	5,50

SOURCE: HOMEM (3)

NOTE: One third of the land was kept in eucalyptus for five more years, one third was planted to coffee and one third in other crops.

system, drawing water from deeper layers of subsoil; however, their characteristics differ from those of native species. These demand a greater amount of water precisely in the dry seasons, while Eucalyptus consumption is less at that time. That means, that Eucalyptus needs more water exactly when more water is available, namely, in the rainy season.

Several studies were designed to exemplify, quantify and compare such water consumption. While Cedrella, at the age of six, transpires 37,500 liters per plant, Eucalyptus loses about 19,600 liters. Another species, Inga edulis, transpires 177,859 cubic meters per hectare per year, as compared to 49,000 cubic meters in the case of a 7-year-old, 2,500 plants-per-hectare Eucalyptus saligna plantation. Such data were obtained in Rio Claro, in the state of Sao Paulo[4]. The standing biomass per hectare was similar.

GOLFARI[5] quotes F.A.O. figures to the effect that, in countries whose hydric resources are scarce, much land is being recovered through the planting of Eucalyptus. Measurements of water-reposition rates in the soil show an increase whenever there is an Eucalyptus forest.

9.4 WILDLIFE

Brazil's geographic location as well as its huge territorial extension have endowed it with a variety and complexity of ecosystems. Both its flora and its animal wildlife are thus among the most exotic and diversified in the world[6].

Wildlife has been threatened as the farming frontier pushes on, ever deeper into land heretofore unexplored. Natural "habitats" have been aggressively destroyed. But the forests which have been planted, in spite of all the criticisms against them, have greatly contributed to the preservation of native resources and, consequently, to the protection of wildlife.

Man-made forests obviously change ecosystems, but if special care is taken particularly in their planning, harm to wildlife can be avoided. A diversified wildlife has an important role in maintaining balance among animal species as well as in the biological control of insects, especially the leaf-eating Lepidoptera.

On-going studies in Brazil show that wildlife and Eucalyptus get along well. Animals feel protected in a Eucalyptus forest and find food in the neighboring areas of natural vegetation.

When a forest stand is planned, all native vegetation must be allowed to remain along water courses, and 50-meter-wide aisles should interconnect islands of native vegetation. Native and man-made forests are then integrated, and effects on the environment are minimal. These native-vegetation areas are also enriched, mainly with both wild and tame fruits, in an attempt at "habitat" enrichment. There are plans for just such a procedure in the future.

9.5 REFERENCES

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10. RECOMMENDATION AND PROCEDURES FOR INSTALLING CHARCOAL PRODUCTION CAPACITY

Forest biomass or charcoal are competitive sources of energy mainly for those countries lacking fossil fuels. Besides use for energy, charcoal can be used in steel industries for pig iron production in competitive terms with imported metallurgical coal as is shown by Brazilian case.

In terms of fuel oil substitution, for the great majority of the current processes, this biomass can be utilized as fuelwood or as charcoal and the choice between them is an economic one, depending on the transportation distances involved.

For each case it is necessary to perform economic feasibility studies where one must take into account the production costs of wood and charcoal, the costs involved in the production of usable energy (for example, steam), added to the transportation costs of wood and charcoal.

Forest biomass comes basically from 2 sources:

* Native forest formations

* Planted forests

In the case of native forests:

* Utilization of woody material resulting from deforestation to increase the area for agriculture and cattle raising.

* Native forest utilization in a sustained management regime (selective cutting).

Usually it is temporary. The utilization of the native formations in both forms is a temporary phenomenon before the planted forests come into production. In Brazil, as we have seen, the utilization of wood from the expansion of the agriculture and cattle raising frontier is very common together with planted forests. The importance of sustained management of native forest, in Brazil, is increasing and many studies and projects are beginning now.

For planning forest utilization it is necessary to know the country's vegetative cover (location, types, amount of wood, etc) as well as:

*Soil capability for other uses especially food production

*Forest areas to be preserved

Based on this information forest zonning must be done, taking into account the distribution of the consuming centers of forest products. The areas for reforestation must be established in those regions where there would not be an adverse influence on food production.

