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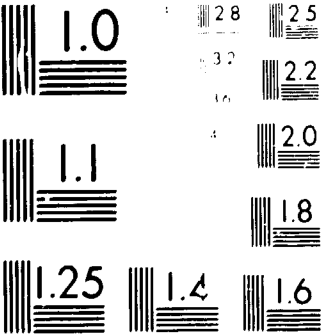
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



MICROCOPY RESOLUTION TEST CHART

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DP/ID/SER.A/397
11 November 1982
English

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ASSISTANCE TO ENERGY PRODUCTION FROM BIOMASS WASTE MATERIALS

DP/PHI/78/022/A/01/37

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 John W. Tatom,
Consultant in Biomass Pyrolysis

United Nations Industrial Development Organization
Vienna

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INTRODUCTION

This document is basically a progress report describing activities during the period 1 July 1981 through 31 July 1982 on UNIDO project number DP/PHI/78/022 A/01/37 conducted in conjunction with the Government of the Philippines and entitled "Assistance to Energy Production from Biomass Waste Materials". In reading the report, reference should be made to the final Project Document, (1)[1] dated 18 February 1981, since several of the sections presented herein are designed to specifically satisfy the terms of this agreement; in particular Section E of the Project Document entitled "Outputs". While the schedule of the reports described in Section E has of necessity been delayed, there have been no reasons found to recommend any basic changes to this document and so, with minor exceptions, it will be followed closely. One small change, however, will be to delay preparation of the final production designs until testing is completed on the initial prototype plant currently under construction. This will allow any improvements developed or modifications required to be reflected in the final production system drawings, which should be one of the more important final outputs of the project.

1)[1] Numbers in parenthesis refer to citations listed in the REFERENCES SECTION.

Therefore this report, with the exception noted, should bring up to date the outputs called for in the Project Document. However, it should be recognized that due to the delay in the implementation of the project, the original project duration of 24 months is not believed to be realistic, and there is no practical way the entire body of work can be completed in the time alloted. Therefore it is necessary that a no cost extension to the project of perhaps 12 months to July 1984 be granted, and formal action in this regard is being initiated by the contracted organization.

Before proceeding into the report itself, it might be useful to observe that a considerable change in philosophy toward greater mechanization of the pyrolysis system has occurred since the original work (2,3) in the Philippines was conducted. This greater emphasis on mechanization has also allowed substantial technical improvements to be made to the system, and these developments, arising and proven from projects in Indonesia, Papua New Guinea, and Costa Rica, have been incorporated into the present Philippine Design.

The movement away from a more labor intensive approach has been necessary because experience has taught that it is unwise to depend upon manual operators to constantly and properly perform functions essential to successful operation of the system; e.g. turning the stirrer which keeps the packed bed from bridging. Moreover, it is noted that most of the additional mechanical devices required can be made or are available in country, and therefore while some loss of overall labor intensity and an increase in cost do occur in taking the more mechanized approach , the system reliability, performance and economics are materially improved by this action. Thus it is believed justified, since in the final analysis the economic viability of the system is the real test it must pass.

Presented in the following sections is first a survey of existing technology for utilization of the pyrolysis products,which is followed by a review of Philippine agriculture and forestry process plant waste production, and a design of the prototype demonstration plant. Presented last are conclusions and recommendations for future work.

SURVEY OF EXISTING PYROLYSIS PRODUCT UTILIZATION TECHNOLOGY

The products of pyrolysis; charcoal, oil and gas, generally have both domestic and/or industrial applications for which considerable study has already been made. This section then is presented as a review of this prior work, but in no way should be regarded as comprehensive, and reference to the earlier papers is advised for a more detailed discussion of the separate utilization methods.

Charcoal

In most cases, charcoal represents the primary product of pyrolysis, and using the packed bed, partial-oxidation technique described herein, the charcoal yields, based on a dry, ash-free fuel, run in the range of about 25 to 30 percent. The ash content of the charcoal, the volatile fraction, and its activation quality are primary properties that not only establish its value, but frequently determine the type market it is traded in. For example, rice husk charcoal may be literally half-ash, due to the high silica content of the husks, and is thereby not very useful in most industrial applications. Thus, it is generally restricted to domestic uses, with a few exceptions. Likewise coconut shell charcoal, because of its extremely high quality, is not wisely used as a fuel in either domestic or industrial applications, but should be activated or sold directly as a feedstock on the activated charcoal market. Wood charcoal, because of its low ash content, has uses both as a domestic and as an industrial fuel.

Regarding industrial uses of charcoal, one extremely well suited application, of special interest in the Philippines, is in very simple, up-draft gasifiers, which could be used to fuel internal combustion engines. While the charcoal would have to be available in lumps or briquets, its value in this case would be particularly great, and could assist in the replacement of imported petroleum products. However, it is important to note that this application to rice husk charcoal should probably be avoided, since there is no known, successfully operating gasifier that can or has run on this high-ash, slagging material.

Another promising application of low-ash charcoal would be as a fuel oil extruder in industrial boilers. Here, the charcoal would have to be finely pulverized and mixed in a slurry with the oil. Recent tests of this technique have been made at the U.S. Department of Energy Pittsburgh Research Center (4) under an EPA sponsored program. Quoting from the summary of these tests reported in (4): "The combustion and handling characteristics of char from pyrolyzed wood wastes were determined in a 227 kg/hr (500 lbm/hr) pulverized-coal-fired (PCF) combustion test facility, and as a slurry with No. 6 fuel oil in a 981 kW (100 HP) oil-fired boiler. In the PCF combustor, tests were also run with a 50-50 blend of Pittsburgh-seam, high volatile coal with a high-volatile pyrolytic char. Stable combustion could be maintained with a secondary air-preheat temperature of 316°C (600°F), the temperature generally used when firing coal, at a carbon combustion efficiency of 97.3 to 98.6 percent. With the low nitrogen content of the char, nitrogen oxide emissions were very much lower than those obtained from coal (0.25 compared to 0.80 lbm $NO_2/10^6$ Btu) at the same firing conditions. The NO_x emissions obtained with the 50-50 blends appeared to be an average of the values obtained for the fuels separately. Similarly, SO_2 emissions were low with the char alone (0.18 lbm $SO_2/10^6$ Btu), and with the blends, were an average of the values obtained with the fuels separately.

A 60-40 blend of pulverized char and char-oil, combined with No. 6 fuel oil to produce a slurry containing 30 percent char, performed will in a 981 kW (100 HP) oil-fired firetube boiler modified to fire coal-oil slurries. Excellent flame stability was experienced, and the carbon-combustion efficiency was similar to that obtained with No. 6 fuel-oil and coal-oil slurry. Nitrogen oxide emissions were significantly lower than those obtained when firing coal-oil slurry, and SO_2 emissions were about

50 percent lower. Some fculing of the small ports in the burner nozzle occured as a results of the accumulation of small fibers passing through the filter screen".

A particular interesting industrial application that includes rice husk charcoal, is as a fuel in cement kilns. Since there is currently a major Philippine program to modify cement kilns to burn coal, in place of the presently used petroleum oil, such an application would be especially convenient, appropriate, and timely. To get an idea of the national quantities involved, up to one million tons/year of high quality Australian bituminous coal are planned to be needed ultimately to supplement the local, poorer quality variety in the kilns. Thus, this market represents an almost bottomless pit, at least initially, and could potentially underwrite the development of a fuel charcoal industry, and provide a way of establishing a baseline price for the charcoal.

Because good quality sand, which is a raw material in cement production, is in short supply in the Philippines, the presence of silica in the rice husk charcoal would represent no problem at all; in fact it would be a substantial asset. And the clinkering characteristic of the ash would not be a handicap, since the cement itself is produced in a hot, viscous, semi-liquid state. Thus the use of rice husk charcoal as a fuel in cement kilns should be of special interest to the pyrolysis project.

It should be emphasized that there are no technical problems in using charcoal in cement kilns, especially once the modifications for burning coal are completed. Indeed, wood charcoal alone has been used in the past to fuel cement kilns in numerous locations throughout the world, including Kenya. Therefore, while this application must be investigated carefully, for example, to insure that the transportation costs are not excessive, it represents an especially promising activity that could have an important impact on charcoal utilization in the Philippines.

There is one other use of high quality charcoal, especially from coconut shells, that is of great interest; i.e. in the production of activated carbon. Since this activity is currently being vigorously pursued in the Philippines, it is especially promising. This is true not only because the market for the charcoal is already established, but because of the high value of the product and because the quantities of coconut shells available are enormous. In addition, there is experience in Papua New Guinea (5) in an identical application which reinforces the economic aspects of such an approach. And conveniently, of all three principal Philippine waste sources, coconut shells are by far the easiest to process, and thus represent the least technical problems using the packed-bed, partial-oxidation process. Thus, at this juncture, coconut shell carbonization would appear to offer a very great opportunity for the pyrolysis project, and gaining experience with these shells would perhaps be of the highest priority.

In regard to domestic uses of charcoal, especially as a fuel, it must be realized that for successful combustion to occur, the charcoal must be in lumps or be briqueted. This requirement introduces a considerable extra production cost to charcoal made from sawdust and rice husks, especially for the briquet binder needed. In addition, there is the problem of briquet ignition which can often be a tedious procedure, and may require the use of a starter fluid such as kerosene or perhaps better, a small bed of dry "kindling" wood located beneath the briquets. This wood can not only ignite the briquets but also provide an initial pulse of heat to start the "pot boiling" while the briquets are better suited to maintaining the boil.

