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FOREST INDUSTRY DEVELOPMENT
SI/BZE/75/807

BELIZE.

Technical report: Chemical processing of forest by-products

Prepared for the Government of Belize by the
United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of A.R. Paddon, chemist

United Nations Industrial Development Organization

Vienna

id. 77-7286

Explanatory notes

References to "dollars" are to United States dollars unless otherwise stated.

References to "pounds" (£) are to pounds sterling unless otherwise stated.

The monetary unit in Belize is the Belize $. During the period covered by the report, the value of the Belize dollar to the United States dollar was $US 1 = Belize $ 1.98 and to the pound sterling £ 1 = Belize $ 3.41.

The following abbreviations of organizations are used in this report:

CIDA	Canadian International Development Agency
dbh	diameter breast height
TPI	Tropical Products Institute (Ministry of Overseas Development of the United Kingdom

Figures in parenthesis ( ) are keyed to the reference list.

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The designs are by the Tropical Products Institute, Ministry of Overseas Development, United Kingdom.

ABSTRACT

Project background

Forests, including forest land and mountainous areas, cover 8,503 (22,023) of the 8,866 mi^2 (22,963 km^2) of land area of Belize. Of this total forest land area, 5,181 mi^2 (13,419 km^2) are in public land and 3,322 mi^2 (8,604 km^2) are in private holdings.

Owing to improper utilization of forestry resources, the forestry sector has been declining in economic importance during the last few decades. After a brief resurgence of forestry activities 1958-1961, Hurricane Hattie, in 1961 devastated large areas. Output of traditional species (mahogany, cedar and pine) declined from Belize $ 4.4 million in 1960 to Belize $ 2.6 million in 1974. However, in the past 10 years there has been a marked increase in the domestic consumption of timber from lesser-known species. On the other hand, there exists an increasing demand for wood and wood products in the export market. Forest utilization has been confined too long to the selective removal of marketable trees of mahogany, cedar and pine.

The Forest Industry Development project (IS/BZE/75/007) was initiated by the Ministry of Trade and Industry of the Government of Belize and a mission of the Food and Agriculture Organization of the United Nations (FAO) (September 1975) with the aim of developing the country's secondary wood processing industries. This aim has been incorporated into the National Development Plan since forests are the country's major natural resource. Exploitation of 31% of the area of these forests, however, yielded a royalty revenue in 1974 of only Belize $ 363,543. The project was approved by the United Nations Development Programme (UNDP) and the United Nations Industrial Development Organization (UNIDO) is the executing agency. It is aimed at re-organizing the Forest Department's Wood Workshop and training counterparts in kiln drying and maintenance of tools and equipment as well as identifying the possibility of utilizing wood residues (currently disposed of by burning or leaving in the forest) by chemical processing.

This project complements the FAO/UNDP project (SI/BZE/75/008), the objective of which is to assist in the primary wood processing industries, and co-ordination between the two projects is being maintained.

This report concerns only that part of the overall Forest Industry Development project that involves the chemical processing of wood residues. Another expert will be assigned to deal with the remainder of the project objectives as soon as the kiln-drying facilities are installed.

The Forest Industry Development project was finally approved on 26 February 1976.

Objectives of the project

The immediate objectives fo this project, together with the complementary one of Forestry Development are (a) the planning of forestry and forest industry development and (b) improvement in the efficiency of the existing sawmill industry and of the quality of the products, and together they emphasize the utilization of the forestry resources of Belize. This is only part of a wider plan of action including conservation of related forestry management techniques and wildlife protection, which guarantees a balanced effort between the conservation and renewal of forest resources and their improved and proper industrial exploitation.

The Belize Government, the Canadian International Development Agency (CIDA) and the Ministry of Overseas Development of the United Kingdom have provided funds and/or equipment for conservation and protection.

Objectives of this mission

Since the recent dramatic increase in world prices of all petrochemical products and precursors, there has been renewed interest in both the developing and developed countries in the exploitation of forestry and other biomass residues as raw materials for the production of indigenous substitutes.

The more traditional processes and raw materials which, over the last three decades, have been discarded in favour of the cheaper petrochemical synthetics are being re-evaluated now that the economics of their use are more favourable.

The specific objective of this report is to prepare brief pre-feasibility studies on some of the minor forest product industries concerned with the processing of wood residues both for export and as import substitutes.

The systems to be studied are:
Charcoal production
Woodwool/cement slab production
The naval stores industry
Tannin production
The logwood industry
Wood fuel systems

The report includes, where possible, quantitative and qualitative details of present utilization, if any, of forest residues; the types and quantities of forest residues available; a plan of action to assure a fuller utilization of these residues through chemical processing; and the recommendation of all measures that have to be taken by the authorities in Belize and/or international organizations to ensure the rapid introduction of such industries that appear to be viable.

The following recommendations were made:

Charcoal

(a) To obtain the services of a charcoal expert to introduce modern charcoal-making techniques for the processing of both roundwood and sawmill wastes;
(b) To purchase two portable metal kilns either from manufacturers in the United Kingdom or manufactured locally from the drawing supplied;
(c) To establish a training unit under the aegis of the Wood Utilisation Section of the Forestry Department where initial

...

training can be given by the expert on manufacture, quality control and marketing of charcoal;

(d) To obtain a market survey on importers of hardwood charcoal in the United States.

Woodwool/cement slabs

(a) To obtain information on the use of woodwool/cement slabs as a building material with particular reference to low cost housing;

(b) To request the Tropical Products Institute, Ministry of Overseas Development, United Kingdom for suitability trials to be carried out on samples of Gmelina arborea, Cecropia mexicana and Pinus caribaea;

(c) If the suggested timber species prove suitable then a feasibility study should be made of setting up this industry.

Logwood dye extraction

A bibliographical search should be carried out on extraction methods for logwood dye including details of the equipment involved and a list of manufacturers.

Tannin industry

(a) A feasibility study should be carried out on the establishment of a small tannery in Belize;

(b) The introduction of local tannin facilities should include an advisory service on small-scale rural tanning methods using locally available tan barks.

Naval stores industry

(a) This industry should not be expanded at this time;

(b) Efforts to upgrade the resin currently produced should be encouraged. Technical training is needed from the parent company in the United States.

Wood fuel systems

Continuing attention should be paid to current developments in alternative energy fields to reduce the existing dependence on fossil fuel imports.

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INTRODUCTION

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The expert's duties were to:

(a) Survey the present utilization, if any, of forest residues, quantitatively and qualitatively;

(b) Survey qualitatively and quantitatively the forest residues available;

(c) Draw up a plan of action to assure a fuller utilization of forest residues through chemical processing (such as - but not limited to - production of tannins, naval stores, charcoal);

(d) Prepare brief pre-feasibility studies for the more promising products;

(e) Recommend all measures that have to be taken by the authorities in Belize and/or international organizations to ensure the rapid introduction of these industries. The expert will also be expected to prepare a final report, setting out the findings of his mission and his recommendations to the Government on further actions which might be taken.

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I. FOREST RESOURCES

Standing volumes of timber in Natural Forest Reserve Areas

The commercially exploitable natural forest areas in Belize can be divided into five main districts (annex I): (a) Mountain Pine Ridge; (b) Chiquibul; (c) Southern Coastal Plain; (d) Belize Estates; and (e) the Columbia River and Maya Mountains, Toledo.

A summary of the results of the 1968-1974 survey by the Land Resources Division of the United Kingdom Ministry of Overseas Development for the volume of commercially exploitable timber in three of these districts is given below. Subsequent data on the privately-owned forest area in the Orange Walk district, to the north of the Mountain Pine Ridge reserve, have also been summarized from data given in a recent survey by the owners, the Belize Estate and Produce Company. A further survey financed by the Ministry of Overseas Development has just been completed in the Columbia River and Maya Mountain area in the south of the country.

Mountain Pine Ridge

Of the 225 mi^2 (58,300 ha) in the Mountain Pine Ridge area, only the best of the pine lands (90 mi^2) with stands of reasonable tree density irrespective of age were surveyed. Much of the unsampled area comprises broad-leaf forests along the western side and areas on the eastern side with no fire protection.

The survey can be broken down into areas of 44,839 acres (18,146 ha) of pine forests (78%), 7,883 acres (3,190 ha) of grassland and pine seedlings (13%), and 5,609 acres (2,270 ha) of pine savannah.

The volume of pine timber found in the area surveyed was 70,410 m^3 (2,486,599 ft^3) for trees greater than 10 in. (25 cm) diameter breast height (dbh), 155,197 m^3 (5,480,940 ft^3) for trees greater than 6 in. (15 cm) dbh and 224,334 m^3 (7,922,583 ft^3) for trees greater than 3 in. (7.6cm) dbh. Trees greater than 10 in. dbh represented only 31% of the total merchantable volume. The mean density of the stocking of all trees over 3 in. dbh was found to be 282 stems per hectare.

The density of regeneration stock involving trees less than 2 in. (5 cm) dbh averaged 1,000 stems per hectare in 12% of the survey area but only 249 stems per hectare in 71% of the area.

The survey indicated that there will be little increase in the amount of exploitable pine timber during the next 10 to 15 years. After this period the volume of comercially exploitable pine stocks will increase at a fairly rapid rate, and the long-term prospects of fully-stocked mature pine forests are good.

<u>Chiquibul Forest Reserve</u>

The Chiquibul Forest Reserve covers an area of 714 mi^2 (1,850 km^2) to the east of the Maya Mountain range; 300 mi^2 (1,000 km^2) are in the readily accessible main felling area, and the remainder are in the less accessible mountain area. The reserve contains almost all broad-leafed species.

The 300 mi^2 of readily accessible forest oontains a total volume of 8,691 m^3 (3[illegible],92[illegible] ft^3) of mahogany greater than 28 in. (70 om) dbh, 16,032 m^3 (566,16[illegible] ft^3) of cedar greater than 28 in. dbh, and 1,434,240 m^3 (50,649,710 ft^3) of secondary hardwood species greater than 20 in. (50 om) dbh.

Replacement stocking of mahogany and cedar stems of more than 6 in. (15 cm) dbh amounted to 170,880 stems in this area. The corresponding number of secondary hardwood species is 9,984,000 stems.

Only 125 mi^2 (325 km^2) of less accessible mountain area was surveyed and a total volume of 30,899 m^3 (1,091,200 ft^3) of mahogany greater than 28 in. dbh, 52,973 m^3 (1,870,700 ft^3) of oedar greater than 28 in. dbh and 1,813,120 m^3 (64,029,730 ft^3) of seoondary hardwood species greater than 20 in. dbh was found. Replacement stocking of mahogany and oedar stems of more than 6 in. dbh amounted to 128,960 stems in this area. The corresponding number for secondary hardwood species is 3,744,000 stems.

The survey indicated that the area has a low standing volume of primary species which would hardly support commercial exploitation. The standing volume of secondary species is not high, but exploitation could continue provided that the replacement stocking is not damaged.

<u>Southern Coastal Plain</u>

The area surveyed is bordered by the Maya Mountains to the west, the Sittee River to the north and Deep River in the Toledo District to the south. This covers a total area of 540 mi^2 (1,400 km^2). Only 175 mi^2 (450 km^2) carry pine and of this 14,815 ha are pine forest, 5,219 ha are mixed pine and broad-leafed forests and the remaining area is grassland scattered with pine seedlings or over-mature pine trees.

The total volume of pine trees is 156,154 m^3 (5,514,530 ft^3) for trees greater than 10 in. dbh and 275,625 m^3 (9,733,610 ft^3) for those greater than 6 in. dbh. In addition, 32,038 m^3 (1,131,4[illegible] ft^3) of defective wood was found in trees greater than 6 in. dbh.

Tree densities were on average 27 stems per hectare for diameters greater than 6 in. dbh and only 10 stems per hectare for trees greater than 10 in. dbh.

The regeneration stock density of pines less than 2 in. dbh was more than 346 stems per hectare in only 25% of the pine area; 75% of the area carried less than 99 stems per hectare.

The survey indicated that the low stocking of commercially exploitable timber will be slow to increase in more than half the area of pine-bearing land. It will take at least 30 years to achieve a modest stocking of 50 exploitable trees per hectare.

<u>Belize Estate</u>

A recenty survey of the 1,000 mi^2 (2,600 km^2) of forest owned by the Belize Estate and Produce Company is summarized below.

The total volume of mahogany and cedar greater than 24 in. (60 cm) dbh is 444,078 m^3 (15,682,500 ft^3). The total volume of sapodilla and cottonwood greater than 24 in. dbh and all other hardwoods greater than 20 in. dbh is 4,357,296 m^3 (153,876,500 ft^3). The survey indicated that an annual harvest of 17,763 m^3 (627,290 ft^3) of mahogany and cedar and 174,292 m^3 (6,155,060 ft^3) of secondary hardwoods can be continued for the next 25 years.

Columbia River and Maya Mountain

A survey of the Columbia River and Maya Mountain area recently completed by a Ministry of Overseas Development forester attached to the Southern Division, shows that in 530 mi^2 (1,390 km^2) of forest area involved the total volume of mahogany greater than 28 in. dbh is 46,540 m^3 (1,643,500 ft^3). The corresponding volume for cedar is 11,244 m^3 (397,080 ft^3) and the total volume of secondary hardwoods grater than 20 in. dbh is 8,152,650 m^3 (287,908,100 ft^3).

Plantations

Compared with natural forests, plantation schemes are not extensive in Belize; at present, they total 8,000 acres (3,200 ha) nearly all of which are concentrated in the Southtern Coastal Plain.

The first plantations were set out soon after the Second World War near the Machaca Forest Station in the Toledo District and in the vicinity of the Savannah Forestry Station near Mango Creek. Subsequent plantations have been established nearby the Melinda Forestry headquarters of the Southern Division near Stann Creek (now Dangriga).

The early plantations were almost exclusively Pinus caribaea and although initial growth rates were encouraging it soon became evident that the soil and drainage conditions were not suitable for the establishment of a commercially exploitable pine forest.

In 1962, planting of Gmelina arborea was started at Mayflower near the Melinda Forest Station. In Belize, this species matures in 12 - 15 years and achieves mean annual growth rates of 350 - 500 ft^3 (10 - 14 m^3) per acre and these plantations are now being harvested. Planting continued until 1965 at an annual rate of 20 - 40 ha; then, because of lack of funds, ceased until 1970 when 150 acres (60 ha) were established. Each year since 1970, 200 acres (80 ha) of Gmelina have been planted and future plans are to increase this to 250 acres (100 ha) per year until 1984 when a total of more than 2,800 acres (1,100 ha) will have been established. A 14-year cycle of clear felling and replanting is then planned which will result in the annual harvesting of 33,600 m^3 (1,186,600 ft^3) of timber. At present, the total area of Gmelina plantations is approximately 1,600 acres (640 ha).

Small-scale trials of several species of eucalypts are in progress to identify one that will be particularly suitable for utility poles. Several species show considerable promise after only three years in plantations.

Unreserved hardwood forests

In 1971, it was estimated that, of the 6,631 mi^2 (17,174 km^2) of unreserved or "non-permanent" forest areas in Belize, 1,500 mi^2 (3,885 km^2) of land was under shifting cultivation (1). Most of this can be attributed to the "milpa" practice, whereby small patches of 5 to 10 acres (2-4 ha) of publicly-owned jungle vegetation are cleared by burning and are then planted with maize for one season. After this the land is allowed to revert to jungle for an indefinite period. There is constant pressure to open up more land for milpa cultivation, often in preference to re-using the same land after a minimum period of six years. According to the Lands Department of the Ministry of Agriculture, annual milpa clearance for corn and rice in the Toledo district alone amounts to more than 7,000 acres (2,800 ha) in addition to over 5,000 acres (2,000 ha) for corn production in the Cayo district.

Extensive land clearance programmes are planned and in operation for large agricultural and dairy projects.

The Corn/Soya Project of the Belize River valley is initially planned to clear 8,000 acres (3,200 ha) at a rate of 300-500 acres (120-200 ha) per year in the neighbouring Creek area. This involves a collaborative venture with the governments of Belize and Jamaica.

A private land clearance scheme is in operation by the Amerioan Kern Company in the Big Falls area of the Belize River valley for the establishment of rice-growing areas. A total clearance of 30,000 acres (12,000 ha) of bush is planned over the next ten to twenty years at a rate of about 1,500 - 2,000 acres ([illegible]-800 ha) per year.

A further 100 acres (40 ha) per year land-clearance operation is to commence for a dairy project in the area north of Belize City with Belize Global as one of the participants.

Some of the local sawmill owners have concessions to remove any commercially exploitable trees from these areas before bulldozing, windrowing and burning is commenced.

Applications are also made to the Lands Department for the 200-250 acres ([illegible] ha) per year of high bush which have to be cleared for the continuing <u>Gmelina</u> plantations in the Mayflower area of Stann Creek District.

No statistical data is available on the total standing volume of timber available in these high bush areas in Belize. In the tropical rain forest of West Africa, the growing stock may vary from 1,400 to 11,500 ft^3 ([illegible] m^3) per acre. For large areas of mature forest, the average is between 3,534 and 4,241 ft^3 ([illegible]-12 m^3) per acre (2).

<u>Mangrove swamps</u>

Mangrove and swamp areas are estimated to cover 924 mi^2 (2,393 km^2) or slightly more than 10 % of the country (3). However, according to Wright (4) the total mangrove-bearing areas in Belize in 1959 occupied 289 mi^2 (750 km^2).

The area comprises:	<u>Acres</u>
Buttonwood/red mangrove/white mangrove assemblage 1/	31,365 (12,693 ha)
Red mangrove consociation 2/	120,810 (48,892 ha)
Red mangrove/white mangrove association 3/	32,700 (13,234 ha)

1/ Mixed colony or assembly of species.

2/ Where red mangrove predominates.

3/ Where the predominance is shared by two species.

Most of the mangrove is low and scrubby being only 4-5 m high. Belts of taller mangrove do exist in the north and south of the country but no mapping of Belizean mangrove by height classes has yet been undertaken. Some commercial exploitation of mangrove was carried out in the 1950s but the industry was closed down in 1961 as a result of the damage wrought by Hurricane Hattie. Vast areas of mangrove were destroyed by the hurricane and it is though that out of the 289 mi^2 (750 km^2) of swamp area there is probably less than 50 mi^2 (130 km^2) of exploitable mangrove (5).

II. AVAILABILITY OF FOREST RESIDUES

Logging areas

The availability of forest floor residues in the form of branches and "lop and top" is very poor. Contributing factors are:

(a) The widespread location of felling areas;

(b) The extremely poor, if not total lack of, roads to these areas;

(c) The sporadic and selective manner in which the prime species are felled making even forest floor processing difficult;

(d) The discontinuation of felling in most areas during the long rainy season (from seven to eight months).

The Mountain Pine Ridge reserve is perhaps the only area where the forest floor waste and thinnings can be exploited. These pine forests have a very good internal road system and the forest floor is reasonably clear and well drained. Unfortunately, the reserve is situated in a remote area and the one road which links it to the rest of the country is extremely poor and hazardous. Transport costs of materials to and from the reserve are expensive because of the increased wear and tear on the vehicles and the time involved.

The pine forests of Mountain Pine Ridge are, in general, immature and no commercial production of timber is carried out at present. Sawmill operations ceased in 1970 when the diameter of timber available was too small for economic milling. Improvements in forest management of the area are being made and the future prospects for a mature pine-lumber industry are good. In the meantime thinning programmes are being carried out and the resultant material is left on the forest floor to rot. As it is hoped that a new sawmill will be built to utilize the largest of this material, only diseased trees and those considered too small for processing on even a small bench saw are being felled at this time.

Information on the total volume of material which could be used for industrial processing is very difficult to obtain. Even an approximate figure on the amount of material involved in present thinning operations could not be found. However, it is known that for 1970, when sawmilling operations ceased, a total of 5,060 m^3 (178,700 ft^3) of pine roundwood was processed in addition to 510 m^3 (18,000 ft^3) of pine thinnings (6).

Assuming an average density of 700 kg/m^3 (43.7 lb/ft^3), this represents 357 tons of thinnings and 3,542 tons of relatively small diameter roundwood. As no sawmilling has been carried out since then, a substantial increase on these figures can be expected for the present situation.

Sawmill residues

An estimate of the total usable solid sawmill waste in Belize is given in annex II.

There are more than fifty separate sawmill operations in Belize. The large majority of these are pathetically small and poorly-equipped mills located over an extremely wide area. Only six can be seriously considered at this time as developing industries using the waste wood associated with their operation. Details of these mills and the quantities and types of timber involved are given in annex III.

One of the main objectives in the co-ordinated Forestry Development Project is to improve the efficiency of the sawmill industry in Belize. This will almost certainly involve the encouragement of larger and more efficient sawmills and most of the existing units should be phased out.

Land clearance programmes

Undoubtedly the greatest amount of timber resources that are currently wasted in Belize are those that are burnt during land clearance and milpa cultivation. With the agricultural development projects that exist and those that are planned for the future, this source of large quantities of waste timber in relatively small areas could be the most viable for industrial processing.

The standing volume of timber in Belize bush can be taken as 3,534 ft^3 (100 m^3) per acre (3). Even if concessions were given to sawmill owners to remove all main stems over 12 in. (30 cm) diameter for sawn timber, at least 30% of the total wood weight would remain.