To begin reforestation it is possible to choose species suitable for some region based on the results of other regions which have experimented with

forest plantation and have similar edaphic-climatic conditions. In the case of Eucalyptus the response of many species to climate conditions and soil properties are known which makes possible a preliminary choice for an immediate commercial activity. However, for future improvements it is necessary to plant species (or hybrids between species) and provenance trials to see which material will give a higher increment and improved quality.

The exploitation of native forests in a sustained management regime depends on the characteristics of the vegetation in each region. For this reason it is necessary to establish experiments to follow the regeneration capability of the various classes of formations. This is a long-term experiment and so it must be well planned to assure the maximum of possible information.

The establishment of energy forests must be followed by a R&D program to quantify the influence of the various silviculture parameters on the productivity and quality of the forest. The following studies must be included in the experimental program:

* Development of the techniques for seedling production by seeding (direct or indirect) and other techniques, for example, vegetative propagation.

* Study of soil preparation methods.

* Experiments on fertilization with the objective to determine the sources, methods and rate of application of fertilizer for those regions to be reforested.

* Development of the techniques of forest management (tree spacing, regeneration, cutting age) based on field experiments.

* Development of methods for forest maintenance as regards weeding, protection against plagues and diseases based on experiments and development of biological combat of insets.

* Development of systems to follow the forest inventory in terms of qualitative and quantitative means.

To complement these activities a program must be planned and implemented to produce seeds and thus to guarantee supply of good quality seeds. This must be done after the identification of the species, varieties and provenances of greater potential for that region, through the establishment of Seed Production Areas (SPA). These SPAs are planted by selecting the "best" trees from a plantation area for commercial exploitation, and cutting the others. In the seed production areas tree spacings are about 10 by 10 meters.

In the medium and long-term there must be included a program of clonal seed orchards and a program to promote natural or forced hybridization of various varieties and provenances to combine productivity and quality.

Personnel training for the execution of these activities is of fundamental importance. Periodical training must be promoted to improve the technical competence of personnel. It must include experts in the following areas:

*Forest Genetics
*Soils and Plant Nutrition
*Planting and Forest Management
*Forest Inventory
*Forestal Exploitation and Transport
*Phytopathology and Forest Entomology.

Once a year it is advisable to have recycling courses in the following areas:

*Seedling growing techniques
*Prevention and combat of insect plagues, plant diseases and fires.

As a part of the training program it is convenient to perform internal seminars to divulge the results obtained from experimental work and to discuss new techniques to be utilized.

In the case of the utilization of charcoal the carbonization is the process by which the wood must be processed.

There are various systems and processes by which wood can be transformed to charcoal, varying from simple ones (brick beehive kilns) to more sophisticated ones (continuous retort with recovery of all by-products). The choice of one of these must be done with care and by taking into account many factors. Normally for developing countries with low capital resources and problems of employment the man-power intensive systems will be preferred because with low capital it is possible to produce a competitive source of energy. In this case we must look for those systems which utilize local basic materials.

Carbonization using brick-beehive kilns requires, good wood conditioning procedures. Wood air drying is essential to obtain a good yield and charcoal quality must be tested experimentally to characterize the product and to optimize the system as a whole. The provenance trails and the experiments on forest management (tree spacing, cutting age, etc) must be followed by carbonization tests with the objective of establishing more encompassing criteria for the choice of species and silviculture parameters.

For these carbonization tests it is necessary to establish a consistent system of measurements of the wood charged (volume, weight, diameter, bark volume, length, etc) and of the charcoal produced (volume, weight, density, chemical and physical analysis) which, normally, cannot be obtained at the production batteries. So it is recommended to that an Experimental Battery be built to perform this and other development work.

This experimental battery can be utilized, too, as a personnel training base which is essential to get good results in the carbonization area.

This training must give to the charcoal men, first, a knowledge of the carbonization principles, wood and charcoal measurement systems and parameters which influence the performance of the process. Later, at the battery they can learn how to conduct the carbonization and do it themselves until they achieve good results.

Another objective of the experimental battery is to develop and test new systems of carbonization or to fit new technologies to the pre-existing one before its implementation in production areas. This battery must have:

* Area for construction and operation of kilns with different sizes and designs.

* Area for storage and handling of wood and charcoal.

* Small laboratory for charcoal chemical analysis (fixed carbon, volatile matter, moisture, ash) and wood density and moisture.

* Laboratory (open shed) for physical analysis (shatter test, tumbler test, bulk density, grainsize etc).