The choice of a briqueting technique is also an additional economic factor which is to a large extent also governed by the market. For wood charcoal produced far from the market, high quality, high density briquets are required to withstand the extended, rough handling involved and to minimize transportation costs. In this case, mechanical pressure formed briquets produced by means of rollers or extruders are probably most practical. Thus, since a higher price for the better quality charcoal can more easily be gotten in the urban areas, it would seem likely that the market for these briquets would most probably be found in the cities.

In passing, it is noted that "Appropriate Technology" briqueting machines with a capacity of up to one tonne per hour can be found in production currently in India in the price range of one to two thousand US dollars (6). Since the Philippine wood wastes are typically produced at fairly large production sites, these machines may be appropriate for such applications, and their design should be investigated with the idea of transplanting this technology to the Philippines.

Because of its lower quality, charcoal produced at the more than 12,000 Philippine rice mills cannot justify a high briqueting cost. However, because of the close proximity of a dominant part of the potential domestic charcoal market to these rice mills, the need for a high quality briquet is considerably less than for wood, since the transportation distances involved will be only a few kilometers. Therefore a simpler, less expensive briqueting technique is appropriate to rice husk charcoal.

One such technique involving agglomeration of the charcoal into spherical "fireballs" has been used recently in Indonesia (7) to produce briquets having a bulk density of about 20 lb/ft^3 or about two-thirds of that of those produced by mechanical pressure. These briquets have a surprising impact strength i.e., they can survive a fall of two meters on concrete with little or no damage. Their bulk "energy density" of about 135,000 Btu/ft^3 is three times that of rice husks, and, combined with the smokeless property, these briquets offer a valuable alternative to wood in rural areas.

Pyrolytic Gas

Because of its relatively low heating value and its oil/water content, pyrolysis off-gas is limited to applications at or near the point of production, since piping it at great distances or compressing and storing it is simply not economical. However, even with this restriction the gas is extremely useful, and can be applied to numerous needs for energy that probably are present at or near charcoal production sites. Most likely the gas can be used for drying, and a great amount of experience with this application has been gained to date (8). The gas burns cleanly, and with a stokiometric flame temperature of more than 2,000°F, provides an ideal fuel for kilns and boilers, as evidenced from a recent experience in Indonesia. In addition, experience in the US (4) and in Indonesia (7) indicates that the dry gas is an excellent fuel for powering internal combustion engines, especially spark ignition engines, which can be easily modified to operate on the gas. However, using the gas there is about a 30 to 40 percent reduction in engine power available, and considerable attention must be given to cleaning and drying the gas before it is introduced into the engine.

In passing it is noted that there had been proposals. to use producer quality gas, such as that from a pyrolysis system, as a fuel in the multitude of small diesels located throughout the Philippines. However, since this application still requires typically 15 to 20 percent diesel fuel to act as an ignition source, it would seem that some thought should be given to modification of these engines to replace the fuel injectors with spark plugs. It would be likely that the cumbersomeness of a dual-fuel engine plus the extra cost of the diesel fuel used would justify this alternative approach, and plans to investigate this alternative are currently being made.

Because of its significant CO content and resulting human health danger, there is probably only limited application of the pyrolysis off-gas to domestic uses. However, if simple safety equipment to automatically close off the gas supply, in the event of an interruption, were available, it is not unlikely that some homes, especially those in the vicinity of the charcoal production plants, could be economically served with this gas.

One advantage of the packed bed, partial-oxidation process is that the gas production can be adjusted (by changing the amount of process air used) to meet the local needs for energy. This allows the system to be operated in a variety of modes and provides economic flexibility, since the most profitable combination of char, oil and gas production can be adjusted as local conditions change.

Pyrolytic Oil

The pyrolytic oil represents the most difficult by-product to utilize at small or intermediate scales of production. This is primarily because of its high acidity (pH of about 4), and the presence of minute dagger-like carbon particles in suspension. Also, the unavoidable presence of 10 to 20 percent water reduces, the heating value to about 10,000 Btu/lb and makes the oil burn in still air with a sputtering flame.

For very large scale industrial applications the oils have their greatest value, since at these capacities it should be practical to refine them to separate out the vast array of valuable organic compounds that they contain. However, such large scale applications are not practical initially when the supply is limited, and an alternate, interim use for the oils must be found.

One obvious application as a boiler fuel, and experience in the US (8) using the pyrolytic oils in combination with bunker oils has been gained. However, due to the corrosive nature of the oils, careful preparations must be made in order to use these fuels, and modifications to the fuel storage and handling system may be necessary. Thus since a boiler operator will not be willing to make these modifications to his system until a guaranteed supply of oil is available, there may be some hesitation on his part until considerable operating experience of the pyrolytic system is gained, and he is confident of its continuing production. Indeed, the need for a continuous, guaranteed supply of these pyrolysis by-products is a major factor in their marketing, and represents a significant delay between the start-up of a plant and operating in a profit making mode. This consideration highlights interest in the application of this technology to coconut shell charcoal, since their market is already established, and minimal delay would occur before the plants would be making a profit.

Another industrial application of the oils is as a diesel fuel and a very limited experience with this use has been gained recently in Indonesia (7). However, because of the need to neutralize the oils and the tendency of the neutralized oil to become almost a solid, there has been a further requirement to dissolve the oil in some solvent. In Indonesia alcohol was used successfully, and then palm oil was added to give lubricity to the mixture. The resulting fuel was approximately 50 percent neutralized pyrolytic oil, 25 percent alcohol and 25 percent palm oil. It did successfully fuel a small diesel engine for a short period, but fouling of the fuel injector occured eventually due to the presence of the carbon particles, even though efforts had been made to filter the oil. These tests suggest that with very careful filtration and further improvements in technique, the pyrolytic oils might be useful in diesel engines, especially the larger variety which are less sensitive to the fouling problem encountere

In Indonesia (7) it was also recognized that the c. which contain substantial quantities of creosol might serve as a wood preservative, and very limited tests confirmed this surmise. However, in the Philippines this concept has been carried much further, and practical experience using oils recovered from a coconut shell charcoaling plant has been gained. A local coconut charcoal producer[1] reports he has successfully used the pyrolytic liquors to treat the soil around concrete foundations to prevent termite and insect infestation. In addition, a local wood preservatation company has expressed interest in buying up to 50 tonnes/month of oil, if it meets certain standards. While this quantity of oil could be supplied by only a relatively few convertors, it does represent a proven market that could materially benefit the start-up of a charcoaling industry using the packed bed technology.

In regard to domestic applications of the oil, especially for lighting or cooking, there has been no success reported in the literature. The poor wicking action of the oil, its moisture content and its tendency to carbonize in the wick have resulted in unstable, flickering, short-lived flames in all the tests conducted. Thus unless some practical means of avoiding a wick can be devised in new designs of lamps and/or stoves, it is not likely that this approach will be a fruitful one. However, a continuing review of this problems should be conducted,

1) This same charcoaler has developed a simple, portable, natural convection operation, partial-oxidation, packed bed pyrolysis system that uses the same basic principles of operation as the system described later. While this retort does not currently allow recovery of the oils, its simplicity makes it of special interest, and further study of this design is warranted.

and if new ideas are uncovered, a prompt investigation of these should be made, since clearly it would be extremely desirable to provide a domestic liquid substitute for kerosene, especially for rural applications.

BIOMASS WASTE PRODUCTION IN THE PHILIPPINES

National Significance of Biomass Waste

There are three main sources of biomass wastes in the Philippines; i.e. rice, timber, and coconuts. Since field residues such as rice straw and logging wastes are difficult to collect, the primary focus of the project has been on process wastes; i.e. rice husks, sawmill wastes and coconut shells and husks. To get an idea of the quantities of process wastes involved, Table I is presented. In regard to the table, which was obtained from secondary data sources, several comments are perhaps appropriate, i.e.:

(1) The total rice husk production may be off by more than a factor of two on the low side, since a simple calculation of annual rice consumption per capita (85 kg/man year) times the Philippine population of 47 million, times a 20 percent rice husk fraction yields a number more than twice that reported.

(2) Since the total waste produced at a sawmill includes sawdust plus bark, off-cuts, slabs and condemned timber, the latter of which may be two or three times the sawdust production, it is also believed that the tabulated results should be increased by at least a factor of 2.5 to include these other wastes.

TABLE 1

PHILIPPINE AGRICULTURAL AND LUMBER WASTES BY REGION

(IN MILLION KG.)

REGION	COCONUT HUSK	COCONUT SHELL	RICE HUSK	SAWDUST
1. Ilocos	31.54	14.19	40.35	10.75
2. Cagayan Valley	14.82	6.68	35.46	53.21
3. Central Luzon	1.37	0.62	56.99	30.86
4. Southern Tagalog 1/	1,229.12	553.11	40.22	104.49
5. Bicol	582.49	262.12	23.57	18.51
6. Western Visayas	147.69	66.46	36.68	16.75
7. Central Visayas	348.23	156.72	7.09	7.92
8. Eastern Visayas	510.96	229.93	13.57	8.32
9. Western Mindanao	549.12	247.10	7.16	30.83
10. Northern Mindanao 2/	535.12	240.81	26.87	99.50
11. Southern Mindanao 3/	1,202.10	540.94	28.08	89.62
T O T A L	5,152.56	2,318.68	316.04	470.76

1/ Includes Metro Manila

2/ Includes Eastern Mindanao

3/ Includes Central Mindanao

- 19 -

(3) No matter whether this rice husk or sawdust data is off or not, the data shows that just the coconut shells alone represent about twice the total waste production from sawmills and rice mills, and when the husks are included the coconut residue is by far the predominant waste. Therefore it deserves a most prominent place in any program for biomass waste utilization in the Philippines.