Assuming an average density of the dry wood to be 400 kg/m^3 (25 lb/ft^3), the dry weight of wood remaining in the forest would be:

$$3{,}534 \text{ ft}^3 \text{ per acre} \times \frac{30}{100} \times \frac{400}{1{,}000} \times \frac{1}{35.34} = 12 \text{ tons per acre}$$

Plantations

Gmelina arborea

The procedures involved in establishing a mature plantation of Gmelina arborea at Melinda are as follows:

(a) Nursery propagation for one year of seeds collected from the forest floor;

(b) Planting of seedlings with approximately 3 meters spacing;

(c) Clearance of forest weeds one year after planting seedlings;

(d) Pre-commercial thinning of plantation once canopy closure has been achieved (4-5 years).

An approximate estimate of the total volume of pre-commercial thinnings was obtained from the local Research Officer. This indicated that at least 212 ft ^{3} (6 m^3) were produced per acre. At present this material is left on the forest floor and assuming a dry weight density of 560.63kg/m^3 (35 lb/ft^3) the total weight of this timber from the annual thinning of 200 acres is 673 tons. These thinnings are between 4 and 10 in. (10 and 25 cm) in diameter.

Almost all of the timber now being harvested from the oldest of the Gmelina plantations is used for making citrus crates. The milling is currently being carried out by the Forest Department on a small bench saw which is only suitable for processing the upper part of the tree which is 6-10 in. (15 - 25 cm) in diameter. The larger diameter timber is sometimes processed at a neighbouring private mill but the majority is being put aside in readiness for a new mill of much larger capacity (8,000-10,000 bd ft per day) which is shortly to be commissioned. Once this new mill is established the use of the old bench saw is planned to continue.

However, in view of the appalling lack of facilities in comparison to the new equipment it would seem likely that the emphasis will be drawn away from this labour-intensive and hazardous operation. If this is the case, much of the smaller diameter timber could be put to other uses. One suggestion is to transfer the small bench saw to Mountain Pine Ridge and to use the large amount of available pine thinnings to make the citrus boxes. This will make available a further 305 tons of the smaller diameter Gmelina for alternative uses.

Pinus caribaea

The volume of thinnings from Pinus caribaea in the Southern area is very small. In general the area is poorly stocked with a predominance of immature trees and few thinnings with diameters greater than 4 in. are produced.

Prolific forest weeds

Much local interest has been generated concerning the utilization of specific forest weed such as Cecropia mexicana (Trumpet Tree). This particular species grows in great abundance in almost every district in Belize. The tree is fast-growing and its regeneration properties are quite outstanding. It grows to a maximum height of about 8-10 m and can attain diameters of up to 14 in. (35 cm). It is easily identifiable by the characteristic shape of its leaves and by its straight silvery-white trunk. A large volume of this timber could be easily harvested from a comparatively small area. A representative area of bush sampled in the vicinity of the new sawmill at Melinda revealed an approximate total of 20 stems per acre. Calculating on a mean volume of 0.4 m^3 (14 ft^3) per stem and assuming a density of 400 kg/m^3 (25 lb/ft^3) this would produce nearly 3 tons of timber per acre.

Mangrove areas

As already explained, the majority of the mangrove areas in Belize contain a mixed tangle of scrubby growth with a maximum height of 5 m. The mean diameter of discernable stems in these areas is between 5 and 15 cm and the land is covered with swamp vegetation and water. Stands of tall mangrove are difficult to find, probably because of the lasting effects of hurricane damage. One or two areas of comparatively large mangrove are located on the northern side of Belize City and these are fairly accessible. The trees were well-defined and varied in diameter between 10 and 25 cm. The majority of these trees were over 10 m in height and although the tree density was in excess of 1,000 stems per acre, the undergrowth was fairly clear. Part of one of the areas had been cleared with axes, undoubtedly by a local firewood merchant.

It was impossible during the short period of this project to undertake a full survey of the mangrove areas in Belize. Indeed not even the full extent of the exploitable mangrove areas or identification of species in the Belize district could be explored.

The exploitation of mangrove, other than the more accessible tall variety, is not commercially viable. Although the existence of land drainage and clearance scheme in the area for housing development could make the material more accessible, the tangled mass of relatively small diameter stems would be difficult raw material for any process.

The larger diameter tall variety could be commercially exploitable for small-scale industries. Until such time as a detailed survey and mapping of the whole mangrove areas of Belize is undertaken, no large-scale industries involving a high capital input should be considered.

Logwood

There are no records (official or otherwise) of the availability of logwood in Belize. Local knowledge and even historical literature indicates some of the more general areas that are reputed to contain relatively large stands of this species. According to the Forest Ranger for the Belize District, the main areas are located in the Belize Valley and in the private land owned by the Belize Estate and Produce Company around Hillbank. The specific areas in the Belize Valley where logwood is common are at Burrell Boom, Sibun River, Crooked Tree, Mexico Works, Washing Tree and Grace Bank. In 1975, a concession for logwood felling was given to a consortium in the Mexico Works area for the export of the timber for subsequent processing of logwood dye. For reasons unknown, this project was not followed through and felling operations were never started.

With the assistance of the Forest Ranger, a small area at Burrell Boom was investigated. Stands of about 40 trees per acre were observed in which the average tree was between 7 and 10 m(23 and 33 ft) high and conained approximately 5 m^3(177 ft^3)of timber. This would produce about 100 tons of logwood per acre in this area.

The writer felt that the small area surveyed was not typical as the most common occurrence of logwood trees experienced were those lining the river banks.

III. CHARCOAL

The production of charcoal in most developing countries is a widespread and long-established craft and provides a valuable product for both domestic and industrial markets.

Since the escalation of fossil fuel prices, many of the developing countries have embarked on intensive efforts to exploit their indigenous biomass reserves and so reduce their dependence on petroleum-based fuel imports.

Systems using wood and agricultural residues have gained increasing importance as fuel sources in processes where the waste material is available in large quantities immediately adjacent to the process plant (coconut shells for copra drying, rice husks for paddy driers and sawmill waste for kiln drying of timber). However, when wood has to be transported for uses in areas away from its source, then it becomes more economic to convert the wood to charcoal. In East Africa, Earl (7) calculated that when comparing the calorific value of wood and charcoal, and the respective costs of production, the distance at which the break-even point is reached is 82 km. The method of calculating delivered cost of fuels is shown in annex IV.

The relative calorific values of some common fuels are shown in the following table.

Table 1. Relative values of some common fuels

Fuel	Calorific value Btu/lb	Calorific value kJ/kg
Kerosene	18,720	43,543
Fuel oil	17,640	41,031
Charcoal	12,780	29,727
Coal (bituminous)	12,420	28,889
Wood (0% moisture content)	8,460	19,678
Dung (air dried)	7,200	16,727
Peat (air dried)	7,200	16,727
Wood (air dried, 30% moisture content)	6,300	14,654
Wood, freshly felled (100% moisture content)	4,320	10,048

It can be seen from this table that charcoal has twice the calorific value of air-dried wood and three times that of freshly-felled wood.

However, factors other than gross calorific values give charcoal advantages as a fuel when compared with wood. In order to utilize the total heat available in wood-burning systems, the wood has to be broken up into small chips and burnt in a specially designed furnace. If the wood is burnt in more simple appliances, then an uneven heat output is obtained and much of the calorific content is lost as smoke, uncombusted vapour or wood gas. This also applies when wood is used as a domestic fuel, when the business of cooking is not usually commenced until a stable fire producing a more even output is achieved. Also, charcoal burns without smoke and as a result the cooking utensils can be kept cleaner and cooking can be carried out inside the house provided adequate ventilation is assured. Cooking with charcoal is normally carried out on simple inexpensive charcoal stoves (annexes V, VI and VII) and considerable economy can be achieved because charcoal can be quickly extinguished with water and then re-used at a later date.

Existing charcoal production in Belize

Apparently, there are only two traditional charcoal-makers in the whole of Belize. One operates at Maskall in the Orange Walk District and the other at Burrell Boom in the Belize District.

Production is carried out using the earth clamp method whereby 2½ to 3 cords (9–11 m^3)of round wood are stacked to form a mount of wood approximately 20 ft (6 m) long, 5 ft (1½ m) wide and 4 ft (1.2 m) high. The wood is then covered with palm leaves and finally with soil. One end is lit and smoke is drawn out with a galvanized iron pipe at the opposite end. The building of the clamp takes only 1 day but the firing period occupies about 14 days. A further 14 days is required for cooling before the charcoal can be extracted and bagged.

The charcoal maker in the Belize District has recently decreased his production (by decreasing the size of his clamps) because of a breakdown in his chain saw. All raw material is now cut with an axe. The wood used is mainly oak with mixtures of other locally-available hardwoods added. The wood varies from 3 in. to 12 in. in diameter and is cut in 5 foot (1 ½ m) lengths.

Between 0.5 and 1.0 ton of charcoal is produced each month and this is sold on site in 25–30 lb (11–14 kg) sacks. All the charcoal is sold during the first week after production and there is a three-week period when no stocks are available. The current retail price is Belize $ 2.50 per sack.

Potential uses of charcoal in Belize

Domestic

Belize is one of the few developing countries that does not base the majority of its domestic fuel needs on charcoal. At at time when other Caribbean communities such as Jamaica and Guyana are carrying out programmes on increased and improved charcoal-production activities both as a substitution for imports and with a view to exports, Belize continues to pay the ever-increasing cost of fossil fuel imports for a large majority of its internal fuel requirements. The situation was not always such. In the past, the use of charcoal was quite common in urban areas, and cooking was carried out on stoves fabricated from old jerrycans or on special cast iron charcoal stoves imported from Europe. Nowadays, however, only a few people use charcoal for fuelling hot irons and cooking, but even so it appears the demand exceeds the supply.

Customs and excise records show that approximately 3 tons of charcoal briquettes are imported from the United States of America each year and sold at the local supermarkets at Belize $ 5.75 per 10 lb (4.5 kg) bag for barbecueing. This is yet another illustration of the way in which the relatively small population is dominated by the life-style and customs of visiting developers and, more recently, by immigrants from the large industrial nations. At a time when these more advanced nations have their own energy problems uppermost in their minds, Belize should be looking to its considerable bio-mass resources as a source of fuel to partially substitute for imports which are too high.

There are social difficulties involved in increasing charcoal markets by persuading the kerosene and bottled gas users of Belize City to adapt a less convenient fuel form but perhaps these will lessen in the near future when the comparative costs of imported fuel will make too large a hole in the family budget.

Small industries

Of the six bakeries visited in Belize City, three were using wood as fuel and three were using kerosene or diesel.

The bakeries using oil had only recently changed over from wood, their reasons being that oil gave them a quicker and more controllable heat output, whereas wood-fired systems had to be lit well in advance of baking operations. In spite of this, two of the oil-fired bakeries were buying wood sticks at Belize $ 1.00 for 7 lb (3 kg) to be used in the event of power failure. Operators of the wood-fired bakeries expressed considerable interest in charcoal as a fuel whereby continuous baking operations could be employed. With their operations, baking could only commence once the wood fuel had produced hot coals and a constant heat output had been achieved. Charcoal could occasionally be purchased in the Belize City Market at about Belize $ 3.00 per 30 lb (13.5 kg) sack, but supplies could not be relied upon.

Charcoal can be marketed in Belize at a price competitive to oil (annex VIII). If regular supplies could be guaranteed, then a considerable market should exist for bakeries, distilleries, soft drink manufacturers and other small processing activities in Belize.

Larger industries

The ability to meet the ever-increasing cost of fuel oil will be a major controlling factor in the future success of many of the large industries in Belize. If the citrus industry is taken as an example, charcoal could be an excellent alternative to fuel oil to provide the necessary heat for the concentrate plant.

Export possibilities

The total wood charcoal imports of France, the United Kingdom and the United States of America and the c.i.f. values are shown in annex IX. Freight costs to the Caribbean, the United Kingdom and the United States are shown in annex X.

From preliminary calculations, it appears that the export of charcoal is only feasible if special cargo rates can be arranged similar to the shipment of coconut-shell charcoal to New York as quoted by Eurocaribb, the agent for the Mexican Shipping lines. If a similar agreement can be obtained for wood charcoal, whereby the shipping charges are levied on unit weight irrespective of volume, and a price of at least $ 120 per ton can be guaranteed[4/], then the export of charcoal to the United States of America could give similar profit margins as that intended for the home market.

	Belize $
Production costs for 2.5 tons of charcoal (less market charge)	197.95
Freight costs for 2.5 tons Belize City to New York	300.00
Total cost	497.95

4/ The average c.i.f. value of imported charcoal in the United States of America in 1975 was about $US 170 per ton.

	Belize $
United States sales at $120.00 per ton	600.00
Total costs	497.95
Net income per 2.5 tons	102.05
Net income per ton	40.82

Annual net income, assuming 50 working weeks with one batch of 2,5 tons of charcoal produced per week 5,102.50

Shipping rates are normally based on unit volume when the bulk density of the product is below 1 ton/m^3. Freight charges on charcoal can be reduced by briquetting, but then, even applying the lowest of the volume rates quoted, the net return would just cover production costs of the lump charcoal. Higher c.i.f. prices for charcoal briquettes could probably be achieved but it is known that the capital cost of a briquetting plant of 1 ton per hour capacity is at least Belize $150,000.

Suitability of raw material

Charcoal can be made from any vegetable material by heating it, in a restricted supply of air, to temperatures above 300° C. The properties of the charcoal produced will depend on the density and chemical composition of the raw material and the method of carbonization. The best quality charcoal is manufactured from wood or nut shells which have a high relative density. This results in the product also having a high density and subsequently a high calorific value per unit volume. As a result, charcoal is mostly manufactured from hardwoods. Softwoods with a lower density can be used but in most developing countries, where charcoal is sold by the bag and not by unit weight, there is an understandable reluctance to buy it.

In Belize, good quality charcoal oould probably be made from any solid hardwood waste including sawmill off-outs, forest clearance residues and mangrove. Pinus caribaea has an unusually high density for a soft wood and its use for charcoal in Belize especially for local consumption should not be overlooked.

Production methods

A summary of charcoal production methods is given in annex XI.

Industrial retorts

Charcoal is produced on a large industrial scale in many countries by using vertical coking retorts which are operated on a continuous basis. The most successful of these systems is the Lambiotte retort which is currently being operated in Australia, Belgium and France. This company has recently introduced onto the market a smaller version with a production capacity of 1,500 tons of charcoal per year. The cost of one of these units is Belize $400,000 and it would need to be sited close to a continuous supply of wood of about 20 tons/day (air dry weight).

Further details can be obtained from:

Lambiotte et Cie. S.A.
Avenue Brugmann 413
1180 Brussels
Belgium

A British manufacturer markets a similar retort and details of this can be obtained from:

Shirley Aldred and Co.
Sandy Lane
Workshop, Nottinghamshire
United Kingdom

Charcoal production in these units demands the maximum efficiency and consequently the highest yields. The wood gases, tars and pyroligneous liquor that are formed during the thermal decomposition of the wood are passed into a furnace where the heat of combustion is returned to the body of the retort. Because of this, no external fuel source is required to sustain the process and, unlike more traditional charcoal-making methods, no air is needed for partial combustion of the charge to produce the necessary heat for carbonization. Charcoal yields in excess of 30% are normal (oven dry basis).

Masonry kilns

Permanently-sited kilns made from materials such as concrete blocks, laterite bricks, cinder blocks and even standard household clay bricks have enjoyed considerable popularity as batch type charcoal-making systems for over 100 years. Designs vary from the circular beehive type to the rectangular Missouri or Connecticut versions that are currently popular in the United States (8).

These units are more suitable for large primary wood processing areas where a regular supply of timber off-cuts and cordwood is available. Mechanical handling aids can also be employed on the larger of these units.

A small masonry kiln, based on the Connecticut design is being successfully operated at the Tropical Products Institute in the United Kingdom (annex XII).

Portable metal kilns

The most versatile method of charcoal production is undoubtably the portable metal kiln. This type of production can be carried out on the forest floor immediately adjacent to the felling area and avoids the relatively high cost of transporting waste wood to a central point.

The kilns are composed of two interlocking cylindrical sections that can be rolled along the forest floor or transported by flat-back truck to a new location. These units can also be used at sawmills, furniture factories and other wood industries where the advantage of portability is not necessarily exploited. Provided the wood used is seasoned to less than 40% moisture content, oven dry weight, then a yield of 25% can be achieved.

The popularity of portable metal kilns is evident by the number of units currently in use in Africa, Asia, the Caribbean and South America. Complete kiln units can be purchased at a cost of £850 each from:

Charkiln and Co.
83 The Grove
North Cray
Sidcup, Kent DA145NG
United Kingdom

freight cost to Belize would be a further £ 180.00.

To avoid the cost of freight, portable kilns may be constructed by a local engineering company with metal rolling and welding facilities.

For maximum efficiency, the kilns are normally operated in units of two and two men can operate two kilns and produce 2.5 tons of charcoal per five-day working week from 10 tons of wood (oven dry weight).

Working drawings and operating instructions for the construction of a kiln designed by the Tropical Products Institute of the Ministry of Overseas Development are given in annexes XIII and XIV. These details have been given to a local engineering firm in Belize City, Earl Lindo and Co., Ltd., so that a budget cost of local manufacture can be obtained.

Earth clamp method

The traditional pit method and earth clamp method for making charcoal are still widely used. These methods are operated by craftsmen of considerable experience and the art of making good charcoal in this way is usually handed down from one generation to the next. Consequently the problems of training and promotion of the techniques involved are considerable. The process is time-consuming and labour-intensive and the product is frequently contaminated with the soil which is used to cover the charge to restrict the access of air. The quality of charcoal produced by these methods varies considerably as there is little control over the burning process and the optimum duration of the burn is difficult to assess.

Continuous moving-bed carbonization for finely-divided forestry and agricultural residues

A considerable amount of interest has been shown for many years in the utilization of residues such as sawdust, coffee husks and groundnut shells. These materials are generated at large centralized processing centres and have in the past given rise to serious disposal problems.

Many of the large boiler-making companies are now marketing units that are specially designed to use these residues to raise steam and in these times of high fossil fuel prices, they are enjoying considerable success.

Advances have also been made involving the processing of these residues into solid fuel. However, briquetting the uncarbonized green material into fuel-logs has met with only a limited amount of success in developing countries because of the instability of the product in climates with high relative humidities. The process is highly capital intensive because the machinery involved is complex owing to the extremely high pressure that must be exerted to produce briquettes from a naturally flexible material without the use of a binder. Also the fuel produced has a relatively low calorific value per unit weight.

A greater degree of success, however, is achieved by companies that are marketing moving-bed carbonization units that reduce the green reisdues to a powdered char. This char is then mixed with a suitable binder (e.g. vegetable starch) and fed into a medium-pressure charcoal briquetting plant and the product, when dried, gives a valuable high-calorific solid fuel.

Two companies that manufacture such units are:

Shirley Aldred and Co., Ltd.
Sandy lane
Workshop
Nottinghamshire
United Kingdom

and:

Simon Carves Ltd.
Stockport
Cheshire SK30RY
United Kingdom

The process is continuous and the cost of these units is about £150,000. Their use is only recommended where there is a reliable supply of more than 5 tons per hour of raw material producing 1 ton per hour of charcoal briquettes.

Wood distillation and recovery of by-products

It is possible to recover methyl alcohol, acetone, acetic acid and wood tars as by-products from the carbonization process. However, in practice, these products are only recoverable from large-scale continuous processes. In addition to the high capital cost of these units there is the expense of isolating the individual components and the refining process for this involves a considerable amount of technical expertise. The refining process would also involve imports of other chemical agents. The by-products are nowadays produced synthetically from petrochemical precursors and in spite of recent price increases they are still relatively cheap to buy.

Manufacturers and operators of the large industrial-scale charcoal retorts do not consider by-product isolation to be viable and all the volatile products of the carbonization are usually used as fuel. The heat produced is passed back into the system to increase the overall efficiency of the charcoal-making process.

A more sophisticated version of the portable metal kiln is manufactured by Shirley Aldred and Co., Ltd. at a cost of £ 1,800.00. This unit could also be manufactured under licence in Belize.

The kiln is similar in size and operation to the basic kiln but the unit is less portable and is raised above the ground on four angle-iron legs. The kiln is provided with a conical metal base that enables the charcoal to be unloaded hot into sealable metal drums by the operation of a mechanical slide valve. This allows the kiln to be immediately re-charged with wood and avoids the extra day for cooling required with the standard unit. Hence charcoal production can be increased by more than 100% and the method of unloading is less labour intensive.

During the carbonization of a 3 ton batch of wood, smoke is drawn up through a single chimney issuing from the lowest point of the kiln. The expert discovered while operating this unit that a considerable amount of wood tar is produced at the base of the chimney and this can be conveniently recovered.

Wood tar can be used as a creosote-type preservative for fence posts and wooden structures but it is only about 40% as efficient as coal tar creosote due to its increased solubility in water. Its use is quite common in the drier climates of Northern Europe and Scandinavia but its application in Belize, with its relatively high rainfall, would not be worthwhile.

Suitability of method for Belize

Because of the widespread location of raw material in a country with bad roads, the use of a large industrial-scale charcoal processing plant is not recommended. However, considerable opportunity exists for the use of portable metal kilns in land clearance or any activity where the clear felling of bush, virgin forest and mangrove areas is being undertaken.

Portable metal kilns could also be operated in the largest of the sawmills using slabwood and off-cuts from the primary and secondary hardwood milling.

Normally the ideal situation for the use of portable metal kilns is in hardwood logging operations where the branches and tops of the trees can be converted to charcoal on the forest floor. This type of production is not feasible in Belize where the felling of hardwoods is very selective and is carried out in widespread areas of main forest where virtually no roads exist. Also, logging operations of this type are only undertaken during the short four-month dry season.

