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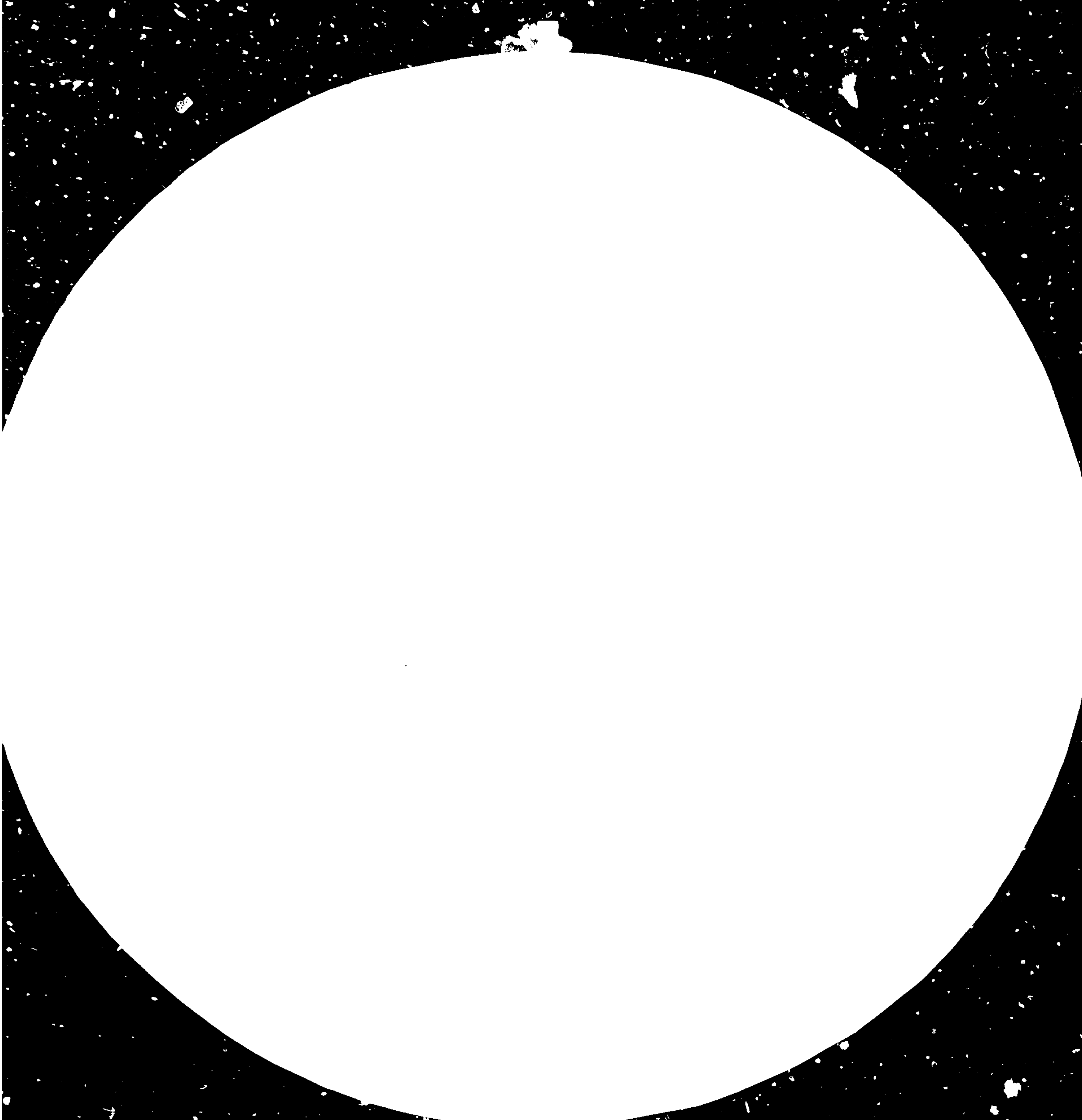

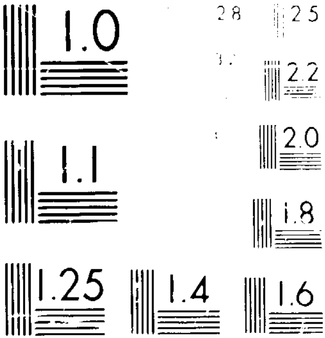
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11 March 1983
English

ASSISTANCE TO ENERGY PRODUCTION FROM BIOMASS WASTE MATERIALS,

DP/PHI/78/022

PHILIPPINES

Technical report*

Prepared for the Government of the Philippines
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Anil K. Chatterjee,
Consultant in Biomass Pyrolysis

United Nations Industrial Development Organization
Vienna

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* The boundaries shown on maps do not imply official endorsement or acceptance by the United Nations.

SUMMARY

Two surveys have been carried out:

- a survey of coconut shells, rice husk and saw dust as biomass feedstocks

- a survey of pyrolysis products market

The biomass resource survey showed an abundant supply of coconut shell in various regions of the country. The regional locations of such feedstock are marked in the map of the Philippines. The greatest amounts of cocnut shells are generated in the following regions:

Region IV - 553.11 million kg per year: Southern Tagalog
Region XI - 540.94 million kg per year: Southern Mindanao
Region V - 262.12 million kg per year: Bicol Region

A number of industries, such as cement factory, wood treatment factories and small scale industries were identified as potential consumers of pyrolysis products such as charcoal, which has a high demand in the export market, and pyrolysis oil.

Preliminary analysis of the pyrolysis oil produced from the pyrolysis of coconut shells showed that the oil is highly acidic (PH = 3.2), but has a heating value of 10,850 Btu/pound. This proves that by proper selection of oil handling pumping and piping system, the oil could be used as a liquid fuel for any combustor. The suggestion that the oil would have a better use in the wood treatment plant, could not be verified at this time. Also a complete analysis of pyrolysis oil produced has to be established first, specially for the creosote content, before the Forest Product Laboratory can make an assessment of its use as a wood-treatment chemical. However, both the oil and the gas can be used as fuels in drying copra, grain, fruits, fish or for the production of steam and/or electricity.

Preliminary calculations for product sales revenues indicate that there is profit in the pyrolytic conversion of coconut shells.

The greatest amount of rice husks (57 million kg/year) was found in the Central Luzon region (Region III). As the charcoal from rice husks contains approximately 50% ash and has a heating value of 5700 to 7000 Btu/pound only none of the cement industries interviewed showed any inclination for using this charcoal in their kilns. Rice husks are not suitable for combustion and pyrolysis and should therefore be used in gasification.

The largest sawdust production was observed in the Southern Tagalog region (Region IV , 104 million kg/year). The char from saw-dust pyrolysis is gramular and of small particle size, with possibility of a high content of water soluable and insoluable, acedic ashes.

Sawdust char, unless briquetted, has very little use as domestic fuel. Cottage industry scale briquetting operation has validity in terms of low capital investment and the simplification of the operation. Sun dried briquettes are not suitable for rough handling, storage and transportation. Therefore, industrial use of such charcoal briquettes is limited.

A review of the pyrolytic converter presently under construction at FNOC/[illegible]DC revealed that some modifications may improve its design. This may become mandatory if the reactor will also be used with heter-geneous materials. Provision of a design manual and a comprehensive testing manual is advisable.

It is recommended to look into the possibility of adopting the pyrolysis system, developed by [illegible]PM Enterprises, Manila, which looks very promising for small scale industries. However, high technology reactors (1[illegible]0-1[illegible] tons per day) with automatic control and continuous operation may be considered for regional application only.

1. INTRODUCTION

Biomass is a renewable resource and therefore, if properly managed, could play a significant role in providing for the future energy needs of the Philippines. A number of the biomass conversion processes such as pyrolysis, gasification, combustion and biochemical conversion are currently being developed. Pyrolytic conversion of biomass is the most attractive renewable alternate energy resource for developing nations, because such processes produce 3 valuable fuel varieties; char, oil and fuel gas.

Char is mostly carbon and contains ash from the original feedstock. Its heating value ranges from 5000 to 13,000 Btu/pound and can therefore be used as a domestic and commercial/industrial solid fuel. Pyrolytic oil is a highly oxygenated organic liquid composed of a complex mixture of organic compounds, highly miscible in water and slightly acidic. Depending on its water content, it can have a heating value of 5000 to 13,000 Btu/pound. Pyrolytic oil can also be a potential source for the recovery of many organic materials. The Air Injection Pyrolysis process produces low heating value fuel gas (80-180 Btu/ft^3), which can be used in any on-site combustor, but this fuel gas can not be transported over pipe lines (1).

This is the report prepared by Mr. Anil K. Chatterjee, UNIDO consultant on biomass conversion about his assignment under project DP/PHI/78/022 - Assistance to Energy Production from Biomass Waste Materials - from 26 July to 13 August 1982 with the Non Conventional Energy Research Center of the Philippines National Oil Company - Energy Research and Development Center (PNOC/ERDC) in the Philippines.

The purpose of the mission was to advise PNOC/ERDC on its on-going biomass conversion programme, involving a survey on biomass resource availability and on pyrolysis products market. In addition, the consultant was expected to present lectures on biomass pyrolysis technology and review the pyrolysis construction at PNOC/ERDC.

2. SURVEY ON BIOMASS FEEDSTOCK AND PYROLYSIS PRODUCT MARKET

The technical and economic justification of a conversion process determines its success or failure. The technical justification is related to the development of state-of-the-art technology. It may be safe to say that the pyrolysis of biomass and its wastes is technologically attainable. It is also assumed that natural and and supporting resources needed to maintain the technology such as, feedstock, trained personnel and other man-power, engineering and fabricating shops and process control equipment systems are readily available in the Philippines.

The economic justification is related to the available initial capital investment, major operating costs and revenue requirements. For industrial ventures, capital investment and cost of money are very important.

Operating costs will depend upon the cost of feedstock, man-power, supplies and utilities. The revenue requirements will depend on desired rate of return on investments (private ventures).

However, one of the most important factors in the economic considerations of a project is the identification of its product sales market. If there is no market for the product or the plant-gate-product cost is too high for sales, the success of the specific conversion process can not be assured.

2.1. Feedstock survey methods

Three different biomass feedstock varieties were chosen for the survey: rice husks, sawdust and coconut shells.

The survey methods were aimed to identify the regions of the provinces where each of the above 3 varieties of feedstocks are available in large quantities. Field trips and site visits to collect marketing data were limited to 2 to 4 hour trips by car. Many remote areas could not be reached because of time and unallocated travel expenses. Statistical data on the available biomass waste resource were then calculated on the basis of the waste generation rate per unit weight of the specific original biomass varieties. Supporting data were then collected through conferences with Federal Government agencies, officials and their published literature.

Already earlier PNOC/ERDC had conducted limited site visits to collect biomass resource data. Their trip reports depict a wealth of information and not only give valuable biomass resource data, but also important socio-economic pictures.

2.2 Pyrolysis market survey

Once the regional resources of the biomass wastes were identified, the work was aimed to identify the industries or consumers for the utilization of the pyrolysis products (char, oil and fuel gas). This was followed by on-site visits to industries that are processing the waste and those who can possibly use the pyrolysis products. The site visits and interview data were recorded then.

2.3. Results of the feedstock and pyrolysis market survey

During the survey, it was learned that current data on the available biomass waste resources could only be procured on a provincial or regional basis. Identification of the actual available biomass waste resource on a locality to locality basis could not be gathered from Government publications.

Furthermmany of the federal Government's statistical data were old. There were also very little supporting data to conduct meaningful extrapolation on a current basis. It became evident that such factual data gathering is an enormous task.

The market survey methods adopted are summarized below:

- Prepare a "waste-market-survey" guideline questionaire format.
- Conduct a literature search (Government publications) and in-house (PNOC/ERDC) data bank and identify biomass waste producing regions.
- Identify associated waste processing industries.
- Identify industries that can use specific pyrolysis products.
- Select the Government and institutional agencies for personal interviews and meetings.
- Contact selective biomass resource centers and waste processing industries and make appointments for on-site visits and/or phone data collection.
- Contact officials of industries that can have possible use of specific pyrolysis products and arrange for plant visits and/or phone data collections.
- Make appointments with appropriate federal Government and institutional organization officials for personal visits and conferences.
- Compile the site visit data.
- Analyze data (tabulation and mapping).
- Discussions

A sample of the waste-market-survey questionaire format is presented in the following pages. Individual plant visit and interview data were recorded.