Then at a national scale, assuming on the average a coconut shell/husk moisture content of 30 percent, a rice husk moisture content of 15 percent and a sawdust moisture content of 40 percent, the total energy value of these wastes, is equivalent to almost 20 million barrels of oil per year, or about twice the 1981 total Philippine petroleum imports. Thus without question the significance of these wastes as a national energy source is established.

While some of these residues are already being utilized; eg. perhaps 10 to 15 percent of the coconut shells are currently being converted to charcoal for export, by far the greatest amount is truely wasted, and thus available for use as an energy source.

Site Visits

In an initial effort to get an on the scene indication of the waste biomass production and availability, visits were made at a number of different locations. Because of the importance of coconut shells as a feedstock, of the six locations visited, five were coconut shell charcoal plants and one was a rice mill. As of this time no sawmill has been visited, but plans to do so are in progress. The six locations visited included:

1) Malolos, Bulacan - rice
2) Rizal, Laguna - coconuts
3) San Pablo, Laguna - coconuts
4) Daraga, Albay - coconuts
5) Tablas, Romblon - coconuts

General conclusions arising from the visits are that:

1) Indeed, great quantities of rice husks are available for utilization in the pyrolysis system
2) While some of the coconut shell charcoalers typically have devised various simple retort designs, the yields are only about 20 percent at a maximum and almost no use of the pyrolysis off-gas and oil is being made currently.
3) In every case the prospects for improved utilization of the wastes were greeted enthusiastically by plant management, who readily agreed to participate in and cooperate with the program.

Survey of Processing Plant Production Rates

In order to properly size the pyrolysis system for appropriate application to Philippine industry, a survey, using a secondary data sources[1], has been made of the production rates at rice mills, sawmills and coconut shell charcoal producers.

Rice Mills - Using annual production data from the more than 12.000 Philippine rice mills, a random, statistically weighted (to account for variations in regional production) sample of 100 mills was chosen. Then using an average of 180 working days per year and an eight hour day, a calculation of hourly rice husk production was made for each sample mill. This data was statistically grouped and a histogram prepared to illustrate the fraction of the 100 mill sample lying in certain rice husk production ranges. This histrogram is shown in Figure 1.

A study of the figure reveals that more than 50 percent of the entire sample population lies in the range of zero to 100 kilograms/hour. Close examination reveals peaks at approximate integral multiplies of 50 kilograms

1) This data was obtained from (1) the National Food Authority (2) The Bureau of Agricultural Economics (3) the Philippine Coconut Authority and (4) the Forest Products Research and Industry Development Commission, whose assistance is gratefully acknowledged.

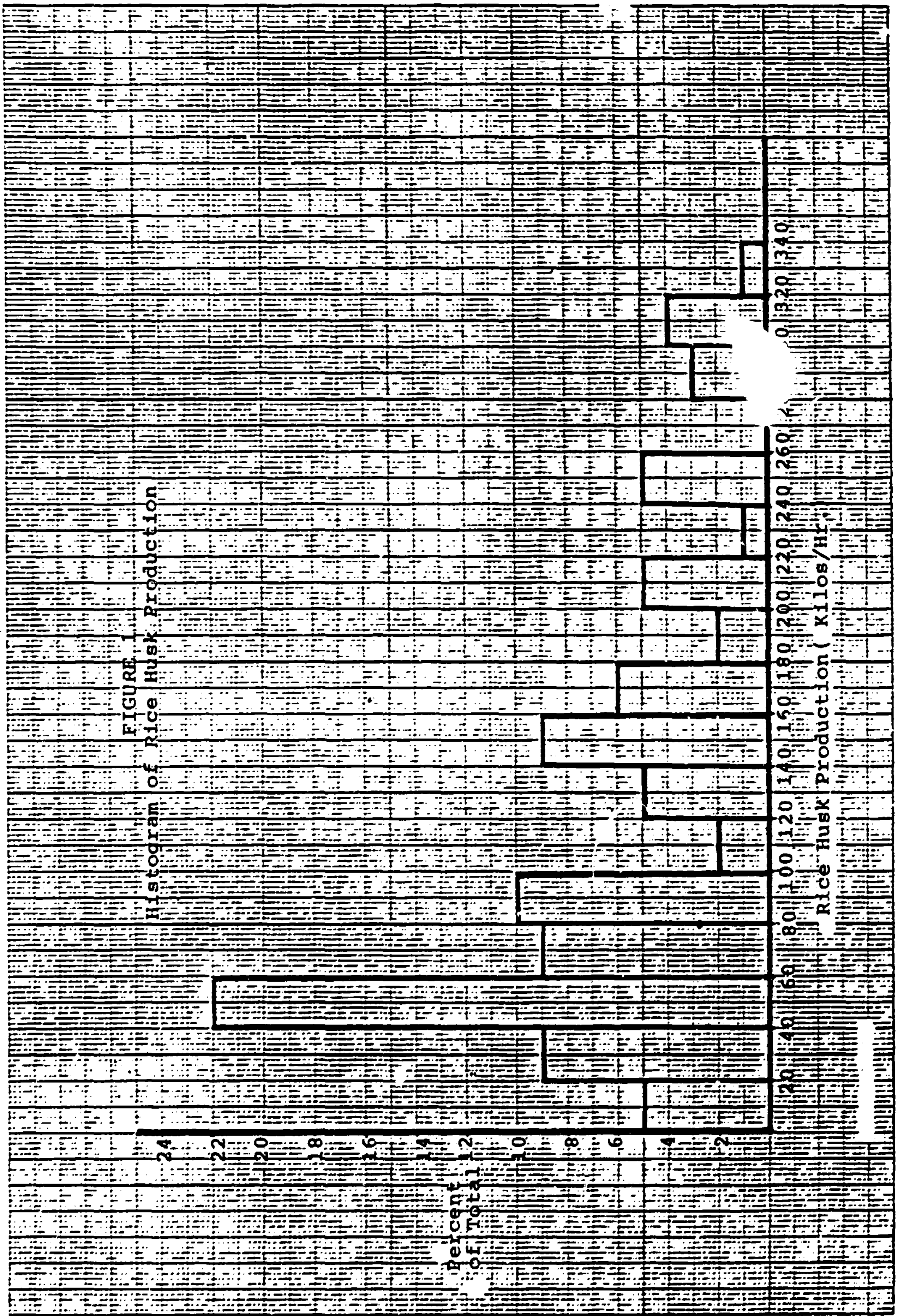


FIGURE 1
Histogram of Rice Husk Production

FPC-RP

per hour; indicating that as the rice mill capacity is enlarged, the number of basic milling machines is simply increased accordingly - rather than by installing larger machines (this surmise has been largely verified in conversations with individual rice millers and sources at the National Food Authority). From the figure it appears that a basic convertor of either 50 kg/hr or 100 kg/hr would be appropriate for rice mills. Since there will no doubt be a lower economic limit on capacity, because the unit cost and manpower requirements at the smallest scale will be very near those of the larger scale, at this point, a unit of capacity of 100 kg/hr is believed to be most appropriate. Thus while a continuing review of this conclusion will be made, for the time being a 100 kg/hr system will be taken as the basic capacity for the rice mill applications. Therefore, the demonstration prototype, to be described in a later section, should be appropriate for a large number of the Philippine rice mills.

Since rice mills frequently are associated with other activities requiring energy input, it is of interest to investigate the waste production per unit of total power required to see if there is indeed a large excess of energy available in the husks in comparison with the plant energy demands. Presented in Figure 2 is a graphical presentation

FIGURE 2
Survey of Excess Energy Available
from Rice Husks

NOTES:
Kg/Hp-Hr > 1 Average= 3.84 Kilos/Hr-Hp ; Std. Deviation=2.674
Kg/Hp-Hr < 1 Average= .6314 Kilos/Hr-Hp ; Std. Deviation= .261

of such an investigation using the 100 mill representative sample. Also shown is: (1) a calculated breakeven condition (which for the units chosen is, almost exactly unity), where the energy available equals the energy demand, and (2) an average of those plants lying above the breakeven line. This data shows that 84 percent of the mills do have excess energy available from the husks while 16 percent do not. As might be expected the data shows a great deal of scatter, but there is a general trend of increasing excess energy with increasing rice husk production. The average of these mills having excess husks is almost four times the breakeven condition; indicating that a great potential for energy production exists. This strongly justifies the basic arguments for pyrolysis as providing a means for converting excess waste into storable, transportable fuels.

