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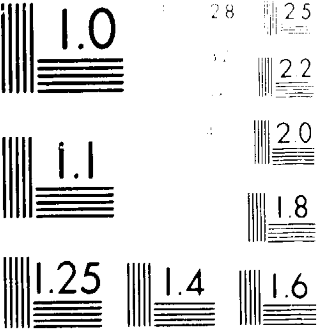
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ASSISTANCE IN CHARCOAL PRODUCTION*

SI/PNG/79/806

PAPUA NEW GUINEA

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Terminal Report

Prepared for the Government of Papua New Guinea by the United Nations Industrial Development Organization, executing agency for the United Nations Development Programme

Based on the work of Allan C. Harris, charcoal expert

United Nations Industrial Development Organization
Vienna

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CHARCOAL PRODUCTION IN PAPUA NEW GUINEA

The details of wood carbonization technology have been published in much literature already available, so that only the main relevant facts need to be set out here.

Natural Cellulosic materials of all types (wood, shells, husks) contain varying percentages of moisture, and the basis on which this moisture is stated is most important. The only scientific and firm basis is on the absolutely dry weight of the wood material (oven dry weight or basic density), with moisture content (thereafter referred to as M.C.) being expressed as a percentage of that weight.

Any statement of M.C. as a percentage of the initial green weight is a misleading, too variable basis, and changes as the wood dries. In this report the basis used will be absolutely dry weight - usually referred to as 'dry weight' as opposed to 'air-dry weight'.

The following table shows the difference of the two bases.

Percentage moisture content	
Dry basis	Wet basis
0.0%	0.0%
10.0	9.1
20.0	16.6
25.0	20.0
30.0	23.0
50.0	33.3
100.0	50.0

The stages of the carbonization process are as follows:

1. Dehydration - 100° - 120 °C. The moisture content has to be driven off before the carbonization process begins.

This takes a lot of heat, as well as slowing down the progress to the point of carbonization. It is important, therefore, to reduce the M.C. as low as possible, economically, by pre-drying (air drying or using hot waste gases).

2. Wood Heating - After the wood dries (Stage 1) the temperature rises slowly, as wood is a poor conductor of heat.

In the presence of air, dry wood will start to ignite at around 170 °C. In a kiln, the air supply is limited and controlled. In a retort it is virtually excluded.

3. Exothermic Stage - As temperatures increase beyond 170 °C, at about 250-270 °C carbonization starts - the wood composition breaks up, with the evolution of a great amount of exothermic heat, which carries on the carbonizing process to its completion, with little additional heat input being necessary.

In kiln operations, where some of the wood is burnt internally, the temperature may rise to 500 °C but normally to about 450 °C.

In externally heated retorts, the temperature normally does not rise above 450°/500 °C. The limiting temperature is that to which mild steel in the retort can be safely subjected without distortion which could cause air leaks.

In the hot-rinsing-gas retort systems higher temperatures can be obtained and tolerated but that requires a more complicated technology.

4. Cooling Stage - When carbonization is completed, no more gas is released unless the resulting charcoal is then heated to higher temperatures to drive off the volatiles absorbed in the charcoal (which may be up to 20 per cent by weight). Depending on the process and equipment used, the cooling of the charcoal in kilns usually takes from a few to many days, to reduce it to ambient temperatures. In retort systems the cooling period can be shortened considerably.

When eventually released to the open air, charcoal should be seasoned for 24 hours to stabilize it against spontaneous combustion. It should then be inert and safe for storage.

Charcoal made in kiln processes may vary from 70 - 85 per cent fixed carbon, (F.C.) with small percentages of ash and 30 to 15 per cent volatile matter, but 80 per cent F.C. is more usual. In ordinary retorts it is usual to obtain 80 to 85 per cent F.C. and in special retorts (e.g. Lambiotte) operating at much higher temperatures, up to 95 per cent fixed carbon can be obtained. In practice 90 per cent F.C. is the usual target.

Products of the Carbonizing Process

During carbonization various products are given off in gaseous form. Typical results for tropical hardwoods have been listed by Dr. D. E. Earl (after Harbottle).

Yields per 1,000 Kilograms of Dry Wood

Charcoal	300 kg.
Gas (inflammable - calorific value 2500 k/cal M3)	140 M3
Methyl alcohol (methanol)	14 litres
Acetone	3 litres
Esters (methyl acetate, ethyl formate etc.)	8 litres
Acetic acid	53 litres
Wood oils and light tar	76 litres
Creosote oil	12 litres
Pitch	30 kg.

In addition some 25 per cent water results from the decomposition of the dry wood.

Other figures given by A. C. Harris ("The Extraction of Chemicals from Wood Distillation" 1978 World Forestry Conference Jakarta), for four woody materials show the approximate yields as percentages by weight of dry woods.

Charcoal	33 to 37 %
Gas	16 to 20 %
Methanol	1 to 1.5 %
Acetone and Esters	0.25 to 0.3 %
Acetic Acid	4 to 7 % (10-12% in coconut shell)
Pyrolytic Oils (including soluble tars)	10 to 15 %
Water of Decomposition	20 to 30 %

The above figures can only be taken as indications, as they can and do vary widely with species of raw materials, carbonizing methods and equipment.

In retort processes, the gaseous products can be condensed and collected, yielding a tarry smelly liquor called pyroligneous acid (abbreviated to P.L.A.) - a mixture of chemicals listed above, and pyrolytic oils, while the non-condensible gases contain carbon monoxide, carbon dioxide, hydrogen, methane and have a calorific value of approximately 300 BTU/ft^3.

Most of the pyrolytic oils settle out of PLA on standing, but some types of tar are soluble in water, remain in the PLA proper, and can only be extracted chemically. The extraction of the chemicals from PLA is highly technical and requires a large expensive refinery.

It will be readily seen that when the gas, the settled pyrolytic oils are removed, the PLA liquor remaining is a dilute solution mainly of soluble tars, acetic acid, methanol and acetone. Unless these can be extracted a highly polluting acid liquor remains, disposal of which is a very serious problem. It can only be burnt in mixture with wood, sawdust or gas firing, and should not be confused with tars or oils. This PLA is not usable for power raising or internal combustion engines. It cannot be allowed to run into streams. or stored in earth dams whence it eats its way through the soil into water supplies causing severe water pollution and discolouration. At Wundowie, Western Australia, in spite of the refinery operation, it has caused serious problems and environmental disputes for years, necessitating special treatments to avoid litigation.

The settled pyrolytic oils can be used very satisfactorily as fuels for power raising.

Some Basic Facts About Wood Carbonization

1. The drier the wood, the quicker it carbonizes, and usually the better and harder the charcoal produced.

2. Wood dries out much faster along the grain than radially. Consequently, the shorter the wood, the quicker it carbonizes, and usually the better stronger and harder the charcoal.

3. Small dimension wood usually makes the better stronger charcoal. Sawmill "edgings" (waste) are particularly good for this reason.

4. The bulk/density of the charcoal usually varies directly as the basic density of the wood used. Heavy woods make for higher bulk densities.

5. The reduction of volatile matter, requires longer carbonizing time and higher temperatures. These factors will raise the fixed carbon as a percentage, but do not increase the actual carbon as a quantity. Whether fixed carbon above 80 per cent is of any advantage depends on the use to which the charcoal is put.

Wood Measuring Units

Without knowledge of the weight per cubic foot of the wood charged, the output of a particular size kiln or retort cannot be predicted with any degree of certainty and can only be determined by actual practical tests. This makes it hard to say how many kilns or retorts are needed at any particular centre to produce a certain weight of charcoal. Facilities for weighing are frequently unavailable, and volume measurement approximations have to be used. The commonest are the "Cord" and the "Stere" - both approximations depending on straightness and billet dimensions, so that their weights are uncertain. This makes true calculation of the charcoal production per tonne of wood very difficult.