Small masonry-type kilns could be used at the larger sawmills for charcoal production where sufficient quantities of hardwood off-cuts exist and where portability is not required. Most of the solid waste seen at these sawmills, however, is of fairly low bulk density and the weight of charcoal produced from each operation would be low. Also the charcoal produced would be rather small in size.

Production costs using portable metal kilns

Details of construction and practical operation of the kilns are given in annexes XIII and XIV. The production costs (in Belize $) are summarized below:

(a) Two men using two metal kilns can produce 2.5 tons per week;

(b) Two metal kilns cost 7,086 c.i.f. Belize City;

(c) Each kiln has a life span of three years or 750 working days (five-day week), if used continuously;

(d) The chain-saw required costs 700 and also has a working life of three years;

(e) The interest charge of the cost of the kiln and the chain saw at 12% paid quarterly in equal instalments over 1.5 years amounts to 816, then the cost of the capital equipment per 2.5 tons of charcoal is

$$\frac{(7,086 + 700 + 816)}{(750 \div 5)} = \text{Belize } \$\ 57.35$$

	Belize $
Labour cost for 2.5 tons of charcoal using two-men and two kilns at 8 per day for a five-day week	80.00
Capital cost per 2.5 tons of charcoal	57.35
Fuel for chain-saw for one week	5.00
Cost of sacks at 0.20 each assuming one sack holds 18kg (40 lb) of charcoal and one batch yields 2500kg (5,500 lb or 139 sacks)	27.80
Transport to market at 0.20 per sack	27.80
Market charge at 0.20 per bag sold	27.80
Total cost per batch of 139 bags	225.75
Revenue from 139 bags at 2.50 per bag (allowing for 50% profit margin)	347.50
Net income per batch 139 bags	121.75
Net income per ton	48.70
Annual net income	6,088.00

Location of portable metal kilns in Belize

The use of portable metal kilns will have the greatest effect when used on the forest floor in land clearance, milpa clearance and mangrove exploitation. At present, land clearance operations for agricultural development are as follows:

(a) There is select felling of exploitable hardwood trees by concessionary logging companies;

(b) The area is cleared with a bulldozer;

(c) Wood and branches are cut up to facilitate windrowing;

(d) The wood is stacked into windrows and burned after seasoning for approximately two months.

The burnt stacks of wood in the windrows provide nutrients for the plants as the rain leaches out the inorganic salts from the ash.

This type of land clearance operation is ideal for charcoal production as a battery of portable kilns can be used to utilize the wood in the round leaving the large diameters for the windrows.

A brief analysis of the charcoal production potential for land clearance schemes in Belize is given below. A detailed survey of the density of the forest was not undertaken and a more accurate estimate is advised as part of any future investigation of developing charcoal.

The diameter of wood recommended for charcoal production in portable metal kilns is between 2 and 10 in.

Assuming that the total volume of wood available per acre of high bush is 3,534 ft^3 (100 m^3) (2) and the percentage of wood in the afore-mentioned range is 30%, then the volume of raw material available for charcoal production in high bush is 1,060 ft^3/acre. If the density of wood is taken as 25 lb/ft^3 (400 kg/m^3), the weight of wood available is 12 tons/acre. A 25% yield of charcoal from dry wood will produce approximately 3 tons of charcoal per acre.

Production costs using masonry kilns

A masonry kiln, constructed and operated successfully by the Tropical Products Institute of the Ministry of Overseas Development, is shown in annex XII. Further details of construction and operation may be obtained from the Institute at 56/62 Gray's Inn Road, London WC1, United Kingdom.

The kiln illustrated has the same 7 m^3 (250 ft^3) capacity as the portable metal kiln but larger versions can easily be made. The masonry blocks used by the TPI version were the hollow variety, each 17½ in. long, 8½ in. wide and 8½ in.deep. Similar hollow blocks can be purchased in Belize but the size is smaller being 1 in. long and 8 in. in square section. The following costing is based on the required amount of Belizean blocks to build a kiln with a 14 m^3-capacity (500 ft^3) with internal dimensions of 14 ft long, 6 ft wide and 6 ft high.

Table 2. Costing of a 14 m^3-capacity kiln built with Belizean blocks (Belize $)

Item	Size	Qty	Price	Cost
Hollow block	16" x 8" x 8"	300	0.65	195.00
Tier block	16" x 8" x 4"	36	0.50	18.00
Conduit	1" diameter, 6' 3" long	15	12.00	180.00
Corrugated iron sheet	6' 3" long	8	10.00	80.00
Builder's sand		5 yd^3	20.00	20.00
Cement		7 sacks	6.30	44.10
Lime		7 sacks	6.00	42.00
Galvanized pipe	8" diameter, 8' long	1	20.00	20.00
Steel plate	1/8" thick x 2' x 3'	1	40.00	40.00
Labour		4 man/days	10.00	40.00
	Total			679.10

The carbonization cycle of this unit is one week because of the increased cooling time required because of the increased insulation value of the building materials used. Consequently two of these units would be needed to equal the output of two portable metal kilns, which although having half the capacity may be used twice in one week.

The charcoal production costs using masonry kilns are summarized below.

On the assumption that:

(a) Two men using two masonry kilns can produce 2.5 tons of charcoal per five-day working week;

(b) Two masonry kilns cost Belize $ 1,358 to construct;

(c) Each kiln has a life span of three years of 750 working days if used continuously;

(d) The chain-saw required cost Belize $ 700 and also has a working life of three years;

(e) The galvanized iron roof sheeting is replaced every six months;

(f) The interest charge on the cost of the kiln construction and the chain-saw at 12% paid quarterly in equal instalments over 1.5 years amounts to Belize $ 258, then the cost (Belize $) of the capital equipment per 2.5 tons of charcoal is (1,358 + 700 + 400 + 258) / (750 : 5) which equals 18.11.

	Belize $
Labour cost per 2.5 tons of charcoal using two men and 2 kilns at 8 per day for a five-day week	80.00
Capital cost per 2.5 tons of charcoal, as above	18.11
One bag of cement and 1.5 bags of lime for re-building the doorway and sealing cracks	15.30
Fuel for the chain-saw for one week	5.00
Cost of sacks at 0.20 each, assuming one sack holds 18 kg (40 lb) of charcoal and one batch yields 2,500 kg (5,500 lb or 139 sacks)	27.80
Transport to market at 0.20 per sack	27.80
Market charge at 0.20 per sack sold	27.80
Total cost per batch of 139 sacks	201.81
Revenue from 139 sacks at 2.50 per sack	347.50
Net inoome	145.69
Net income per ton	58.28
Annual net income assuming 50 working weeks with one batch of 2.5 tons of charcoal produced per week	7,285

Looation of masonry kilns in Belize

Masonry kilns could be used to carbonize slabwood and sawmill off-cuts in any sawmill where a minimum of 20 tons per week of this type of hardwood waste is generated. The greatest yields of charcoal will be achieved when the wood used has been allowed to dry down to a moisture content of below 40% (oven dry basis).

Conclusions and reoommendations

The introduction of modern oharcoal-making techniques in Belize would provide a valuable local fuel source from the large quantities of waste timber available.

Although the existing domestic market for charcoal is small, this should increase when more charcoal is available at a price competitive with kerosene. However, the biggest local outlet may be the small industries that are burdened by high fuel costs.

The export potential for charcoal appears to be good provided a high quality can be maintained and a stable market found in the United States.

It is recommended that a market feasibility survey should be carried out on all potential charcoal-using industries in Belize to identify areas in which fossil fuel substitution may be viable.

It is also recommended that a market survey is carried out on importers of hardwood charcoal in the United States.

A charcoal production training unit, under the aegis of the Forestry Department, should be set up using modern carbonization techniques on both sawmill waste, and roundwood waste from forestry thinning and land clearance programmes. The charcoal produced could be introduced into local markets and export trade evaluation could be made at the same time.

IV. WOODWOOL/CEMENT SLABS

Woodwool/cement slabs are increasing in popularity as a wood-based panel product both in the developed and developing world. Because of their exceptional properties of low thermal conductivity sound-proofing, flame-retarding and resistance to decay, they are being widely adopted as a building material in many low-cost housing projects throughout the developing world. The material is ideal for stockpiling as a valuable building material reserve for hurricane relief programmes. This would be particularly relevant for Belize.

There is an abundant literature that deals with the manufacture properties and applications of this product (9) (10) (11) (12).

As a building material the woodwool/cement slab is versatile. It is used for partitioning and cladding, exterior walling, roofing, for permanent shuttering and as a base for flooring materials and can be sawn and nailed as required. Its use in temperate climates for all these purposes is well-documented and details of methods of application of the slabs in developed countries can be obtained from the manufacturers.

The strength properties of woodwool slabs as specified by the DIN standard 1101, April 1970, are given in annex XV.

Manufacturing process

Manufacturing varies according to the raw material, the degree of automation required or available and the ultimate use of the product. The woodwool slab,as known in most industrially developed nations is a product of a highly-automated industry. The raw material used are species of pine, spruce and fir seasoned to a moisture content of 20-30%, debarked, cut into billets approximately 20 in. (50 cm) long, and machined along the length of the billet to produce strands of woodwool. The woodwool is treated with a suitable mineralizing agent such as calcium chloride, dosed with cement, mixed, spread onto timber and plywood moulds, compressed and then stacked in the moulds under pressure for 24 hours. The slabs are then demoulded, trimmed and stacked in the open to cure for from two to four weeks before being sold.

The woodwool machine and cement-dosing system are generally the only parts of a potential woodwool/cement slab plant that need to be imported into a developing country. All other equipment can be made or obtained locally or purchased second-hand if reconditioned by specialists. In this respect, and in the suitability of the process for small-scale operations, woodwool/cement slab manufacture is the only panel produce ideally suited to many less developed countries, although this situation is altered slightly these days because of increased prices of fuel that are reflected in the higher cost of cement.

Raw materials

Suitability

The need to determine the suitability of any timber species before it is used in the commercial production of a wood/cement product is imperative. Much work has been carried out at a number of research institutes to develop a test method, involving a minimum quantity of raw materials and labour, of evaluating the possible use of various species but it had limited success. A method that is more applicable to use in the field as a "go - no-go" test is one that requires no sophisticated equipment. In this test small pieces of wood are partially inserted in a cement paste, if, after two days, the wood can be pulled out by hand or a with a pair of pliers, the timber is unsuitable. This rough sorting is invaluable in terms of labour in those areas of the tropics concentrating on the use of indigenous mixed hardwood species where full-scale testing of all species is impracticable in terms of time and cost. Having roughly sorted the possibles and probables from the unlikely species, complete assurance must be obtained that a usable product can be made from a given material. To do this there is no alternative to making test slabs, using the material under investigation, and testing them physically according to the standard methods. The preparation of test slabs will also give an indication of the machineability of the timber being tested and the effectiveness of the application of mineralizing agents to negate the action of cement setting inhibitors (mainly sugars) present in the wood.

Availability

Wood. The ideal raw material for woodwool/cement slab production is roundwood thinnings or large sawmill wastes from plantation species, from which a regular supply of timber of pre-determined species can be assured.

Of the forest residues surveyed during this project, the *Gmelina* thinnings and roundwood waste form the plantations at Melinda seem to be the most promising source of raw material. The available and potential quantities are sufficient to supply even the largest of woodwool/cement slab plants.

Another species worth considering is Cecropia mexioana (trumpet tree). A large volume of this forest wood species can be harvested from a relatively small area. Woodwool/cement slabs are reputed to have been manufactured from this species in Puerto Rico but no literature on this can be traced.

Cement and oalcium cloride. Cement is not manufactured in Belize, although all the raw materials necessary for production are available. The average annual consumption of cement in the whole country is only 10,000 tons and the smallest economically viable cement plant has an output of more than 50 times that amount. Consequently all cement is imported and at Belize $ 6.30 per 96 lb sack, is relatively expensive to buy.

The mineralizing agent is also an import item but the relative cost involved in the production is small.

Woodwool/slab plant in Belize

Annex XVI shows the order of physical capital requirements in establishing a woodwool/cement slab industry in Belize. The figures given for the various size plants and their corresponding outputs are based on similar studies in other developing countries. It must be stressed that a woodwool/oement slab plant is normally designed to meet the conditions and requirement of each specifio area and potential market. Consequently a full soale feasibility study would have to be carried out before such an industry is established. All oosts are based on information obtained from the Lands Department except for the oosts of supplying, installing and oommissioning the plant whioh are very approximate and are based on 1975 prices quoted for a similar study elsewhere in the developing world. The TPI is able to design various sizes of woodwool/oement slab plants and will arrange the supply of the required oomponents. The budget cost of the TPI-designed plants, given in annex XVII, could be reduced by manufacturing some of these oomponents looally and making use of looally-available reconditioned equipment.

Annual operating input data

Details of raw materials, fuel and labour requirements are given in annexes XVIII and XIX.

Annual operating costs

Raw material costs were supplied by the Forest Departemnt Purchasing Officer in Belize City and are as follows (Belize $):

(a) Timber (assumed intrinsic value)= 20/ton;

(b) Cement (more than 100 bags) = 5.70/96 lb (44 kg) sack;

(c) Diesel (bulk) = 1.20/gal (0.317/l);

(d) Electricity = 0.18/Kwh.

Labour costs were calculated at government rates and were estimated from information given in a recent CIDA report (3). The remaining costs were calculated from data obtained by private communication with TPI and the machinery manufacturers. Details of the annual operating costs of the various sized plants are given in annex XX.

Production cost

The cost of producing 1 m^3 of woodwool/cement slabs varies from Belize $ 102.85 to Belize $ 170 8 (annex XX) depending upon the size of the plant and the operating schedule. The quadruple-acting TPI Plant No. 111 operating on a single shift basis incurs a maximum total initial cost of Belize $ 355,680. This plant will consume 296 tons of wood and 607 tons of cement and will produce 2,220 m^3 (78,400 ft^3) of slabs per year. Production costs are shown to be about Belize $ 21.92 per m^3 or Belize $ 3.10 per m^2 of 25 mm (1 in.) thick slabs.

Competing building materials in Belize

The retail prices of some commonly used building materials are given below:

Table 3. Partition supported on a 50 mm x 50 mm timber framework

Item	Unit cost of material	Total cost of installing 1 m^2 of partition
	Belize $	
Woodwool /cement slabs 25 mm thick, rendered on both sides with cement plaster	4.65/m^2 of 25 mm thick wood - wool cement slabs	10.00
Unrendered	"	8.50
Woodwool/cement slabs 50 mm thick, rendered on both sides with cement plaster	9.30/m^2 of 50 mm thick woodwool cement slabs	14.50
Unrendered	"	13.00
Hardboard 3 mm thick on each side	3.20/m^2 3 mm thick hardboard	10.00
Hardboard 4.5 mm thick on each side	4.88/m^2 of 4.5 mm thick hardboard	13.50
Hardboard 6 mm thick on each side	6.22/m^2 of 6 mm thick hardboard	16.00
Hardboard 9.5 mm thick	18.50/m^2	22.00
Plywood 13 mm thick	25.23/m^2	29.00
Plywood 19 mm thick	37.00/m^2	40.50
Sawn timber 25 mm thick	4.84/m^2	10.00
Concrete blocks 8 in. thick, hollow type	0.65/per block 16" x 8" x 8"	10.50
Concrete blocks 4 in. thick, hollow type	0.50/per block 16" x 8" x 8"	8.50

Conclusions and recommendations

The estimated retail cost of woodwool/cement slabs in Belize compares favourably with existing building materials. The potential use of this unique material within current and future programmes (e.g. the low cost housing development scheme at Belmopan should be fully explored. Details on the use of this material in building construction in developing countries can be obtained from: Tropical Products Institute, Industrial Development Department, Ministry of Overseas Development of the United Kingdom.

The possible siting of such a plant should be considered. Stann Creek may seem, at first, an obvious choice, being close to the supply of raw material. However, with the reluctance to transport goods by barges along the coast and the very poor condition of the Hummingbird Highway to Belmopan and other markets, other sites should not be overlooked. It may even be more economic to transport the seasoned timber to a factory in Belmopan / considerable potential market exists in the expansion of the new capital and the road from Belmopan to Belize City is good.

Before any feasibility study is carried out on this industry, the suitability of the raw materials must be explored. The TPI has complete raw material testing facilities for woodwool/cement slab production. It is recommended that suitability trials on Gmelina arborea, Cecropia mexicana and Pinus caribaea should be requested to the TPI under the United Kingdom technical aid programme. The Institute could advise on all aspects of this industry, including a complete feasibility and market study, should the raw materials prove suitable.

V. NAVAL STORES INDUSTRY

Existing commercial production

Establishing the industry

The first large-scale attempt at establishing a naval stores industry in Belize appears to have occured in 1963 when the American Hercules Company installed a wood naval stores plant at Big Creek, near Mango Creek, Stann Creek District. This factory carried out solvent extraction of pine stumps left over from timber working in the Southern Coastal Plain pine forest and the turpentine and rosin products were exported to the United States. Because of the eventual shortage of exploitable stumps the enterprise was not as successful as had been anticipated and operations ceased in 1965.

The extraction equipment was transferred to Nicaragua, but much of the other infrastructure (storage tanks, building etc.) was left intact.

Late 1972, another American company, Minter Naval Stores, set up a gum oleoresin tapping operation on Mountain Pine Ridge, installing a second-hand Olustee type unit (13) for processing the oleoresin to turpentine and rosin. This firm obtains its raw material by tapping under licence in the Mountain Pine Ridge Reserve. The tapping season normally extends from January to November and the trees exploited are mainly Pinus caribaea,var hondurensis and some P. oocarpa.

Approximately 110,000 trees are being worked. The first area exploited by the company has 13 crops fitted with a total of 60,000 cups (i.e. approximately 4,600 cups per crop). In the United States, the economic scale for tapping is regarded as 10,000 cups per crop.

Gum resin collection

The faces on the trees are prepared by the bark-chipping method, and these are freshened (streaked) every two to three weeks with sulphuric acid to stimulate gum flow. Each streak yields an average 8 oz. (228 g) of gum oleoresin. Assuming a three-week streaking cycle and an effective tapping period of nine months per annum, the average yield of gum oleoresin per tree is 6.5 lb (3 kg).

The manpower for the tapping operation is divided into two groups, the tappers and the collectors. These people are paid on a piece-work basis, receiving Belize $ 70.00 per barrel (about 400 lb or 182 kg) of gum oleoresin.

Olustee method of processing

The crude gum oleoresin received at the factory is first diluted with turpentine and is then filtered into a vat with a capacity of approximately 100 barrels (40,000 lb). This volume can be processed in one shift of about 11 hours.

The unit incorporates two stills (measuring about 6 ft (1.8 m) high and 6 ft in diameter) for distillation of the diluted filtered oleoresin. Each still takes a charge of approximately 15 barrels, yielding 14 barrels of rosin and 1 barrel of turpentine after a two-hour distillation. The rosin is stored and shipped in barrels that are constructed on site from imported galvanized sheet steel. The turpentine is stored in 2,000 gallons bulk storage tanks and second-hand 40-gallon oil drums.

Although tapping is carried out only between January and November the factory is normally kept in operation throughout the year. Five men are employed in running the factory.

Output

The major problem encountered in this operation is the relatively low yield of oleoresin per crop of trees worked. Owing to heavy felling of timber in the past and restocking occurring by natural regeneration, most of the pine trees on the Reserve are fairly young and of a more or less uniform age. The Forestry Department permits tapping of only those trees above 10 in. (25 cm) in diameter and then only on one face. According to the Forestry Department there are only 12-18 trees above 10 in. diameter per acre and the present tapping operation is exploiting less than 10 per acre.

In 1974, the operation produced 750,000 lb (340,200 kg) of rosin and 7,000 gal (26,495 l) of turpentine. The bulk of the turpentine and the entire rosin production was shipped to the parent company in the United States. The local management is not permitted to to undertake any independent sales apart from dispensing small volumes of turpentine locally.

The effects of the world trade recession, which resulted in low demand and prices for naval stores products, affected the venture in 1975 and tapping and processing operations were stopped in October of that year. Tapping was not resumed until October 1976. During the close-down period, considerable stocks of undisposed material were held in store at the factory. Stocks began to be shipped out in August 1976 when 540 barrels of rosin were exported (1 barrel = 517 lb). Since then a further 698 barrels have been exported and the entire production of rosin processed during the four months since May 1977 (363 barrels) is awaiting shipment.

Poor markets, however, exist for the turpentine: although 3,000 gal of the 4,250 gal of old stock has been sold since 1975 the remainder is stored in 54-gallon drums on the site. The 5,000 gal of new turpentine processed since January 1977 is being stored in bulk containers.

Quality of products

Considerable difficulties were encountered in operating the plant in the first years of the venture. The operation is manned entirely by local staff and, apart from the period when the plant was being erected, it appears that the parent American company did not provided much assistance or advice in its management or with technical problems. These problems were eventually overcome independently by the local staff and the colour quality of the resin has been improved to WG Grade. Attempts to obtain the top grade (WW) of rosin have not been successful. Samples of turpentine produced by the factory have been analysed by the TPI (14). The quality seemed reasonable and the composition of the turpentine was consistent with what one would expect from material obtained from Mountain Pine Ridge P. caribaea in which a little P. occarpa was included. The major component was found to be alpha-pinene (78.6%) while the content of any of the other individual components was less than 10%. While being a useful raw material for the isolation of alpha-pinene by the chemical industry, it is of less value than American turpentine which normally contains 65% alpha-pinene and 30% beta-pinene.