Sawmills - there are 375 registered sawmills in the Philippines. From this total population, a representative sample of 100 mills was randomly chosen, and using a waste fraction of 60 percent (based on estimates obtained from the Forest Products Research and Industry Development Commission) a histogram, showing the distribution of mills in certain waste production ranges, was prepared. This histogram is shown in Figure 3. The figure, like Figure 1, shows that the mills come in capacities that are integral

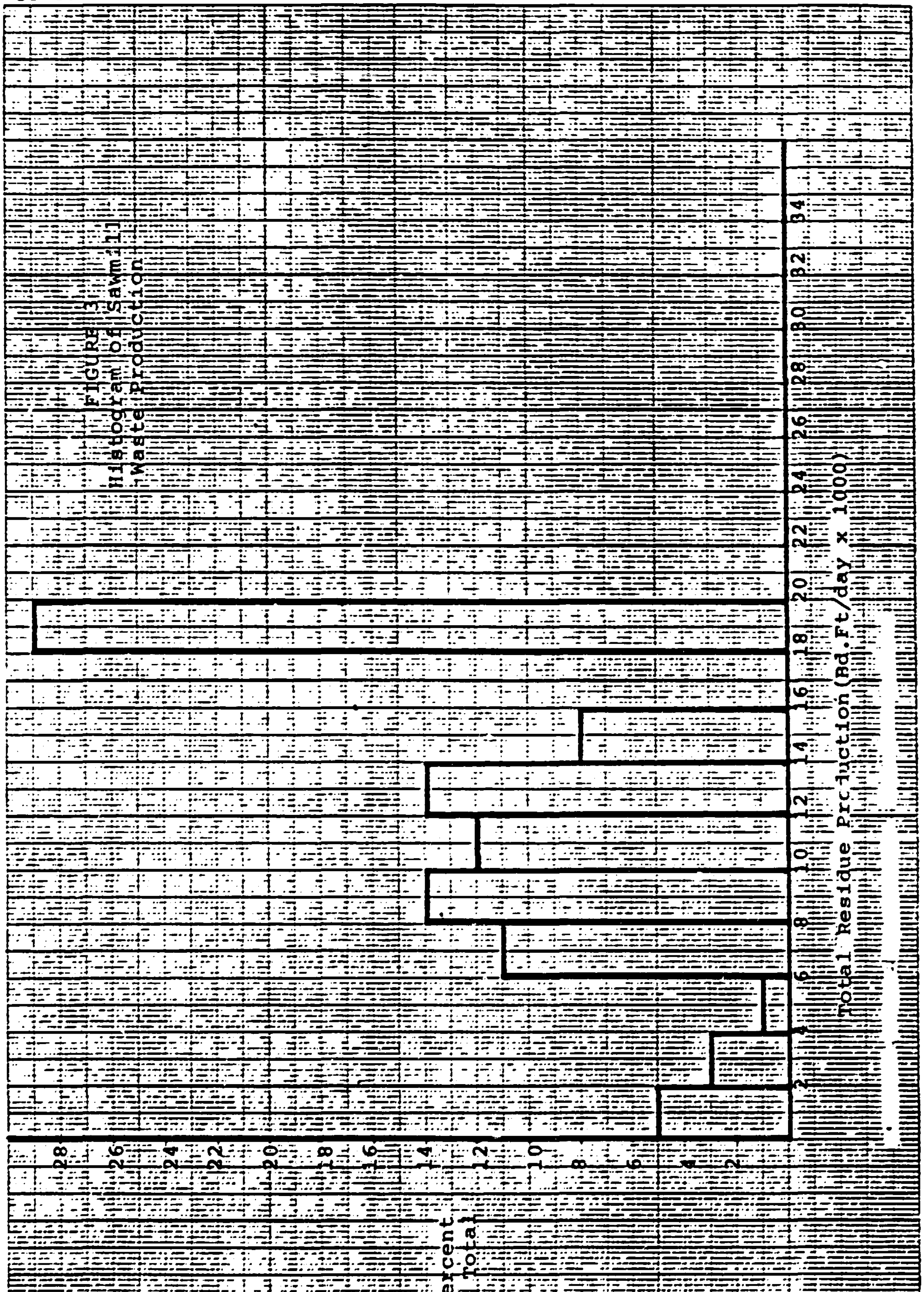


FIGURE 3
Histogram of Sawmill Waste Production

multiplies of each other, and with a predominant fraction centered at about 10,000 board feet/day of total residues produced. Since there are about two kilograms per board feet, the figure indicates that if all the residues were carbonized, and assuming a moisture fraction of 40 percent, a reactor of about twelve tonnes/day input capacity would be an appropriate design. Based on eight hours/day operations this capacity would be about 15 times that appropriate for rice mills. But it seems likely that, at this scale, two or even three shift operation would be justified to reduce capital costs, and there is also the possibility that the non-sawdust residues, which represent more than half the total, would have some other application. Thus perhaps a unit of three to five hundred kg/hr input capacity would be most appropriate. This is obviously a basic question that must be resolved soon. As part of the planned sawmill site visits, this issue will be thoroughly investigated to obtain a better indication of the basic convertor size appropriate to sawmill operations.

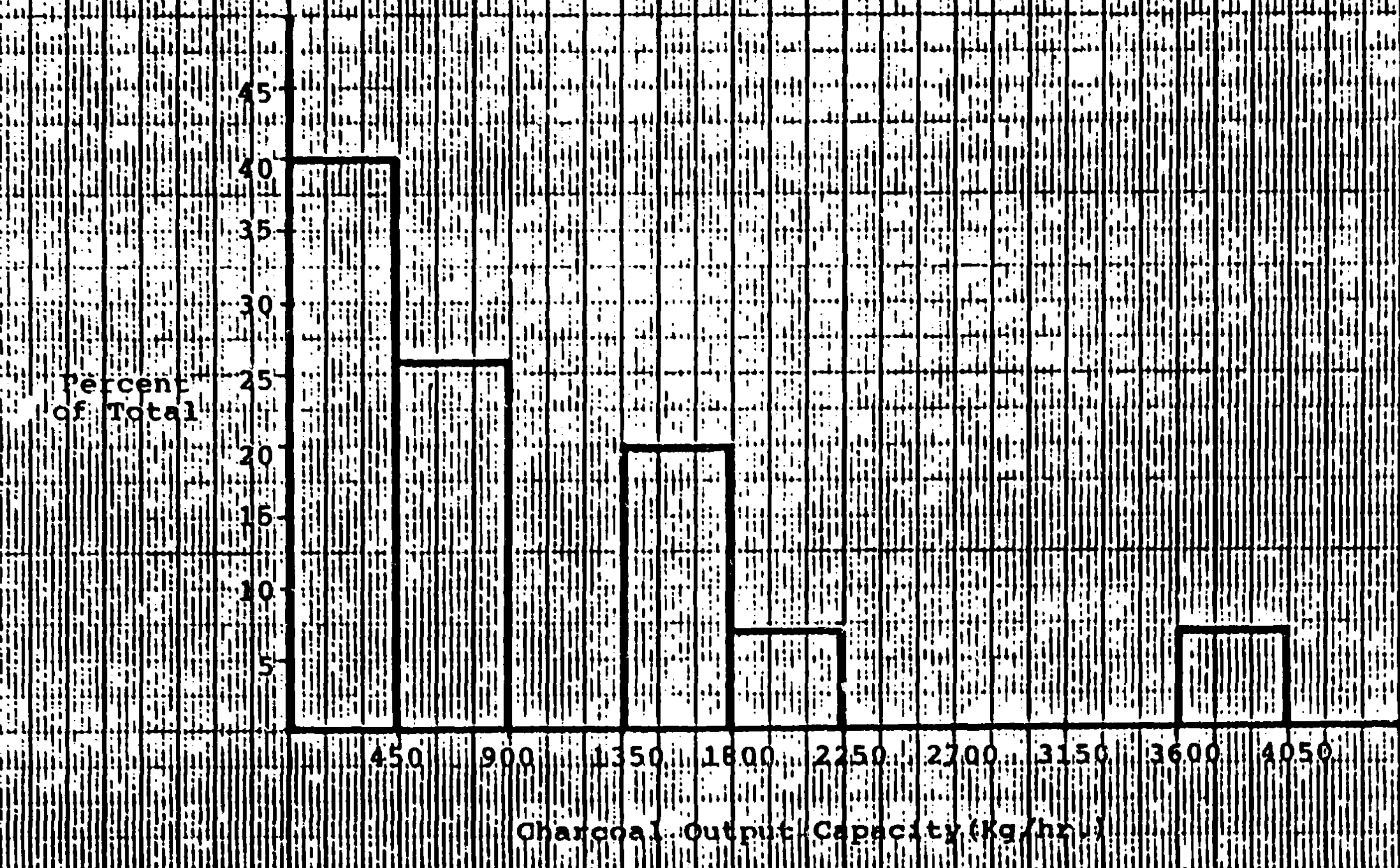
<u>Coconut Shells</u> - normal practice in the Philippine copra industry is that the coconut shells are not collected, but are left in the coconut groves near the original harvest sites. However, the high value of the shells and the great quantities involved have inspired a significant charcoal industry, with the result that something like 10 to 15

percent of all the shells are now being collected and brought to central sites for carbonization. Thus these existing charcoal producers represent the basic market for the pyrolysis system, and a study of the production of these plants is necessary in order to determine an appropriate convertor capacity.

There are 15 registered Philippine coconut shell charcoal plants for which production data is available. Data from all these plants has been compiled and a histogram prepared showing the number producing charcoal over certain capacity ranges. This histogram, based on the assumption of 210 working days per year and 16 hour days, is shown in Figure 4. Study of the histogram reveals a tendency of the units to again occur in clusters that are approximate integral multiplies of a basic system production capacity; in this case, this output is about 900 kg/hr. However, when it is recognized that the yields of these plants are typically no better than 20 percent, it becomes apparent that the convertor input capacity must be about 4.5 tons/hr or about 10 times that for the sawmill convertors. This size is too large to be practically considered for a single reactor using existing technology, and so even at the smallest scale production units, there would likely be clusters of units of about one tonne/hr input capacity.