PNOC-ENERGY RESEARCH AND DEVELOPMENT CENTER

PYROLYSIS OF WASTES MARKET SURVEY:

NAME OF FIRM: ______________________________

NAME OF PERSON INTERVIEWED: ______________________________

POSITION: ______________________________

LOCALITY: ______________________________

LAND AREA OF FARM OR PLANT: ______________________________

DATE: ______________________________

QUESTIONS:

1) What is the input capacity of your plant? ____________
2) How many hours per day do you operate? ____________
3) Is your operation seasonal or daily? ____________
4) If seasonal, indicate the no. of months/year. ____________
5) If not, how many days per year do you operate. ____________
6) How much wastes(ricehulls,sawdust and others) do you produced per ton of feedstock. ______________________________
7) Do you make use of these wastes?
8) If yes, please indicate below their uses and amount used.

USES	AMOUNT USED
a) ____________	____________
b) ____________	____________
c) ____________	____________
d) ____________	____________

9) If no, how and where do you dispose these wastes.

FOR CHARCOAL PRUDUCERS:

10) Where and how do you get your supply of raw materials?

____

____

11) How much is your raw material cost? ______________________.

12) What is the current labor rate in your locality? ______________.

13) How much is your production cost? ________________________.

14) What is your method of charcoaling? ______________________.

15) What is your yield? ______________________________________.

16) What is the current price of coconut charcoal? Local- __________
Foreign- ____.

17) Where do you market your product? ________________________.

18) Are you deriving other products aside from charcoal? __________.

19) If yes, please indicate below:
____.
____.

20) Are you using coconut shells other than as raw feed for charcoaling?
____.

21) If yes, please indicate below;
____.
____.

2.3.1 Coconut shell resource and product market

The Philippines is the world's largest producer of coconuts, with an estimated total production of more that 10^{10} nuts per year (2). The total cultivated land for coconut plantation in the Philippines is approximately 2.7×10^6 hectares, in which nearly 400×10^6 coconut trees are situated. The number of nuts produced per tree per year ranges from 28 to 59, with an average number of nuts/tree/year being equal to 40. 70 to 80% of the coconut plantations are contained in 2 to 5 hectares of plantation areas and each hectare of coconut plantation contains an average of 100 coconut trees. The Government of the Philippines is planning to plant, in open areas, about 15,000 to 30,000 hybrid coconut trees per year. Each of the hybrid trees will bear 2 to 5 times, by weight, the nuts to that of the ordinary variety of coconut trees.

Table 1 shows the coconut tree inventory by regions as of 1988. Figure 1 shows by ranking 1 through 5 in descending order of rank, the potential coconut shell producing regions.

The endocarp of the coconut, commonly called the coconut shell, weighs about 180 to 200 grams each and represents 15% of a whole coconut or 25% of a husked nut. One tonne (1000 kg) of coconut shells can normally be generated from 4240 to 6000 pieces of whole shells. By adopting an appropriate carbonization (pyrolysis) process, one tonne of whole shells may produce 0.2 to 0.4 tonnes of coconut-shell charcoal (3).

The chemical composition of the coconut shell is given below (3):

Composition	% By Weight
Moisture	8.0
Ash	0.6
Lignin	29.4
Cellulose	26.6
Pentosans	27.7
Solvent Extractives	4.2
Uronic Anhydrides	3.5

The heating value of the shells is approximately 9000 Btu/lb. From the above composition, it is noted that because of low inherent moisture and ash content, and high ligno-cellulosic characteristics, coconut shell is ideally suited for pyrolytic conversion processes. Such a feedstock will not require any predrying and can produce, through appropriate pyrolysis processing, high quality char, pyrolytic oil and fuel gas.

Pyrolytic coconut shell char has various uses for domestic, metallurgical and chemical purposes. Philippines export of coconut shell charcoal to the world market has been increasing steadily from 11,577 metric tons in 1971 to 32,212 metric tons in 1981 (3).

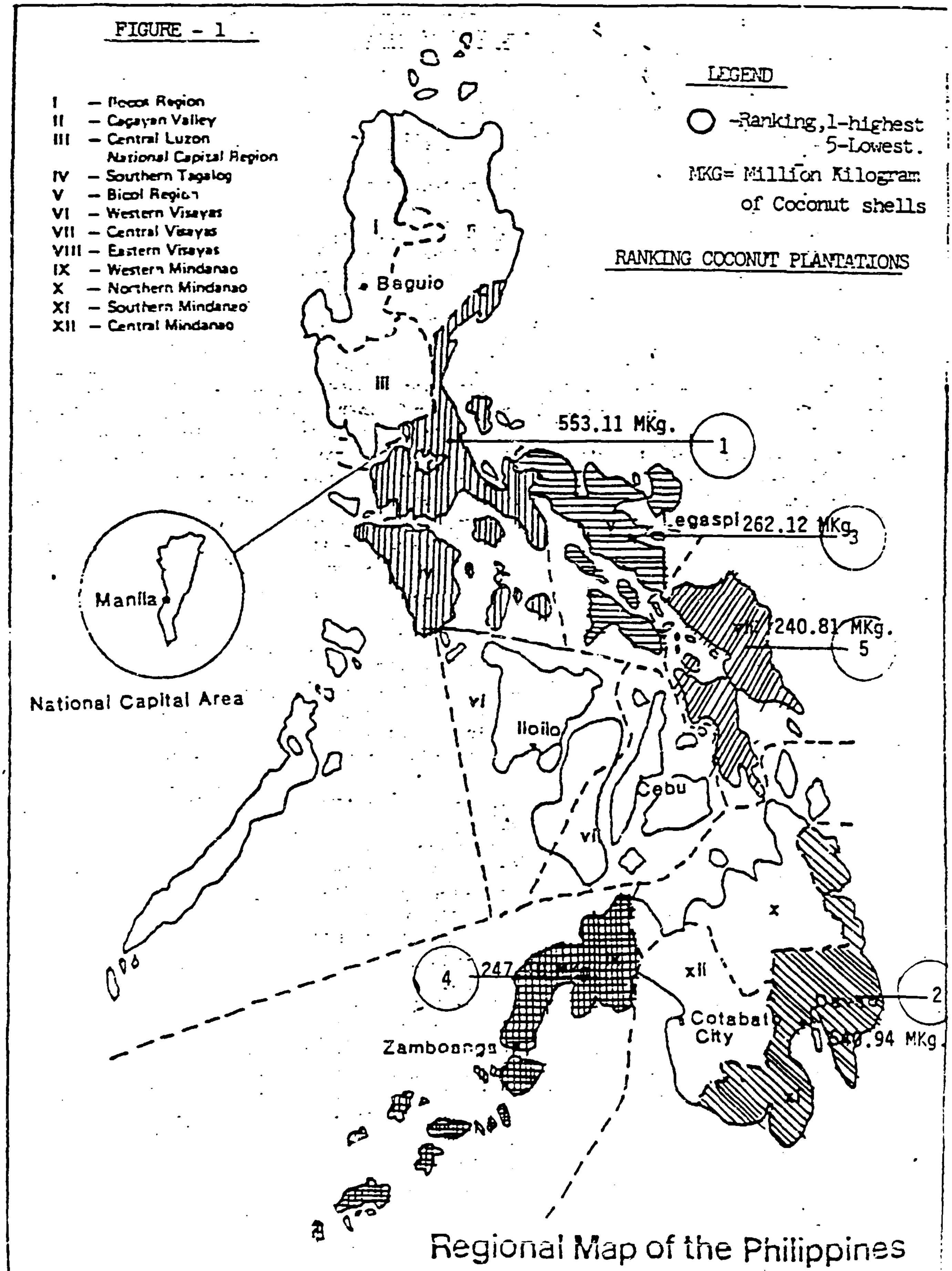
Japan absorbed 90% of the volume, contributing 88% of the value, the United States have a volume share of 8% pitching 9% to the dollar earnings and other markets composed of France, UK, Guam, Korea, Australia and Taiwan had an aggregate volume share of 2% with a 8% volume contribution. Coconut shell charcoal export volume, revenue earned and the unit price (US $/MT) are shown in table 2 and figure 2 respectively. Because of the higher absorption characteristics and more resistance to abrasion, coconut shell charcoal activated carbon is superior to other carbons. Coconut shell activated carbon can fetch 10 to 15 times more export dollars than the ordinary coconut shell pyrolytic char.

TABLE -1 COCONUT TREES INVENTORY BY REGION AS OF 1978

	REGION	TOTAL COCONUT TREES (IN THOUSAND TREES)	COCONUT BEARING TREES (IN THOUSAND TREES)	AVERAGE NUMBER OF NUTS YIELD PER TREE	TOTAL NUTS GATHERED (IN MILLION NUTS)	EQUIVALENT HUSK (IN MILLION KG)	EQUIVALENT SHELL (IN MILLION KG)
1	Ilocos	2,337	1,791	44	78.84	31.54	14.19
	Cagayan Valley	993	735	50	37.04	14.82	6.68
3	Central Luzon	197	116	30	3.43	1.370	0.62
4	Southern Tagalog	174,357	75,602	41	3,072.81	1,229.12	553.11
5	Bicol	29,537	24,688	59	1,456.24	582.49	262.12
6	Western Visayas	17,275	11,390	32	369.22	147.69	66.46
7	Central Visayas	34,562	31,153	28	870.69	348.23	156.72
8	Eastern Visayas	54,188	43,690	29	1,277.41	510.96	229.93
9	Western Mindanao	36,380	31,711	43	1,372.80	549.12	247.10
10	Northern Mindanao	48,644	33,990	39	1,337.81	535.12	240.81
11	Southern Mindanao	84,703	70,289	43	3,005.25	1,202.10	540.94
	T O T A L	483,173	325,155	40	12,881.54	5,152.56	2,318.68

SOURCE OF DATA: PHILIPPINE COCONUT AUTHORITY

FIGURE - 1



Regional Map of the Philippines

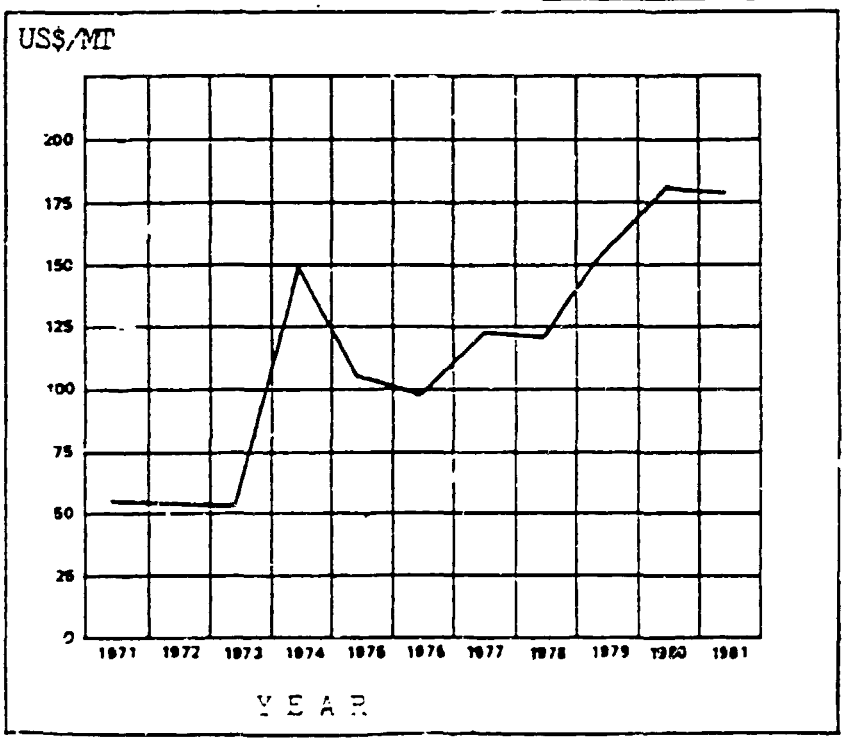
TABLE- 2

COCONUT SHELL CHARCOAL EXPORTS
1971-1981
(Volume in MT, Value in US $ FOB)

Year	JAPAN Volume	JAPAN Value	USA Volume	USA Value	OTHERS Volume	OTHERS Value	TOTAL Volume	TOTAL Value
1971	9,939	546,866	986	71,380	652	38 699	11,577	656,943
1972	11,650	647,652	–	–	–	–	11,650	647,652
1973	16,408	919,157	40	2,200	857	63,860	17,305	975,[illegible]7
1974	25,870	3,655,085	435	69,934	1,566	335,053	27,871	4,060,072
1975	15,061	1,638,959	467	83,646	227	41,619	15,449	1,451,865
1976	12,799	1,174,307	2,540	265,998	110	11,560	15,449	1,451,865
1977	17,035	2,121,753	1,538	174,340	201	48,774	18,949	2,344,867
1978	16,786	2,066,521	3,697	442,863	380	40,310	20,863	2,549,694
1979	25,656	4,243,969	4,411	569,067	274	65,757	30,341	4,979,793
1980	32,638	5,855,707	7,634	1,481,498	5,915	1,218,815	46,187	8,556,020
1981	24,123	4,185,917	1,443	281,888	6,646	1,247,419	32,212	5,715,224

Source: Market Development Department, PCA.