Proposed expansion of industry

Under the terms of its agreement with the Forestry Department, this company was persuaded to start tapping operations in the Swassy Bladen Forest Reserve (Southern Coastal Plain) in 1975. However, tapping was carried out for only a short period before operations were curtailed, mainly because of labour problems and the reluctance of workers in the south to accept piece-work rates. Other reasons were the poor market that existed at the time and a fire in the area that destroyed the cut faces. There were 4,584 cups employed in the tapping of this crop and the 5.5 barrels of oleoresin collected during the six-week period has yet to be processed. Plans are being made to resume tapping in this area using labour transferred from the Mountain Pine Ridge area.

The company is also considering stump extraction in the area and because the Hercules venture has shown that there are insufficient stumps to support a solvent extraction plant, it proposes to ship the stumps to the parent plant in the United States for final processing.

Future development of the naval stores industry

The expense of pine forests in Belize offers a considerable potential in providing additional income and employment from the production of gum naval stores as an auxiliary to timber. The royalties on 6.5 lb of resin per tree per year for five years is worth Belize $ 0.975 ($ 0.03/lb).

A second face might give 5 lb of resin per tree per year, worth further royalties of Belize $ 0.75, giving a total revenue of Belize $ 1.75 per tree. From volume tables, a tree of 35 cm dbh at felling is 19.88 ft^3. With timber royalites of Belize $ 0.10/ft^3 a further Belize $ 1.988 is generated. The total royalty potential of pine trees could be in the region of Belize $ 3.71 per tree.

Resin production by the continuing operation of Minter Naval Stores can be expected to contribute a significant proportion of total revenue from the Mountain Pine Ridge Reserve.

At the present time, however, most provenances are too young for a large scale naval stores exploitation. It will take perhaps ten years before many of these provenances are sufficiently mature and for a long-term rotation system to be established. In the meantime, the continued small-scale operation of Minter Naval Stores is desirable to provide a nucleus for future development. The scale of its existing operation, however, is such that it may encounter profitability problems, being particularly susceptible to fluctuations in world demand and prices and to pressures of wage inflation. Moreover, a large increase in naval stores production is expected in North America as a result of the widely adopted paraquat treatment associated with the suphate (kraft) process (15).

Whether the effects of this, together with the inability of home markets to offset the periods of low export demand, can be overcome by increased efficiency of production and more available raw material remains to be seen.

Conclusions and recommendations

Years will have to pass before there are sufficient mature pines in Belize to establish a substantial gum-tapping industry. For the immediate future, serious attempts should be made to up-grade the rosin for the one company operating in Belize. Sufficient expertise should be available within the parent company, if it seriously wishes to overcome these technical problems.

The manager of the plant has, through his own efforts, made considerable improvements to the quality of the products and is anxious to continue to do so. Further improvements can only be achieved by a period of intensive training either at the parent plant in the United States or on-site by a technical trouble-shooter from that company.

Because of the present poor export market for turpentine (no doubt partly because of the low beta-pinene content) an expansion of the markets in the neighbouring country should be encouraged.

VI. TANNIN

The study shows that there are insufficient quantities of commercially exploitable tannin-containing materials in localized areas for processing to be carried out on a large industrial scale.

Although mangrove-growing areas exist in the majority of coastal regions, the harvesting of the bark from the red variety (Rhizophora mangle L) to supply a tannin extract plant on a minimum economic scale would not be viable. This would involve the processing of 30-40 tons of bark (air dry weight) per day in order to justify the high capital cost of the plant (16) (17) (18). Moreover, the tannin content of the bark of the small diameter trees that grow in Belize would probably be too low as it has been found that only trees with diameters greater than 8 in. (20 cm) are worth exploiting (19). As an export product mangrove tannin has a low value compared to other tannins owing to the coarse leather it produces and the high red colouration with which it is associated.

There is, however, a growing need for tannin facilities in Belize. It has been reported (20) that over 6,000 head of cattle are slaughtered each year in the slaughter houses of Belize. This is in addition to the 4,000 or so animals slaughtered by farmers and small-holders in rural areas.

Fresh salted hides, valued at between Belize $ 100,000 and Belize $ 300,000, are exported each year to Mexico and other countries. Most of these are obtained from the municipal slaughter houses and only a fraction of the total number of hides available in rural areas are recovered.

In rural areas, the valuable hides are mostly buried with the offal as there is a complete lack of know-how regarding the preservation and tannin process.

The leather consumed in Belize is small. Many of the shoes sold there are made from plastic. Even the shoes with leather uppers have, in the majority of cases, synthetic composition soles and the consumption of sole leather is relatively small. Processed leather valued at approximately Belize $ 20,000 is imported annually for the manufacture of quality shoes, saddlery and other leather goods. If tannin facilities were available these imports could be reduced and the hides that are available each year in increasing numbers as a result of the fast-growing cattle industry could be up-graded by processing, and exported.

The number of small-scale tanneries is decreasing rapidly. Most of these concern one-man operations on the premises of small leather goods shops. Imported tannin extracts are mainly used except in one case in Hattiville where a leather merchant uses a tannin solution extracted from locally obtainable oak bark in crude concrete tanks.

Suitability of tannin materials in Belize

Details of locally-available tannin materials are given in annex XXI.

Most tannin materials are variable and difficult to assess without trials. It is doubtful that any one source used alone would give satisfactory results and suitable blending would probably be required. Most of these materials would produce heavy leathers because of the predominance of the more astringent catechol-type tannin in the extracts.

Synthetic mineral tannin agents are mostly used nowadays for the lighter leathers. Modern blending techniques and chemical additives, however, could increase the versatility of these materials.

Availability of tannin materials in Belize

As with many of the forest products in Belize, availability is a problem because of the widespread and selective harvesting of the primary products. The tannin material should be processed as soon as possible after the harvesting of the timber or primary product. Ideally the bark should be partly removed from the living tree, and the remainder removed immediately after felling. It should then be air dried and the tannin extracted before any decomposition of its structure can take place.

Unfortunately, the large quantities of nargusta and mahogany bark removed at the sawmills have suffered serious rotting and insect attack before arriving at the sawmill. Much of the tannin originally present in the bark would by then have been converted to non-tannin and the old bark would be less suitable for extraction (21).

The most promising course is from non-commercial timbers from which the bark could be removed and the wood used for an associated process (e.g. charcoal production, fuel or woodwool/cement slabs).This would be particularly suitable for mangrove and oak of which areas of relatively concentrated growth can be found.

Industrial-scale tannin extraction unit

In the industrial-scale tannin extraction plants the bark is leached several times with a total of 1,500 gallons of water to every ton of bark (22). The water should be free from such impurities as iron, calcium and magnesium salts and the leaching liquor should be maintained at a temperature of between 60°C and 70°C by the use of copper steam-coils.

The leaching is carried out on the counter-current system using between four and six wooden vats each equipped with a perforated copper false bottom installed at approximately 2 ft from the bottom of the vat.

Each wooden vat is manufactured from pine-wood and is approximately 12 ft (3.6 m) in diameter and 12 ft high. The liquor is heated by the steam-coils under the false bottom of the extractor.

The liquor is continuously pumped forward through the several leaches. The fresh water enters at one end of the battery where the weakest material is held. At each leaching vat, the liquor gets stronger and the strongest "first" liquor is used for leaching the fresh material in the primary leaching vat. The resultant liquor is evaporated in specially triple-effect climbing film evaporators.

No iron or iron-containing materials should be used in the construction of the plant. Copper or gun-metal is usually employed for all units that come into contact with the liquor.

Because of the special materials used in the construction of these plants, the capital cost involved is high. The smallest viable unit would cost something in excess of $US 750,000 and would need a daily input of 40 tons of bark (equivalent to 40 cords of stacked bark).

Small-scale tannin solution plant

Small-scale industrial plant could be considered for the production of suitable tannin solutions in rural areas. In the past, tannin solution have been prepared using local tan barks and single cold water extraction methods. More efficient leaching can be effected by using water previously heated to 60°-70°C on a counter-current system. This could be carried out in a battery of four wooden barrels, each approximately 6 ft (1.83 m) in diameter and 4 ft (1.2 m) deep, made locally by the same people that manufacture wooden reservoirs that are commonly used to collect rain water.

The transfer of bark material could be carried out manually using wooden spades and the liquor transferred in plastic containers. Initially some technical input would be necessary to perfect such a process and evaluate the suitability of various types of liquor for tannin purposes. Leaflets could then be prepared to advise potential tanners on methods of processing the hides that are at present being wasted.

If and when a commercial tannery is installed in Belize, a demonstration unit could be included in the project to show the use of imported tannin extracts and locally-produced materials.

Conclusions and recommendations

The study showed that the industrial-scale use of tannin extract is not worthwhile. There is insufficient raw material to supply the smallest viable plant and the world market for mangrove tannin is poor.

The establishment of a number of low-cost units to produce tannin solutions for the processing of the increasing number of locally-available hides should be encouraged.

If the services of a leather expert are requested for the installation of a small tannery in Belize, it is recommended that his project should include the potential use of locally-available tanning materials for the processing of hides in rural areas.

VII. LOGWOOD INDUSTRY

(*Haemotoxylon campecheanum*)

The logwood trade dominated the early economic history of Belize until a heavily overstocked market forced the price down (23). Later, mahogany became a more important export than logwood, and finally with the introduction of relatively cheap dyes, the demand for logwood completely disappeared. However, in recent years, because of the spiraling cost of petrochemical-based syntehtics, increasing interest is being shown in these traditional vegetable dyes.

Logwood was always exported in the round for subsequent processing in the industrial countries of North America and Europe. Nowadays, because of increasing freight costs, it is doubtful that the dye could be produced at a price competitive with the synthetic alternative.

The extraction of the dye (*Haematoxylin*) in Belize, however, would produce a high-value, low-bulk commodity and the economics of exporting this product would be considerably more attractive.

Availability of raw material

There may be sufficient quantities of logwood in concentrated areas to supply a suitable processing industry. For a reliable estimation of the total standing volume of exploitable timber in Belize, a complete survey is required of all the logwood areas. The size of plant required can then be estimated.

Markets

No potential markets for the dye produced are known and a thorough market survey would be needed in the industrial nations before any such industry is considered for Belize.

Extraction process

The processing of logwood involves the hogging of the timber into small chips followed by the extraction of the dye in steam autoclaves at a pressure of 80 pounds per square inch (18). The resulting liquor is then evaporated, using climbing film evaporators, and the final product is dried in a vacuum spray-drying unit.

Technical input and costs

Details of the cost and operation of extraction plants of various outputs should be obtained from the manufacturers and requests for this information and the technical input required can be made to agencies such as UNIDO's industrial inquiry service in Vienna or the Ministry of Overseas Development in the United Kingdom.

Conclusions and recommendations

A logwood dye extraction plant could provide a valuable export product in Belize but first the following surveys must be carried out:

(a) On the exploitable standing volumes of logwood in selected areas;

(b) On potential international markets for haematoxylin dye;

(c) On costs and technical input required for extration plants of various sizes.

VIII. WOOD RESIDUES FOR FUEL

The great potential of waste timber as an indigenous fuel in developing countries is often overlooked in studies on obtaining marketable products from wood residues.

Many international organizations and research institutes are currently engaged in projects to update and promote the more traditional energy systems, such as steam engines, wood-fired units, producer gas and generators, that use forestry and agricultural wastes as fuel. Many manufacturers are already marketing such power units and examples of these are given in annex XXII.

Producer gas

Development work is being carried out at the Tropical Products Institute of the Ministry of Overseas Development in the United Kingdom on producer gas generators which will enable diesel and spark ignition engines to run on forestry and agricultural residues or charcoal. Similarly, at the University of California in the United States commercial trials are being carried out in collaboration with industry.

A Swiss company (Thalonat AG, Feldstrasse 51, CH-8400 Winterthur) has been selling wood gas producers for years and will supply details of costs and applications.

The producer gas system involves the controlled passage of air through a bed of charcoal (or "green" uncarbonized residues such as wood, nutshells or rice husks). Localized combustion in the presence of an excess of carbon produces gas with the following composition.

Component	Per cent
Carbon monoxide	32.0
Hydrogen	8.0
Nitrogen	58.3
Carbon dioxide	1.5
Methane	0.2

The calorific value of the gas is about 140 Btu/ft.^{3} (5.2 MJ/m^3).

Producer gas can be burnt directly for heating furnaces, ovens or raising steam and very few modifications are needed to convert existing gas or oil burning system.

If, however, it is to be used as fuel for internal combustion engines, the gas must be throughly cleaned to remove any traces of dust or tar. This is especialy important when wood or any green, uncarbonized residues are used as the wood tar and the volatiles produced are caried over with the gas.

down-draught system can be used to reduce the quantity of volatiles by passing them through the fire-bed before they are released. This will result in a further decomposition of the volatiles into non-condensable gases.

The technology of producer gas is by no means new. It was used as an automotive fuel for much of the public and private transport in Europe during the Second World War when fossil fuel supplies were restricted. Many of the old designs are being updated and more modern materials used. Sweden, for example, has accumulated a large stock-pile to be used in the event of a sudden restriction of their oil supplies.

Steam engines

The advantages of steam engines as a motive power source for sawmills and other cellulosic industries have long been recognized. Waste disposal costs are averted and a constant supply of fuel is assured without the ever-increasing commitments of fossil fuel imports. Many steam-powered units are still in use but supplies of new installations and spares are rarely available. Renewed interest is being shown by certain manufacturers in marketing new systems but because of economic restrictions in development projects in industry, progress is slow.

A British manufacturer(J.L. Coltman of Clonsast Ltd.,Sarsfield House, Bransgore, Christ Church, Hants, United Kingdom) has recently developed a 100 hp (75 kW) steam engine and is proposing to market this as an addition to their normal range of standard boiler systems. Further details can be obtained directly from the manufacturer.

Fuel requirements in Belize

Nearly all motive power units in Belize, including electricity generation units, are diesel powered. In only one of the many sawmills that exist is the waste wood used as fuel in a steam engine to supply power to the mill.

In all the other sawmills, the slabbings and off-cuts are either used as landfill or burned.

Oil burning units are used to supply heat to industries such as soft drink factories, distilleries, citrus processing, food processing and most of the local bakeries.

The ability to meet the increasing cost of fuel oil will be a major controlling factor in the success of many of the large industries in Belize. If alternative energy sources can be employed, using the motive power systems described above, or if wood (producer) gas can be used to replace oil in existing furnaces and ovens, then the savings in operating costs (and in foreign exchange) could be considerable.

Conclusions and recommendations

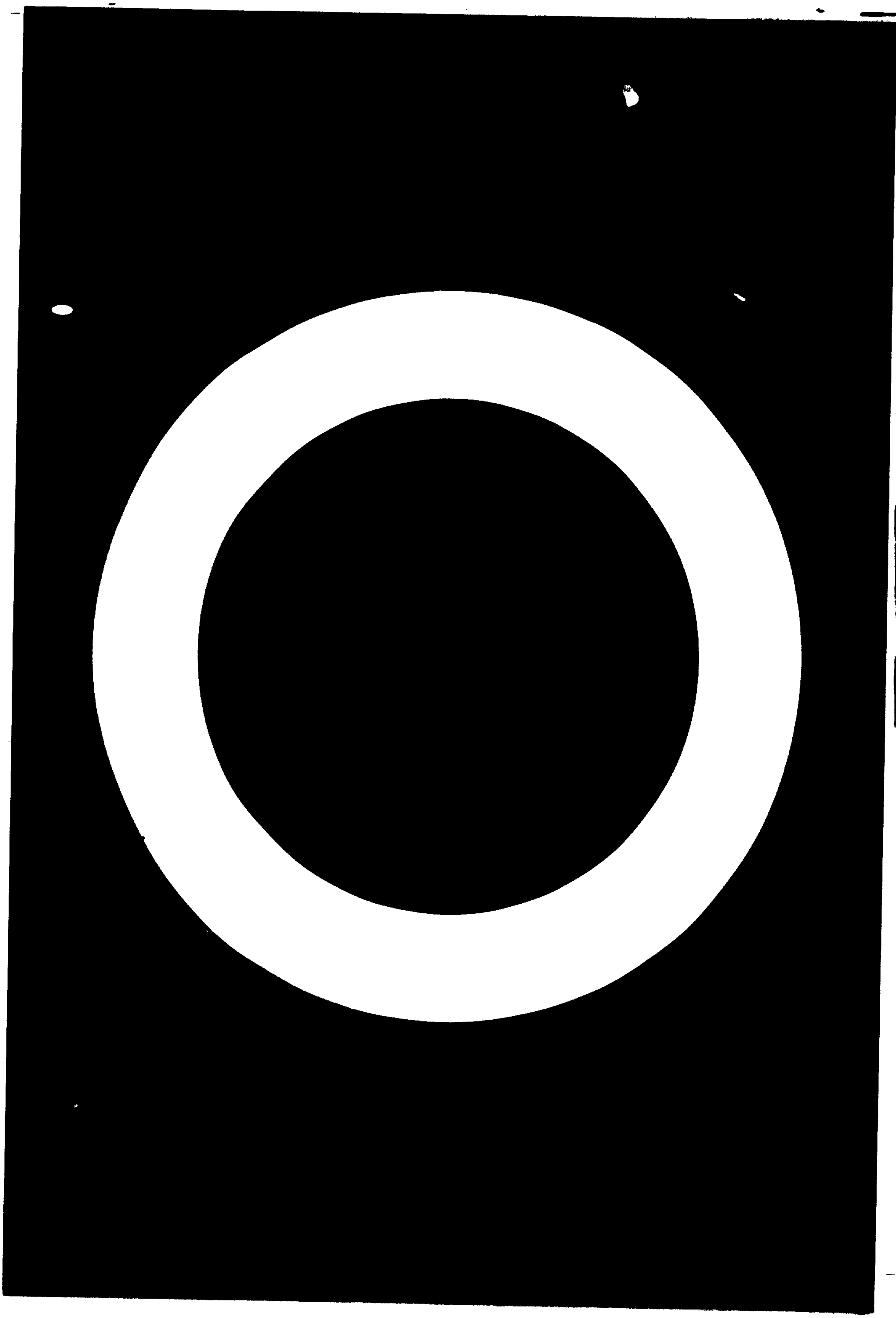
Continuing attention should be paid to the current developments in the alternative energy systems that are relevant to the fuel demands in Belize. Information on suitable systems can be obtained from:

(a) The Forest Products and Fuels Section
Industrial Development Department
Tropical Products Institute
Ministry of Overseas Development
Culham, Oxford, United Kingdom;

(b) United States Department of Agriculture (USDA)
Forest Products Laboratory
Madison
2801 Marshall Court
Wisconsin, 53705, United States;

and other international organizations.

Detailed technical information and costs can be obtained from the manufacturers (annex XXII).