FIGURE 4

Histogram of Charcoal Production



Observation

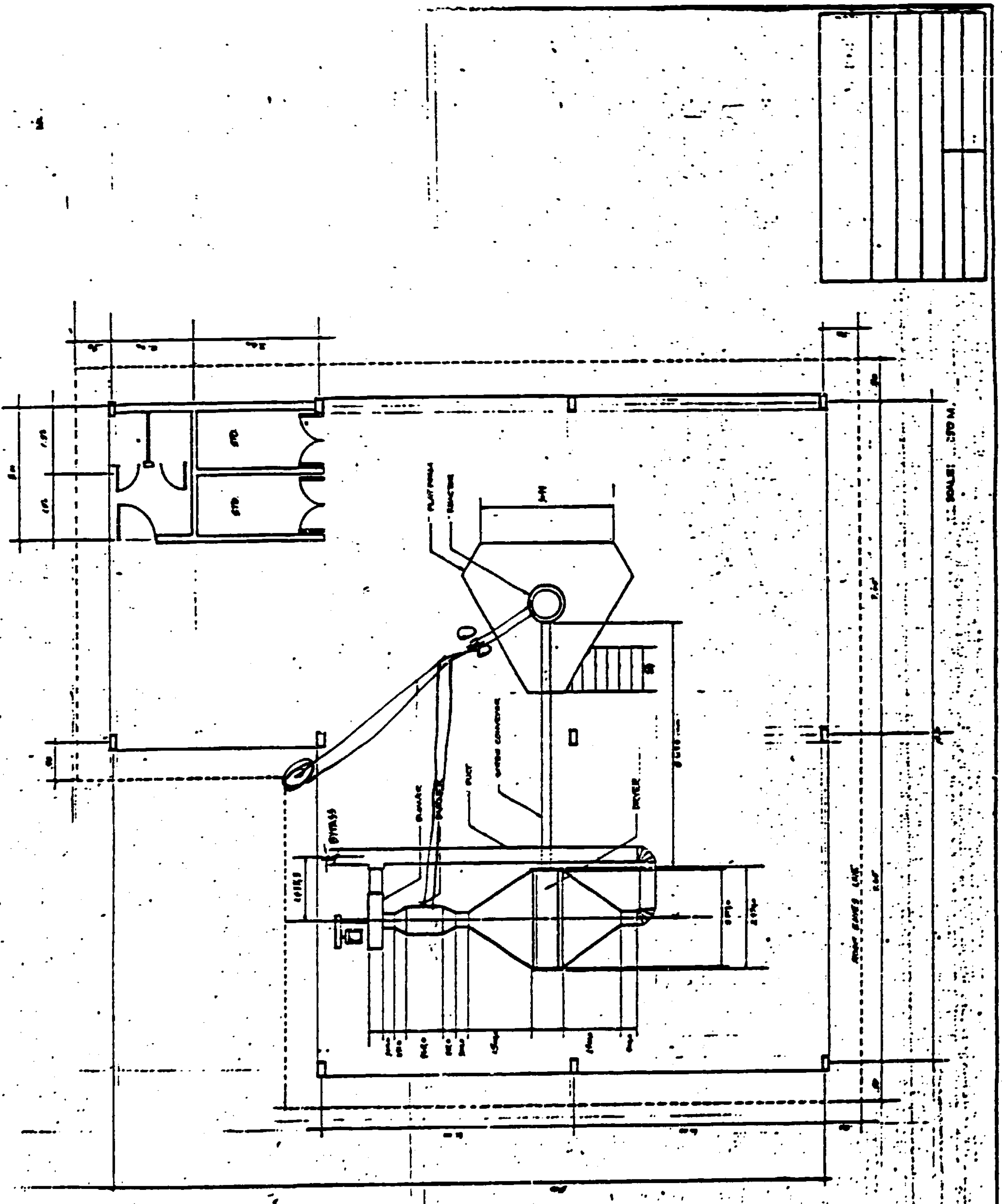
From a review of the required plant capacities for the three main wastes studied, it appears, at present, that units of about 100 kg/hr, 400 kg/hr and 1 tonne/hr are appropriate to the needs of the Philippines. Obviously, the choice of the unit capacities is of basic importance to the future of this program and a continuing review will be made of this question. However, for the present, these numbers represent the best available, and until better estimates are developed they will be used for project planning purposes.

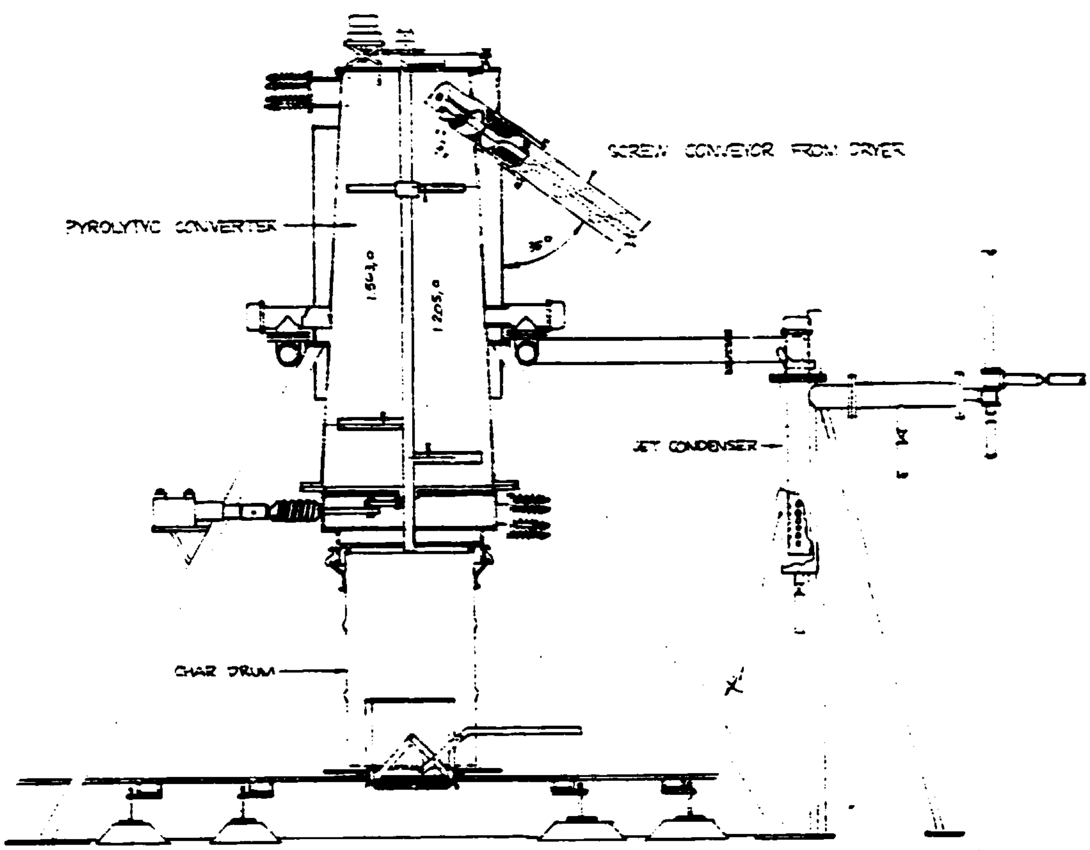
PROTOTYPE PYROLYSIS SYSTEM CONSTRUCTION

This section briefly describes the prototype pyrolysis system currently under construction at the Energy Research and Development Center of the Philippine National Oil Company located on Don Mariano Marcos Avenue, Quezon City. The pyrolysis system itself is the outgrowth of projects in the U.S., Indonesia, Papua New Guinea, and Costa Rica. Both the technology and the design philosophy have evolved from a basic, labor intensive approach, as used in Ghana, to the current more mechanized, "Intermediate Capital Intensive" concept.

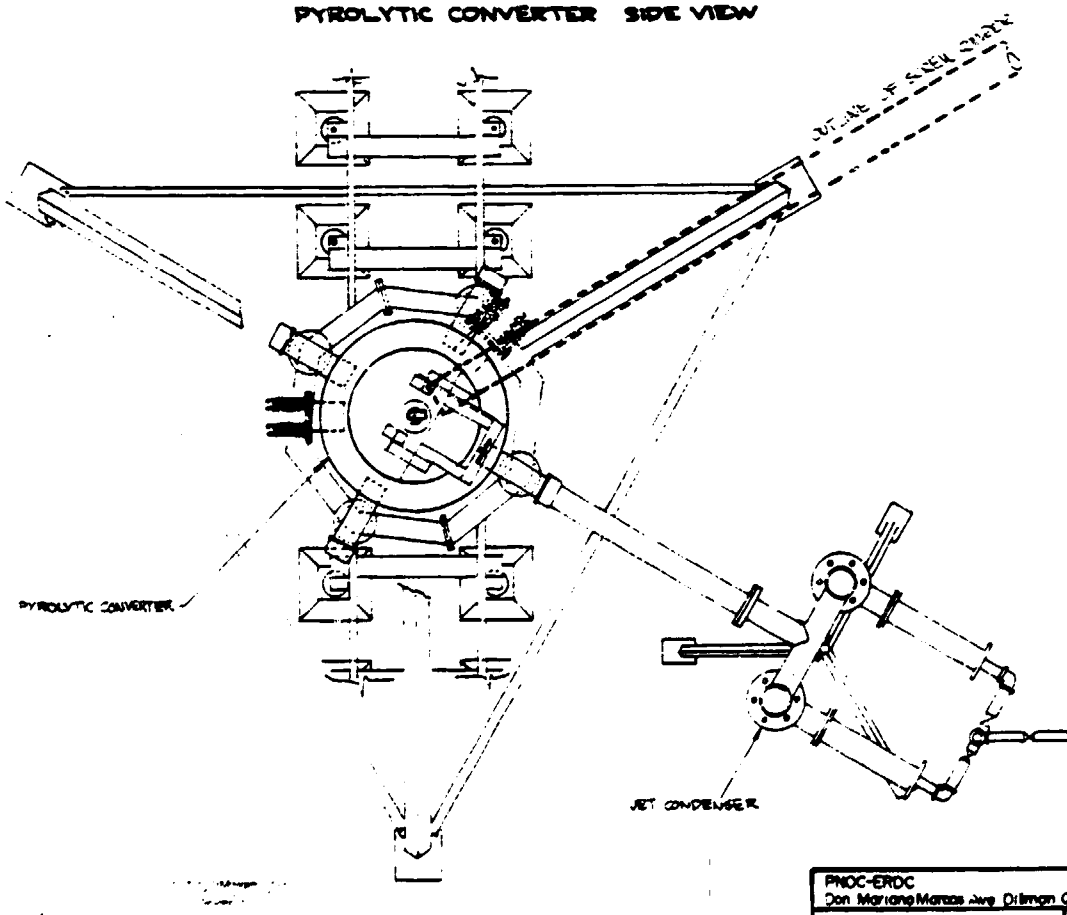
While the current design does include some new technical/design innovations arising from experience with previous systems, these changes are small in comparison with the use of proven hardware. Therefore, while some technical problems will undoubtedly arise, it is believed that they should be relatively mild, and the primary job of the project will be to introduce this technology into the Philippine economy.