COCONUT SHELL CHARCOAL EXPORT PRICES
1971 – 1981
(IN US$/MT, FOB) FIGURE- 2

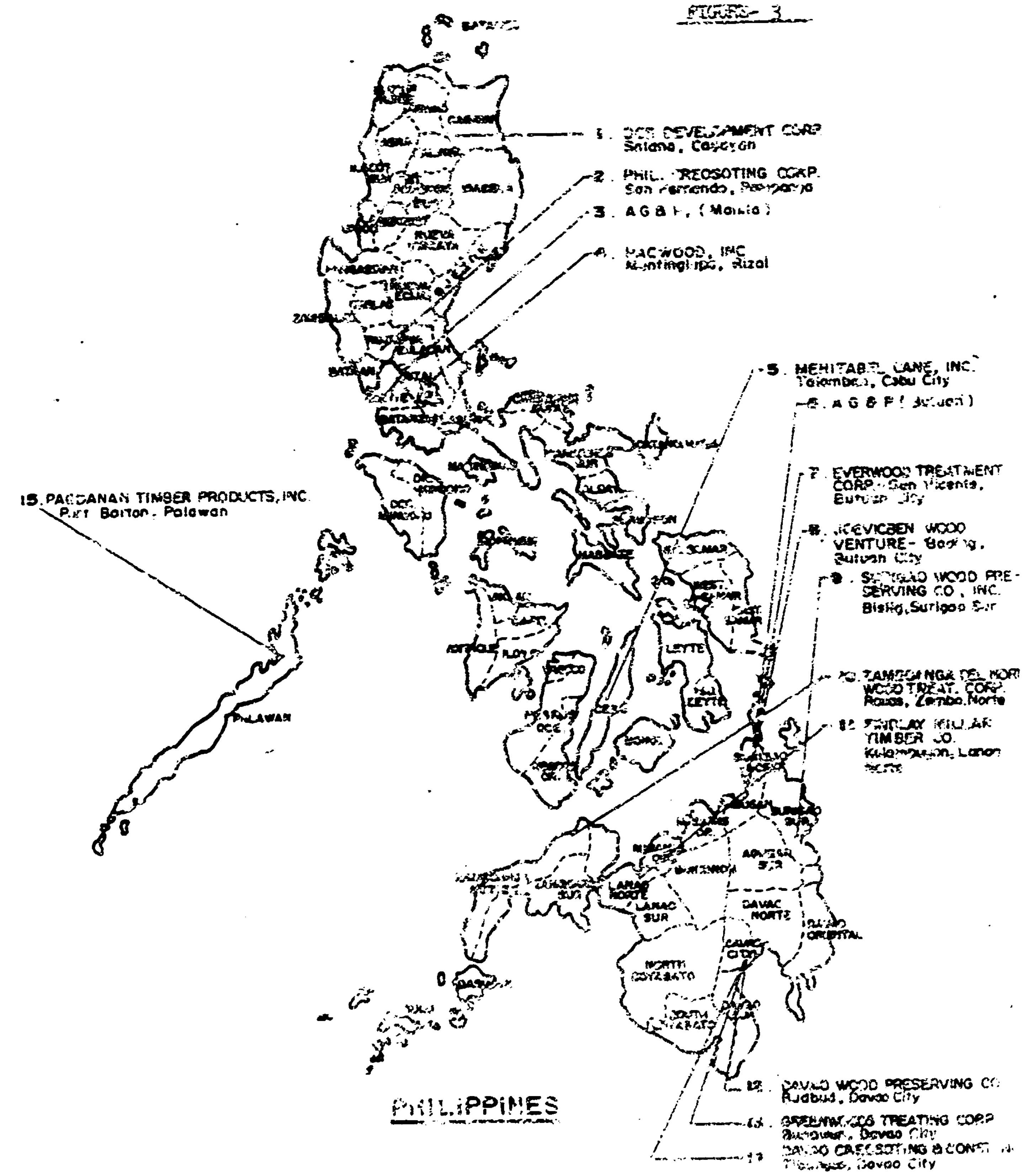


The pyroligneous liquor and pyrolytic oil that are produced from the pyrolysis of coconut shells are also a valuable commodity. Over and above its common use as a fuel oil substitute, other possible uses of the oil are as a wood preservative for the treatment of utility poles. Because of its creosote and other phenolic constituents, it seems to be very attractive as a fungicide agent. Laboratory analysis of the coconut shell Pyrolytic oil is being done now at the near-by university laboratory. The forest product research laboratory will then examine the oil and give their opinion as to its suitability as a wood treatment chemical. Until such confirmation is received, the claim for the value of this oil as a wood preservative, cannot be made. The plant visit data did not point out such use.

Philippine National electrification administration data showed that the present government programme of rural and urban electrification will require 200,000 creosote treated poles per year. At present, all the creosote used in the treatment of electric poles are imported from Japan, China and Australia. The interview with Packwood Inc., (an Electric wooden pole treatment company), revealed that normal wood treatment chemical consists of 70% creosote and 30% bunker 'C' oil. For the plant treating 3000 average size poles per month, the quarterly comsumption of creosote is approximately 500 tons and 214 tons of bunker 'C' oil. If the pyrolytic oil is acceptable to replace the bunker 'C' oil, a substatial savings in the bunker 'C' oil import could be achieved by the wood treatment industry.

Figure 3 shows the locations of accrediated wood treatment plants. When this map is superimposed on figure 1, it is noted that there are locations where large coconut plantations exist along with the wood treatment plants. This would be an ideal situation in which the products of pyrolysis will be used in nearby industry. It should be understood that due to the high (Ph= 3.2) acidic nature and low creosote level in pyrolytic oil, the definite acceptance of the oil by the wood treatment industry could not be assured at this time.

VICINITY MAP OF NEA ACCREDITED TREATING PLANTS



The low btu gas produced from the pyrolysis operation has a ready market as a fuel gas for drying and dessicating copra. Excess fuel gas could be used in producing the activated charcoal and even for power generation. One government official gave us the information that 70 to 80% of the coconut shells and husks are now used in open fire dryers to dry the Copra. If this statistic is true, valuable coconut shells are now being wasted. It was stated in the above meeting that recently, one University of Philippines Professor has designed a Copra dryer having the equivalent heat output of the present design, that will require only 40% of the coconut husks and save the shells for charcoaling.

Unfortunately, the Philippine government has no immediate plans for an all-out effort to replace all existing old design Copra dryers. The present plan calls for gradual replacement of the wornout and broken-down dryers only. Thus, the on-going regretable wasting of this nation's biomass resource will be continued for a long time in the Philippines. The details of this new design dryer were not available from the University of Philippine

2.3.2 Rice Husks Resource and Product Market

The Philippines is a large rice producing country. It produces more rice than her people can consume and exports a large quantity of rice to neighboring countries. When the export demand is low, many rice millers idle their plants. The rice plant that was visited runs about 150 days a year and even these running days are not continuous. The National Food Administration (NFA) controls the rice milling and the Palay quota is allocated by the NFA. As a result, in a given region many plants may be idle while in another region most of the rice millers will be operating at full capacity.

Data on rice husk generation for the year 1980 and 1981 in the eleven regions of the Philippines are shown in table 3. The

TABLE 3

RICE HUSKS GENERATION
CAPACITY

(Source- National Grain Authority- Philippines)

Region Number	Region Name	1980 Annual Million Kg 300days/yr	1981 Annual Million Kg 300days/yr	1980 MT/Day	1981 Mt/Day
I	Ilocos	40.35	39.28	134.5	130.9
II	Cagayan Valley	35.46	33.30	118.22	110.0
III	Central Luzon	56.99	66.43	190.00	221.4
IV *	Southern Tagalog	40.22	40.20	134.0	134.0
V	Bicol	23.57	23.33	78.6	77.8
VI	Western Visayas	36.68	40.88	122.2	136.2
VII	Central Visayas	7.09	10.44	23.6	34.8
VIII	Eastern Visayas	13.57	16.27	45.2	54.2
IX	Western Mindanao	7.16	5.85	23.9	19.5
X **	Northern Minanao	26.87	32.60	89.6	108.7
XI ***	Southern Mindanao	28.08	10.16	93.6	33.9

* Includes Metro Manila
** Includes Eastern Mindanas
*** Includes Central Mindanas

National grain authority compiled the rice husk production data for the year 1980. On the basis of the 1980 yield of rice husks from the milling operation, and from the data of regional rice production, the 1981 data of rice husk generation were calculated.

The computed values of regional daily rice husks production for the year 1980 and 1981 are also noted on the same table. On examining these data, it will be evident that region III is the largest producer of rice and of rice husks for both 1980 and 1981, with the second largest producer for 1980 being Region I. But in 1981, region IV shows to have produced more rice, than region I. The considerable decrease of the rice production in region XI in 1981 may be accounted for the insufficient data recieved from such territory.

Ranking of annual rice husks generating regions are noted in figure 4. Regional milling capacities were further subdivided in in table 4. This breakdown shows the number of rice mills and their aggregate milling capacities. This data is useful in deciding the preferred location of the pyrolytic converters that will operate with rice husks as a feedstock. For example, it is noted from table 4, that in region 1, Benguet province has the largest number of rice mills, but the aggregated milling capacity of these mills are the lowest in the region. It is evident that Ilocos Sur should be the first choice, because only 7 millers produce about 1/2 the rice produced by the 518 mills of the Ilocos Norte province. Two important data that are still missing are:

1. What is the distance between two milling facilities.

2. How many days per year can each of these rice mills operates.

The appearance of the machinery at the rice mill visited was that of a closed shop. The machinery was covered with dust and cobwebs and looked like they had not been in operation for a long period. An ideal location for a pyrolytic converter should be where there is year round feedstock (rice husks) available.

Table 5 identifies the top rice millers in several provinces of a region. This data is not conclusive. For example, in region 1, the top mills for Ilocos Norte were identified but none of the millers from Ilocos Sur were selected as the choice locations for the pyrolytic converters. However, the value of table 5 can be found only from the point of view that more elaborate localized data will be needed to identify the best feedstock supply centers. It has been demonstrated that the rice milling operation of a plant is not continuous for [illegible] year [illegible]ng period. Therefore, the rice husk production of a si[illegible] [illegible]nnot be expected to ensure continuous operation of [illegible] [illegible]nversion system. Thus, the preferred location of [illegible] [illegible]erter is in the vicinity of several millers supplyi[illegible] [illegible]k