1 cord = 1 stack of wood billets 8' x 4' x 4' (or their equivalent)

$= 128\ ft^3 = 3.63\ m^3$

1 Stere = a stack of wood billets 1.1 metres high, x pieces 1.3 m. long x 1 m. wide
$= 1.43\ M^3$

Reputed to = $1m^3$ of solid wood

In practice 1 cord = 2.5 steres (approx.)

1 cord of wood at 50 lbs/ft^3 weights approximately 2 tonnes.

WOOD CARBONIZATION PROCESSES

The processes and equipments used to carbonize woody materials divide into 2 main types.

A. KILNS - In these portion of the wood charge is burnt internally in the presence of a limited, controlled quantity of air. The heat thus engendered, raises the rest of the wood to the temperature (270° approx.) where the "charcoaling" starts, the wood is decomposed, a strong exothermic reaction sets in and this release of heat carries on the carbonizing through the remainder of the wood charge with little additional consumption of wood by burning. Temperatures rise to 40° - 450 °C usually, not sufficient to reduce the volatile matter below 15-20 per cent. Often 25 per cent volatiles result.

The 'burning' period may take several days, and requires skill and eternal vigilance to control or shut off as required, the amount of air being admitted.

The gaseous effluents (tars, chemicals, and inflammable gases) are given off to the open air in a heavy grey to black smoke, very smelly, unpleasant and polluting.

Depending on the type of kiln the cooling period can be very long ranging from days to weeks, and still requires vigilance in case the charcoal ignites from accidental access of air:

Main types of kiln in use today are:

1. Earth Kilns - pits, caves, or earth covered mounds above ground, a special type, which can be used at sawmills, replaces earth with sawdust, and is described at length elsewhere in this report. These are all labour intensive, using virtually no capital. Their use is well documented in the literatures, output on a per day basis is low and the product of uncertain quality.

2. Steel Kilns - The Uganda Mark V. developed especially by D. E. Earl is the best of its type in use today. It is portable, but is a low producer and has many of the disadvantages usual to kilns. Its life is short, (said to be 3 years) and it has become expensive. It uses much more wood to produce 1 tonne of charcoal than other types. The writer has seen it used and abandoned in Sri Lanka and Gurinan.

3. Brick Kilns - The large beehive type which may have an operating cycle of a month, and operational problems similar to other types. It cannot be recommended for Papua New Guinea. A particular version, is the small Brazilian Beehive Kiln, used for the charcoal-iron industries in the State of Minas Gerais, Brazil. The writer believes this to be the best of this type, and there has been recently developed in Brazil an improved type. (See later references). It could have a place in Papua New Guinea today.

4. Cement (Reinforced) Kilns - The best and most commonly used of this type is the Missouri Kiln of USA which lends itself to large scale operating and more mechanization than other types. It is significant that Earl the developer and champion of the Uganda Mark V portable steel kiln, is now using the Missouri in Ghana, under his direction as FAO representative.

An improvement, enabling the burning of the effluent vapours to eliminate the usual pollution from kilns, is available, and the literature has been made available by the writer to the PNG Department of Minerals and Energy. Details concerning the erection and operation of this Kiln have also been made available to the PNG authorities concerned. However it is an expensive addition.

5. Other Types - Many other types have been tried and abandoned. It was interesting to find near Rabaul an old abandoned Thomas Continuous Kiln a type which never really succeeded and was horrible to operate.

In 1969, Earl on a visit to USA found that no Thomas Kilns were any longer in existence.

General Remarks

In general, kilns use more wood per ton of charcoal than efficient retorts, which recover the heat from the effluent gases produced, and in some cases from extracting the heat of the charcoal in the cooling process, and re-using it.

Retorts

Retorts are charged with wood, then sealed against entrance of air, the wood then being 'baked' and not 'burnt' as in kilns.

There are 2 main types of large retorts in use today:

A. Externally heated by gas, wood or oil. These are all operated on a batch system.

B. Internally heated by hot inert gas (free from air). These types are all described at considerable length in literature made available by the writer to the PNG authorities, and are covered by the writings of Earl, Harris and Constantine as listed in the bibliography at the rear of this report. They may be either continuous or batch operated.

TYPE A

(i) The Crossett - horizontal, batch operated, used in USA and at Wundowie, West Australia (1947-78). Now superseded.

(ii) The Constantine - large horizontal, batch operated - a great improvement in design on the Crossett, eliminating most of its problems; still used at Wundowie, though being superseded by the Lambiotte retort, but not for reasons of failure.

(iii) The West Indies small horizontal retort, being experimented with near Chimbu and at Lae University of Technology. It is discussed later on in more details.

TYPE B

Retorts internally heated by very hot "rinsing-gas" free from oxygen. The gas used can be wood gas, blast furnace gas, producer gas or natural gas, depending on the best available source. When operating, some of the retort's own vapours are re-heated and re-used as 'rinsing-gas'.

The best known in use today are:

(i) The Reichert - a batch operation with the charcoal discharged hot into sealed air tight containers to cool.

(ii) The Lambiotte - a continuous retort - the high point of wood carbonization technology.

The hot rinsing-gas comes from the same source as for the Reichert. Charcoal is cooled in the base of the retort by passing cold inert gas (oxygen free) through it; this gas thus becomes very hot and passes up into the carbonizing zone of the retort, thus conserving heat with corresponding economies. The retort operates at high temperature (600-650° C) and requires heat and acid resistant steels in the top half.

(iii) The Constantine System

A batch of vertical retorts similar to the Reichert, internally heated with hot rinsing gas as in the Reichert and Lambiotte; then cooled with cold inert gas as in the Lambiotte. It is obviously a system mid-way between the other two. Can be made in mild steel if operated at temperatures not exceeding 550° C. (This applies also to the Reichert). Its advantages and operation are set out in Harris's 1978 paper to the 8th World Forestry Conference in Indonesia. Also in Constantines paper "Manufacture of Charcoal" (1975).

These hot-rinsing gas retort systems are highly technical and suitable mainly for large scale operations backed by competent technical staffs. They involve large capital expenditure, but have low labour and maintenance costs. They last indefinitely.

Portable Retorts

1. The Lambiotte Portable - see also Harris' 1978 paper. Sure to be technically excellent, but too expensive for its productivity rate. Technologically complex. Not considered suitable for PNG.

2. The Constantine Portable - See also Harris' 1978 paper, where it is discussed at length.

   There are two versions producing 1 and 2 tons per cycle respectively. The production rate depends on the time cycle, which is affected by climate, humidity, M. C. of the wood, basic density, size of wood etc. Under West Australian conditions, the time cycle is 2 days. It might be 2 1/2 to 3 days in tropical regions. Only experiment would tell.

Continuous Furnaces

These are virtually continuous hot-rinsing gas 'retorts' for carbonizing fine materials - sawdust, chips, nutshells, small cellusosic wastes of all types. They are described in the literature made available to PNG authorities by the writer. They are large units producing 7,000 tons of charcoal (or more) per annum.

The two best known types, which are very similar are:

1. Herreshoff - of New York.

2. B. S. P. Envirotsch - of California.

They are capital intensive but have low labour costs. Production rates are high. They have been operating for a long time successfully.

3. A related system, Tech-air from Georgia, is being reported on in PNG by Dr. J. Tatom of USA - as described in his report to the PNG Department of Minerals and Energy. (See bibliography). The writer has no personal experience of this system, beyond the literature. A similar operation is being experimented with by Tatom in Indonesia, and

has been currently investigated by Dr. K. Newcombe, Energy Planner, PNG Department of Minerals and Energy and Professor David Fussey of the Lae (PNG) University of Technology. The writer is not in a position to make much comment on this new process at present. Only time will tell if Tatom's 25 ton/day retort (7,500 T/year) will be an improvement on the Herreshoff and B. S. P. systems which are well proven over many years.