The basic system design, improved and modified for the Philippines, is shown in Figures 5 through 11. Referring to Figure 5 it is seen that the system, which is nominally rated at 100 kg/hr input, comprises a drier, a conveyor, the pyrolytic convertor itself, and a condenser. Wet feed is introduced in a batch mode into the drier, which operates





PYROLYTIC CONVERTER SIDE VIEW



PYROLYTIC CONVERTER TOP VIEW

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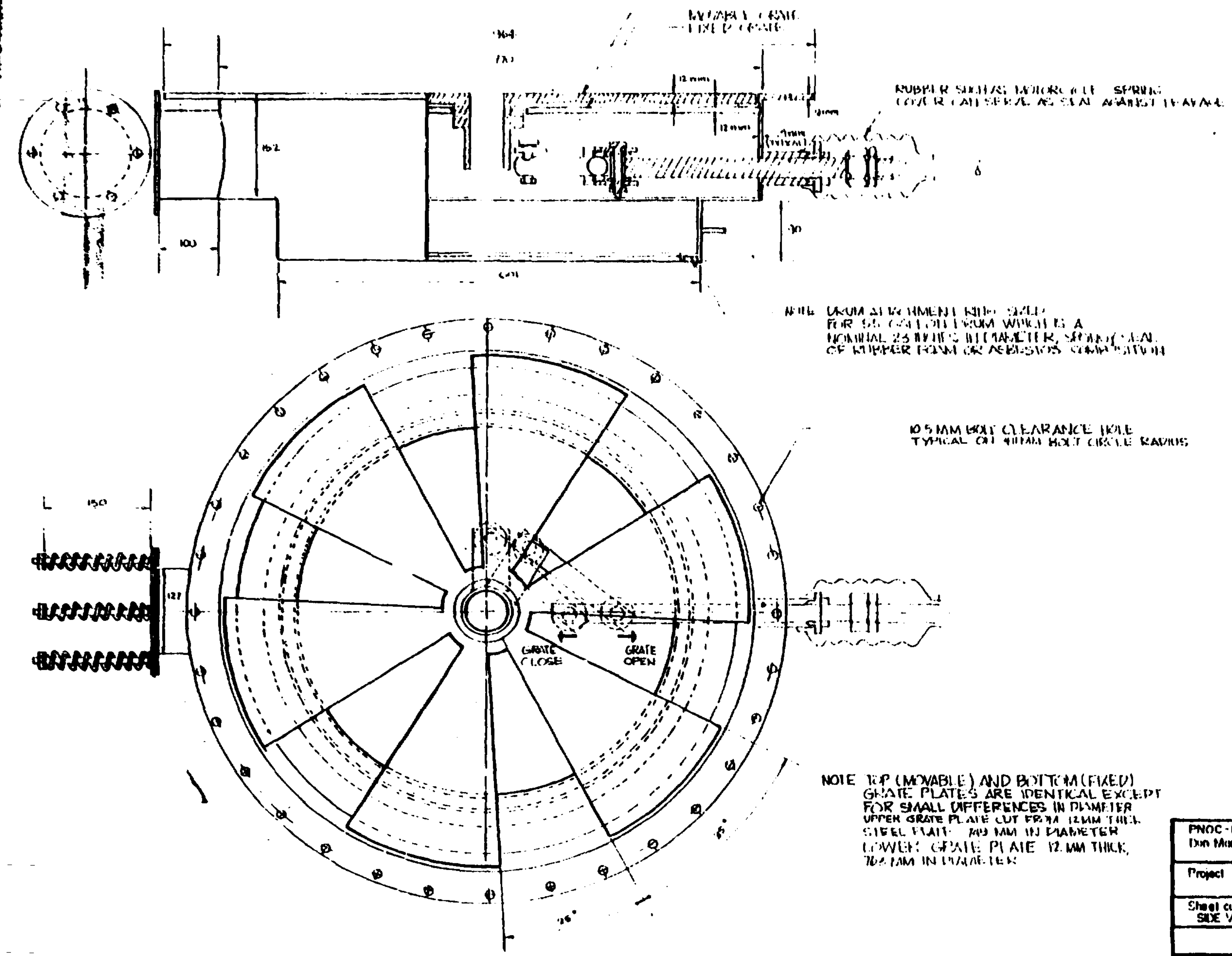
ASSEMBLY OF
PYROLYTIC CONVERTER
SIDE / TOP VIEW

continually and then, upon demand of the control system, the dry feed is conveyed to the convertor where it is carbonized. The charcoal is recovered in drums which are periodically removed from the bottom of the convertor. The off-gas leaves the convertor almost midway up to the reactor, passes through a filter system and into a simple jet condenser where the oily fraction is separated and recovered from the combustible gaseous components which are used to fuel the drier burner. Pyrolytic convertor process air is introduced via a slowly turning "Airgitator" (see Figure 6) which not only continously stirs the bed to break up any fissues or bridges that may form, but, because of the rotating action, tends to avoid the formation of these troublesome cavities which often plague the operation of the packed-bed reactors. The location of the off-gas burner (see Figure 11) on the low pressure side of the drier fan not only facilitates getting the off-gas out of the reactor and into this component, but it also allows continuing drier operation during the short periods when the char drums are being changed and the process air is shut off. This occurs because during this period ambient air is drawn up through the bed via the rotating "star grate", which is operated periodically by a pneumatic cylinder whose action is controlled by a timer-solenoid system. A level control mechanism located at the top of the reactor calls for dry feed, when the bed level falls below a certain point, by activating the drier and conveyor system.

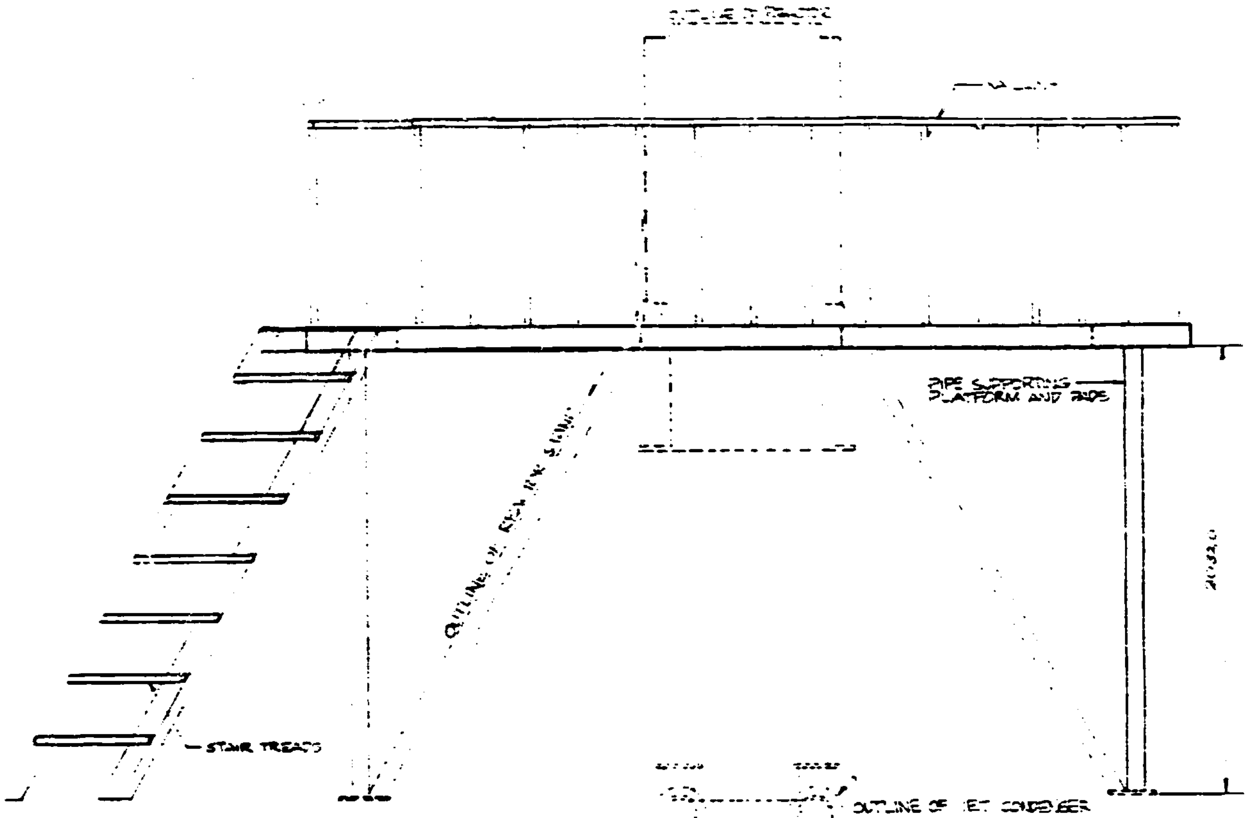
The drier, (see Figures 9 and 10) is a relatively new component, which allows continous dehydration to occur, but with intermmittant introduction and exit of the feed. This is a special advantage, since it not only avoids the necessity for a surge bin, as would be required with a rotary drier , but it also allows mechanization of the feed input and/or the feed exit handling. Because of its recent origin this component is most likely to be the source of technical problems, and therefore, its operation will receive special attention. Another significant feature of the drier is the recirculation of up to 70 per cent of the hot gasses. This allows a much more efficient drying to take place and reduces by up to 50 percent the heat required.