ANNUAL RICE HUSKS GENERATION CAPACITY
(BASIS 300 Days / Year

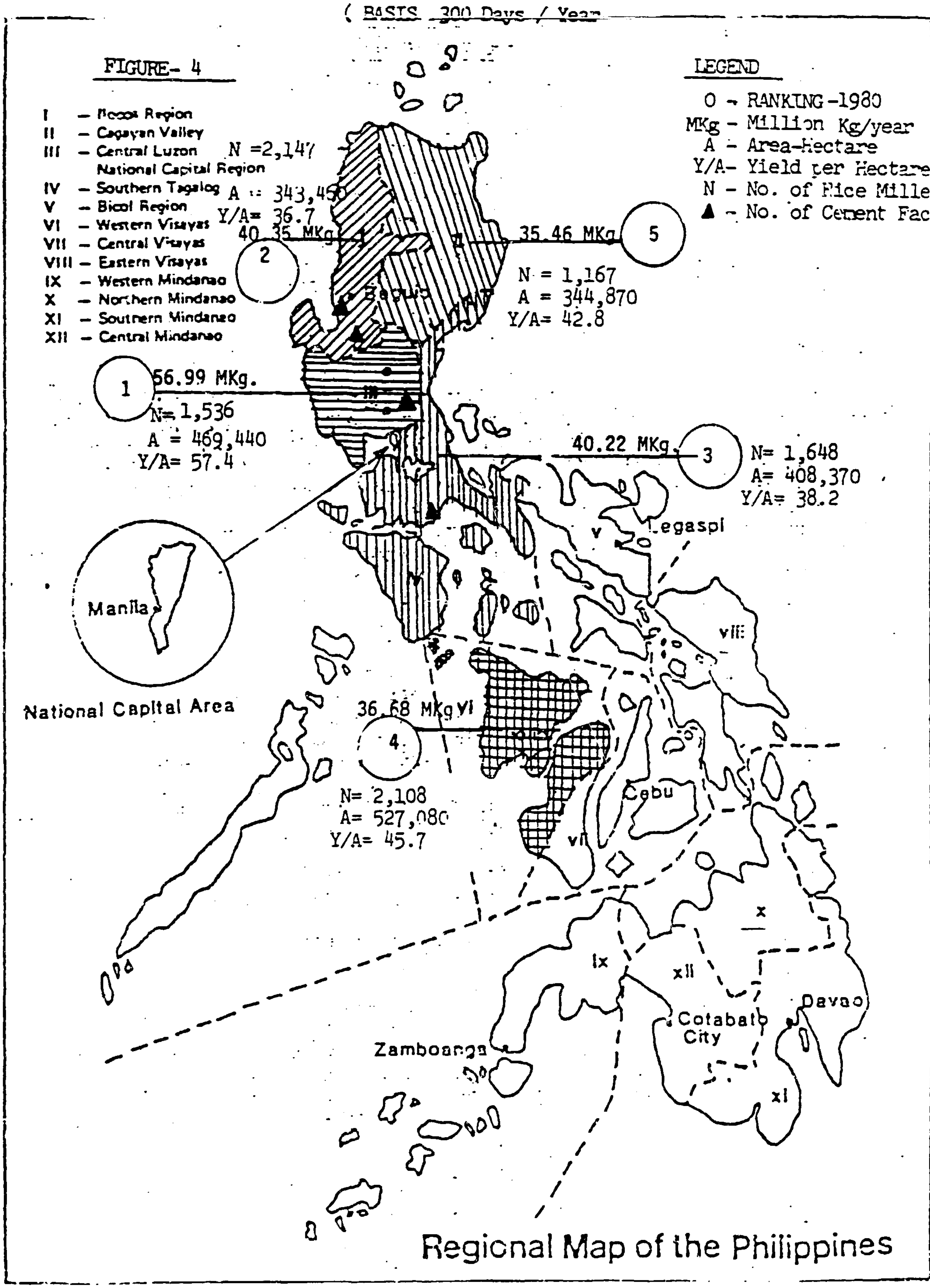


TABLE 4 MILLING CAPACITIES OF RP RICE MILL BY PROVINCE PER REGION
AS OF 1979

REGION	PROVINCES	NUMBER OF RICE MILLERS	CAPACITY (Milling)	
			(BAGS/DAY)	(MILLION KG/YR) @ 300 days/year
1	Abra	121	740.96	11.114
	Benguet	714	27.00	0.405
	Ilocos Norte	518	2,882.64	43.240
	Ilocos Sur	7	1,587.63	23.814
	La Union	469	1,551.95	23.280
	Pangasinan	318	5,436.33	81.545
	TOTAL	2,147	12,226.51	183.398
2	Cagayan	614	4,253.63	63.804
	Ifugao	4	71.50	1.073
	Isabela	266	3,967.65	59.515
	Kalinga/Apayao	166	829.00	12.435
	Mt. Province	23	86.00	1.290

Source: National Grain Authority

Region	PROVINCES	NUMBER OF RICE MILLERS
	Nueva Viscaya	82
	Quirino	12
	TOTAL	1,167
3	Aurora Sub-Province	85
	Bataan	95
	Bulacan	299
	Nueva Ecija	421
	Pampanga	194
	Tarlac	260
	Zambales	182
	TOTAL	1,536
4	Batangas	195
	Cavite	122
	Laguna	166
	Marinduque	65
	Occidental Mindoro	234

MILLING CAPACITY (BAGS/DAY)	(MILLION KG/YR)
1,205.16	19.277
253.00	3.795
10,745.94	161.102
423.10	6.481
794.74	11.921
5,179.76	77.696
5,147.98	77.220
2,127.46	31.912
2,598.16	38.922
989.32	14.840
17,269.52	259.042
1,240.27	18.604
941.00	14.115
1,444.00	21.660
427.40	6.405
1,918.07	28.771

Table - 4 Continued

REGION	PROVINCES	NUMBER OF RICE MILLERS
	Oriental Mindoro	259
	Palawan	240
	Quezon	255
	Rizal	49
	Romblon	43
	Metro Manila	20
	T O T A L	1,648
5	Albay	200
	Camarines Norte	110
	Camarines Sur	541
	Catanduanes	45
	Masbate	30
	Sorsogon	125
	T O T A L	1,051

MILLING CAPACITY

(BAGS/DAY)	(MILLION KG/YR)
2,829.59	42.444
978.48	14.677
1,680.00	25.200
299.20	4.488
168.00	2.520
262.01	3.930
12,188.02	182.814
1,532.10	22.981
806.50	12.097
3,225.10	48.376
228.00	3.420
289.74	4.346
1,063.66	15.955
7,145.10	107.175

Table-4 Continued

REGION	PROVINCES	NUMBER OF RICE MILLERS
6	Aklan	162
	Antique	261
	Capiz	494
	Iloilo	950
	Negros Occidental	241
	TOTAL	2,108
7	Bohol	152
	Cebu	5
	Negros Oriental	36
	Siquijor	3
	TOTAL	196
8	Eastern Samar	49
	Northern Samar	99
	Western Samar	46
	Northern Leyte	322
	Southern Leyte	55
	TOTAL	571

Table 4 continued

MILLING CAPACITY (BAGS/DAY)	MILLING CAPACITY (MILLION KG./YR.)
827.50	13.087
1,348.33	20.225
2,007.23	30.108
4,931.50	73.972
1,956.38	29.346
11,115.94	166.738
1,226.50	18.379
205.00	3.075
687.11	10.307
31.50	0.473
2,150.11	32.252
253.00	3.795
526.27	7.894
352.04	5.281
2,706.40	40.596
274.00	4.110
4,111.71	61.676

REGION	PROVINCES	NUMBER OF RICE MILLERS
9	Basilan	-
	Sulu	-
	Tawi-Tawi	-
	Zamboanga City	-
	Zamboanga Del Norte	31
	Zamboanga Del Sur	135
	T O T A L	166
10	Agusan Del Norte	24
	Agusan Del Sur	29
	Bukidnon	95
	Camiguin	10
	Lanao Del Norte	19
	Lanao Del Sur	21
	Misamis Occidental	67
	Misamis Oriental	6
	Surigao Del Norte	42
	Surigao Del Sur	36
	T O T A L	349

Table 4 Continued

MILLING CAPACITY (BAGS/DAY)	(MILLION KG./YR)
-	-
-	-
-	-
-	-
454.00	6.810
1,717.10	25.756
2,171.10	32.566
2,758.87	41.383
561.66	8.425
1,503.73	22.556
79.00	1.185
630.00	9.450
406.17	6.092
964.00	14.460
586.60	8.799
279.00	4.185
395.00	5.625
8,144.03	122.160

REGION	PROVINCE	NUMBER OF RICE MILLERS
11	Davao Del Norte	99
	Davao Del Sur	64
	Davao Oriental	29
	Maguindanao	33
	North Cotabato	147
	South Cotabato	202
	Sultan Kudarat	145
	T O T A L	719

Table -4 Continued

MILLING CAPACITY

(BAGS/DAY)	(MILLION KG. /YR)
1,381.74	20.726
1,175.65	17.635
262.79	3.942
562.00	8.430
1,588.54	23.828
2,158.39	32.376
1,381.00	20.715
8,510.11	127.652

TABLE- 5

TOP RICE MILLERS

	ADDRESS	HUSK PROD'N MT/day 20% recovery	INPUT Palay of 50 kg/bag (12 hrs. operation) (Bags/day)	(MT/day)
1. ILOCOS NORTE (Region 1)				
a. Federico Acob	Barangay 2, Bacarra	1.704	14.2	8.52
b. Felipe R. Vea	Tamicalao, Bacarra	1.55	12.9	7.74
2. PANGASINAN (Region I)				
a. Ildefonso Ong	Mangaldan	4	33.33	20
b. Carlo Cayabyab	Malasiqui	3.8	31.66	19
c. Benigno del Camp	San Jacinto	3.7	30.82	18.5
3. BULACAN (Region III)				
a. Lorenzo Trinidad	Paniqui, Bulacan	6	49.3	30
b. T. I. P.	Tiaky, Malolos	10	83	50
4. NUEVA ECIJA (Region III)				
a. Cuyapo Rice Mills	Canilo	5	41	25
b. Bartolome Ramos	San Leonardo	7.2	60	36
c. Eleuterio Violago	Malaria, San Jose City	4.6	38.5	23
5. OCCIDENTAL MINDORO (Region IV)				
a. Faustino M. Guillermo	San Agustin	5.4	45	27
b. Rizalino Pablo	Labangan, San Jose	2.5	20.83	12.5
6. ORIENTAL MINDORO (Region IV)				
a. Arnulfo C. Sison	Poxas	16.6	1.38	83
b. ABCD Cacha Rice Mill Corporation	Calapan	6.2	51	31
7. CAPIZ (Region VI)				
a. Patria Booth	Cuartero	3	25	15
b. Alfonso Palencia	Dao	2.4	20	12
8. ILOILO (Region VI)				
a. Julian Ballaret	Barotoc, Visjo	7	58	35
b. Candelaria Dayot	Potetas	4.2	35	21

feedstock. Such locations in each of the regions have not been identified in this survey.

There are two important considerations that should be examined before the decision to pursue the pyrolytic conversion of rice husks is adopted. One is the sufficient and continuous supply of feedstock. We have discussed this subject matter in great detail in earler sections and it has been shown that adequate feedstock is available at selected centers. The second consideration is the ready market for the products of the pyrolysis of rice husks. To examine this aspect, it is necessary to examine the ultimate and proximate analysis of rice husks:

Ultimate Analysis	Weight %
Carbon	36.2
Hydrogen	5.24
Nitrogen	0.5
Sulfur	0.2
Oxygen	34.5
Chlorine	0.2
Ash	23.16

Proximate Analysis (Bone Dry Basis)	Weight %
Volatile Matter	57.86
Fixed Carbon	18.98
Ash	23.16

NOTE- The moisture content of the rice husks when it comes from the milling process ranges from 9 to 10%

Gross heating value- 6500-7200 Btu/lb.

From the above analysis data, it should be noted that both volatile matter and fixed carbon contents are included in the total carbon data of the ultimate analysis. It is the fixed carbon that shows up in the char. All the volatile carbon and a portion of the fixed carbon are either vaporized or combusted in the pyrolysis process. The high oxygen content of the rice husks, makes the pyrolytic oil a highly oxygenated organic liquid. The char that is produced from the pyrolysis of the rice husks "may be literally half-ash, due to the high silica content of the husks, and is therefore not very useful in most industrial applications (4). The fixed carbon to ash ratio is 0.72. This situation is further complicated by the fact that the purity of the silica cannot be guaranteed. The water soluable and acid insoluable inerts of the ash will vary over a wide range. The heating value of the rice husks char will vary between 5700 to 7000 Btu/lb. The average value of the proximate analysis of the rice husk char in the bone dry basis, as reported in the Georgia Tech report(5), is as follows:

Volatile matter-	3.60 by weight
Fixed carbon-	38.02 by weight
Ash-	58.38 by weight

The ash content actually varies from 51 to 61% by weight.

The high volatile carbon, oxygen, and water contents (free and bound) of the rice husks are reflected in the composition of the pyrolytic oil as [1]:

Composition	% by Weight
Carbon	62.4
Hydrogen	5.8
Nitrogen	1.4
Sulfur	0.1
Oxygen	29.4
Chlorine	0.3
Ash	0.6
Btu/Lb	10,400
Oil Yield %	44.2
Water Yield %	11.2

A high yield of pyrolytic oil from the pyrolysis of rice husks will require feedstock having less than a 5% moisture level.

The commercial use of this oil has not been established yet. It was noted from the experiment conducted using the Georgia Institute of Technology's pyrolysis converter design with rice husks as feedstock, that "the moisture content of the oil produced varies widely from 30 to 90%. In steady state operating conditions, the water content of the oil is about 30 to 40% (5).

The principal combustible component of the offgas is carbon monoxide, hydrogen and methane. On a dry basis their compositions are as follows (5):

CO	-	11.2 to 23.6 % volume
H_2	-	0.4 to 6.93 % volume
CH_4	-	1.0 to 2.6 % volume

2.3.3 Sawmill residues resource and product market

Normally when one talks about sawmill residues one only thinks of sawdust. Although sawdust is the major part of the residues, other valuable biomass wastes are produced in sawmill operations. It is therefore important that we focus our attention on the total sawmill residue and then consider if we should be looking into pyrolyzing the sawdust only or focus our attention on the entire family of sawmill residues. A short essay on this residue, is therefore in order at this point.