TYPES OF CARBONIZING SYSTEMS RECOMMENDED FOR PAPUA NEW GUINEA

Because of the varied nature of the situation met within Papua New Guinea, it is considered desirable to experiment with several types to determine their suitability and applicability to the local scene; and to local labour particularly

Kilns:

1. The Brick lined Pit System used in Sri Lanka for coconut shell.

2. The Sawdust covered kiln - at or near sawmills. Described elsewhere.

3. The Missouri Kiln - The best of the large kilns, especially at sawmills with large wood wastes already accumulated. Sizes used in USA range through 30, 40, 50 to 80 'Cord' capacity.

   The 50 cord kiln is the commonest and for various practical reasons, seems the best and safest size for PNG conditions. It is discussed at more length further on.

   A smaller size (say 30 cord) can be used, of course, where wood supplies are lower. In general, the larger the kiln within reason, the lower the capital cost per ton of capacity. The kiln door frame and door costs are the same for all sizes and have to be well made to keep a good air seal. The one piece door is often preferred today, over the 2 door ringed type, and is handled by a front end loader for removal and replacement. The door is tightly wedged onto the frame with a gasket for sealing purposes.

4. The small Brazilian Beehive Kiln (brick construction). Details of this kiln are given in Earl's USA/Brazil report (1969) a copy of which has been left with the Department of Minerals and Energy. It contains drawings for construction, but it is suggested that while in Brazil, Dr. Newcombe try to obtain more precise details.

Retorts

A. For coconut shell and wood

1. The West Indian retort - fully discussed elsewhere.

2. The Constantine "Portable" retort

(a) 1 tonne type - for small operations

(b) 2 tonne type - for large scale operations.

B. For large accumulations of sawdust, shavings, and small cellulosic type materials

1. The Herreshoff continuous furnace (Retort)

2. The BSP/Envirotech continuous furnace (Retort)

These are very similar. Both have been in use satisfactorily for many years, are reliable, efficient and high producers. A typical unit produces some 7,000 tonnes of charcoal per year, but larger ones are available. By-product gases can be burnt or condensed for 'oils' etc. Information on these has been given to the Department of Minerals and Energy. Whether one of these is to be used could only be decided after completion of the Georgia Tech-Air system demonstration currently projected.

3. The Georgia (Tech-air) system

The principles involved are not new. It is undergoing tests in Indonesia and a pilot plant is proposed for Lae. It remains to be seen whether it is any better than the Herreshoff or BSP/Envirotech which are tried and proven. At this stage, it is not possible to say whether the claims made for yields of charcoal, 'oils' and gases, based on USA experience and woods will be substantiated for the tropical hardwoods of PNG. Experience elsewhere with tropical hardwoods suggests otherwise.

(See figures quoted by Earl elsewhere in this report.)

ADVANTAGES AND DISADVANTAGES OF MAIN CARBONIZING SYSTEMS SUITED TO PAPUA NEW GUINEA CONDITIONS

These are set out fairly well generally in Dr. Earl's book "Forest Energy and Economic Development" p. 30.

Comparison between Missouri Kilns and Constantine portable retorts must be more specific for Papua New Guinea.

ADVANTAGES	DISADVANTAGES
Missouri Kiln	
1. Can use long wood, short blocks, and larger dimension wood.	1. Effluent gas heat is lost. Needs an after-burner to avoid pollution of air, soil etc.
2. Mechanised loading and unloading (front end loader)	2. Needs skilled operation and constant watching, over some days.
3. If used in large groups of kilns, is not labour intensive and skilled supervision is easier (1 foreman per shift). With large groups of kilns continuous operation of a shift basis is virtually necessary.	3. Long cycle, slow carbonizing and cooling (10-14 days) 4. Life: Comparatively short - 8 years - depending on maintenance standards 5. Quality control of charcoal more difficult than in a retort.
4. Can be built locally from cement and steel reinforcing rods. (Details have been given to the Department of Minerals and Energy).	6. If 'burn' goes out, restarting is more difficult. May need to cool off, before recharging to avoid fire breaking out. 7. Severe internal fire may reduce the charge to ashes. 8. At renewal in 8 years capital cost should be higher due to inflation.
Constantine, Mark II Report	
1. Has to use short (10 cm blocks) but at a sawmill, these are cheaply produced. Short wood dries out and carbonizes quicker.	1. Cost of reducing wood to short blocks - a small cost at sawmills, with slashery saws. Elsewhere, it needs simple 'docking saw' machinery to cut blocks. A mobile unit has been used at Wundowie (see under 'Selectively logged areas').
2. Loading can be mechanized; unloading - partly so.	2. Unloading - can be mechanized in part - not completely. May need a little more labour than the Missouri Kiln process.
3. Life span - 15 years (possibly 20 years). Longer life than kiln offsets inflation escalations.	3. Higher capital outlay initially, per unit. (But is compensated for by longer life). (Based on its longer life (15 years) capital cost per tonne is approximately equal to Missouri Kilns).

Constantine Mark II Report

Advantages

4. Less skill needed to operate than for kilns. Uses less wood per tonne of charcoal.
5. Short cycle - 2 to 3 days depending on M.C.
6. Good quality control.
7. Large scale operation easily supervised by a skilled foreman. Continuous operation possible with 3 shifts.
8. Burns all its own effluent gases thus avoiding pollution.
9. External heat provided by wood plus its own gases (800 kg wood/1 tonne charcoal). The wood can be low grade - even coconut husks.
10. The smaller Mark I version, could be operated by a family group, on a smaller scale.

CAPITAL COSTS

Missouri Kiln:

Capacity - 50 cords. Life - 8 years

Using concrete roof - cycle 14-15 days

Using steel roof - cycle 10-11 days

Cycles per year 30 - USA output 20 tonnes per cycle

- Because of M.C. and lighter wood in PNG will probably not exceed 480 tonnes/year output.

Cost per kiln (estimated)	K10,000
Cost per kiln after-burner	K 3,500 (necessary to stop air pollution)
Total:	K13,500

Capital cost per tonne of charcoal over its life

$$\frac{K13,500}{8 \text{ years} \times 480 \text{ tonnes}} = \underline{K3.50}/\text{tonne}$$

In practice 1 burner can cope with 2 kilns if they are operated on a staggered cycle basis. Cost of each burner (estimated) K7,000. Such burners are in use in USA.

Constantine Mark II Retort

Capacity	- 200 tonnes/year of charcoal under PGN conditions
Life	- 15 years (may be 20 years - At Wundowie, a similar type of externally heated retorts has lasted up to 25 years).
Capital Cost	- K10,000 and K200 licence fee (approx. say).
Total Licence Fee	- K10,000 - single payment initially, no subsequent payments for any number of retorts.

In view of the possible use of such retorts at Goroka (Lapegu) Bulolo, and Lae (possibly 75 retorts) the licence fee is negligible - about K133 per retort. Any number can be built from drawings and know-how supplied, without any additional fees.

GENERAL APPRAISAL OF THE MISSOURI AND CONSTANTINE PROCESSES

For use at fixed sites (sawmills) with long life, there is little to choose between the Missouri and the Constantine. Each system has its own merits, and demerits which would probably cancel out. Both would produce charcoal at around 80 per cent F.C.

It might be advisable to try out both systems at the same sites. They are not incompatible. Only experience in PNG conditions will decide the issue.

In some places, the smaller portable Constantine (MKI) may have advantages, but is less economic. Where air pollution is not any real concern, the Missouri can cost less to install because no after burner is necessary, though desirable. However in large groups of kilns, burners would be necessary as the air pollution would be intolerable, in the present age, especially near roads and towns.

Neither system will make the collection of 'oils' possible. But the heat of the off gases is lost in the case of the kiln. Some way to use it for drying may be worked out.

A battery of Missouri kilns would take up less area than a battery of Constantine retorts, for the same output. The latter need more space left around each for the loading, firing and unloading operations. This aspect could be important at Lae where the land area available might be limited. This aspect alone, might make the use of Missouri kilns preferable.

Deciding between the two systems is difficult, but on the whole, the writer leans toward the Missouri, at this stage. The licence fee for the Constantine may be a drawback, whereas the Missouri does not involve one. The writer would have to negotiate for PNG over the use of Constantine Mark II. The smaller Mark I, would be easier in this regard and cost very little to obtain but it is less economic in terms of capital and operation costs, and does not seem the way to go for any large operation. It was this aspect which led to the development of the larger Mark II version.