Drying the last two months, a contract for the construction of this system was awarded to a local fabricator, after a competition involving several Manila shops. While this equipment is yet to be installed, it is essentially complete, as of this writing, and photographs of the important components are presented in Figures 12 through 15.

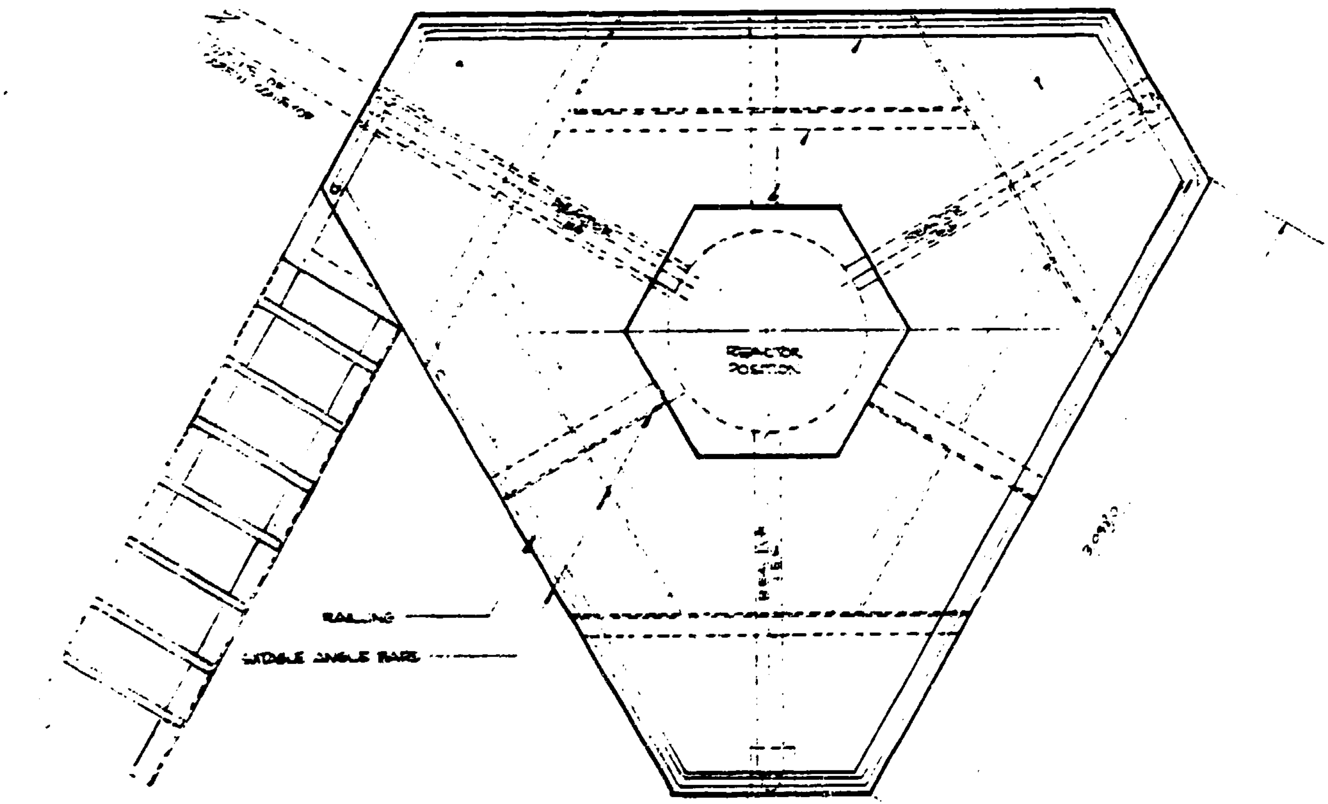
As part of the local contribution to the project, a facility to house the pyrolysis system has been designed,



PNOC - ERDC Don Mariano Marcos Ave Diliman Q C Philippines	
Project GRATE ASSEMBLY	
Sheet content SIDE VIEW SECTION / TOP VIEW	