ANNEX I

EXPLOITABLE STANDING VOLUME OF TIMBER IN NATURAL FOREST AREAS

LOCATION	TOTAL AREA (hectares)	STOCKED AREA (hectares)	PINE Volume (m^3)	PINE m^3/ha	MAHOGANY Volume (m^3)	MAHOGANY m^3/ha	CEDAR Volume (m^3)	CEDAR m^3/ha	SECONDARY HARDWOODS Volume (m^3)	SECONDARY HARDWOODS m^3/ha
MOUNTAIN PINE RIDGE	58300	23320	(>10" dbh) 70410	2.96	–		–	–		
			(> [illegible]" dbh) 155197	6.67			–			
			(> 3" dbh) 224334	9.63	–	–	–	–		
CHIQUIBUL					(>70 cm dbh)		(>70 cms dbh)		(50 cms dbh)	
(a) Readily Accessible	185020	(a) 77733			(a) 8691	0.112	16032	0.206	1434240	18.4
(b) Less Accessible		(b) 32389			(b) 30899	0.954	52973	1.635	1813120	55.98
(c) Unsurveyed		(c) 74899			(c) –		–			
SOUTHERN COASTAL PLAIN	139919	45500	(>10" dbh) 156154 (> 6" dbh) 275625	3.43 6.06						
BELIZE ESTATE	255000	255000					TOTAL MAHOGANY & CEDAR (>60 cms dbh) 444073	M ≠ C 1.74	[illegible] cotton [illegible] others [illegible]50 cm dbh 4357296	17.09
COLOMBIA RIVER AND MAYA MOUNTAINS (TOLEDO)	137287	137287			(>70 cms dbh) 46540	0.339	(>70 cms dbh) 11244	0.082	(>50 cms dbh) 8152650	59.38

ANNEX II

ESTIMATE OF USABLE SOLID SAWMILL WASTE

	ROUNDWOOD INPUT cu. ft.	SAWNWOOD EQUIVALENT bd. ft. (1)	TOTAL SAWMILL WASTE cu. ft.
TOTAL SAWMILLS	1.200.000	7.500.000	575.000
BELIZE ESTATE	320.000	2.000.000	153.333

Remaining sawmill waste after subtracting waste from Belize Estate which is used as fuel for steam engine.	=	421.667	cu. ft.
Assuming 50 % solid waste	=	210.833	cu. ft.
	=	5.966	m^3
Assuming a mean timber density of 700 kg/m^3	=	4.176	tonnes

Footnote

(1) Output figures are based on 6.25 bd. ft. per cu. ft. of roundwood

ANNEX III

LARGEST SAWMILLING OPERATIONS IN BELIZE

Annual production of sawn wood 1976, 1000 BDFT / Total usable (1) solid waste produced 1976 (m^3)

Sawmill	District	MAHOGANY	CEDAR	OTHER HARDWOODS	PINE	TOTAL
BELIZE ESTATE	BELIZE	1673 / 1897	205.5 / 230	174.4 / 195	- / -	2052.9 / Nil (2)
JOSE B. MENA	BELMOPAN (CAYO)	92.2 / 103	6.4 / 7	615.4 / 690	- / -	714.0 / 8[illegible]0
BELIZE TIMBER LTD.	CAYO	98.4 / 110	(3) / (3)	256.9 / 299	- / -	365.3 / 409
CARIBBEAN INVESTMENTS	CAYO	7.8 / 9	(3) / (3)	552.2 / 619	- / -	560 / [illegible]
HABET BROS. LTD.	VACA (Chiquibul)	120.4 / 135	7.3 / 8	856 / 959	- / -	984.7 / 1103
JOE LASHOT	ORANGE WALK	297 / 333	12.0 / 13	6.5 / 7	- / -	315.5 / 354
					GRAND TOTAL	4591 / 3294

FOOTNOTE:
(1) [illegible] annex II.
(2) Belize Estate [illegible]
(3) [illegible]

ANNEX IV

TRANSPORTATION OF FUEL

Method of comparing total delivered cost of fuel production cost and transport costs

Given that:

Calorific value of air dry wood (30 % m/c)	=	6300 Btu/lb
" " " charcoal	=	12780 Btu/lb
" " " coal	=	12420 Btu/lb
Production cost of charcoal (at B$ 1.70 per 40 lb sack)	=	B$ 95.20 per ton
Production cost of wood	=	B$ 9.00 per ton
1 ton coal equivalent (C.E.) = $1 \times \frac{12420}{12780}$	=	0.97 tons charcoal
1 ton coal equivalent (C.E.) = $1 \times \frac{12420}{6300}$	=	1.97 ton air dry wood

Then:

Production cost of 1 ton C.E. of charcoal = 95.20 x 0.97 = B$ 92.34
Production cost of 1 ton C.E. of air dry wood = 9.00 x 1.97 = B$ 17.73

Total delivered cost of 1 ton C.E. of fuel assuming a transport cost of B$ X per ton per mile

$$= \text{Production cost of 1 ton C.E.} + \left(\text{No. of miles} \times X \times \frac{\text{calorific value coal}}{\text{calorific value fuel}}\right)$$

Examples

Assuming a transport cost of B$ 2.00 per ton per mile

a) total cost of 1 ton C.E. of charcoal delivered over 50 miles

$$= 92.34 + \left(50 \times 2 \times \frac{12420}{12780}\right)$$

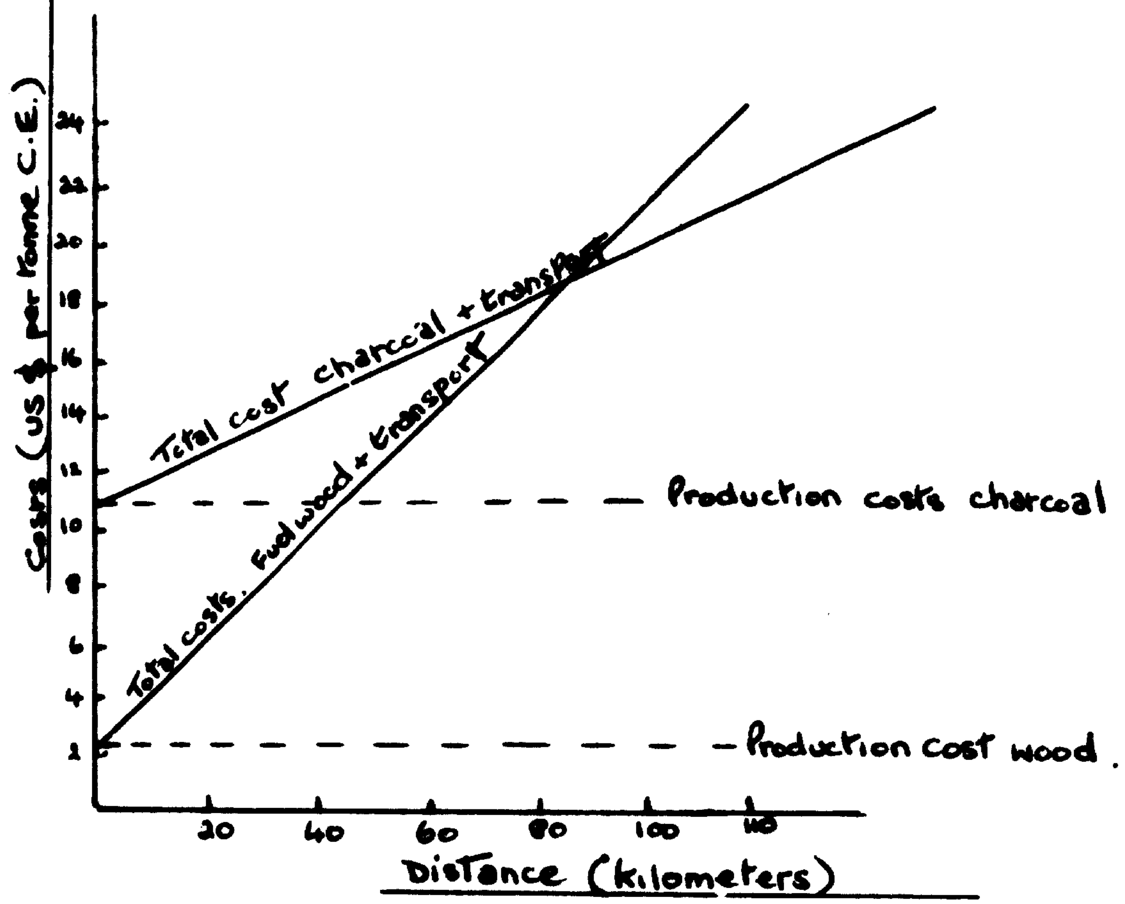
$$= \text{B\$ } 189.52$$

b) total cost of 1 ton C.E. of wood delivered over 50 miles

$$= 17.73 + \left(50 \times 2 \times \frac{12420}{6300}\right)$$

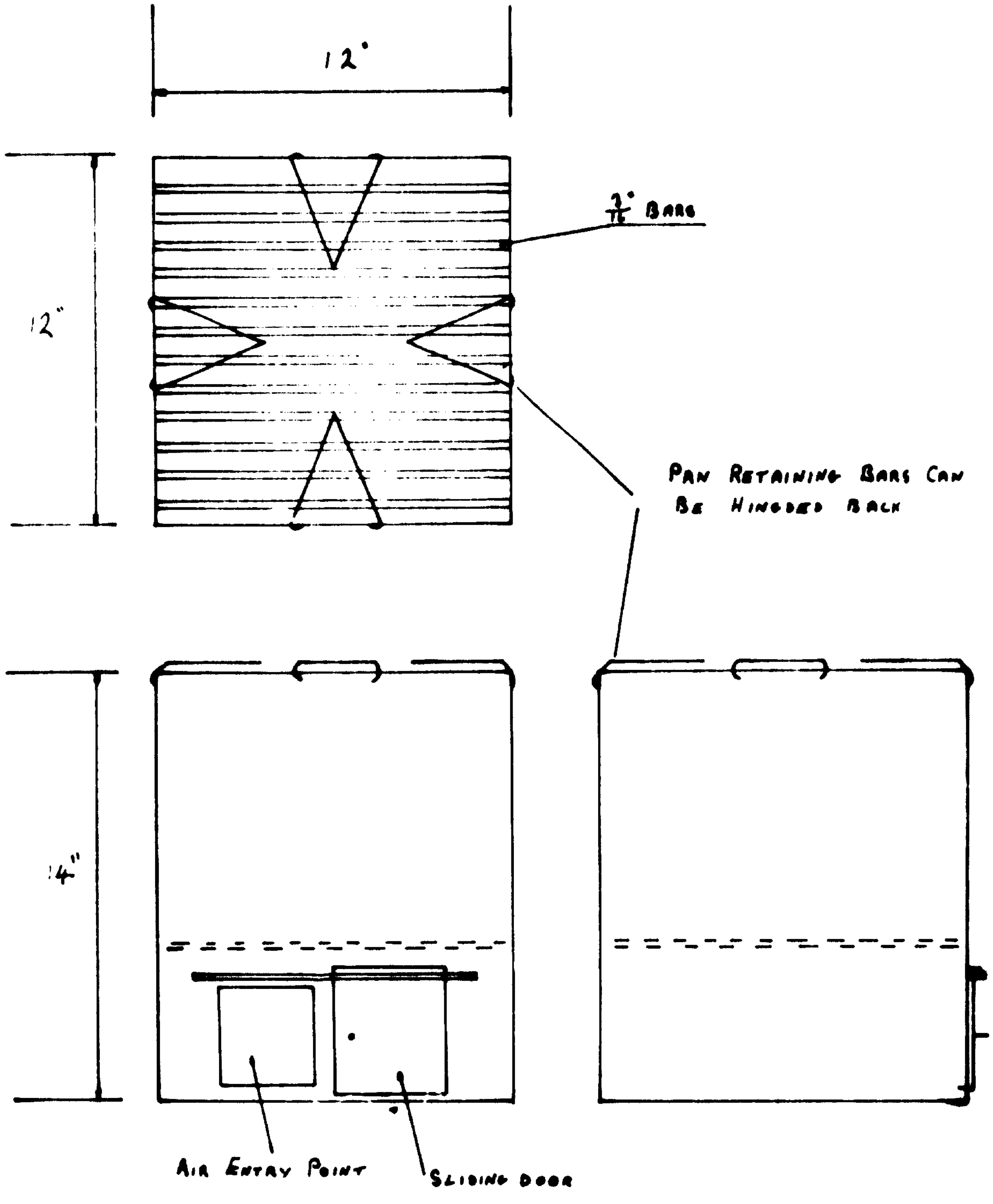
$$= \text{B\$ } 214.87$$

Net production costs (US $) per tonne C.E. of fuelwood and charcoal from natural forests, East Africa. 1970.
(CE = 1 coal equivalent)



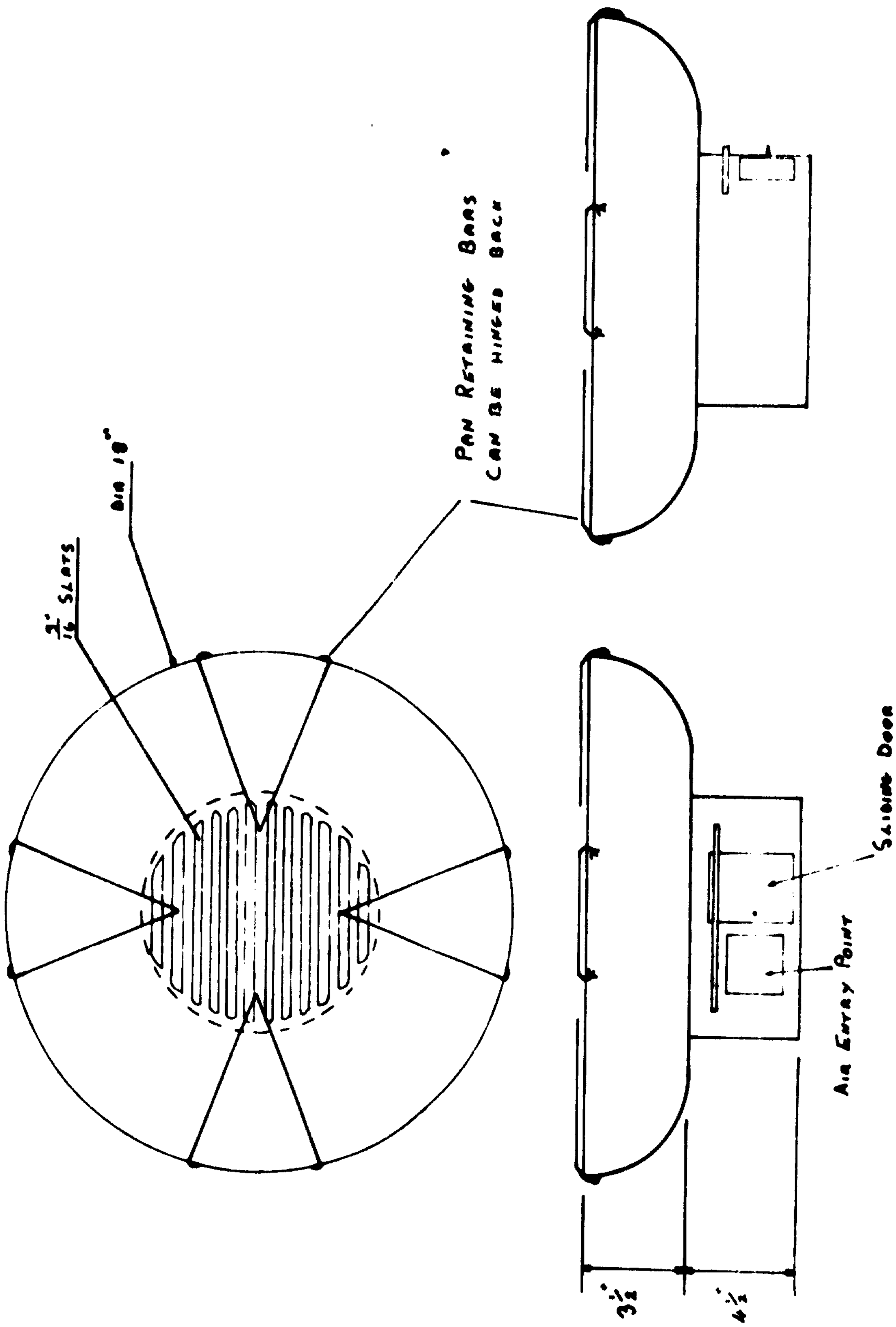
Annex V

CHARCOAL STOVE (square)



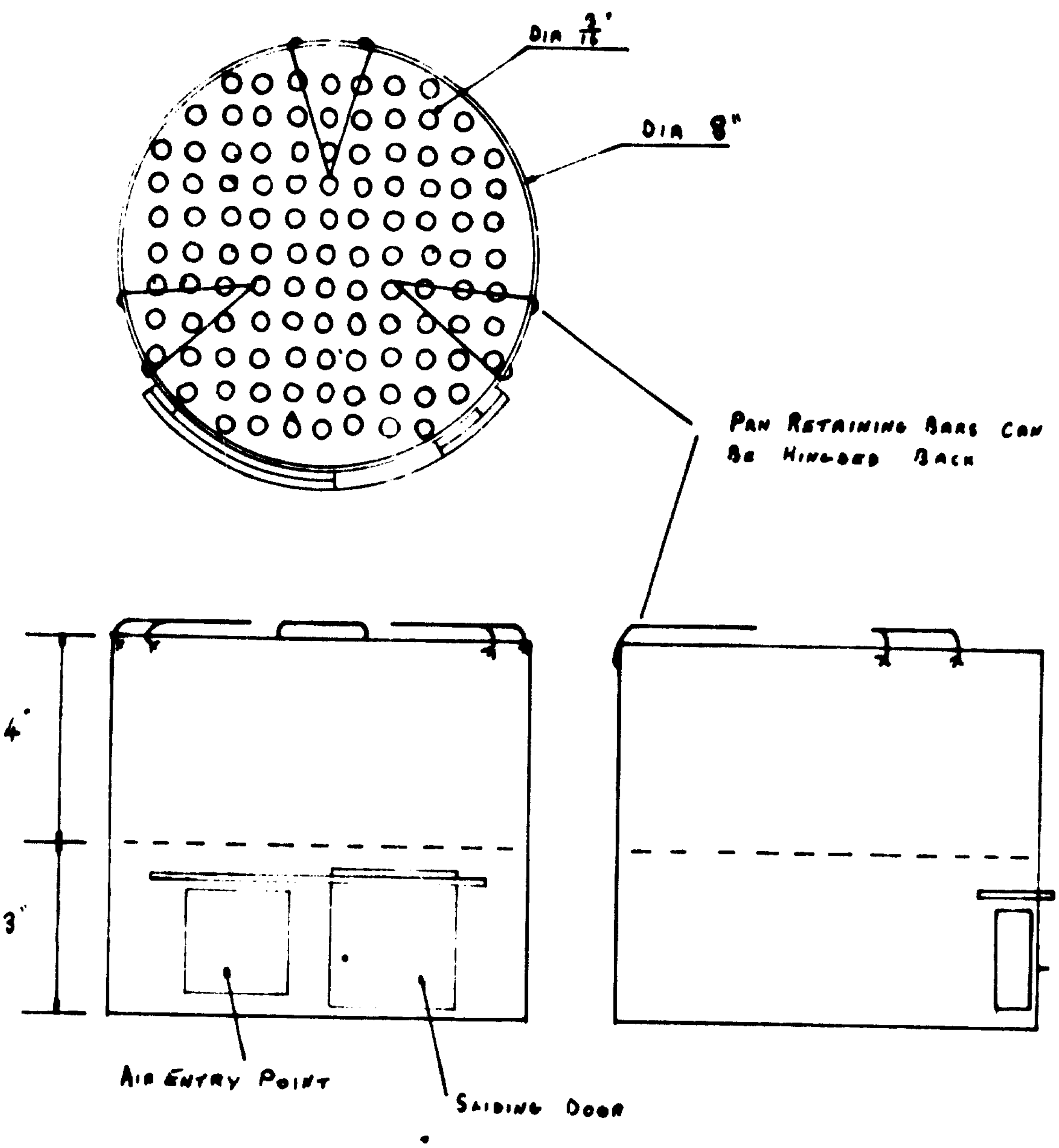
Annex VI

CHARCOAL STOVE (West Indian)



Annex VII

CHARCOAL STOVE (Indian)



ANNEX VIII

COMPARATIVE FUEL COSTS IN BELIZE

Fuel	Calorific Value Kj/Kg	Calorific Value Btu/lb	Retail Selling Price	Kj/B$	Btu/B$
Kerosene	43543	18720	B$1.20/U.S. Gall.	118498	112320
Wood (air dry 25-30% m/c)					
Stick wood sold in bundles of 3 per 24 ¢	14654	6300	B$1.00/7 lb.	46526	44100
Charcoal (proposed)	29727	12780	B$2.50/40 lb.	215726	204480
Electricity	1 Kwh=3601 Kj.	1 Kwh.=3413	B$0.18/Kwh	20005	18961

Allowing for the fact that this table gives no indication of the efficiency of the burn obtained from the different fuel sources, charcoal is confirmed as the cheapest source of domestic fuel. In one isolated small industry, the owner had a regular supply of oak cordwood delivered to his bakery at a cost of B$ 12.50 per ton.

This was the only example found where the gross calorific value per B$ exceeded that of charcoal. However, the owner was dissatisfied with wood as a bakery fuel and would prefer to use charcoal if he could be assured of a reliable supply because of the delay in starting baking operations after lighting the ovens would be reduced.

In that case the corresponding figures are:

Split cordwood (oak) sold in bulk to industry	14654	6300	B$12.50/ton	1191053	1128960

ANNEX IX

TOTAL WOOD CHARCOAL IMPORTS FOR THE UNITED KINGDOM, FRANCE AND THE UNITED STATES

Country	1971	1972	1973	1974	1975	
U.K. 1/	9,743 1,110,000 114	7,033 888,000 126	8,502 1,130,000 133	10,365 2,194,000 212	7,516 1,495,000 199	Tons US $ $/ton (C.I.F.)
U.S.A. 2/	23,545 2,023,000 86	17,063 1,891,000 111	13,220 1,231,000 93	16,981 3,595,000 212	7,942 1,695,000 213	Tons US $ $/ton (C.I.F.)
France 3/	18,729 1,536,000 82	13,137 1,368,000 104	12,276 1,368,000 111	16,390 3,705,000 226	14,580 2,713,000 186	Tons US $ $/ton (C.I.F.)

Sources:

1/ The Trade of the United Kingdom H. M. Customs and Excise

2/ U.S. Foreign Trade - Imports (F.T. 135)

3/ Statistiques du Commerce exterieur de la France

ANNEX X

SHIPPING COSTS FOR PROPOSED EXPORT OF LUMP CHARCOAL AND BRIQUETTES

Route	General Cargo and Examples of Cargo attracting special terms	Freight Rates — Equivalent Units		Freight Cost — Lump Charcoal Bulk Density = 168 kg/m^3		Freight Cost — Charcoal Briquettes Bulk Density = 429 kg/m^3	
		US$/tonne	US$/m^3	US$/tonne	B$/tonne	US$/tonne	B$/tonne
BELIZE.C.–USA	GENERAL (Harrison lines. Belize Estate and Produce)	N/A 1/	75.22	447.20	894.40	175.22	350.43
BELIZE.C.–USA 2/	Special Rate for empty oil drums (Harrison lines. Belize Estate and Produce)	N/A 1/	35.40	210.46	420.92	82.46	164.92
BELIZE.C.–USA (New York) 2/	Special Rate for Nut Shell Charcoal (Mexican Lines. Eurocarib., Belize.C.)	60.00	-	60.00	120.00	60.00	120.00
BELIZE.C.–U.K.	GENERAL (Harrison lines. Belize Estate and Produce)	N/A 1/	68.80	409.04	818.07	160.26	320.52
BELIZE.C.–U.K. 2/	Specail Rate for dehydrated papaya (Harrison lines. Belize Estate and Produce)	N/A 1/	48.16	286.33	572.65	112.18	224.37
BELIZE.C.–General Caribbean Area 2/	Special Rate only for "coal" (Harrison lines. Belize Estate and Produce)	N/A 1/	48.00	285.38	570.75	111.81	223.62

Footnotes: 1/ Not applicable if 1 tonne > 1 m^3

2/ Special rates were not published specifically for wood charcoal. The examples of cargo given are the nearest available.