Where a number of Missouri kilns are used together, competent supervision would supply the extra skill involved. Their construction in PNG might be easier and quicker, and there are no obstacles to securing any licence quickly. The writer is also conscious of his closer involvement with the development of the Constantine retort, and wishes to avoid any appearance of bias toward it.

In both cases, productive capacity will be affected by the basic densities of the wood to be carbonized, moisture content, and general weather conditions, which could well vary, for instance, between the highlands (where air drying is said to be better) and the coast at Lae. Thus production rate predictions for PNG must be accepted with some caution and reservations. Only practical testing will give the correct answers.

With a conversion rate of 6 to 6 1/2 tonnes air-dry wood per tonne of charcoal, the kiln consumes somewhat more wood per tonne of charcoal, but the writer does not consider this important for the foreseeable future in PNG. Markets for the final product will be the most important consideration and there could be a surplus of wood to dispose of.

After some years of experience, more definite conclusions can be formed about the way to go in future.

Operation of Constantine Portable Retorts

1. The original design (Mark I) produced "1 tonne" of wood charcoal per cycle (2 days) under West Australia conditions (warm, dry Oct. - April; rainy (25") during May - Sept.), the cycle was 43-48 hours from loading to emptying cold charcoal. Internal capacity 190 ft^3. Actual weight of wood charged was 95 per cent of the theoretical volume.

2. A "2 tonne" version (Mark II) on similar lines has been developed. Cooling time is somewhat longer. In PNG conditions, the cycle could be 3 days. There have been improvements to the design for loading and unloading, for a more mechanized operation, more suited to Australian working conditions and labour costs, than the Mark I, but suitable for PNG also.

3. The original design was restricted to an overall diameter of 8 ft. to allow road movement under Australian traffic regulations. This restriction may not apply here.

4. Some increase in diameter would be possible under less strict traffic regulations but there is a limit imposed by heat transfer from the perimeter of the retort chamber to the centre of the charge, and from the central chimney.

5. The operation of Mark I version was as follows, for a single retort:

(It would be virtually the same for the larger Mark II).

Operation	Manpower	Time (hours)
Loading	2	4
Drying)	1	4 to 6
Carbonizing)		9
Cooling	-	20
Emptying into bags	2	4
		43 hours

This was based on air dried 12" long blacks - (2,100 kg weight) at about 14 per cent M.C. (dry basis) (over-dry weight of charge approx. 1,800 kg).

Yield was 900 kg charcoal at fixed carbon 79 to 80 per cent, ash 1 per cent, volatiles 19-20 per cent (including free moisture 1.5 per cent). The charcoal yield on a dry basis was approx. 40 to 45 per cent. The fuel wood used for externally heating the retort was approx. 800 kg per charge, obviously due to the low M.C. of the charge, aided by the off gases from the retort. The fuel wood was also at about 15 per cent M.C.

6. Such good results would probably be hard to duplicate in Papua New Guinea, because of:

(a) Lower basic density of woods;

(b) Higher moisture content of woods;

(c) Higher atmospheric humidity.

Both the latter would hinder air drying.

Operational Procedure

Loading: Wood is cut to 12" maximum lengths. It is stacked through side doors placed near the top as lightly as possible to avoid air pockets. The retort held 3 tonnes of air dry wood.

(The Mark II loads through doors on the top.)

Carbonizing: After lighting a wood fire in the fire box, increase the firing as fast as possible to start carbonization of the outer layers of the wood charged. This starts the exothermic reaction which hastens further carbonization.

The butterfly valve at the top of the central chimney remains only slightly open to ensure even heat distribution over the total heating surfaces, and slow down the passage of the heating gases.

Depending on moisture content, drying should be virtually complete in 4 to 6 hours when the first traces of "pyroligneous acid" grey vapour will appear. As this gas flow increases, the amount of firewood used in the firebox can be reduced, but it is important to keep the firebox grate at all times with burning wood. The exothermic reaction action in the retort can be quite violent, and some of the effluent gases may have to be passed to atmosphere, for 4-6 hours, otherwise the fire may be smothered by the excess gaseous fuel, depriving the fire of sufficient air.

During this period, the gaspipes ("downcomers") leading to the firebox have to be cleaned of condensed tars - about every 2 hours. Only the lower parts clog up, and caps are removable to allow this.

Carbonization is complete when the pyroligneous vapours change colour from smokey grey to a bluish haze, and the volume of vapour diminishes. At this stage, the operator should fill the firebox with wood for a final heat up, to drive off occluded volatiles as much as possible.

Cooling: Open the flue damper fully and the firebox door for rapid cooling. Convection draws air around the retorts external surfaces and through the central chimney.

Emptying: When the retorts feel lukewarm open the bottom retort doors only, and rake out the charcoal into bags. Hooks for the bags are provided on the sides of the retort.

General: If two retorts were coupled and operated out of phase, it would be possible to avoid some of the loss of pyroligneous vapours discharged to atmosphere, but this could go on ad infinitum, and could run into some practical difficulties in so doing.

The solution for waste of gas may lie in having some pipes into the firebox away from the firing door to admit extra air to overcome the blanketing effect of the rush of pyroligneous vapours.

In a situation where portability is not needed (e.g. a coconut shell situation where the crop is drawn annually from the same area, unlike forest fuels) some fuel heat may be conserved by external insulation. Some tar deposition in the 'downcomers' could also be obviated by insulation, keeping the gases hotter.

Obviously moisture content of the charge has a limiting and critical effect on the time cycle and therefore output capacity.

Where road transport regulations can be relaxed a somewhat larger diameter could be considered. The retort's inner diameter could be increased from 7 ft. to 8 ft., and the central chimney from 9 inches to say 15 inches, without significantly impairing heat transfer from the heating surfaces. Such a change could increase the retort capacity by about 20 per cent but increase the heat transfer surface area by 23 per cent, and the radial distance between the chimney and the retort's outer surface by only 4 inches, which should not be significant.

Likewise the height of the retort chamber could be increased. Loading from the ground becomes more difficult, but is not an insuperable problem. The Mark II has greater height to give increased capacity, in any case, but provides for mechanized loading.

There is obviously room for experiment with the principles involved.

Operational advantages

The retort operation requires less skill and less prolonged vigilance than that of a kiln. The firebox cannot be overloaded to any appreciable extent. If neglect allows the fire to go out, the retort charge just "sits" until the fire is relit. The carbonizing time is much shorter than in a kiln, and also the cooling time.

With a kiln, constant vigilance is needed, and skilled manipulation to increase or decrease the air intake. Carelessness can allow the kiln fire to go out, whereupon the whole charge may have to be dismantled, and rebuilt; alternatively too much air could reduce the charge to ashes.

This vigilance is needed over a much longer period than with a retort operation, and is far more critical.

The longer time cycle of kilns is offset to some extent by their larger size (e.g. the Missouri).

The life of the retort properly made, should be much longer than a kiln's based on experience with large externally fired steel retorts, and maintenance should also be much less.

It is essential however that the retort is well constructed and air tight, with proper attention to the gaskets of the loading and unloading doors.

Finally, air pollution is avoided quite inexpensively, by burning the gases produced in the firebox.

Disadvantages

The need to reduce wood to 1 ft. lengths is one 'disadvantage' but it is not a serious problem at sawmills where simple docking equipment is available. On a larger scale e.g. at Lae, a simple multiple saw arrangement can be installed to reduce long slabs to blocks quickly, automatically, and cheaply.

Loading into retorts would be by hand, though the Mark II provides for using a front end loader if available.

The blocks being shorter, dry out and carbonize more quickly.

On the other hand, the large Missouri kiln can use long sawmill waste slabs cut to 6 ft. say, for better stacking, and loading can be done by front end loader.