Sawmill residues, produced in the primary wood-using industries, include (a) coarse material like alaba, edgings and lumber trims from the sawmills; log trims veneer cores, round-ups, spur trims, green veneer trims and some dry-end residues in plywood mills; and (b) fine material such as sawdust, sander dust and shavings.

Sawmill Residues

These are classified into:

1. Slab- The discarded exterior portion of a log shaved only on one side.

2. Edgings- The waste strips, in the process of squaring boards at the edge which may have two, three or four sawn sides, depending on the size of the log and the practice of sawing.

3. Lumber trim- The residue item produced either by trimming defects such as knots, planky portions and the like, as well as, by trimming the boards to standard lengths.

4. Fine material- This wood waste includes sawdust, produced by the head saw, edger, resaw and trimmer saw, as well as shavings from the planer in the sawmill.

Inital studies in sawmilling operations revealed the following percentage distribution of lumber mill residues, based on the gross volume of logs processed:

Lumber	48%
Residues	35%
1. Sawdust	16%
2. Slabs	7%
3. Edgings	7%
4. Lumber trims	5%
Defective material	17%
TOTAL	100%

The above figures show that the proportion of residues to lumber is about 70 bd.ft. of residues for every 100 bd.ft. of lumber. Hence, with an average annual lumber production of 400 million bd.ft., the country's sawmills are producing no less than 250 million bd.ft. of sawmill residues every year.

Regional annual sawmill's rated capacity and equivalent sawdust generation rates are shown in table 6. Five ranking locations, 1 through 5, in decending order, are noted in figure 5. The number of sawmills located in different provinces of a region and their rated capacities are noted in table 7. Figure 5 identifies that region IV, the Southern Tagalog region has the highest sawdust production capacity. Each of the five regions indicated in figur^ 5 is a suitable location for the pyrolytic conversion center using sawdust as a feedstock.

The product end of the pyrolysis process can now be examined. Georgia Institute of Technology's experiment with Tech-Air's pyrolysis reactor produced the yields of pyrolytic products using an input feed of pine bark and sawdust, in the ratio of 70 to 30 (6) :

Char	23%	by weight
Pyrolytic Oil	25%	by weight
Non-Condensable gases	68%	by weight
The remainder is water vapor.	33.9%	by wegiht

TABLE - 6 RATED CAPACITY OF RP SAWMILLS BY REGION AS OF 1980

	REGION	RATED CAPACITY (Bd. Ft./day)	(cu.m./yr)	ANNUAL LOG REQUIREMENT AT ATTAINABLE CAPACITY (cu.m.)	EQUIVALENT SAWDUST (IN MILLION KG.)
1	Ilocos	190,000	134,505	179,243	10.75
2	Cagayan Valley	1,241,000	886,775	878,529	53.21
3	Central Luzon	539,000	381,570	516,321	30.86
4	Southern Tagalog	1,715,280	1,214,282	1,741,541	104.49
5	Bicol	327,000	231,490	308,491	18.510
6	Western Visayas	296,000	209,544	279,243	16.75
7	Central Visayas	140,000	99,109	132,075	7.92
8	Eastern Visayas	136,000	96,277	138,717	8.32
9	Western Mindanao	451,000	319,272	513,859	30.83
10	Northern Mindanao	1,462,400	1,035,263	1,658,320	99.50
11	Southern Mindanao	1,326,000	938,702	1,493,618	89.62
	TOTAL	7,823,680	5,546,789	7,837,957	470.76

600 Kg./(cu.m.)

Source of Data: Bureau of Forest Development
Ministry of Natural Resources

SAWDUSTS REGIONS (ANNUAL)

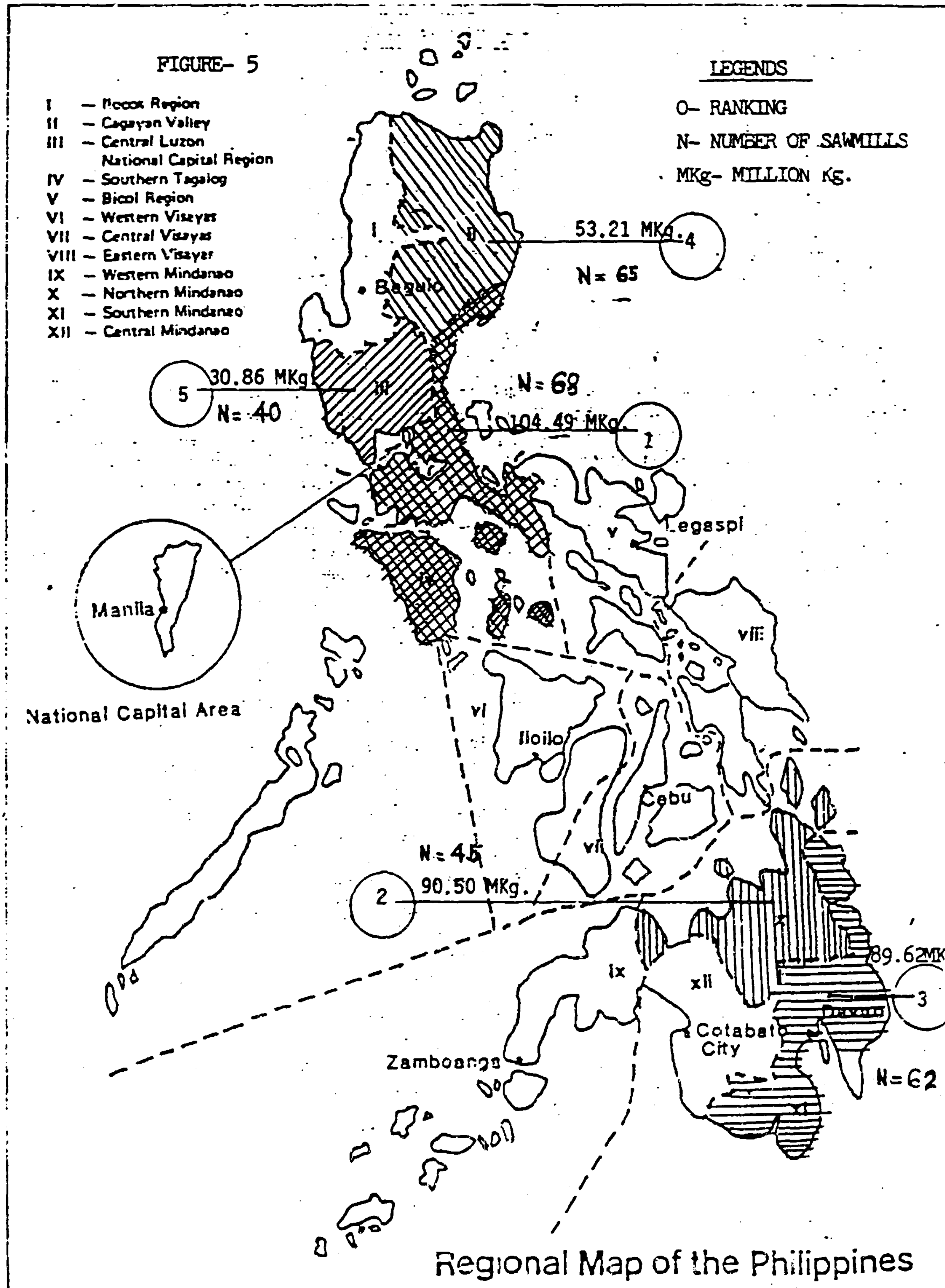


TABLE - 7 INVENTORY OF RP SAWMILLS BY PROVINCE PER REGION AS OF 1980

REGION	PROVINCE	NO. OF SAWMILL	TOTAL DAILY RATED (Bd. Ft.)	Annual Log Requirements (ALR) AT ATTAINABLE CAPACITY (cu.m.)
1	Ilocos Norte	2	40,000	37,735
	Mt. Province	2	35,000	33,019
	Benguet	3	75,000	70,754
	Pangasinan	2	40,000	37,735
	TOTAL	9	190,000	179.243
2	Cagayan	15	362,000	289,695
	Kalinga-Apayao	1	30,000	20,376
	Isabela	32	527,000	358,002
	Nueva Ecija	15	250,000	169,802
	Quirino	4	72,000	48,900
		67	1,241,000	878,529

REGION	PROVINCE	NO. OF SAWMILL
3	Nueva Ecija	6
	Zambales	4
	Pampanga	1
	Bulacan	12
	Bataan	1
	T O T ALL	24
4	Metro Manila	36
	Rizal	2
	Laguna	6
	Batangas	1
	Quezon	30
	Occidental Mindoro	5
	Oriental Mindoro	1
	Palawan	4
	T O T A L	85

Table - 7 Continued

TOTAL DAILY RATED (BD. FT.)	AIR AT ATTAINABLE CAPACITY (Cu.M.)
125,000	117,925
64,000	60,378
15,000	14,151
285,000	268,867
50,000	53,000
539,000	514,321
865,280	817,001
45,000	42,453
62,000	58,490
15,000	14,151
560,000	488,667
36,000	29,529
20,000	18,868
112,000	272,382
1,715,280	1,741,541

REGION	PROVINCE	TOTAL NO. OF SAWMILLS
5	Camarines Norte	10
	Camarines Sur	7
	Albay	1
	Sorsogon	1
	T O T A L	19
6	Negros Occidental	11
	T O T A L	11
7	Negros Oriental	5
	Cebu	2
	T O T A L	7
8	Samar	6
	T O T A L	6

TOTAL DAILY RATED (Bd. Ft.)	AIR AT ATTAINABLE CAPACITY (Cu. m.)
205,000	193,397
103,000	97,170
4,000	3,773
15,000	14,151
372,000	308,491
296,000	279,243
296,000	279,243
115,000	108,490
25,000	23,585
140,000	132,075
136,000	138,717
136,000	138,717

Table -7 Continued

REGION	PROVINCE	NO. OF SAWMILLS
9	Zamboanga Del Norte	7
	Zamboanga Del Sur	16
	Basilan	2
	T O T A L	25
10	Misamis Occidental	4
	Misamis Oriental	11
	Lanao Del Norte	5
	Lanao Del Sur	5
	Bukidnon	8
	Agusan Del Norte	21
	Agusan Del Sur	1
	Surigao Del Norte	3
	Surigao Del Sur	8
	T O T A L	66

Table -7 Continued

TOTAL DAILY RATED (Bd.Ft.)	ALR AT ATTAINABLE CAPACIT (Cu.M.)
150,000	169,811
297,000	339,520
4,000	4,528
451,000	513,859
90,000	101,886
250,000	201,030
90,000	101,886
41,000	46,414
193,000	218,390
682,000	698,491
4,000	4,000
26,000	29,057
156,000	177,057
1,462,400	1,658,320

REGION	PROVINCE	NO. OF SAWMILLS
11	Davao Del Norte	11
	Davao Del Sur	26
	Davao Oriental	11
	South Cotabato	5
	Maguiñdanao	7
	Sultan Kudarat	3
	T O T A L	63

Table -7 Continued

TOTAL DAILY RATED (Bd.Ft.)	ALR AT ATTAINABLE CAPACITY (Cu.M.)
196,000	218,396
529,000	598,867
284,000	318 017
130,000	146,603
145,000	164,151
42,000	47,584
1,328,000	1,493,618

It is noted that the above total yield is greater than 100%, since the non-condensable gases include the nitrogen from the the process air. The yields of pyrolytic products can be varied within certain limits depending upon the feed-material, the operating pressure, temperature, and duration. For most wood wastes, about 50% of the mass of the dry input feed material is available in the form of char and pyrolytic oil.

From the energy output point of view, the char and pyrolytic oil produced from the sawmill wastes, each account for 35% of the dry feed input energy, non-combustible gases 22% and the rest of the energy can be accounted for as heat losses from the reactor and the system components.

Depending upon the pyrolysis reactions, the wood waste char heating value may range from 10,000 to 12,000 Btu/lb. The low Btu fuel gas that is produced from the air draft pyrolysis of wood waste may have a heating value in the range of 125 to 180 Btu/ft^3 and this gas has to be comsumed (burned) on-site. Such a fuel gas generally contains high moisture (15 to 50%) and therefore, to burn this gas, the moisture has to be condensed out before the gas is ignited in the burner, or a special volute type burner with high swirl action has to be provided (7).