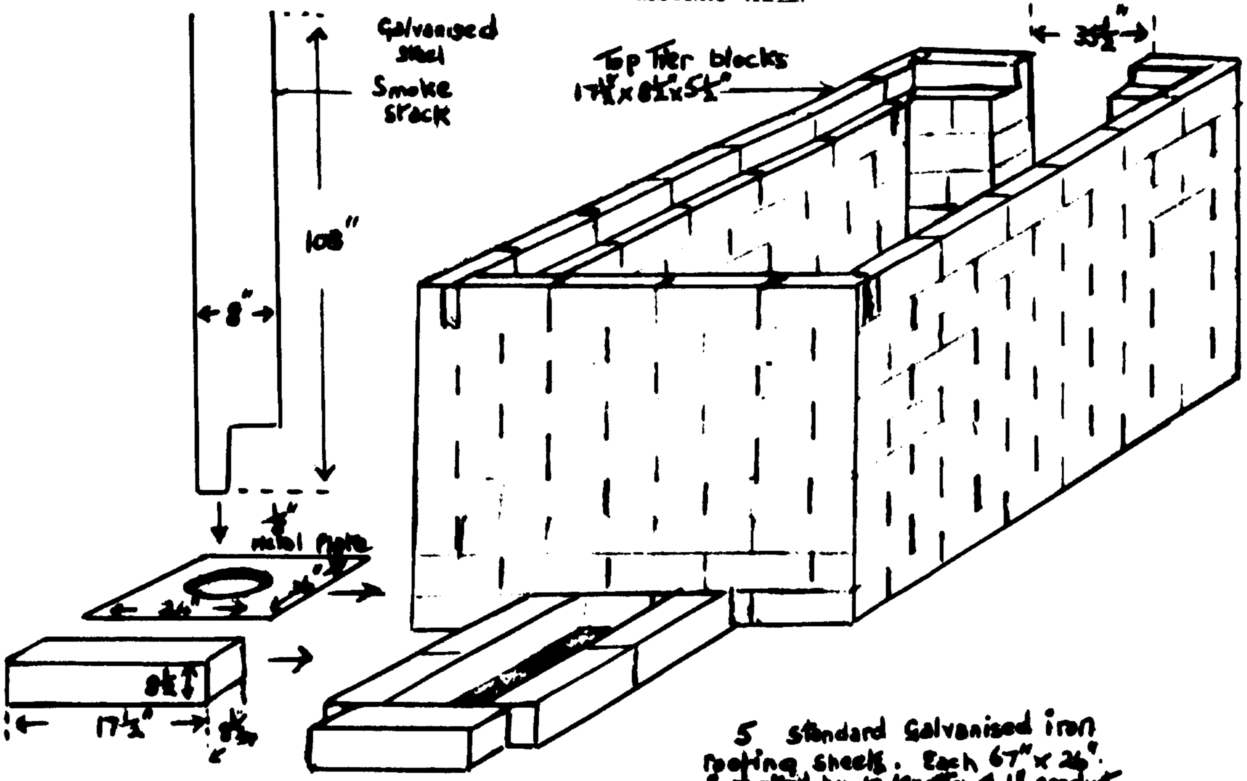
ANNEX XI

CHARCOAL PRODUCTION METHODS

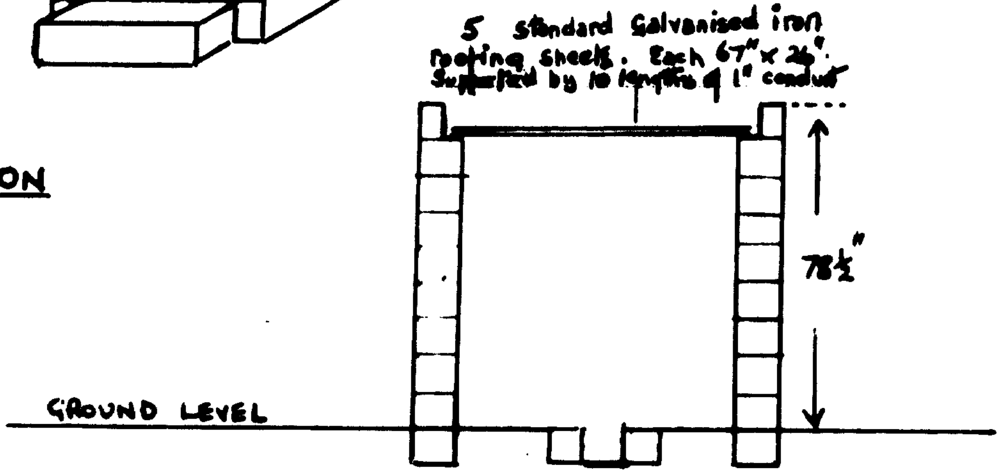
TYPE	CAPITAL COST	WOOD INPUT TYPE	WOOD INPUT QUANTITY	CHARCOAL OUTPUT	YIELD (OD BASIS)	LABOUR	SITE REQUIREMENTS
1. Industrial Carbonisation Retort	Belize$400,000 (Ex-works) + Belize $20,000 (for CIF and installation) Total CIF cost Belize $420,000	Sawmill Off-cuts or Cordwood 40 cm long 15 cm diam	20 tons/day (40% m/c oven dry basis)	5 tons per day	33%	2 men	Near to large primary wood processing complex. Good roads and access to port facilities for export potential or near to local markets. 30 Kw/220-380 V.50 PS. A/C
2. Masonry kiln	Belize$km485 (self-built)	Sawmill Off-cuts or Cordwood 30 cm. diam. 200 cm long	7 tons/week (40% m/c oven dry basis)	1.25 tons per week (2.5 tons per week for 2 units)	25-30%	2 men for 2 kilns	Large sawmills or adjacent to large clear felling programmes.
3. Portalbe Metal Kiln	Belize$3,543 CIF Belize	Sawmill Off-cuts or Cordwood 30 cm diam. 90 cm long	7 tons/week (40% m/c oven dry basis)	1.25 tons per week (2.5 tons per week for 2 units)	25%	2 men for 2 kilns	Forest floor production-small and large sawmills-clear felling programme-mangrove exploitation
4. Semi-portable Upright Metal Kiln (Shirley Aldred esign)	Belize$6,190 Ex-works + Belize$1,120 for CIF no installation required total CIF cost Belize$7310 CIF (or manufactured in Belize under license)	Sawmill Off-cuts or Cordwood 30 cm diam. 90 cm. long	14 tons/week (40% m/c o.d. basis)	2.5 tons per week	25%	2	Large sawmills - Large clear felling programmes - Mangrove exploitation
5. Continuous-bonization Retort for Finely Divided Residues	Belize$500,000 (Ex-works) + Belize $20,000 for CIF and installation. Total CIF cost Belize $ 520.000	Sawdust or Wood Chips and Shavings	5 tons/hour (60% m/c o.d. basis)	1 ton/hour or briquettes	33%	2	As in 1. above
6. Earth Clamp and Pit Kilns	Labour only	Cordwood	tons/month	Variable	Variable	2	Forest Floor Production

ANNEX XII

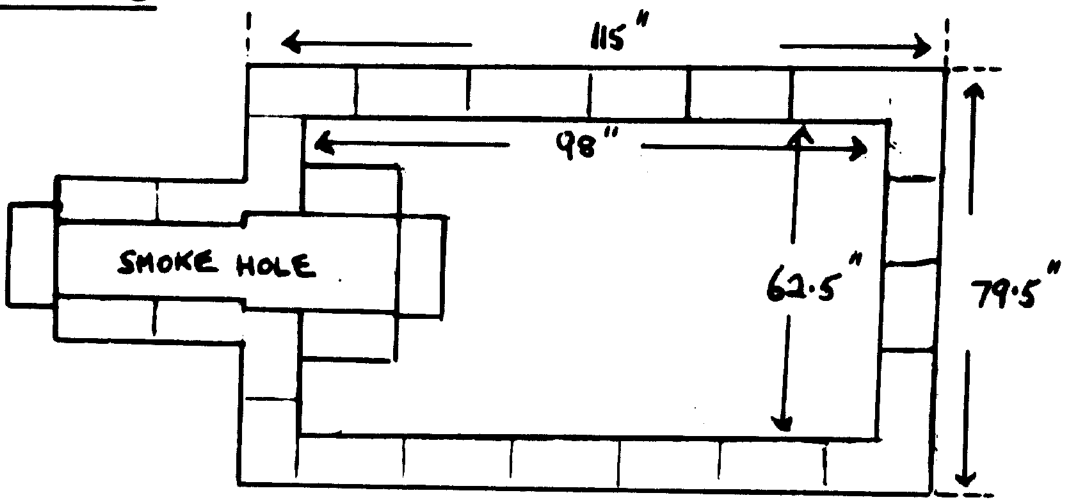
TPI MASONRY KILN



SECTION



FOUNDATIONS



ANNEX XIII

TPI PORTABLE STEEL CHARCOAL KILN

The most important feature of this kiln is its simplicity in both manufacture and operation. The kiln uses the well tried down-draught carbonisation principle.

CAPACITY

The kiln holds about 7 steres of wood (2 cords) producing approximately 500 kg of charcoal. Two men can handle two kilns and the complete process takes about two days.

DESCRIPTION

The kiln is made from rust resistant sheet steel and consists of two cylindrical sections and a cover. The bottom section is made from 3mm (10g) thick sheet and is 2320mm in diameter and 900mm high. The top section is made from 2mm (14g) sheet and is 2290mm in diameter and 800mm high. The conical cover is 2260mm diameter and 460mm high in the centre and is also made from 2mm (14g) thick sheet steel. 50mm angle hoops, welded to the inside of the top rims of the two cylinders, serve as supports for the upper section and the cover. A third hoop welded to the outside of the lower rim of the base section is necessary for increased strength and durability (Fig.1). A 50mm wide strip of 3mm thick flat tack is welded to the inside of the bottom rim of the upper section and the cover, again for strengthening purposes.

The kiln rests upon eight 200mm x 100mm section channels, each prepared by bending a single sheet of 3mm thick steel 500mm long by 500mm wide as shown in Fig.2. A 130mm diameter hole is made with its centre 100mm from one end of the channel to locate the smoke stack. Four metal smoke stacks, 127mm in diameter, and 2300mm high are required to fit into the holes at the time of draught reversal and as required during the carbonisation process. The base of each stack is cut away to half its diameter to a distance of 80mm from the bottom so that the smoke may pass freely from the channel into the stack.

RAW MATERIAL

The carbonisation time is largely proportional to the size of the wood used. However, the excessive use of fuel and man-power in cutting up the raw material is to be avoided. As a compromise the most practical size of timber for use in this kiln is about 45-60 cms long and up to 20cms in diameter. Wood with a diameter greater than this should be split prior to loading into the kiln.

It is strongly recommended that even in the tropics, wood should be cut at least 4 weeks before kilning. The high moisture content of unseasoned wood lengthens the carbonisation time and gives a lower yield of charcoal. A moisture content of less than 35% (air dry weight) is recommended. Care should be taken when seasoning for periods greater than 3 months, as deterioration of the wood could arise from fungal or insect attack.

ASSEMBLY

Site The site chosen should be well drained and roughly levelled to form a 3 metre diameter circular base. The floor of the kiln should be made as firm as possible by stamping down, and it is important to ensure a good supply of loose earth or sand around the outside of the kiln so that the air supply to the kiln can be blocked off as required.

Using a lever, the eight inlet/outlet channels should be arranged radially at equidistant intervals underneath the bottom section of the kiln.

LOADING

It is important that the inlet/outlet channels are not blocked when the bottom of the kiln is loaded with wood. This is achieved by supporting the charge on "stringers". The "stringers" are medium diameter cordwood (15cms) arranged radially like the spokes of a wheel as shown in Fig.3A. Dry kindling wood together with any inflammable waste should be placed between these billets from a point 30cms in from the outside edge of the bottom section of the kiln to the centre, (Fig.3, Section B), to provide at least 4 lighting points. A layer of wood and "brands" (incompletely carbonised wood from a previous firing) should then be placed crosswise upon the oillets and channels to form air ducts to facilitate the lighting of the charge, (Fig.3, Section C). Some old sump oil may be added to the dry kindling to assist the lighting operation. The bottom section of the kiln is now loaded with successive layers of wood, filling in as many voids as possible and placing the larger diameter timber towards the centre of the kiln. When filled the top section is lifted into place and the loading continued until the wood forms a conical shape above the brim of the top section but taking care that the cover can be located into the rim without hinderance. During the first 30 minutes of the lighting procedure, the level of the charge falls considerably. Experienced operators may wish to overfill the kiln to allow for this.

OPERATION

The cover is raised at the opposite side of the kiln to the direction of the wind (lee-side) and propped open with a piece of wood, (Fig.4). A flame is then applied to the prepared lighting points. When the kiln is well slight, and the bottom section of the kiln is hot enough (usually 30 to 60 minutes after lighting) so that a spot of water applied to the side of the kiln evaporates immediately, the spaces between the channels are covered with sand or soil, making sure that the channels are not blocked. The cover is then allowed to settle into the top rim by removing the wood used as a prop and the smoke stacks are fitted into the holes in four alternate channels, ensuring that the cut-away area of the stack is directed towards the kiln centre. The ends of these outlet channels and the base of the smoke stacks are covered with sand or soil to ensure a satisfactory 'draw' of the exhaust. The air entering the kiln flows up through the centre of the charge and the exhaust is drawn down the outer edge of the charge and is emitted via the smoke stacks.

After about 15-30 minutes each stack should emit a column of thick white smoke. If however there is a slowing down of smoke production due to lack of air then sand or soil is temporarily removed from the lighting points adjacent to the smoke stack until a satisfactory emission of smoke is achieved. After 8-10 hours the smoke stacks are moved into the adjacent channels to convert inlets to outlets and vice versa. This creates a more even carbonisation and prevents the excessive production of ash at the air inlets.

When carbonisation is complete, the colour of the smoke takes on a 'bluish' tinge and becomes almost transparent. At this stage the kiln is closed by removing the smoke stacks and completely blocking all channels with soil. Sand or soil is used to seal the angle iron rims supporting the top section and cover, and any other places where air may enter. The kiln is then allowed to cool for between 12 and 24 hours before opening. It is advisable to have a quantity of water available when unloading the charcoal so that any localised fires that may occur can be quenched. A sieve-shute may be used to assist in the unloading of the kiln and this is shown in Fig.5.

PRODUCTION

Two experienced kiln operators can produce up to 3 tons of charcoal a week using two portable metal kilns. The loading and lighting procedure for each kiln should take them approximately 3 hours followed by an 18-24 hour carbonisation period. Cooling should be achieved in 12-24 hours and the unloading of the charcoal a further 2-3 hours.

COCONUT SHELL CHARCOAL PRODUCTION

Kiln description

Although it is possible to use the same kiln as previously described for wood charcoal production, it is advisable to modify the kiln lid so that a 20cm diameter hole is made in the centre which can be closed up by means of a well-fitting cap. This will give better control during the initial lighting stages of the run. If it is not possible to provide a hole in the kiln lid, then the lid must be carefully propped open for the first 4 hours leaving a gap of not more than 5 cm on the lee side.

Raw Material

The material should consist of $\frac{1}{3}$ to $\frac{1}{2}$ size shells and these should have a moisture content of less than 20%. The best results are obtained with shells with the lowest possible moisture content.

Loading procedure

Care is taken to ensure that the shell material does not block the ends of the inlet/outlet channels inside the kiln. This is achieved by resting a flat piece of wood (a piece of rib from a dead palm frond will suffice) on the top of the end of each channel before covering with shells. The kiln is then filled leaving a 25cm deep depression in the centre where a fire is built with kindling. The kiln lid is then lifted on and propped open with a 25cm thick block of wood on the lee side.

Lighting procedure

The fire is lit at the top of the charge underneath the centre hole in the lid of the kiln. The kiln is left propped open for 20 minutes until the entire surface of the charge is well alight. At this point the lid is lowered into the top rim and the shells are allowed to burn with a completely free access of air into the kiln base. The smoke is allowed to escape through the hole in the centre of the lid, or through the 5cm gap between kiln rim and lid arranged where no centre hole in the lid exists. This state is allowed to continue for about 4 hours, until the whole of the top section of the kiln is too hot to touch with bare hands (70°C-90°C). The cap is then fitted on to the centre hole in the kiln lid (or the arranged gap between kiln rim and lid is removed) and the four chimneys are fitted into the outlet channels to promote the reverse draught.

The spaces between the channels are partially filled in with sand and left until the chimneys are producing thick white smoke. The base of the kiln, with the exception of the air inlet channels, is then totally blocked up with soil and the carbonisation is allowed to continue until the overall surface temperature of the kiln reaches about 200°C. This usually takes a further 20 hours.

At this point the quantity of smoke produced from the chimneys is seen to rapidly decrease and finally disappear to be replaced by a transparent blue haze. The kiln is then shut down.

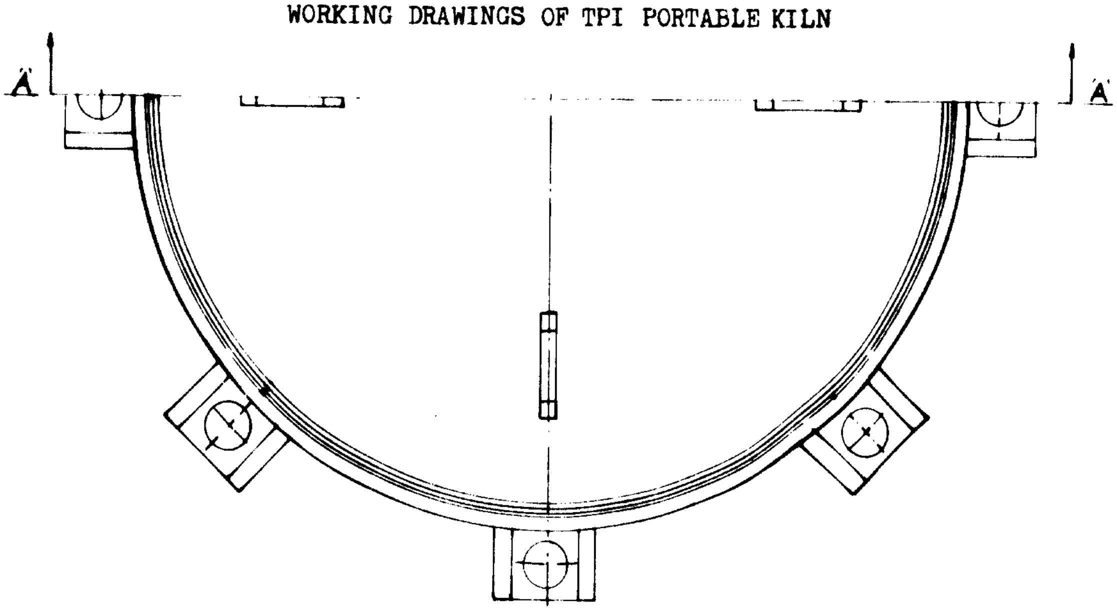
Shutdown procedure

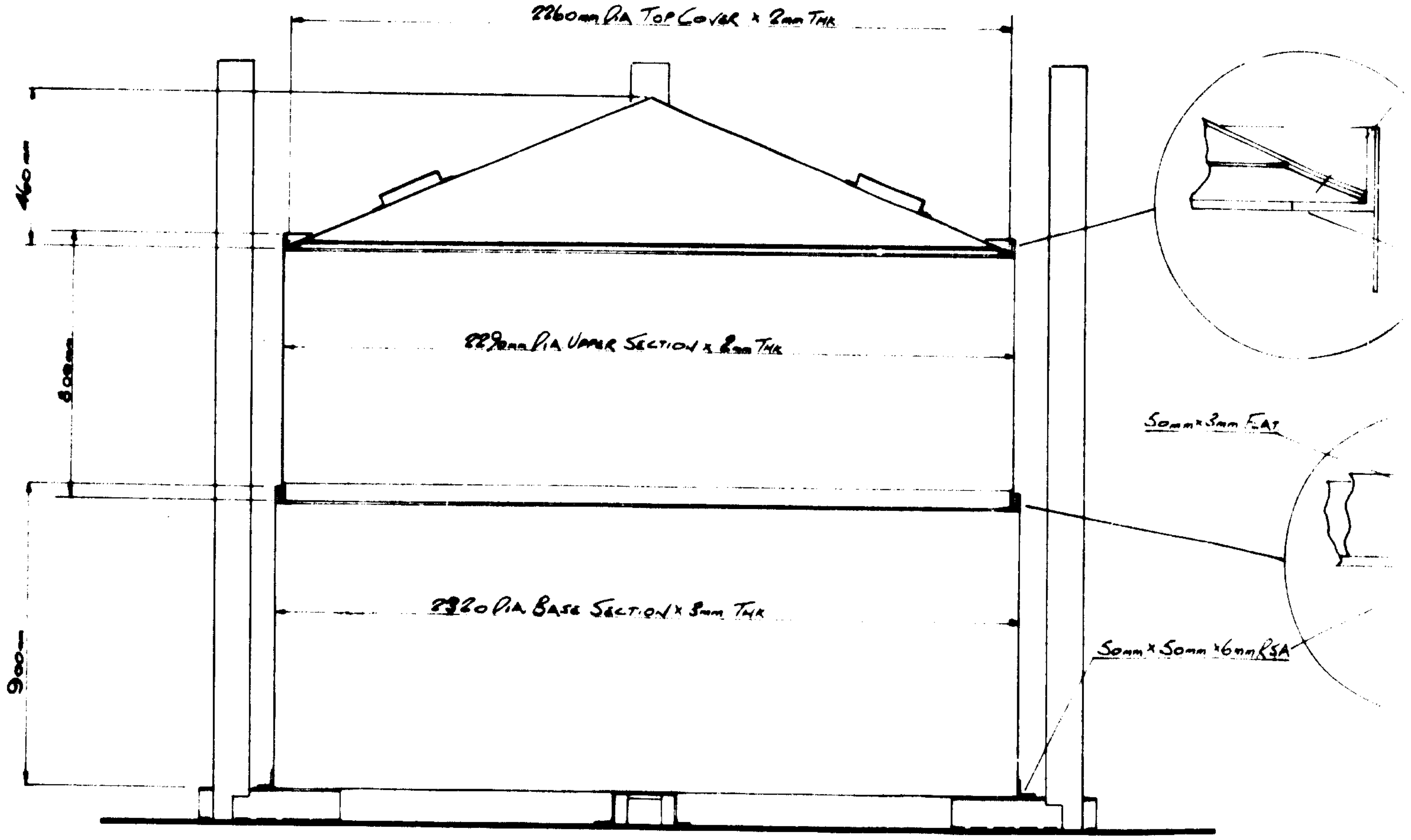
The chimneys are removed and all inlet/outlet channels are blocked up with soil. The base of the kiln is banked up with soil and fine sand is used to fill in the joints between the lower and upper section and the upper section and lid. The kiln is allowed to cool for about 20 hours.