VISITS TO TYPICAL SITUATIONS

The main situations in PNG under consideration for carbonization technology are of 5 types, depending on the source of the wood to be used.

1. Eucalyptus plantations
2. Sawmill wastes (edgings, sawdust, shavings)
3. Rubber plantation replanting
4. Coconut shells.
5. Logging wastes - natural forests.

Typical cases of these various situations have been visited and studied by the writer, in the company of government officials and operatives in industries with the projects. These are discussed hereunder separately.

MT. HAGEN

Tea factories using oil or direct wood firing, but interested in charcoal as an alternative, were visited.

The plantations at Wahgi Swamp, were composed of Eucalyptus (E. robusta, E. grandis) both excellent, and another E. (punctata??) - apparently a Northern NSW coast eucalypt which showed excellent growth and should be identified. If it were a species of higher basic identity than E. grandis it would be important to know. This plantation scheme showed great promise, for fuel wood/ charcoal supplies.

It was also inspected with 2 Victorian cement industry executives. They stated that in their process (vertical kiln) charcoal usage would not be likely to improve beyond 1 ton of charcoal to 5 tons of cement. A Belgian company, Cimenteries CBR S.A. is also showing interest and claims to have a vertical kiln which would operate at a ratio of 1 to 9.

A visit was made with Dr. Newcombe to Mr. V. Chamberlin - a missionary who is undertaking charcoal production with earth and also sawdust kiln types of operation. He was not happy with the problems and cost involved.

Also he was importing steel to make some Uganda Mark V type portable kilns. These seem likely to be very expensive (in excess of K2,000) and disappointing in operation. It is hard to see them improving his cost structure and he may have labour problems with them. Their "portability" may prove an illusion in this mountainous terrain.

The construction and operation of a Philippines type simple kiln using sawmill wastes, covered with sawdust instead of earth was described to Mr. Chamberlin. His operations in future should be kept under observation as he may have problems he does not yet realise, although he has obviously made some study of charcoal making literature. His efforts seem worthy of encouragement and advice.

THE PHILIPPINES SAWDUST KILN

This simple kiln is a variant of the earth kiln, suitable for operation at or near a sawmill, preferably on a slight slope. Green sawdust is used instead of earth, to cover the wood to be charred, which may be mill waste, or even bush wood, though mill waste is the logical material. Mill edgings seem to make the best charcoal. Stakes from mill edgings are driven into the ground to support two fences of other mill edgings or 'face cuts', about 6 feet apart, and 3 to 4 ft. high running up the slope, for about 30 feet. Inside these fences mill waste is stacked closely longitudinally. At the top end two pipes are placed vertically to act as chimneys. The whole stack is then covered deeply with sawdust. At the lower end kindling placed under the wood charge is lit and that end is kept open until a strong blaze is going. Then sawdust is applied to almost cover the end allowing only enough air in to keep the fire going sufficiently. From then on the operation is the same as for an earth kiln. When heavy grey-black smoke comes out the chimneys at the top end the charring process has begun. Access of further air is then controlled just enough to keep the process going. When only a simmering hazy light blue smoke finally emerges from the chimneys, the air entrance at the bottom is closed completely with green sawdust packed down hard with the flat of a shovel.

The kiln is then left to cool. Only experience will tell how long this will take - perhaps 2 to 3 days. The kiln is then opened progressively from the bottom - the first wood charred and therefore likely to be the coolest charcoal.

If it appears still to be hot and liable to burn, cover it up again with green sawdust, until testing shows it is cool. The superiority of sawdust over soil is that it dries out more slowly and if it starts to smoulder it goes black and tends to hang together and "bridge". A hot spot can be covered with more green sawdust which will tend to stop any further charring and breakthrough.

If the lower level of sawdust next to the wood chars, as some will, it will only make charcoal dust, which unlike soil is not contaminating to the lump charcoal.

Even for carbonizing bushwood, it might be advisable to cart sawdust from a nearby mill, a reasonable distance, rather than use soil.

On top of the stacked mill waste in the kiln, it would be a good idea to have a layer of the widest flattest slabs to form a support for the sawdust.

Any insufficiently charred wood ("brands") should be put back into the next kiln built.

The use of a slope ensures the heat and "smoke" travelling up the kiln to the chimneys at the top.

This kiln should be easier to watch and control than an earth kiln. The technique warrants serious study and experiment. Keeping the length of this kiln to 30 feet seems desirable, as it reduces the burning/cooling cycle. Better to have more kilns, operating on a staggered time basis, so that as new ones are burning others are cooling and being opened.

In the Philippines, the writer has seen this kiln operated by a mother and young children with the mother (a Chinese) explaining the process! Her husband operated the nearby small sawmill.

Samples of the charcoal were obtained. The lumps gave a metallic ring on striking pieces together and were strong and of good quality. From the writer's experience the F.C. was probably 80 per cent.

Very rough examples of this method were seen at some sawmills just by covering large spread out waste stacks. But there was no real control, and the quality seemed very uneven, and poor. That practice is too slapdash and uncertain.

KUNDIAWA

At Kundiawa near Chimbu, a small West Indian retort was being made by Mr. Carl Loeffler, using corrugated steel culvert materials instead of old 44 gallon drums. Various aspects of its operation were discussed. For small scale operations by individuals it has obvious merits. Made from old oil drums it should be cheap to construct.

Some improvement might be made if more than one exit was made for retort gases into the firebed below, to spread the gases more evenly, and thus ensure more uniform carbonization throughout the whole length of the retort. This idea would warrant experimenting with. The sudden rush of gas through one small exit at one end could have a dampening effect on the fire, and might even lose some gas from the front of the fire bed. Closer study of this operation is warranted.

Mr. K. Tissaverasinghe and Mr. Mike Blowers of Lae University have conducted some experiments at Lae with such a retort. The charcoal resulted in fixed carbon ranging from about 71 to 80 per cent at the extremes, but most batches ranged about 75 per cent fixed carbon. No tests were made to compare the fixed carbons of charcoal at the front and rear ends of the retort, and whether it was uniform from top to bottom. Eventually such checks on quality should be made. Some charcoal if not properly carbonized can look black but have low fixed carbon, about 65 per cent.

SIZE OF A WEST INDIAN RETORT

Some experiment should be made with a larger diameter West Indian retort say by 25 per cent, which would increase the retort volume by 55 per cent, or by 50 per cent with an increase of 125 per cent for the same tending period.

Possibly a curved sheet of $\frac{1}{8}$th steel should be welded along the bottom third of the 'retort' cylinder to shield the bottom metal from the more intense heat from the wood fire to which it will be subjected, as compared with the sides and top, as wood fires are notoriously very hot. This strip should prolong its life, yet not impede heat transmission from the fire bed.

Improperly carbonized wood is easily recognised on withdrawal, as only the surface charcoal breaks away. Such 'brands' should be put back in the next wood charge.

Judging from experience with the dimensions of the Constantine retort, a diameter of 3.125 ft. in this drum type retort would allow adequate heat penetration, aided by the exothermic reaction. The drum retort has an internal diameter of 1.8 ft. Therefore this larger diameter (74 per cent increase) would give 3 times the internal volume, i.e. 3 times the charcoal per cycle.

The cooling period may be a little longer, but could be hastened by a series of several chimney pipes 6 inches in diameter through the covering of earth covered by caps, so that they are inoperative during carbonization. On starting the cooling phase, these caps would be removed. Convection should then draw cool air through the firebox around the retort. In this way, it may be possible to still keep the cycle to 24 hours. Experiments on these lines should be made as only experience will confirm the ideas involved.

GOROKA DISTRICT

With Mr. Ian Prochtor, Manager of Eastern Highlands Timber Co., Mr. K. Tissaverasinghe and Prof. D. Fussey of Lae University, a visit was paid to the company's sawmill. This was reached by a long very rough mountain road.

The mill produces large quantities of wood waste and sawdust. Discussions ranged over the best type of carbonization equipment for this site. It was considered not feasible to use Constantine Portable retorts (1 ton/day) due to the difficulties of access. After assessing the waste supply, the use of a 50 cord Missouri Kiln was recommended, as the construction materials (Cement, steel rod, etc.) could be more easily carted in.