3. DISCUSSIONS ON A PILOT PLANT PROPOSAL

Coconut shell, biomass waste rich regions and the estimated daily availability of such feedstock is noted in table 8. It is noted from this table that in region 4, for example, the coconut plantations in Quezon, Laguna, Romlelon, Mindori-oriental, and Batangas have ample feedstock for many small (1 to 5 MT/day) pyrolytic converter systems. It was learned from interviews that the feedstock price (coconut shell in P/1000 nuts) increases 3 to 4 fold when it is to be procured from a distance beyond 5 Km. A 5 km radius has an area equivalent of 7850 hectares. A 200 kg/hr Pyrolysis plant using coconut shell, each weighing approximately 200 grams, and the plant operating 24 hours a day, will require 24,000 whole nuts per day or 7.2×10^6 nuts/year for a 300 days per year operation. This amount of nuts could be available from a plantation area of 1800 hectares (assuming 100 trees per hectare and 40 nuts per tree per year). Therefore, a 5 Km radius plantation area can easily support 4 such 200kg/hr or approximately 5 MT/day capacity pyrolysis plants. A reactor having a 36" diameter hearth area will be able to pyrolyze this 200 kg/hr of chipped coconut shell feedstock. Such a reactor design can be achieved without much of an uncertainty factor. A larger scale-up unit (6 to 10 ft diameter) may require a radical change in mechanical design criteria, (stirrer fed air feeding versus tuyere injection air blast).

Assuming a mass yield ratio of char, oil and fuel gas as 23, 25 and 68% respectively, a 200 kg/hr plant will produce:

Char	- 46 kg/hr	or 1.1 MT/day
Oil	- 50 kg/hr	or 1.2 MT/day
Fuel Gas	- 136 kg/hr	or 3.26 MT/day

having an average energy level for char and oil each of 1.4×10^6 Btu/hr and gas 0.8×10^6 Btu/hr.

The Product Sales revenue can now be estimated on the following basis:

TABLE 8

Data on Localized Available
Coconut Shell Feedstocks

	QUANTITY **(Nuts)/Year	CAPACITY- @ 200 Days Year	*TONNE/DAY @ 300 Days Year
Region 4			
1. Cavite	13,567,773	13.57	9.04
2. Batangas	53,074,119	53.07	35.38
3. Laguna	108,950,442	108.95	72.63
4. Marinodque	25,882,764	25.88	17.26
5. Mindoro Occidental	2,331,710	2.33	1.55
6. Mindoro Orriental	81,962,930	81.96	54.64
7. Palawan	37,682,676	37.68	25.12
8. Quezon	332,700,550	332.70	221.80
9. Rizal	1,421,750	1.42	.94
10. Romblon	40,476,292	40.48	26.98
TOTAL	698,051,006	698.04	465.34
Region 5			
1. Albay	102,642,554	102.64	68.43
2. Camarines Norte	87,116,450	87.12	58.07
3. Camarines Sur	102,986,112	102.99	68.66
4. Masbate	109,056,185	109.06	72.70
5. Gatanduanes	7,403.148	7.40	4.94
6. Sorsogon	122,740,577	122.74	81.83
TOTAL	531,945,026	531.95	354.63
Region 6			
1. Aklan	24,301,074	24.30	16.20
2. Antique	9,752,144	9.75	6.50
3. Capiz	13,184,213	13.18	8.79
4. Ilo-ilo	22,336,195	22.34	14.89
5. Negros Occidental	23,195,728	23.20	15.46
TOTAL	92,759,354	92.77	61.84

TABLE 8

Data on Localized Available
Coconut Shell Feedstocks

	QUANTITY **(Nuts)/Year	CAPACITY- @ 200 Days Year	*TONNE/DAY @ 300 Days Year
Region 8			
1. Leyte	237,013,172	237.01	158.01
2. Leyte Sur			
(a) Southern Leyte	54,046,761	54.06	36.03
3. Samar	82,802,796	82.80	55.20
4. Eastern Samar	99,939,235	99.94	66.63
5. Northern Samar	165,798,080	165.80	110.53
TOTAL	639,600,044	639.60	426.40
Region 9			
1. Zamboanga Metro Descom (Zamboanga del Sur)	235,797,189	235.80	157.20
2. Basilan	-	-	-
3. Sulu	98,567,065	98.57	65.71
4. Tawi-Tawi	-	-	-
5. Zambo (Zamboanga del Norete)	133,783,170	133.78	89.19
TOTAL	468,147,424	468.15	312.10
Region 10			
1. Agusan Del Norte	56,349,179	56.35	37.57
2. Bukidnon	3,681,795	3.68	2.45
3. Davao Orriental	199,444,235	199.44	132.96
4. Soutern Cotabato	212,397,697	212.40	141.59
5. Surigao Sur-			
a) Surigao del Norte	54,501,894	54.50	36.33
b) Surigao del Sur	66,382,654	66.38	44.26
TOTAL	592,757,454	592.75	485.06
Region 11			
1. Davao del Sur	176,544,451	176.54	117.70
2. Davao del Norte	84,711,508	84.71	56.47
3. Davao Orriental	199,444,235	199.44	132.96
4. South Cotabato	212,397,697	212.40	141.60
5. Surigao del Norte	54,501,894	54.50	36.33
TOTAL	727,599,785	727.59	485.06

TABLE 8

Data on Localized Available
Coconut Shell Feedstocks

	QUANTITY **(Nuts)/Year	CAPACITY- @ 200 Days Year	*TONNE/DAY @ 300 Days Year
Region 12			
1. Lanao del Sur	72,783,868	72.78	48.52
2. Lanao del Norte	111,702,898	111.70	74.47
3. Maguindanao	-	-	-
4. Sultan Kudarat	-	-	-
5. North Cotabato (Cotabato)	140,628,478	140.63	93.75
TOTAL	325,115,244	325.11	216.74

Plant Size Capacity - 200 kg/hr

Product available for sale = 0.8 x Product yield rated capacity

Char sales price = US $140/MT

Heating Value Pyrolytic Oil = 10,000 Btu/lb

Heating Value Bunker-"C" oil = 14,000 Btu/lb

Cost Price of Bunker-"C" oil = P2 per liter

(1 liter = 0.00096 MT)

Heating Value of LBG (fuel gas) = 125 Btu/ft^3

Heating Value of LPG = 1000 Btu/ft^3

LPG Price - P5/kg (1000 Kg/MT)

Peso Conversion Rate P9 = 1 US $

Product Yield:

Char Yield = 1.1 MT/Day

Pyrolytic Oil Yield = 1.2 MT/day

LBG Fuel Gas = 3.26 MT/day

Revenue Yield from the Sale of:

Coconut Shell Pyrolytic Char = US $ 123 per day

Coconut Shell Pyrolytic Oil = US $ 198 per day

Coconut Shell Pyrolyic LBG = US $ 181 per day

TOTAL = US $ 500 per day

= P 4500 per day

The plant-gate-product cost and the total operating cost can now be estimated from the following assumptions:

Venture Capital:	Provided by the government or international agency. No cost of money.
Feedstock Cost:	P 10 per 1000 nuts.

Feedstock Supplies:	24,000 nuts per 24 hour day.
Operating Labor:	3 per 8 hour shift.
Operating Labor Cost:	P 20 each per 8 hour shift.
Utilities and Supplies:	P 450 per day.
Plant Supervision:	15% of operating labor.
Maintenance Labor:	20% of operating labor.
Administrative Labor:	15% of total labor (operating + supervision + maintenance).
Payroll Burden:	15% of all labor costs.

Cost Factors	P/day	
Materials and Supplies		
Coconut Shells 2400 pieces/day	240	
Maintenance Materials	50	
TOTAL	290	
LABOR		
Operating Labor (9)	180	
Supervision	27	
Maintenance	36	
Adm. and Support Service	35	
Payroll Burden	40	
TOTAL	318	
Purchased utilities (water and electric)	400	
FIXED COST		
Property tax (Govt. Financed Project)	0	
Insurance	10	
TOTAL Daily Operating Cost	P 1018	= US $113/day

P = Philippines Peso.

From the above rough estimate, it is seen that there are p.enty profit incentives from such pyrolytic converter center ventures.

It had been proposed to use the pyrolysis oil also as a wood-treatment chemical.

Preliminary analysis of the pyrolysis oil produced from the pyrolysis of coconut shells showed that the oil is highly acidic (PH=3.2), but has a heating value of 10,850 Btu/pound. This proves that by proper selection of oil handling pumping and piping system, the oil could be used as a liquid fuel for any combustors. The proposal that the oil would have a better use in the wood treatment plant, could not be verified at this time. One plant operator objected the acidity of the oil and the other operator disputed the fact that acidity of the oil is a hinderance in its use. He felt that the oil will coat the metal surface first, so that the acidic constituent will not penetrate to the metal surface. Unfortunately, as of this time, the complete analysis of the oil was not available. It is important to know the complete constituents of the oil, specially the % composition of the creosote in the oil. Such oil when produced from sawdust and barks, showed creosote is only 1 to 2% by weight. Once this composition of the oil is known, the Forest Product Laboratory can give the opinion as to the suitability of the oil as a wood treatment chemical.

PNOC/ERDC staff members should investigate further into this matter. They have 4 main points to be resolved;

1. How the acidity of the oil will affect the hardwares of the wood-treatment facility.
2. Does the oil has the required wood preservative components.
3. Will the oil be stable at the operating temperature of 200 °F, and a pressure of 200 psig.
4. Will such oil be available in large quantities, for example, 100 to 150 MT/month, so that the oil can replace the creosote chemical for an average size wood treatment plant.

Assuming that the above 3 items are positive, then the question will be to produce sufficient quantity of oil in a given region. A 200 kg/hr pyrolysis plant will be able to produce:

Char 46 kg/hr = 1,104 kg/day
oil 50 kg/hr = 1,200 kg/day
gas 136kg/hr = 3,264 kg/day.

Therefore, we would need 3 to 5 such 200 kg/hr size pyrolysis plants to supply the creosote replacement oil to the wood treatment plant. There are a few selective regions that can supply such a huge quantity of coconut shells for the pyrolysis plant.

However, both the oil and the fuel gas can be used for their fuel values in drying copra, grain, fruits, fish and even to produce steam and electricity (cogeneration or combined cycle processes).

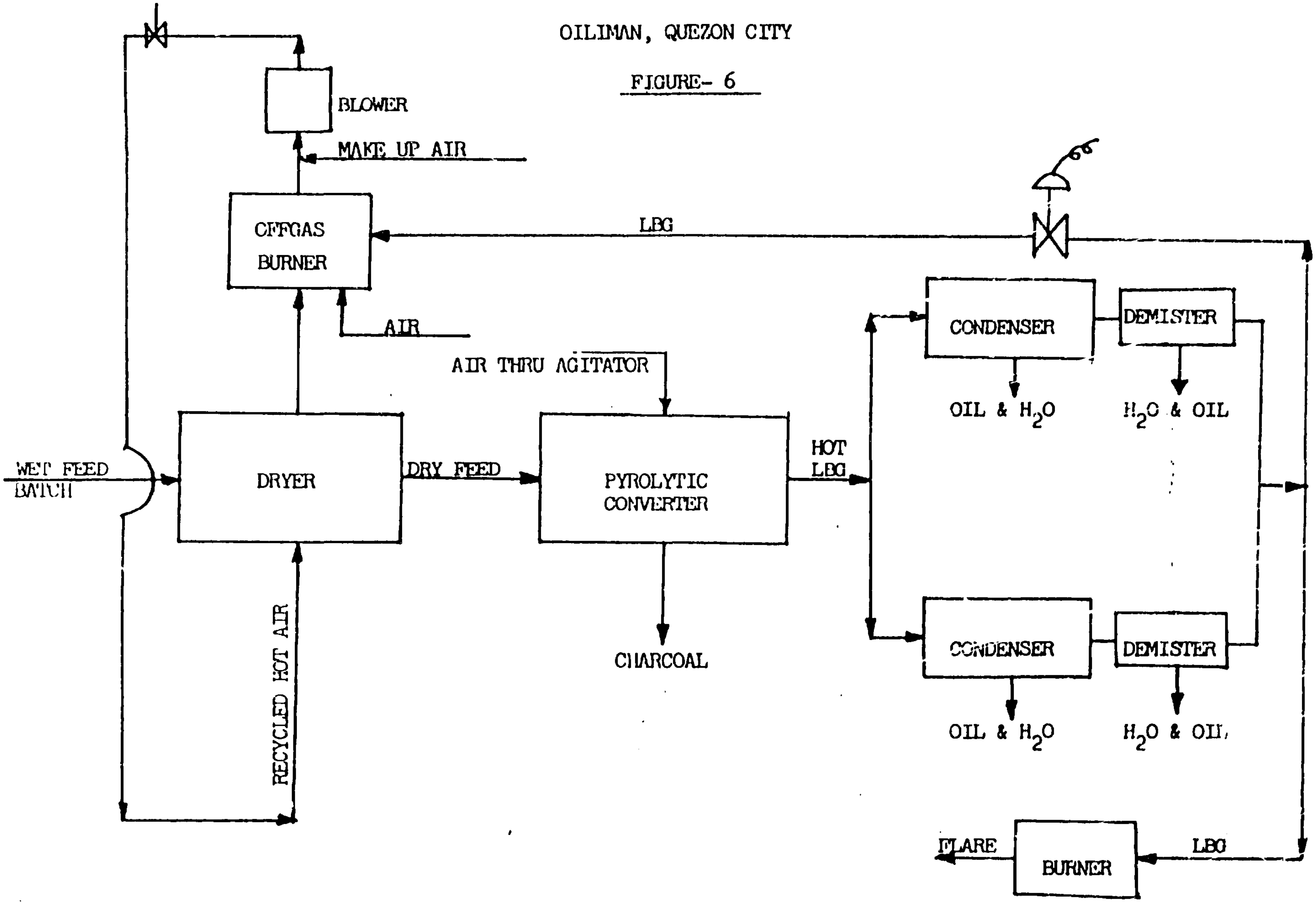
Similar calculations can be performed for other feedstock varieties (rice husks and saw dust). The advisability of pyrolytic conversion of rice husks and sawdust is not as clear cut as for coconut shell feedstock. The main reason being that the char produced from rice husks has no market. The cement industries to maintain their quality control standard, will require high purity silica. Rice husk char contains contaminated silica and the quality of the char will depend on its feedstock. Further, the cement industry requires that the char's fuel value be in excess of 10,000 Btu/lb, to accomplish the calcining operation. The heating value of char from rice husks ranges from 5000 to 7000 Btu/lb. The interviews with cement industry executives showed that they are very reluctant even to consider such a char as a fuel or a silica source. Their reluctance comes from the fact that the ingredients for cement manufacturing are fed from quality controlled automatic scaled feeders. With char as fuel as well as silica, such automated preset mixing of ingredients could not be followed with char derived from rice husks. The oil production from the rice husks will require extreme predrying (5% level) thereby wasting much valuable fuel gas in addition to adding the maintenance cost burden of an expensive dryer. Also coconut shell feedstock does not need any predrying. The average moisture level of coconut shell is 8% by weight.