THIRD ANGLE PROJECTIO

ANNEX XIV

WORKING DRAWINGS OF TPI PORTABLE KILN





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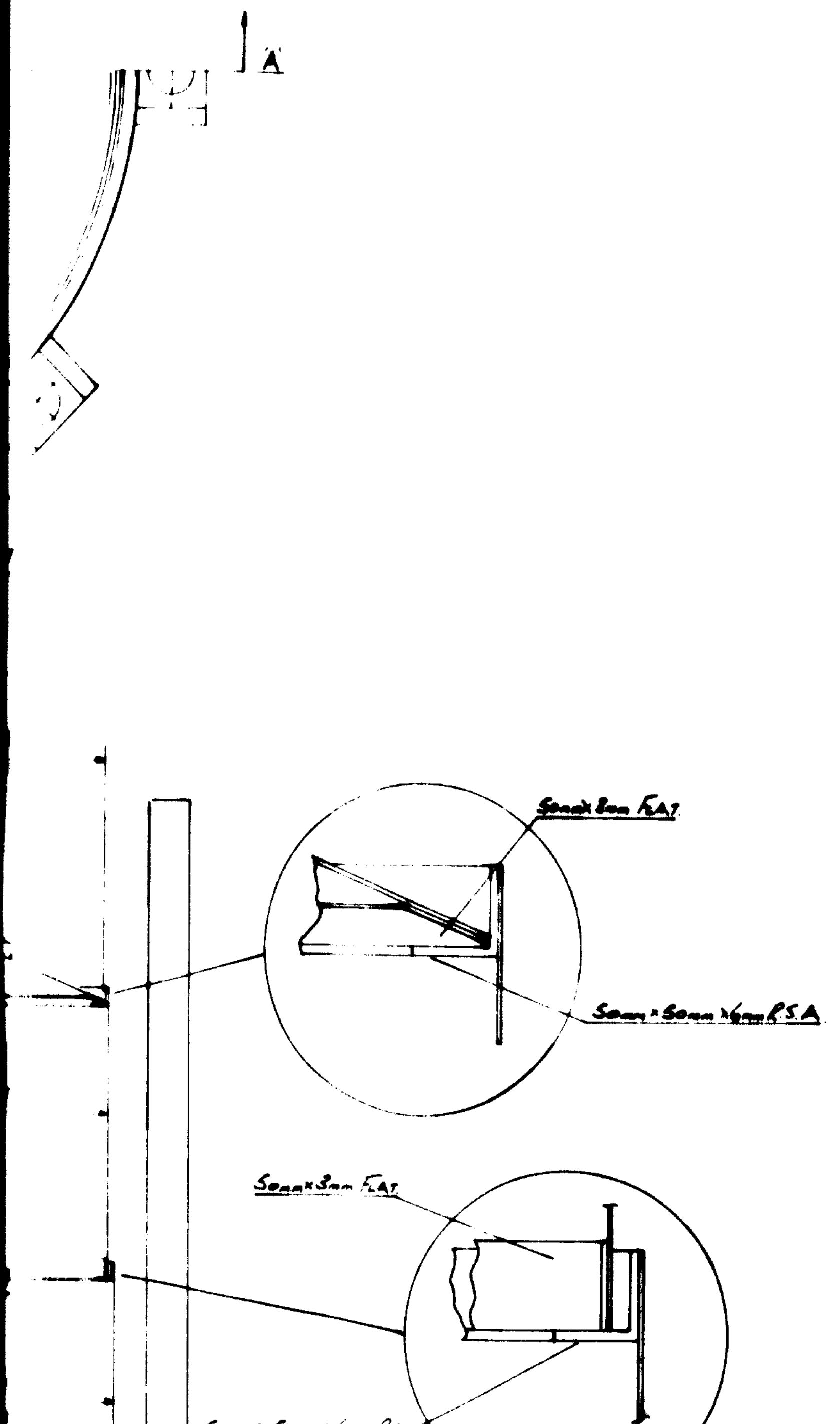
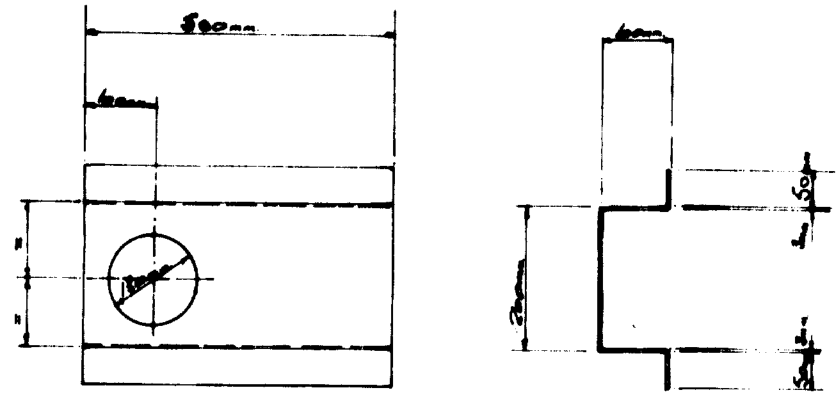
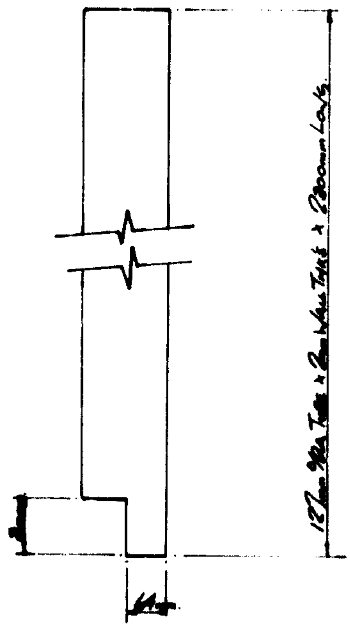
SECTION A-A

THIRD ANGLE PROJECTION

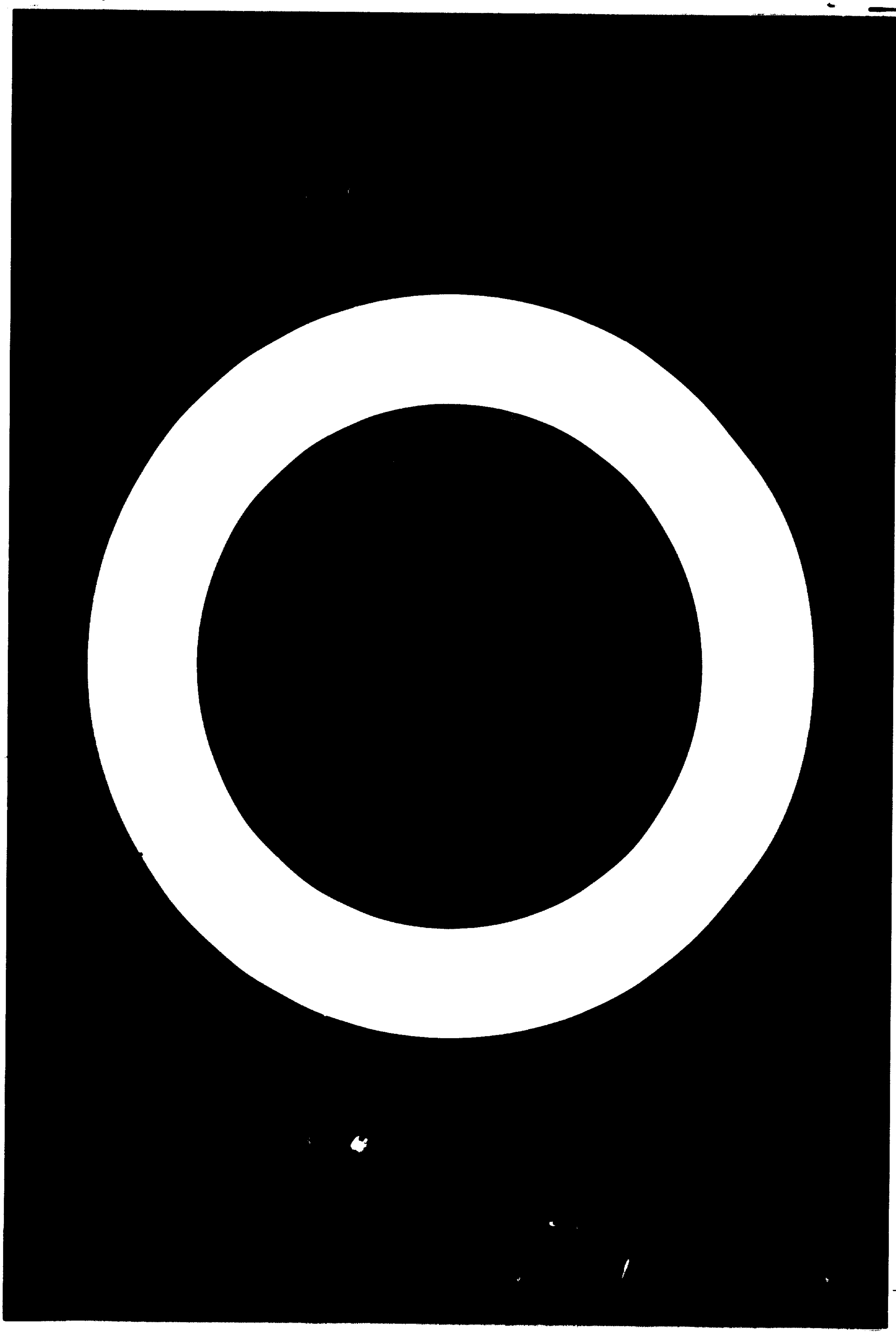




INLET/OUTLET CHANNELS
8 REQD



SMOKE STACKS
4 REQD



T.P.I. PORTABLE METAL KILN

Fig.1 **Kiln**

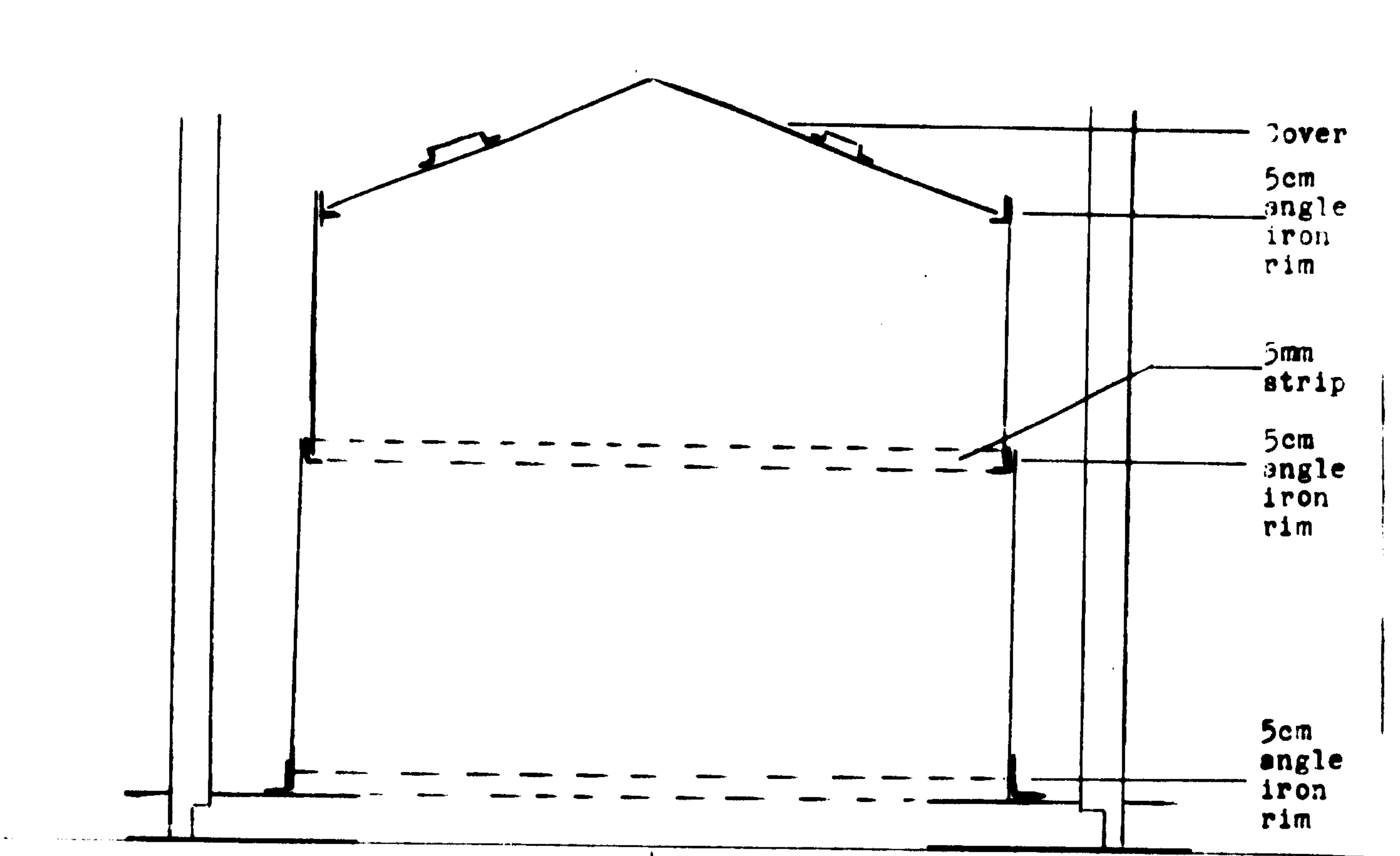


Fig.2

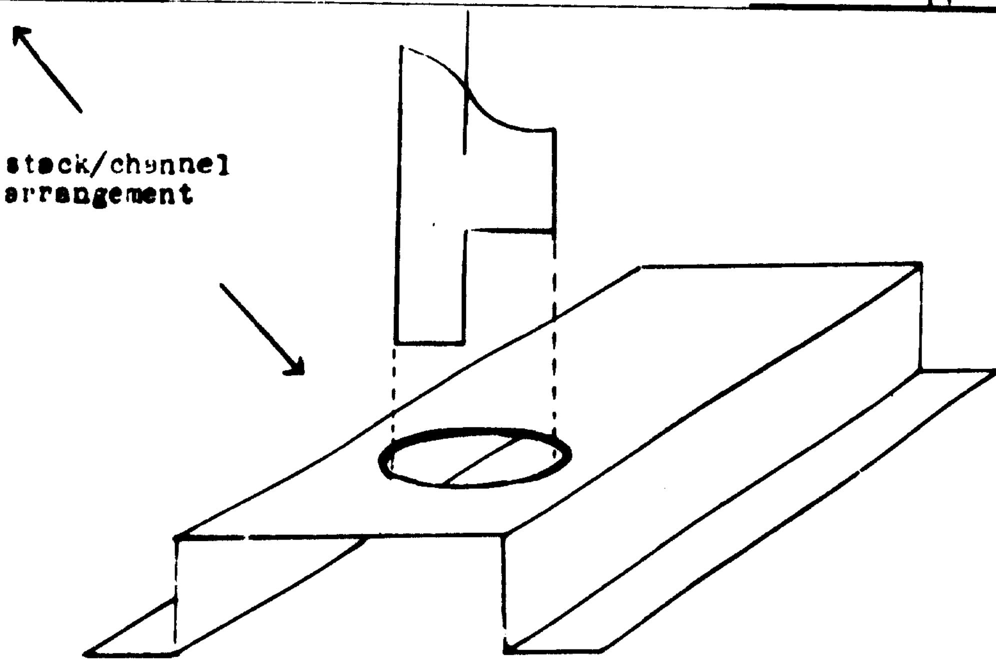


Fig.3

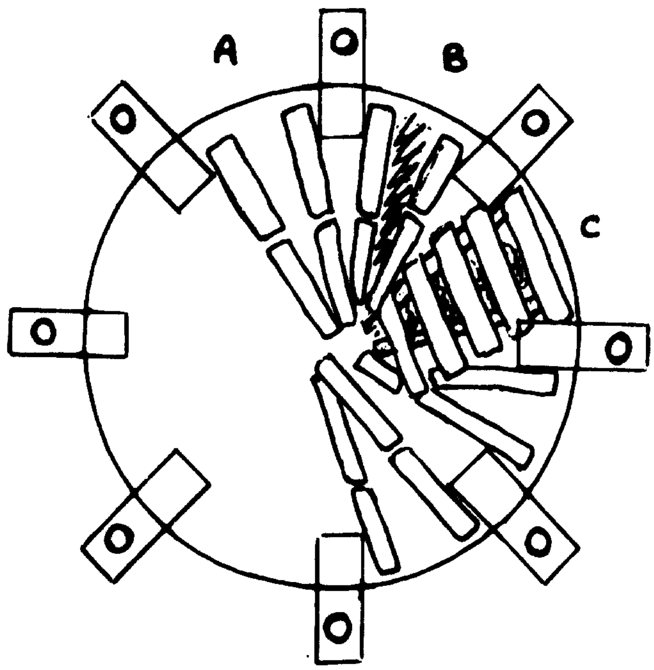
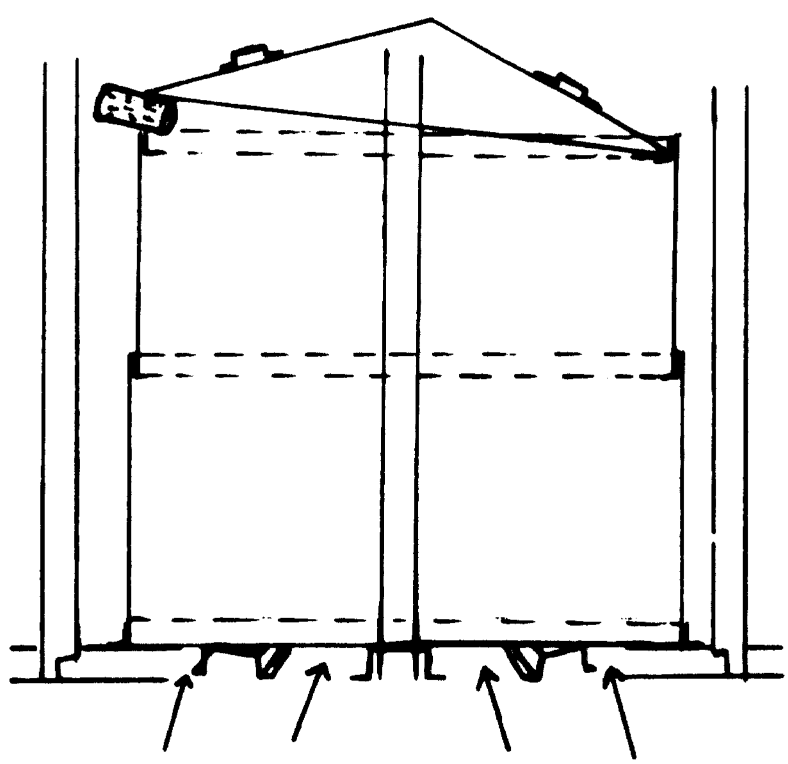
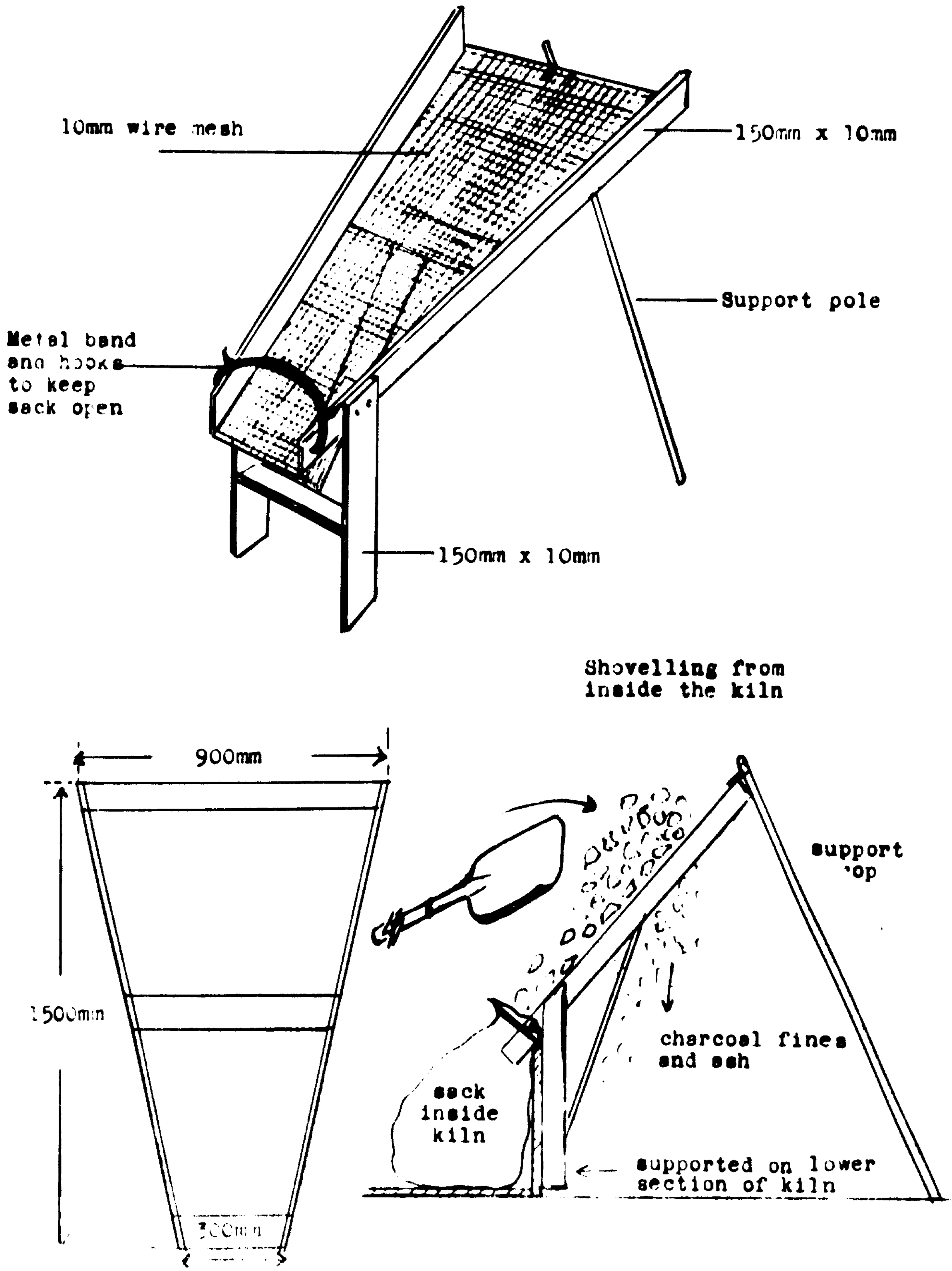