The accumulation of a continuous reserve of mill waste to air dry was also recommended. The operation of a sawdust covered kiln was described; such would be preferable to an earth kiln in any case, but considerations of space and terrain seemed to rule out such kilns.

A visit was also paid to the proposed Lapegu mill site at the pine plantations, where there will be a lot of waste wood in a couple of years. Here the easy terrain would permit of using a Constantine retort, but a Missouri Kiln would be a good alternative. As this project is still some time away, more knowledge of the probable waste supply must be obtained before deciding on what process to use.

Pine waste wood will make good charcoal, and as Pinus patula predominates (a heavy wood) it would be comparable with charcoal from many native species as regards weight.

About 80 tonnes per week of mill wastes were expected.

LAE

South Pacific Timber Co. - This appears to be the most promising site for a large charcoal operation. This is a very large sawmill complex. Mr. Bervan Peterson, Production Manager, of this mill, accompanied the writer on an inspection tour, and supplied the following information.

Log Intake 70,000 m^3/year. There is talk of a 20 per cent increased intake soon.

Timber recovery	-	42%
Sawdust	-	10%
Waste	-	45% (= 31,000 m^3)
Estimated mill waste	-	150 tons/day
Estimated log yard dockings	-	40 tons/day
Estimated Veneer mill waste	-	10 tons/day
Total		200 tons/day

This is more than Dr. Tatom's estimates, but the differences do not affect the overall approach to the situation. (1000 super feet of waste = 3 tons (green) - say 2 tons, oven dry weight).

The climate is very wet, but mill waste will air-dry if kept for some time; no hope of drying below 20 per cent M.C. Timber kiln dried to 12 per cent returns to 20 per cent in the open air at Lae.

Planer mill shavings	-	16% of 20,000 super feet
= 3200 super ft/day	=	approx. 6 tons/day, dry weight

Mr. Peterson considers that the sawmill has 30 years log supply ahead. This would have an important bearing on the type of charcoal plant to be installed.

It was pointed out that a charcoal retort would require waste edgings to be docked to at least 12" lengths. He saw no difficulty in putting in a slasher saw deck to achieve this economically.

After discussions of the effect of moisture content on carbonization, he realised that large stocks of wood must be left to air dry, perhaps for some months - either in block form for retorts or 6 to 8 ft. lengths depending on kiln dimensions.

If a retort system was used, 200 tons of waste, after air drying should yield about 40 tons of charcoal per day or 40 t x 5 days x 48 weeks = 9,600 t/yr. The Constantine 2 ton retort would be suitable for this, also.

Assuming that in this climate, such a retort would produce 200 tons/year, it would require 48 retorts!! All effluent gases would be burnt under the retorts, thus avoiding air pollution!

Alternatively, Missouri Kilns could be used. They would have to be equipped to burn all the effluent gases, because so close to Lae, the air pollution and smells would be intolerable. Literature on such burning equipment has been made available to the Department of Minerals and Energy, but it increases the cost of the kiln very considerably, and could have some technical problems in a large scale operation due to congestion in the area. This burning problem is discussed elsewhere in a detailed examination of the Missouri kiln. It would require some 25 x 50 cord kilns, in place of the retorts.

Mr. Peterson stated that some 30 per cent of log intake is Anisoptera with a basic density of 35 lbs per cubic foot, the balance being much lighter woods. This would affect calculations of charcoal yields, as available experience of yields from overseas operations is with heavier woods. Charcoal yields vary directly with basic density.

Bulolo Mill - Mr. Peterson estimated that this company's mill at Bulolo would yield about 2,250 tons, dry weight of waste per month, say 27,000 t/year. In addition there are big stacks of waste accumulated already.

As air pollution from off gases may not be of so much concern in that locality, Missouri kilns can be the equipment to use for charcoal production. This mill was not visited, but the writer did see it some years ago and has a general idea of the locality.

In any case, the off gases could be burnt if necessary, but this involves extra capital expense.

Of course Constantine retorts could be used, if road conditions would permit of them being transported into Bulolo from the coast.

RUBBER PLANTATIONS (Sogeri, Kanussia, Maribor)

These were visited with Plantation Manager - Mr. Davis Longhurst, and Mr. Jack Zieck of the Forestry Department. The letter to Mr. W. H. Hastie (of 2/7/79) from the Department of Minerals and Energy was studied. It gave estimates of rubber wood availability for carbonization, and output of charcoal.

It was stated by Mr. Longhurst that 75 per cent of the rubber plantation area was steep mountain country. Only 25 per cent was reasonably easy terrain. The problem here would be one of logistics - getting wood to kilns, and charcoal down out of the steep slopes. Possibly the wood could be snigged downhill to the valley. Portable kilns (e.g. Uganda Mark V) could not be moved about on such slopes. Brazil Brick Beehive type kilns being fixed would pose logistic problems in steep country. If earth kilns on the slopes were used, serious soil and terrain disturbance would result - leading to erosion and possibly ruining the soil horizons. Charcoal would have to be carted out in bags by man power - a difficult operation.

The wood volumes stated (100 trees/acre x 1 ton per tree) seemed too optimistic. It would in my opinion be not more than half of that volume on the average. Therefore the whole rubber plantation charcoal scheme needs to be re-thought.

On the 25 per cent area, with easy terrain, Brazilian Kilns should be all right. They should be operated in batches of at least 10, as in Brazil, to conserve labour spent in long hours merely watching the kilns.

A Brazil operation at Dionisio, in Minas Gerais State had a 21 kilns unit. It is understood that Dr. Newcombe will be visiting Brazil, and he should try to inspect this operation carried out for the Monlevade Charcoal-iron and Steel works of Belgo-Mineira Company near Belo Horizonte. He should also get details of the organization of the operative labour, which is very efficient. (See also Earl's 1969 report on his visit to Dionisio. The writer visited it in 1973 and confirmed Earl's data and report on it.)

A recent improvement in design has been the subject of a report by Laercio Osse, who works in that region. This is held by FAO Rome, it is in Portuguese, but a Spanish translation by H. E. Booth of FAO Rome is available there. Mr. Booth passed this information to the writer very recently. (FAO should be approached for a copy of their report - "Lena carbon y Carbonizacion".)

In Brazil, each kiln produces about 160 tons of charcoal per year, operated continuously, but the climate is not so wet as in PNG and the eucalyptus wood used is allowed to air dry first for from 3 to 6 months. Therefore the annual production in PNG may be much less. The charcoal produced weighed 250 kg/m^3 bulk density, the wood used being predominantly Eucalyptus grandis. Heavier eucalypts produce 290 to 300 kg/m^3.

Mr. Colin Levy, Forest Products Research Branch thinks that a percentage of the rubber trees would be suitable for sawn timber. This would make extraction more viable, e.g. by snigging all wood in long lengths down to a valley bottom. There the segregation of logs and charcoal wood could be done. He should be consulted for details of this proposal. A solution is desirable for the renewal of rubber plantations at minimum cost. In this approach Constantine retorts could well be used, as a sawmill operation would make production of short blocks easy and cheap.

COCONUT SHELL CHARCOAL

Rabaul District

A general survey of the situation near Rabaul was carried out with Mr. Edward Owen of Department of Labour and Industry. Coconut Shell Charcoal is recognised as a very superior grade of charcoal if properly made.

It is hard, strong and much sought after for activated charcoal manufacture. The main problem in its production is the collection of sufficient shells at various places to warrant establishment of good charcoal producing units.