Similar case studies will also show that sawdust pyrolyzing is also not very justifiable. Sawdust is normally discarded outdoors and therefore is subject to wet weather conditions. Like rice husks, for a good yield of oil from sawdust, they have to be predried. The char that is produced from the sawdust pyrolyzing process has to be briquetted for easy handling storage and for domestic use. Commercial use for such char as a char-oil slurry has not yet been proven to be economically justifiable, even in the U.S.A. Limited tests at the Pittsburg Energy Center showed more problems than promises (8). The use of char-oil slurry does not seem a very realistic approach for developing countries.

PROPOSED PILOT PLANT OF PNOC-ERDC

OILIMAN, QUEZON CITY

FIGURE- 6



4. REVIEW OF EXISTING DESIGN CONCEPT

4.1 How the present design meets the project objectives

The market survey data revealed high demand for coconut shell pyrolysis products and very little, if any, for the same for rice husks and sawdust. Market survey data may be interpreted to conclude that for the Philippines, pyrolysis of coconut shells or wood chips is an appropriate alternative energy technology. On the other hand, it seems that the gasification is the proper method of converting rice husks and sawdust to energy products. Rice husks and sawdust may be densified for easy handling, storage and feeding to the gasifier. Dr. Ibarra Cruz has demonstrated the successful gasification of rice husks and sawdast gasification products (fuel gas) can be used to generate on-site power and through cogeneration and/or combined cycle operations, the thermal energy need for drying of Copra could be met. The problem associated with the disposal or sale of pyrolysis products of high ash content char from rice husks, granular char from sawdust and their pyrolytic oils will not therefore arise in the case of gasification conversion process.

Another very important information that surfaced during the market survey, is that, most of the large coconut plantation areas have no electricity and the residents of these areas are of agricultural labor class, without much formal technical educations. This puts severe restraints to introduce a high technology, fully or semi-automated power driven pyrolysis trains in these regions.

In the backdrop of the above survey data the present completed design of pyrolysis equipment system can now be examined. It is evident that a pyrolysis system was designed which is very similar to that developed by the Georgia Institute of Technology, USA, in 1980 under UNIDO project - Indigeneous Energy Resources, Development of a

Pyrolytic Converter to Use Rural Wastes in the Philippines. This reactor design has been used for some projects in Africa, Asia and recently in Costa Rica.

This reactor system is designed for pyrolyzing granular feedstock like rice husks and sawdust with a low temperature, slow pyrolysis process, predominantly producing char and oil.

However, the project objectives call for the development of a more universal reactor system that can use a wide variety of feedstocks of homogeneous and heterogeneous character. Its design should be such that it could be used either as a slow, low temperature reactor for the production of mostly char and oil or as a fast, high temperature reactor for maximizing fuel gas production and char yield. The present reactor can be applied only to the pyrolysis of rice husks or sawdust.

4.2. Comments on specific equipment design

In checking the equipment system design, the author found no as-built drawings of equipment, no design flow diagram, no design calculations, no mass and energy balance data, and instrumentation and measurement drawings. It is therefore assumed that the structural designs of the equipment components are sound and without knowing the mass and energy balance of the system, the flow parameters and equipment system capability are appropriate and adequate.

Figure 6 shows the schematic view of the pyrolytic reactor system presently under construction. In the following sections major equipment system will be studied in respect to their functional characteristic and modifications will be proposed, if necessary.

4.2.1 Feed conveyor

The screw conveyor used will work properly only with dry, homogeneous particle size feedstock. To handle also heterogeneous, wet or dry, feedstock a hopper with a guillotine door, a weighted lever dump door, or a single/double bell design door would have been better.

Another possible alternative feeding device is the ram type feeder. For granular feedstock, the internal of the reactor should be provided with a spreader plate for even distribution of the feed, inside the vessel, otherwise the granular feedstock have the tendancy to pile up at the middle or at the feedpoint in the reactor vessel.

For atmospheric or near atmospheric pressure reactor operation, a single guillotine or single bell or ram is quite adequate. A hopper with a 60" angle of repose will adequately ensure flow of feed. A simple belt conveyor can carry the feed to the hopper. Level control device could be used to open and close the trap door to the reactor.

4.2.2 Reactor vessel

The reactor is designed with 40 to 44 lbs/hr-ft^2 design load factor. This is quite conservative and therefore, in actual operation, the reactor will be able to process at least 50% more that the design capacity (100 kg/hr of biomass feedstock). The reactor is internally unlined and the outer cylindrical jacket over a cone shaped reactor vessel has been provided for indigeneous insulating material (rice husks). The concept may be quite attractive for applications in many developing nations. However, for the Philippines a proper internal refractory lining, seems likely to be more appropriate. On examination one finds that the top section of the reactor which is cooler than the bottom part of the vessel will have the thickest insulation. The hearth area (the hottest section) has no insulation and the cooling was left to be done by natural convection. Had the equipment been located outdoors and the wind was blowing over the reactor, such natural convection cooling might have been adequate. But this reactor is located inside an enclosure and natural convection cooling may not be adequate. Another consideration is that such a reactor is meant to be operated in a low temperature pyrolysis mode. Low temperature pyrolysis (450 °C) is a highly variable process and the pyrolysis yields depend upon:

(a) Temperature level
(b) Heating duration
(c) Pressure
(d) Feedstock variety
(e) Particle size of the feedstock

Therefore high char and oil yields are geared only for pyrolysis of homogenous particle size feedstock like rice husks and sawdust, in a low temperature pyrolysis mode.

Refractory materials are available in the Philippines as all of GEMCOR's gasifiers are lined with refractory. Another question is for the use of rice husks as insulation material. When the reactor was operating, the rice husks lying close to the hot reactor shell will carbonize and thereby loose its insulating property. Who is going to check routinely how much carbonization has occured to the rice husks and how often new husks will be needed to replace the carbonized materials.

Increased heat loss from the shell of the converter means increased oxidation of feedstock will be required to supply the required heat of pyrolyzation. The author is not sure, if such thermodynamic consideration was made in designing the reactor insulation.

The reactor vessel is equiped with agitator which serves also as the air supply tube. The idea and the design is very novel but will this design work for heterogenous size feedstocks such as coconut shell, wood chips, corn cobs, etc? Will the rotor shaft and the agitator extension rods rotate in a packed bed reactor with such coarse material? Further, can this design be scaled up for large diameter reactors?

The type of level controller (paddle design) used may not be proper for any feedstock other than rice husks or pure sawdust. No opening for the insertion of level controller elements to the reactor vessel and jacket were noticed. Did the author miss this opening or is it meant to be done in the laboratory?

Can the reactor as designed be operated in the fast, high temperature pyrolysis (780 - 850 ^{o}C) mode? It seems that the reactor design concept does not fulfill the objectives of the PNOC/ERDC's project.

The following alterations are recommended:

1. The reactor should be lined with proper refractory, thickest at the hearth area and thin at the top.
2. Air injection by tuyeres will give high penetration and such a design can be scaled up. A bussle pipe should be provided for even distribution of air. The number of tuyere nozzels will depend upon reactor diameter.
3. The top of the reactor should be provided with a feed hopper and a gate or ram feeder and a gate.
4. The height to hearth diameter should range between 5 to 8.
5. Level controller design should be modified to accommodate a wide range of feedstock varieties.

4.2.3 Grate

The present design of the grate is excellent for homogeneous granular char, but what will happen if the rice husks feeds carry stones or rocks into the reactor vessel or the sawdust feedstock contains chunks of wood or bark. The char in either case will contain such materials as stone or half pyrolyzed or unpyrolyzed chunks of wood that may obstruct the operation of the present design grate.

It is therefore recommended to apply cascading rotating grate which is universally used for coarse feedstocks. PNOC/ERDC has incorporated such a grate design in their gasifier.

4.2.4 Dryer

It is noted that the feed flow control of the dryer is controlled by two rotating cylindrical shafts and the shafts are mounted on pillowblock bearings.

In reviewing the dryer design,which is suitable for homogeneous feedstocks like rice husks and sawdusts, the question arises whether of the dryer will successfully operate with granular feedstock,contaminated, larger particle size feedstock, like stones, rocks, large hunks of wood, large slabs of bark. It is feared the shaft rotation may freeze and damage the equipment. Scale-up of this dryer for large model reactor is hardly justifiable. There is no room in the dryer design for accommodating these larger size materials.

On the other hand, a rotary dryer (single or double pass) can accept any or every size of feedstock. It is true that such a dryer will require surge bins, but these are standard equipment, the reliability of which have been proven over the years of use. Why then go for a new development programme for a new dryer design that has only a narrow range of use?

Without appropriate design documents, the effectiveness of the dryer or its performance in terms of energy conservations can not be studied. From figure 6 it is noted that the blower is located on the hot gas flow path. It is not known how much cooling air is blended with the hot product of combustion. A blower with hot gas, may cause severe problems. It is said that in this arrangement the recirculation of hot gas will provide savings in fuel. This may be true, but it will also require a hot fan for keeping the recirculation going. In case of cooling air failure, or occasional temperature incursion that may occur due to change in heating value of fuel gas, the blower will be subjected to severe thermal load and operational problems may follow.

Gas cooling and oil separation

The following considerations should be taken into account before standardizing this set condenser design for scale up models:

1. Can this design be scaled up effectively?

2. Will the pores of the inner cylinder clogg during prolonged use?

5. INSTRUCTIONS

Two sessions of instruction classes were conducted at PNOC/ERDC. The staff members directly involved with the development work related to the pyrolysis of biomass wastes were invited to attend the sessions.

As the details of the lecture series and description of the hand-out materials are of little interest to the main intent of this report, only the classroom discussion topics will be identified here.

Session I was devoted primarily to discuss the fundamentals of Bioresource energy conversion processes. Transparencies for overhead projection of instructional materials were used and each participant received a set of working and reference materials. The main topics of the discussions in this session were:

1. Scope of bioresource conversion processes, such as pyrolysis, gasification, combustion, biochemical and direct liquifaction.
2. Fundamental factors that distinguish a pyrolysis, gasification and combustion process.

3. Reactor varieties and characteristics

   a) Classical pyrolysis reactor design

   b) Starved-air or partial oxidation reactors designs in:

      - Packed bed (vertical shaft)
      - Entrained bed (moving inert heat carrier)
      - Fluidized bed (direct and indirect heating)
      - Tumbling bed (direct and indirect heating)
      - Multiple hearth bed

4. Typical zonal reactions in a pyrolytic reactor

5. Case study of a typical wood chips feedstock pyrolysis system: flow diagram, mass and energy balance, plant facilities investment cost, operating cost, and cost/benefit analysis.