Fig.4



SIEVE-SHUTE FOR UNLOADING KILN

Fig.5



ANNEX XV

DIMENSIONS AND PROPERTIES OF WOODWOOL BUILDING SLABS ACCORDING TO **DIN 1011, 1970**

Tested after 14 days curing at 20 + 20°C and 65 + 2% relative humidity

Parameters	**Length** mm	**Width** mm	**Thickness** mm	Weight per unit area average value Kg/m^2		Gross density average value Kg/m^3		Bending strength average value minimum Kp/cm^2	Compressibility* in % of the measured initial thickness Average value maximum
Tolerances	Individual Values			Individual Value +15% Average Value... +10%				Individual Value -10%	Individual Value +10%
	+5 -10	±5	+3 -2	Single layer	Two layer	Single layer	Two layer		
Nominal Values	2000	500	15	8.5	-	570	-	17	-
			25	11.5	-	460	-	10	15
			35	14.5	-	415	-	7	18
			50	19.5	-	390	-	5	)
			75	28	36	375	480	4	) 25
			100	36	44	360	440	4	)

* **Under a load of 3 Kp/cm^2**

ANNEX XVI

WOODWOOL/CEMENT SLAB PRODUCTION -

PHYSICAL CAPITAL REQUIREMENTS

	TPI Designed Plant				MASCHINENFABRIK		ELTEN	
	DOUBLE - Acting		QUADRUPLE - Acting		REHAU PLANT		PLANT	
	I	II	III	IV	V	VI	VII	VIII
ANNUAL OUTPUTS (1)	1 shift 1110 m^3	2 shift 2219 m^3	1 shift 2219 m^3	2 shift 4439 m^3	1 shift 2108 m^3	2 shift 4217 m^3	1 shift 2416 m^3	2 shift 4832 m^3
1. Plant	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
2. Building (floor area in m^2) Inclusive of storage space for raw materials and product. The design should provide adequate protection of the contents against wind driven rain.	1451	1551	1771	1871	710	800	1080	1200
3. Land (area in m^2)	5438	5438	5800	7020	4854	6032	5100	6750
4. Works transport (10-ton lorries)	1	1	1	2	1	2	1	2

Footnotes: (1)/ At 70 % operating efficiency.

(2)/ As per T.P.I.'s or manufacturers' standard specification.

ANNEX XVII

WOODWOOL/CEMENT SLAB PRODUCTION -

CAPITAL COSTS AND WORKING CAPITAL REQUIREMENTS

(Belize $)

	TPI designed Plant				MASCHINENFABRIK REHAU PLANT		ELTEN PLANT		
	DOUBLE - ACTING		QUADRUPLE - ACTING						
	1 shift	2 shift	1 shift	2 shift	1 shift	2 shift	1 shift	2 shift	
	I	II	III	IV	V	VI	VII	VIII	
ITEMS ANNUAL OUTPUT	1110 m^3	2219 m^3	2219 m^3	4439 m^3	2108 m^3	4217 m^3	2416 m^3	4832 m^3	NOTES
PLANT	106.500 (1)	111.800 (1)	131.000 (1)	135.800 (1)	264.100	272.100	467.200	467.200	1975 Prices Includes 10% Import Duty
INSTALLATION AND COMMISSIONING	18.400	19.500	19.500	20.600	43.400	43.400	75.900	75.900	Estimated
BUILDING	69.416	74.200	84.725	89.509	33.966	38.272	51.667	57.408	Costed at $40/sq. yard
LAND	161	161	172	208	144	179	151	200	Costed at $120/acr[illegible]
OTHER CAPITAL COSTS (eg. STORAGE)	11.974	12.533	14.020	16.806	19.331	22.198	31.996	34.535	5% of Capital Item[illegible]
WORKS TRANSPORT	45.000	45.000	45.000	90.000	45.000	90.000	45.000	90.000	10 ton flat - bed truck cost B$45.0[illegible]
WORKING CAPITAL	42.262	76.685	61.262	116.095	57.264	109.147	59.329	111.717	3 months operatin[illegible] costs
TOTAL INITIAL COSTS	293.713	339.879	355.679	469.018	463.205	575.296	731.243	836.960	

Footnote: (1) The cost of the T.P.I. designed plants could be reduced by manufacturing some of the components locally and making use of locally available second hand equipment.

ANNEX XVIII

TPI DESIGNED WOODWOOL/CEMENT SLAB PLANT

ANNUAL OPERATING DATA. (1 shift = 8 hours. 1 working week = 5 days. 235 days/year)

NPUTS (1)		DOUBLE - ACTING 1 shift	DOUBLE - ACTING 2 shift	QUADRUPLE - ACTING 1 shift	QUADRUPLE - ACTING 2 shift	
		I	II	III	IV	
ANNUAL OUTPUTS (2)		1110 m^3	2219 m^3	2219 m^3	4439 m^3	
1 Timber tonnes		148.0	296.1	296.1	592.1	
2 Cement tonnes		303.3	606.6	606.6	1213.3	
3 Calcium chloride tonnes (anhydrons)		3.15	6.30	6.30	12.60	
4 Water tonnes		542.7	1042.5	871.9	1711.8	Mains supply. Includes process requirements and an additional personal consumption of 10 gallons (45.5 litres) per head per day.
Personnel:						
5 Manager	No.	1	1	1	1	DAY SHIFT ONLY
6 Supervisor/Foreman	No.	1	2	1	2	ONE PER SHIFT
7 Skilled operatives	No.	4	7	5	9	Includes one maintenance engineer per shift:
8 Semis-skilled operatives	No.	13	26	15	30	N.B. (all labour): Where the two - shift figures are odd numbers, one less operative is employed on the day shift than on the night shift. If figures are even numbers, day-shift and night-shift complements are equal except in case of row 9, column IV, where division is 10:8 (day:night)
9 Unskilled operatives	No.	6	11	9	18	
10 Clerk	No.	1	1	1	1	
11 Electricity. day. Kwh		57.528	57.528	60.348	60.348	
Electricity. night. Kwh		-	72.568	-	79.148	INCLUDES ALLOWANCE FOR LIGHTING
12 Diesel Oil litres		409	818	818	1.636	REQUIRED FOR CROSS-CUT SAW IN T.P.I. PLANT

Sources: - **Machinery manufactures and T.P.I. estimates.**

Footnotes: (1) Other, less quantifiable, recurrent inputs include lubricants spares insurance, vehicle taxation, interest payments, product promotion, social security payments, delivery, contingencies etc.

(2) These figures assume a 70% oeprating efficiency, which should be possible to achieve in Belize.

ANNEX XIX

COMMERCIALLY AVAILABLE WOODWOOL/CEMENT SLAB PLANTS

ANNUAL OPERATING DATA. (1 shift = 8 hours. 1 working week = 5 days. 235 days/year)

		MASCHINENFABRIK PLANT V	MASCHINENFABRIK PLANT VI	ELTEN PLANT VII	ELTEN PLANT VII	
INPUTS (1)		1 shift	2 shift	1 shift	2 shift	
ANNUAL OUTPUTS (2)		2108 m^3	4217 m^3	2416 m^3	4832 m^3	**Notes (see appendix.**
1 Timber tonnes		299.5	599.0	336.3	672.6	
2 Cement tonnes		614.0	1228.0	688.8	1378.0	
3 Calcium chloride tonnes (anhydrous)		7.08	14.16	7.95	15.90	
4 Water tonnes		562.8	1104.4	557.7	1094.0	
Personnel: -						
5 Manager	No.	1	1	1	1	
6 Supervisor/Foreman	No.	1	2	1	2	
7 Skilled operatives	No.	4	7	4	8	
8 Semi-skilled operatives	No.	9	18	8	16	
9 Unskilled operatives	No.	8	17	7	14	
10 Clerk	No.	1	1	1	1	
11 Electricity. day Kwh.		131.600	131.600	97.760	97.760	
Electricity. night Kwh.		-	144.760	-	110.920	
12 Diesel		-	-	-	-	Only necessary with T.P.I. Plant

Footnotes: (see APPENDIX)

ANNEX V

WOODWOOL/SLAB PRODUCTION IN BELIZE

ANNUAL OPERATING COSTS — **ALL FIGURES IN BELIZE $**

NB. 1 shift = 8 hours - 1 working week = 5 days - 1 working year= 47 weeks = 235 days

			T. P. I. PLANT			
			Double-Acting		Quadruple-Acting	
			1 shift	2 shifts	1 Shift	2 shift
			I	II	III	IV
		ANNUAL OUTPUTS	1110 m^3	2219 m^3	2219 m^3	4439 m^3
		RAW MATERIALS				
	1	Timber	2960	5922	5922	11842
	2	Cement	39611	79222	79222	158457
	3	Calcium Chloride	2236	4473	4473	8946
	4	Water	163	313	262	514
	5	Lubricants	1110	2219	2219	4439
	6	Sub-Total	46080	92149	92098	184198
Personnel	7	Manager	5000	5000	5000	5000
	8	Supervisor/Foreman	3000	6000	3000	6000
	9	Skilled	11200	19600	14000	25200
	10	Semi-Skilled	30420	60840	35100	70200
	11	Unskilled	11856	21736	17784	35568
	12	Clerical	2500	2500	2500	2500
	13	Additional Labour	8930	16429	10807	20529
	14	Sub-Total	72906	132105	88191	164997
Energy	15	Electricity(Demand Charge)	-	-	-	-
	16	Electricity(Energy Charge)	10355	23417	10863	25109
	17	Diesel oil	130	259	259	517
	18	Sub-Total	10485	23676	11122	25626
Other Costs	19	Transportation	9238	13071	13071	25984
	20	Insurance	2606	2803	3205	3424
	21	Spares and Maintencnace	7552	8029	9235	9704
	22	Product Promotion	3255	4340	4340	5425
	23	Contingencies	16928	30569	23787	45023
	24	Sub-Total	30341	45741	40567	63576
Depreciation	25	Plant	7102	7450	8738	9055
	26	Buildings	9034	9656	11023	11646
	27	Vehicles	4461	5735	5735	11471
	28	Sub-Total	20597	22841	25496	32172
Delivered Costs	29	Total before deperciation	169050	306742	245049	464381
	30	M^3 before depreciation	152.3	138.23	110.43	104.61
	31	M^2 at 25 mm(1")thickness(ditto)	3.87	3.52	2.81	2.66
	32	Total after depreciation	189647	329583	270545	496553
	33	M^3 after depreciation	170.8	148.53	121.92	111.86
	34	M^2 at 25 mm (1")thickness(ditto)	4.35	3.78	3.10	2.85

Annex XX (cont) WOODWOOL SLAB PRODUCTION IN BELIZE

ANNUAL OPERATING COSTS — ALL FIGURES IN BELIZE $

N.B. 1 shift = 8 hours - 1 working week = 5 days - 1 working year = 235 days (47 weeks)

		MASCHINENFABRIK REHAN PLANT		ELTEN PLANT	
		1 shift	2 shift	1 shift	2 shift
		V	VI	VII	VIII
	ANNUAL OUTPUTS	2108 m^3	4217 m^3	2416 m^3	4832 m^3
1	Timber	5990	11980	6726	13452
2	Cement	80188	160377	89957	179967
3	Calcium chloride	5027	10054	5645	11289
4	Water	169	331	167	328
5	Lubricants	-	-	-	-
6	Sub-Total	91374	182742	102495	205036
7	Manager	5000	5000	5000	5000
8	Supervisor/Foreman	3000	6000	3000	6000
9	Skilled	11200	19600	11200	22400
10	Semi-skilled	21060	42120	18720	37440
11	Unskilled	15808	[illegible]	13832	27664
12	Clerical	2500	[illegible]	2500	2500
13	Additional Labour	8162	[illegible]430	7559	14340
14	Sub-Total	66730	124242	61811	115344
15	Electricity (demand)	-	-	-	-
16	Electricity (Energy Charge)	23688	49745	17597	37562
17	Diesel Oil	-	-	-	-
18	Sub-Total	23688	49745	17597	37562
19	Transportation	13045	26082	14058	27966
20	Insurance	2000	2215	3238	3476
21	Spares and Maintenance	7933	8428	13380	13827
22	Product Promotion	4340	5425	4340	5425
23	Contingencies	19946	37710	20398	38231
24	Sub-Total	34219	53778	41356	60959
25	Plant	17605	18141	31146	31146
26	Buildings	4420	4976	6727	7471
27	Vehicles	5735	11470	5735	11471
28	Sub-Total	27760	34587	43608	50088
29	Total before depreciation	229056	436589	237317	446867
30	M^3 " "	108.66	103.53	98.22	92.48
31	M^2 at 25 mm(1")thickness (ditto)	2.76	2.63	2.50	2.35
32	Total after depreciation	256816	471178	280925	496955
33	M^3 " "	121.83	111.[illegible]3	116.28	102.85
34	M^3 at 25 mm(1")thickness (ditto)	3.10	2.84	2.96	2.62

ANNEX XXI

TANNIN CONTAINING MATERIALS IN BELIZE WITH COMMERCIAL POTENTIAL

SPECIES	COMMON NAME	TANNIN CONTENT % BARK	WOOD	LEAVES	AREA FOUND	PREVIOUSLY USED
Acacia spp.		10 - 32				World wide
Achras zapota	Sapodilla	21			Augustine M.P.R. High Bush	Philippines Tropical America
Anacardium occidentale	Cashew	9 - 21		23	M.P.R. Stann Creek Haltiville Burrel Boom	-
Aspidosperma megalocarpon	Milady	34			Toledo M.P.R. High Bush	Brazil
Musa sapientum (Unripe)	Banana	(skin) 30 - 40	(fruit) 8		Toledo and General	-
Bucida buceras	Bullet tree					Belize
Byrsonima crassifolia	Craboo	25			M.P.R. Stann Creek General	Belize Brazil
Dioscorea			(Tubers) 31%			Indo-china
Dalbergia stevensonii	Rosewood	14				India
Cedrela mexicana	Cedar	12.6				India, Belize
Inga spp.		17 - 25			Common Low bush	Paraguay
Persea spp.	Avocado	10 - 27			High Bush + cultivation	Chile
Pithecolobium arboreum	"Barba jolote"	12 - 37			High Bush	Philippines Belize
Quercus oleosides	Oak	20 - 35			M.P.R. Belize Valley General	World wide
Rhizophora mangle L.	Mangrove	20 - 35			Coastal Swamps	World wide
Spondias mombin L.	Hogplum				General	West Indies Guyana
Swietenia mahogarie	Mahogany	15	6		Broad leafed Forests	Belize, Jamaica
Terminalia obovata	Nargusta				Broad leafed Forest	Belize, Jamaica

ANNEX XXII

MANUFACTURERS OF SYSTEMS USING CELLULOSE WASTES AS FUEL

Energysystem	Fuels	Manufacturer
Steam Raising Boilers	Wood, Sawdust, Nutshells, Agricultural residues	Robey of Lincoln Ltd., P.O.Box 23 Canwick Road, Lincoln, LN5 8H9, U.K.
"	"	Towler and Sons. Gorse Lane Industrial Estate, Telford Road, Little Clacton, Essex, U.K.
"	"	Perkins Boilers Mansfield Raod, Derby, U.K.
"	"	Parkinson Cowan G.W.B. Ltd. P.O.Box 4 Burton Works, Dudley, Worcestershire, U.K.
"	"	International Combustion Holdings Ltd., 19, Woburn Place, London W.C.1., U.K.
"	"	Clonsast Ltd. Sarsfield House, Bransgore, Christchurch, Hants., U.K.
Air heaters using finely divided cellulosic residues as fuel.	Sawdust, Woodshavings, Groundnutshells and Coffee husks.	Riley (IC) Products., P.O.Box 115, 19, Woburn Place, London W.C.1, U.K.
"	"	Air Plants (Leicester) Ltd. Batten Street, Leicester LE2 7PB, U.K.
"	"	Tyneside Engineering Co. Ltd. Walker Road., Newcastle-upon-Tyne NE6 IBQ, U.K.
Steam Engines	Wood and Forestry and Agricultural residues	Mr. Coltman Clonsast Ltd., Sarsfield House, Bransgore, Christchurch, Hants., U.K.

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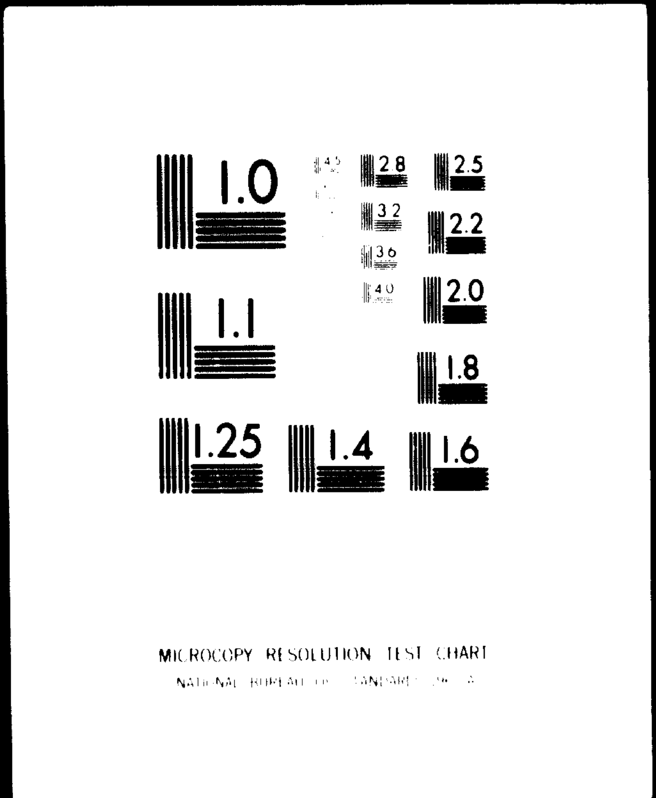

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Energy System	Fuels	Manufacturer
Steam powered generators	Steam	W.H. Allen and Sons Queens Engineering Works., Bedford, U.K.
"	"	Turney Turbines Ltd. High Mead Works, Harrow Middlesex, U.K.
Producer Gas Units	Wood off-cuts	Thalopat A.G. Feldstrasse 51 CH-8400 Winterthur Switzerland
	Charcoal	Neil and Spenser Ltd. Station Road Leatherhead Surrey, U.K.

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