Present knowledge of quantities and supply centres seems inadequate and a careful thoroughgoing census is essential. It may involve a personal visit by officers of the Department to all potential suppliers and very searching questioning. Traditional methods in Sri Lanka involve brick lined pits, but have all the disadvantages of kiln systems. It may not be easy to get workers to use pits, as the work is unpleasant. Quality control is uncertain. Details of the pits and operation could be secured from Hayley's of Colombo, and/or the Coconut Research Institute there. Small scale production by private operators could be based on the use of the West Indian retort which seems a better approach. At larger plantation centres, Constantine "portable" retorts (1 tonne and 2 tonne types) could be used. In all cases the shells need to be broken up a bit, to enable closer packing than is possible with hemispherical shells. This is essential in a retort to reduce air inside and maximize the charcoal produced per cycle - i.e. use the retort to full capacity.

Retort firing could be done by shell, husks or wood, assisted by its own effluent gases (Constantine system).

Earth kilns are too likely to produce charcoal contaminated by dirt - a serious drawback for activated charcoal.

Fixed carbon of 80 per cent is desirable for charcoal for activation. However Hayley's pit kiln charcoal is only 75 per cent F.C.

Hayley's steam activation process in Sri Lanka which the writer has inspected, is simple. An inclined rotary kiln has high temperature steam passed through it from the lower end. This removes the volatiles (tars and gases) adsorbed in the charcoal, leaving a microscopic honey comb structure which is the basis of its activation properties.

Some of the charcoal is oxidized also in the process, so that the weight of the charcoal decreases considerably, but this is offset by the higher prices obtainable. The steam process itself is not highly technical - marketing is the problem as there are restrictive policies to be overcome. However, the Department of Labour and Industry is aware of these problems and has information on outlets.

Some shopping around might find that the price of the know-how currently asked by one interested company is rather high, and the company's real value may be more in its marketing know-how and contacts. However, there appears to be a number of interested organizations. The writer has not available knowledge of their proposals and terms, on which to express an opinion to guide the Department of Labour and Industry in its choice.

Valuable information on Activation is given in Earl's "Forest Energy and Economic Development". Also a copy of a Wundowie W. A. report compiled by G. Gouteff on Activation processes has been given to the Department of Minerals and Energy. Several relevant leaflets from the Philippines have also been made available with this report.

It is understood that Bayley's estimate that 4,000 tons of charcoal would be necessary for an economic activation plant, producing 1,000 tons. This would require at least 16,000 tons of shells - approximately 100 million shells per year.

The shells are thin and consequently dry quickly to a low moisture content; also their thinness allows rapid heat conduction. Consequently they carbonize more quickly than wood, produce harder stronger charcoal, and less fuel is consumed in the carbonizing process. These factors would account for the unusually high conversion ratio claimed, of 4 tons of shell to 1 ton of charcoal; it is sometimes claimed to be only 3 to 1, but accurate weights of shell are difficult to get.

A solar kiln being used for drying Balsa wood at Keravat sawmill near Rabaul, could be adapted for copra drying. Such a development could release a great quantity of shell now burnt in that process, and avoid contamination of the copra by smoke. It seems desirable to get Mr. Colin Levy of the Forestry Department's Research Branch, who is a kiln drying expert, to study and co-operate in the development of the solar kiln. From discussions with him, the writer has concluded that his ideas could make a valuable contribution.

(Although there is said to be no price differential currently for copra not smoke affected, that may not always be the case, and clean copra could conceivably have some edge in a more competitive market.)

In the vicinity of this sawmill, where sawdust is available, a sawdust kiln operation for coconut shell could be tried out. The shells should be covered with banana leaves to support the sawdust. Any sawdust which carbonizes could be sieved out at the finish.

In the Madang District, a visit was made to Dylup Plantations Limited, the biggest coconut palm plantation in the region. The Managing Director Mr. Alan Cammack, was very co-operative and detailed his past experience of coconut shell carbonizing and marketing. He promised to undertake a feasibility study and make a report available to the Department of Labour and Industry in the near future. Much shell is used for copra drying. The advantages of producer gas in place of dieselene for drying, and for diesel engine operation were pointed out. He indicated keen interest in these aspects, and in the West Indian retort.

The possibility of export of charcoal to Japan was discussed possibly using wood-chip ships. A special pack, said to hold 1 ton of charcoal was exhibited. Large purchases of this should bring its price down from the current single bag price of US$20. It would protect charcoal from dust and rain, and improve handling. Mr. Cammack thought that the charcoal production of the district would not exceed 500 tons/year, so that an activation plant there would not be feasible.

MADANG

Bush Operations for JANT. Chip mill. (Gogol).

These were inspected where actual logging was going on. The mill appeared to be taking all the chip-wood logs from the forest that it could be reasonably expected to recover.

The remaining debris was a tangled mess and not likely to be economic to extract for charcoal making, being costly and difficult to extract.

It might well be burnt up or even left to rot. Such areas have had a lot of "clearing value" put on them, and should be used for horticulture, vegetable growing or tree planting before they revert to jungle and the value of the clearing is lost. Large debris should just be left to rot away - it could not be economically used in this situation in the writer's opinion.

WEWAK TIMBER MILL

The mill waste from this mill was all sent to the chip mill (JANT) - said to be about 8,000 tons/year.

The sawdust would be about 2,000 tons/year. Added to JANT's fine splintery waste of about 7,200 tons/year a suitable sawdust carbonizing unit should be viable, with some 9,000 tons/year available.

SELECTIVELY LOGGED AREAS

Though none of these were inspected, the situation is quite familiar to the writer. Additional to the debris on the ground, there may be a big volume of wood left standing in trees of no commercial timber value, which should be removed for the good of the forest, and any good trees left standing.

Together with logging debris, the volume per acre cut down should be sufficient for a viable charcoal operation.

In such cases groups of Constantine Mark II semiportable retorts could be used, drawing wood supplies from say 1 to 2 kilometres radius before moving to a new site.

The Constantine retorts need the support of a simple mobile "docking" saw, developed in Western Australia. A simple saw bench tray or platform is fitted to the rear of a small Fordson farm tractor, which has a power "Take-off". From this "take-off" a belt drives a circular saw (3 ft to 3 ft 6" diameter, 7 gauge), which is hinged and counterweighted to allow it to swing up and down (similar to a sawmill docking saw) cutting off 1 foot lengths from longer billets prepared in small heaps around the bush. The blocks are picked up by a truck for transport to the retort site. The tractor can be second hand provided the engine is in good condition, as it only travels a few hundred metres per day from heap to heap of wood stacks. It could cut between 20 and 30 tons of wood blocks per day, so it would depend on the size of the retort operation as to how many such units were needed.

One helper after another feeds the billets on to the bench or tray for the saw operator to dock off a block which falls to the ground. The helper then pushes the billet along for another block length.

It will be found that 2 helpers and 1 sawyer are needed for full production. This team of 3 could alternate their jobs to relieve fatigue and monotony. Such an operation can be organized on a piece work basis, if suitable methods of measurement of the product can be worked out. That would maximize production and fullest use of the sawing unit. Other cutters would prepare the billets for the docker saw.

Alternatively the billets (usually called "cord wood") can be transported to docking saw units near the retort operation site. The same type of sawing units would be used. Their mobility is an important feature however.

The retorts would be shifted at long intervals by a mobile jib crane. This system is capital intensive, but good.

Since Brazilian beehive kilns are cheap to build, they could be used instead and abandoned when the hauling distance became too far. There could be good bricks used again. With this kiln wood need not be cut to shorter lengths than 1 man can load and another handle and stack in the kiln. Though not capital intensive it is labour intensive.

Both systems have their usual advantages and disadvantages, and both should be tried, to see how they suit the particular forest and labour situation.

Earth kilns could be used, of course, especially for large diameter debris, which is too expensive to break up, or collect. But the soil disturbance over the area can be very serious and inhibit later use. Therefore large debris might be better left to rot. In some cases, smaller debris could be stacked over and around big logs, and thus an earth kiln created. This kiln operation has the usual kiln disadvantages however, and on the local labour scene, it will have to be found out whether suitable labour can be found to operate it.

If a sawmill were within reasonable distance from which to truck sawdust to the bush on the return trip, sawdust kiln operation could well replace the earth kiln, with some obvious advantages, as set out in the description of the sawdust kiln in this report.