6. Batch and continuous charcoaling methods.

7. Continuous briquetting train technology.

8. Equipment systems for feed preparation as hammer mills and dryers.

Session II was devoted primarily on the instrumentation, data gathering, data compiling and data reduction steps, precautions, calibrations and reporting. Actual class room problems were used to practice data computation steps. The attendees were required to solve actual classroom problems. The topics discussed in this session were:

Lecture series 1 (Morning)
Test preparation

a. Sample preparation
b. Instrumentation
c. Identification and measurement of feedstock
d. Moisture determination technique (improvised)

e. Gas and Air Flow Measurement Techniques

f. Gas Composition by orsat and sample collection for G.C.

g. Methods of Calculating BTU/Value of Feedstock and Products from ultimate analysis

h. Identification of Thermodynamic Equilibrium state of Reactor Operation

i. Calculation of Conversion Efficiencies for the overall and Component Systems

k. Preparation of data sheet

l. Interpretation of data

Lecture series 2 (Afternoon)

1. Sample Calculation of Mass and Energy Balance
2. Sample Calculation of Conversion Efficiency
3. Sample Calculation on Performance Testing Data
4. Instructions on Evaluation Techniques and data representation
5. Report Writing
6. Exercise to calculate plant facilities investment (PFI) cost, operating cost and cost/benefit analysis

6. RECOMMENDATIONS

1. Prepare a design manual so that PNOC/ERDC staff engineers can design pyrolytic reactors of various sizes and for variety of feedstocks. The design manual would address to both fast, high temperature and slow, low temperature pyrolyzer designs.

2. Prepare a comprehensive performance testing manual. This manual would identify measurement parameters and locations, instrumentation and test variables. The test manual would show sample calculations for computing system and component efficiencies. Data gathering format should be patterned for computer entry and computer aided evaluaions.

3. Conduct performance tests with the recent pyrolysis equipment system and use the equipment as the training base for the staff engineers. Proper understanding and interpretation of the operating data, would point out the short-comings or adequacies of the present design. Evaluate system yields and product quality with "as received" and dry feedstocks.

4. Design a reactor system that will accept wide varieties of feedstocks, specially coconut shell with and without husks, wood chips, block-wood, barks and slabs, corn cobs and densified agricultural biomass wastes. Incorporate equipment train design for maximum char and oil, and char and gas yields from "as received" and dry feedstocks.

5. Procure an on-line computer like 'PET-Commodore' type, for data gathering and data computation. The data gathering, data storage and data evaluation work for a long term development project should be assigned to an on-line computer. The inevitable human errors associated with repeating and similar data collections, could be costly and would be avoided by using a computer.

6. As it was learned that most of the project sites (coconut plantation areas) have no electricity, the introduction of the high-technology electric motor driven equipment system to these regions will have problems. It is therefore recommended that an improved version of pyrolytic converter design of RRM Enterprise, 36 Bannag St. PINEDA, PASIG, Metro Manila, be fabricated and tested along with the system developed by PNOC/ERDC. Photographs of the stationary and mobile units of the RRM Enterprise are shown in fugures 7 and 8. This reactor has no moving parts and requires no motive power to operate. A schematic view of the process is shown in figure 9. Mr. R.R. Mesias Sr. President of the RR Enterprise may be contacted to get the design data. This is a low technology pyrolytic converter. Native plantation workers can operate this plant without much difficulty. This indigenous technology should be fully developed and if proven successfully, wide spread use of such reactor may be promoted.

7. Pyrolytic conversion technology should be practiced primarily for coconut shell and wood chip feedstocks. Gasification conversions of rice husks and sawdust are more appropriate, in terms of product utilization and marketing.

8. Market survey data gathering is not complete. It should be completed by either PNOC/ERDC staff members or by any outside agent.

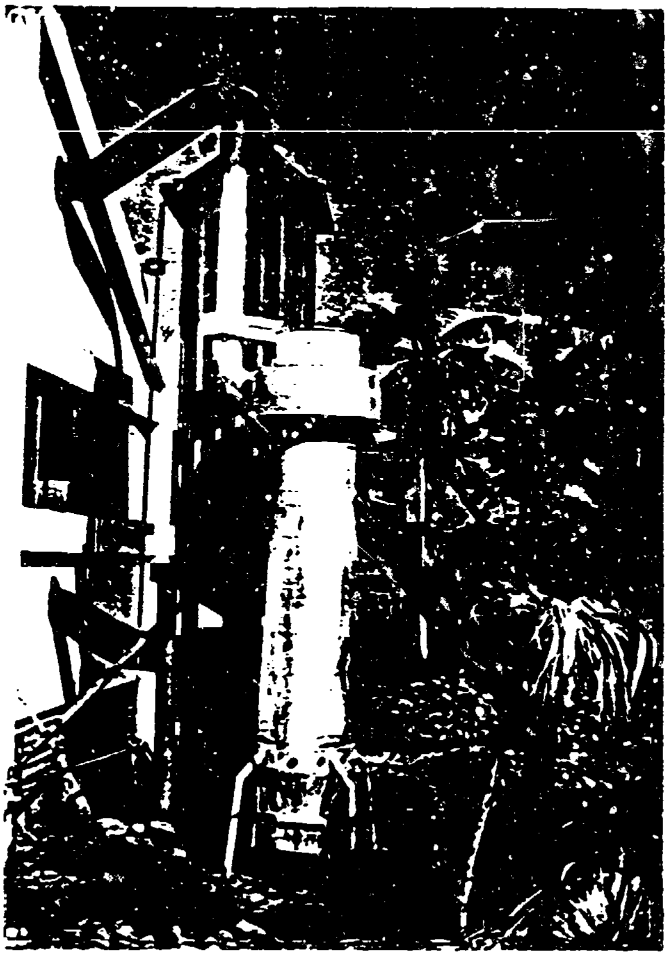


FIGURE- 7

RRM ENTERPRISE STATIONARY PYROLYSIS REACTOR SYSTEM

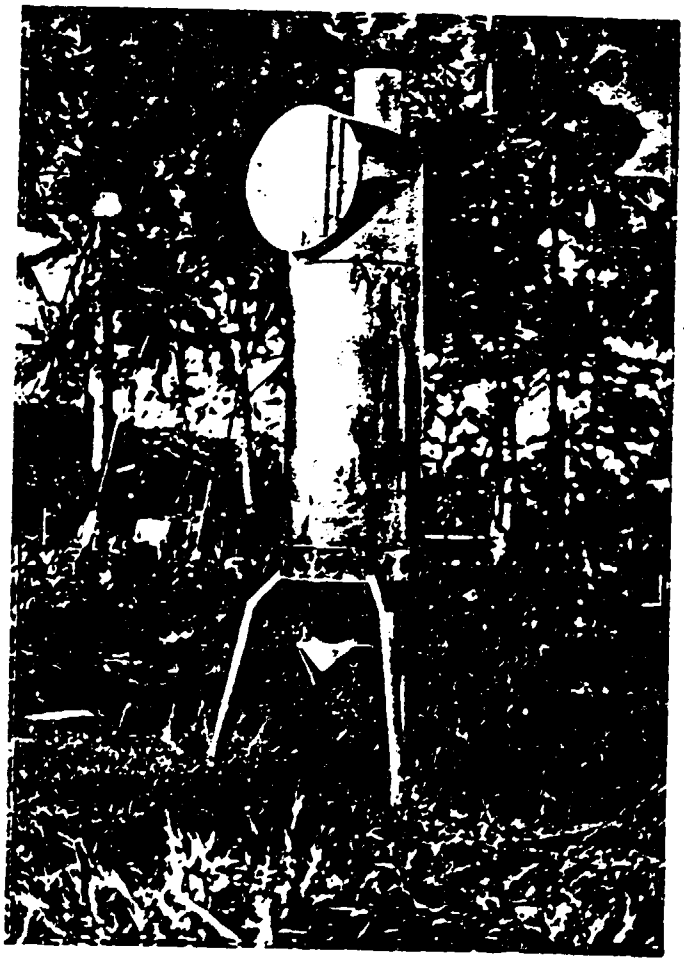
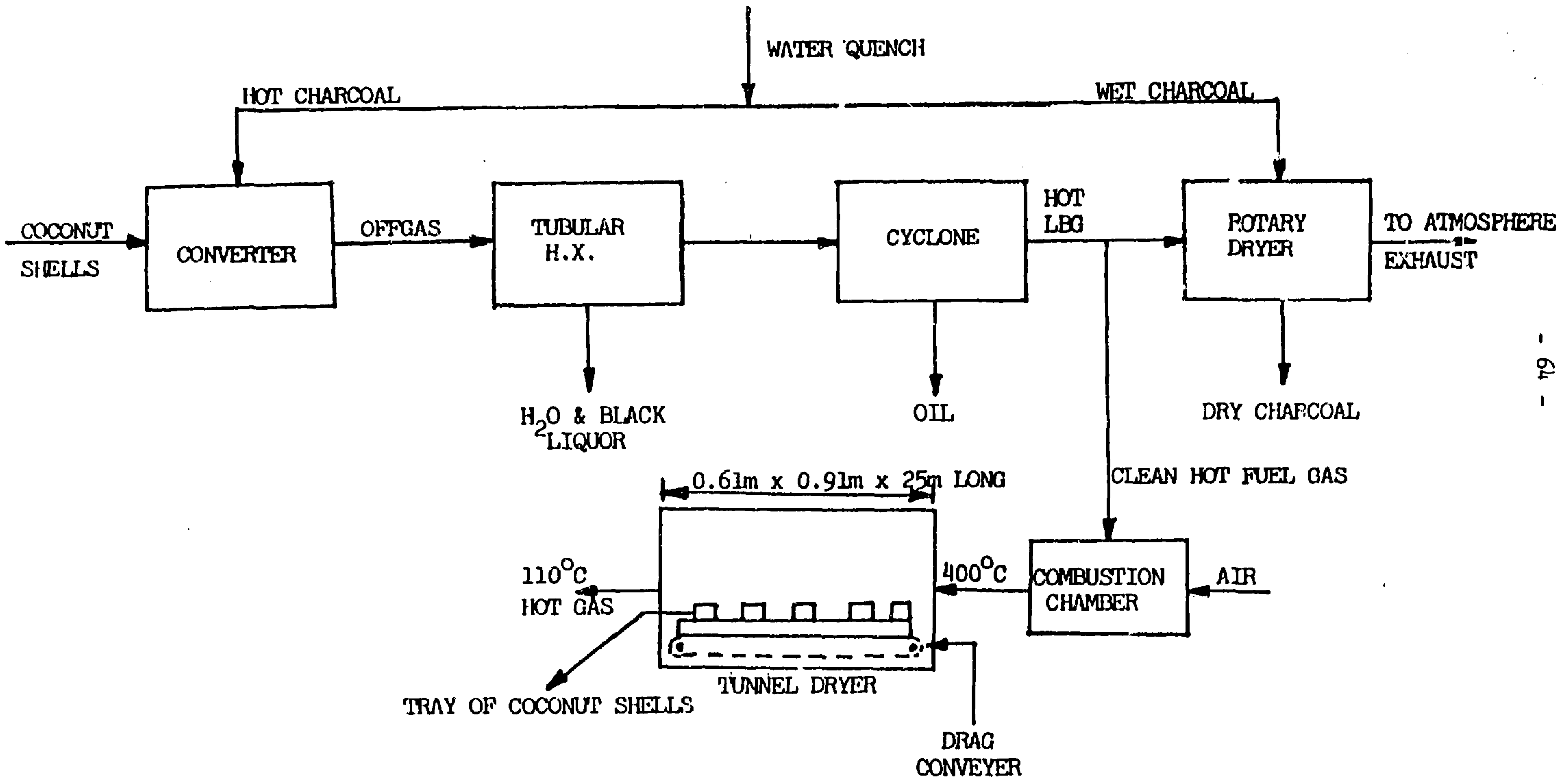


FIGURE- 8

RRM ENTERPRISE MOBILE PYROLYSIS REACTOR

ROMMYR ENTERPRISE INC. PYROLYSIS FLOW DIAGRAM

DARAGA, ALBAY BICOL REGION V



SCHEMATIC FLOW DIAGRAM OF RR ENTERPRISE PYROLYTIC CONVERTER SYSTEM

FIGURE - 9

7. ACKNOWLEDGEMENT

The author wishes to express his appreciation to all the staff of the Energy Research Development Center for their excellent co-cperation and valuable discussions.

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