A sawdust kiln should not be made wider than 12 feet (4 metres) so that the centre can be easily reached to cover any breakout with shovel loads of sawdust. Preferably it should not be longer than 30-36 feet (10 to 12 metres).

USE OF CHARCOAL FOR PRODUCER GAS

If oil shortages begin to affect road transport as time goes on, recourse to producer gas units such as were widely used in wartime, may become necessary.

Mr. C. V. Pederick of Western Australia is an acknowledged expert in this field. His engineering works made more than 10,000 such units during the last war. He has continued to study and improve the technology and has given advice to such places as Tonga, Fiji, Philippines.

Currently he is working with the University of Western Australia on using producer gas with diesel engines - both stationary and on trucks and tractors. Producer gas is made from charcoal - a gas mixture of H [illegible] CO. It has been demonstrated there that a diesel engine can be operated on 80-85 per cent producer gas (15-20 per cent dieselene) without loss of power and without engine modification. A switch over to 100 per cent dieselene can be made instantly if necessary. Producer gas could also be used for copra drying in the Ceylon system in place of dieselene.

Literature on this subject provided by Mr. Pederick was made available to Prof. Fussey (Lae University) and Dr. K. Newcombe (Department of Minerals and Energy). Producer gas units are of simple construction and could be made in Papua New Guinea.

Mr. Pederick is well-known personally to the writer, who spent several hours with him recently discussing his recent work. His address is - 2 Langsford, Crescent Clarement, Western Australia. He may be willing to act as a consultant in this field.

PUBLICATIONS MADE AVAILABLE

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SUPPLEMENTARY REPORT AND SUMMARY OF RECOMMENDATIONS ON CHARCOAL PRODUCTION IN PAPUA NEW GUINEA

Carbonizing systems and equipment can be classified basically under five headings:

(A) No capital, labour intensive systems

(B) Low capital, labour intensive systems

(C) Medium capital, less labour intensive system with medium scale production

(D) High capital, low labour intensity systems with large scale production

(E) Sawdust carbonizing systems.

The cost of producing and collecting wood or woody materials because of its high labour content is usually the greatest cost element in charcoal production, and over time, can be a far more serious cost than the capital costs. Large wood wastes available at sawmills provide the most favourable situation, as such wood is virtually "no cost" material - in fact it costs plenty to get rid of it. However, in the short term, capital requirements in a developing country can be the most serious problem and these would largely dictate the system to use, in any particular situation. The types recommended for Papua New Guinea are as follows:

(a) No capital, labour intensive systems

Where sawdust supplies are readily available, the use of the sawdust kiln should be developed. It is preferable to the earth kiln, the use of which should be avoided except as a last resort.

(b) Low capital cost systems

The West Indies retort made from oil drums should be developed, for small scale operations.

A larger version, say 4 ft (120 cm) diameter made from 1/4" mild steel plate should prove satisfactory. It would have 5 times the capacity. A design for this larger version is being prepared here for Papua New Guinea. Consideration is being given to design an even larger version (say 5 ft diameter with 7 1/2 times the capacity). However, there are some practical but not serious problems, not met with in the smaller versions, to be worked out.

This retort has good possibilities for wide application in Papua New Guinea.

Increase in retort size will make these retort operations less labour intensive, and its use in batches will bring about more labour economies and efficiency. The simplicity of this equipment would enable its removal to other sites, if desired. In its simplest cheapest form made from drums it is very suitable for small scale operators, and on fixed sites at small coconut plantations.

A low cost Kiln is the Brazilian, but construction know-how and skill may be more difficult to obtain quickly in Papua New Guinea. It is not so simple to operate as a retort however. Details have been given to Papua New Guinea in Earl's 1969 report. However, its use should not be ruled out. It seems better to develop the larger versions of the West Indies retort, initially, designs for which are being prepared.

(c) Medium capital cost systems

The two possibilities for Papua New Guinea in this category are:

(I) The Missouri Kiln
(II) The Constantine Retort - portable (both sizes)

The two systems have different advantages and disadvantages already set out, which on balance appear to cancel out. In different situations, one could have advantages over the other, and vice versa. For that reason, it is considered that both systems should be introduced into Papua New Guinea so that experience under local conditions can be gained.

If anything, the 'Constantine' is simplest and more foolproof to operate. Being of steel construction, it can probably be produced more quickly in PNG conditions. Training in its use would be quicker and easier.

While the portability of the larger 1 tonne/day Constantine retort is not essential for long term operation at fixed sites (e.g. sawmills) it does give some flexibility and options if a mill closes, or market situations change. The Missouri is permanently fixed in situ. Initial capital outlay per unit of capacity is likely to be somewhat less for the 'Missouri' but its "economic life" should be shorter. Over the full life of the units, there is no capital advantage likely.

At Lae sawmill for instance, where charcoal production would be very large, both systems could be tried, for comparisons in the local context. When the time comes for production at other sawmills, yet to be established, the choice will then be easier in the light of such experience.

(d) High capital cost retort systems

These large systems are considered not suitable for the Papua New Guinea situation at the present time, i.e. the Lambiotte, Reichert, and large Crossett - Constantine systems described in the report proper, hot rinsing gas systems with high output, and advanced technological requirements. These were all discussed in reports made available, in Papua New Guinea. They are all producers of lump charcoal from wood blocks.

(e) Sawdust carbonizing

For carbonizing sawdust and small size cellulosic wastes, the Papua New Guinea Government is testing a pilot plant, similar to the Tech Air process, under the direction of Dr. Tatom at Lae University. Until this process is proved or otherwise, as suitable for PNG situations, there is no point in introducing either the Herreshoff or BSP/Envirotech systems - both large capital high production systems of proven merit however. They would require large supplies of raw material at any particular site, such as Lae sawmill and Jant Chipmill which may be two suitable sites at present in Papua New Guinea.

AVENUES FOR FUTURE UNIDO ASSISTANCE TO PNG

While in Papua New Guinea, the possibility of the consultant studying latest developments of Missouri Kiln technology in USA was discussed, especially the question of pollution control. In earlier times, air pollution controls in USA were not insisted on, but of recent years and especially close to towns etc. there has been rigid enforcement. These controls introduce problems to the technology of the Missouri operation, and various methods are being developed to overcome it.

There is also the question of finding someone in USA, suitable to supervise construction of these large kilns and training personnel in their operation. It was considered that a visit by the expert to the USA operations would be advisable. The writer has some suitable long term contacts in the USA industry for arranging such on-the-spot investigations. (It is some years since his last visit to USA in this respect.) It might be advisable at the same time to inspect the Georgia Tech Air process for comparison with Dr. Tatom's related process now being tested in Papua New Guinea. Also the latest developments in the Herreshoff and BSP/Envirotech equipment used at various places in USA, in view of the increasing importance of the use of sawdust charcoal as an additive to fuel oil for power raising.

The writer can arrange for an expert from Australia to train PNG personnel in the operation of Constantine retorts. Some UNDP financial assistance for this expert could well be provided for PNG.

Also some financial assistance to PNG might be helpful for the design of a wood blocking saw bench for attachment to small agricultural tractors commonly used there (e.g. Ford, Massey Ferguson etc.) for mobile wood-block producing units. A suitable designer can be arranged for in Australia under the writer's direction. This type of unit is essential for producing short blocks for retorts, more especially for bush wood.

Waste wood at sawmills can be converted by typical built in block cutting equipment well known to sawmillers and discussed with them. If the sawmill cannot design it, a design can be arranged here.

The importance of producer gas for power raising (both fixed and mobile units) could be great in PNG, which has no local oil. Assistance for experiment at the University of Technology at Lae, PNG, to develop suitable local technology might well be considered. Guidance can be supplied by a top Australian expert. An especial application developed in Western Australia is the use of up to 85 per cent producer gas with dieselene in Diesel engines.

In the person of Dr. Newcombe and Professor Fussey, PNG has the services of competent people keenly interested in the technology, who can judge what methods to adopt in any particular context at present existing.