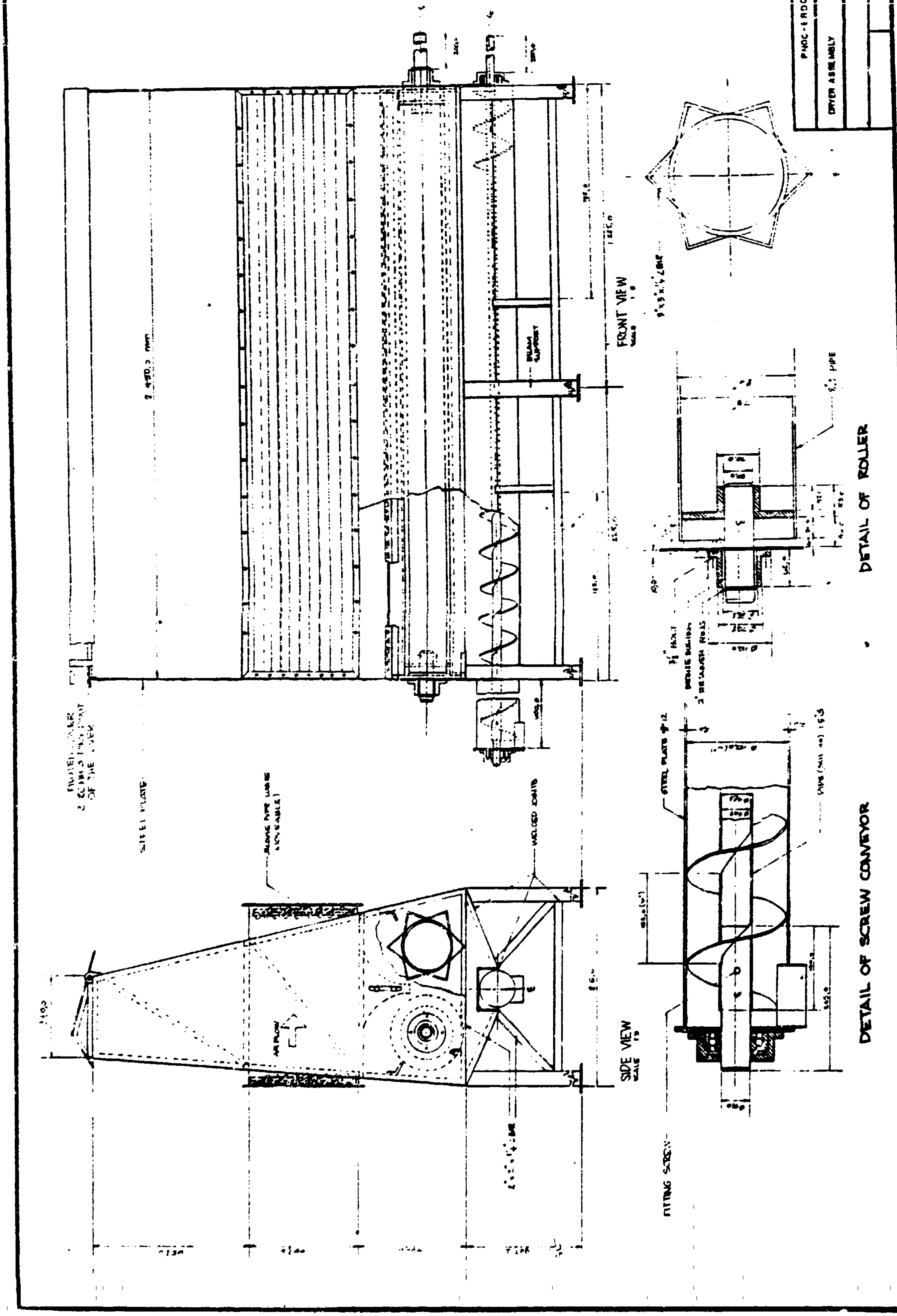


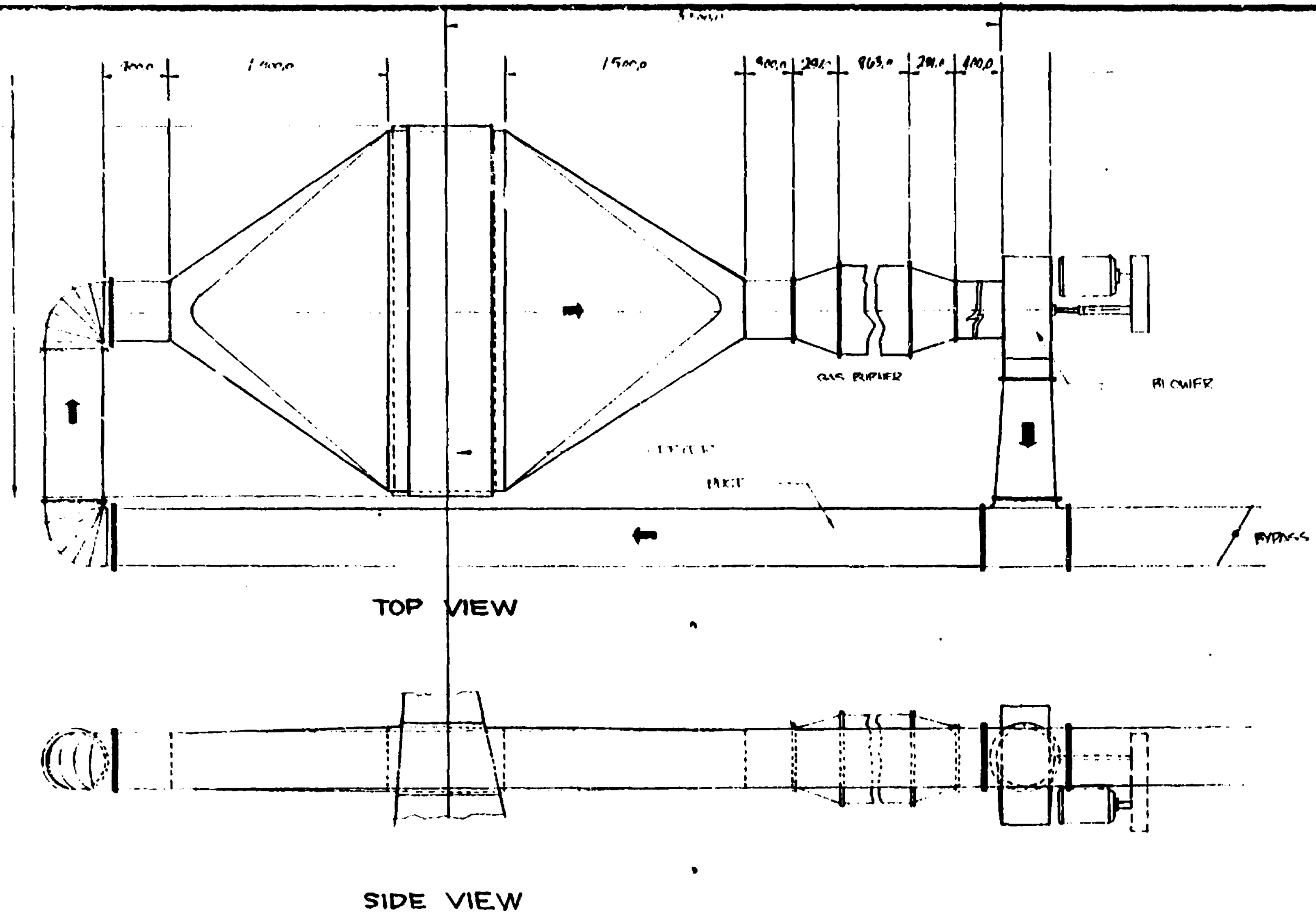
REACTOR PLATFORM SIDE VIEW
SCALE 1:20



REACTOR PLATFORM TOP VIEW
SCALE 1:20

PNOC-ERDC Don Mariano Marcos Ave. Diliman Q.C. Philippines	
Project REACTOR PLATFORM	
Sheet content TOP VIEW / SIDE VIEW	


PHDC-ERDC
DRYER ASSEMBLY
FRONT VIEW
SIDE VIEW
DETAIL OF ROLLER
DETAIL OF SCREW CONVEYOR
2 450.0 mm
BEAM SUPPORT
STEEL PLATE
WELDED JOINTS
AIR FLOW
FITTING SCREW
STEEL PLATE



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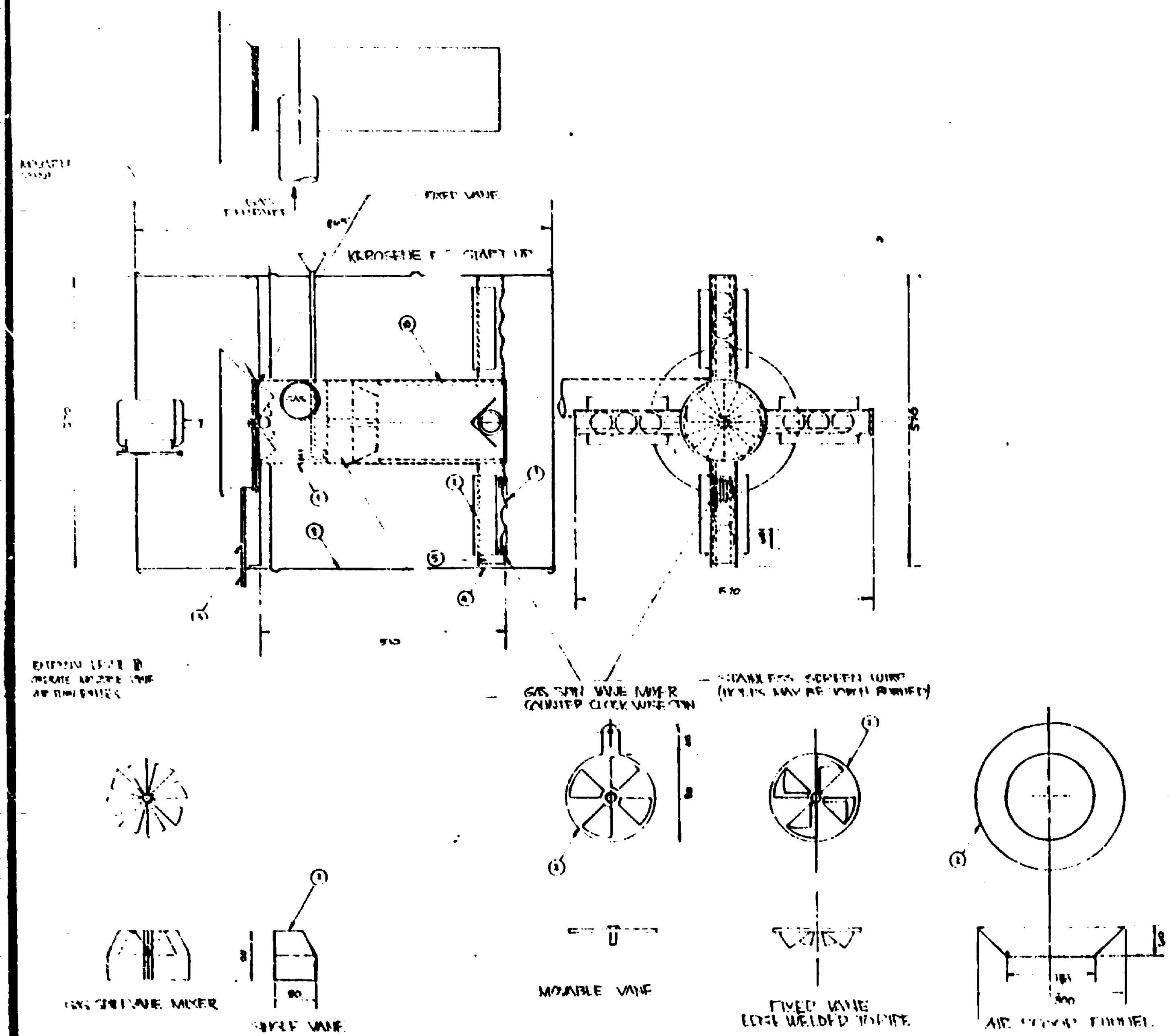
DUCT SYSTEM
(Top / Side View)



NO	MATERIAL	SIZE	NO REQD	COMMENT
10	KAOWOOL #8	12 mm Thick		
9	STEEL PIPE	5 MM ø		
8	STEEL DRUM	55 GALLON		
7	STAINLESS STEEL SCREEN	~ 60 MESH		
6	STEEL PIPE	15 MM ø		
5	STEEL PIPE	50 MM ø		
4	STEEL SHEET	3 MM		
3	STEEL ROD	8 MM DIA		
2	STEEL SHEET	2 MM		
1	STEEL PIPE	180 MM ø		

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Project:
PYROLYSIS GAS BURNER

Sheet content:
BLOWER/BURNER OF DRYER

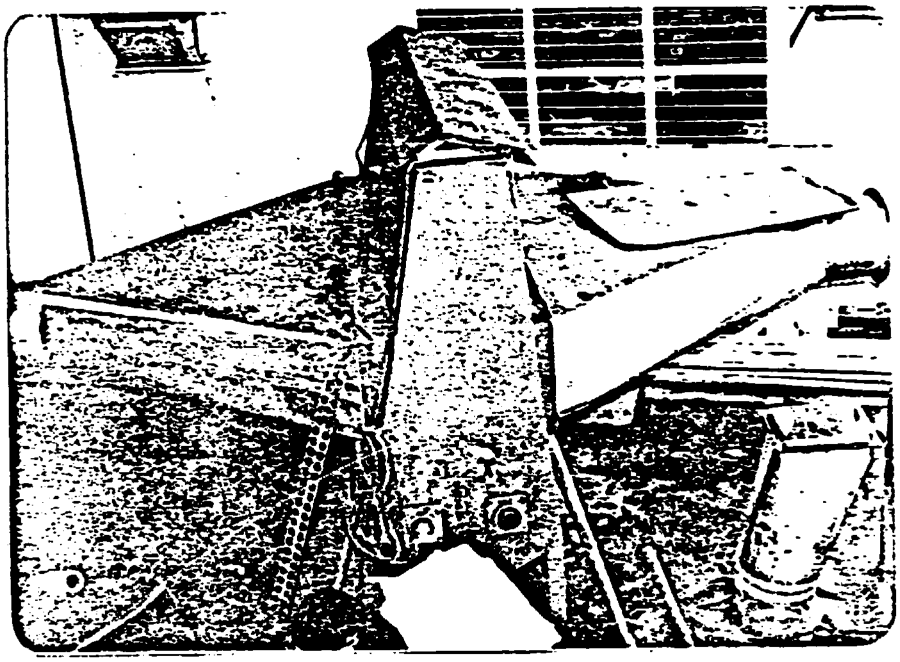


FIGURE 12. Drier for Prototype Pyrolytic Conversion System.

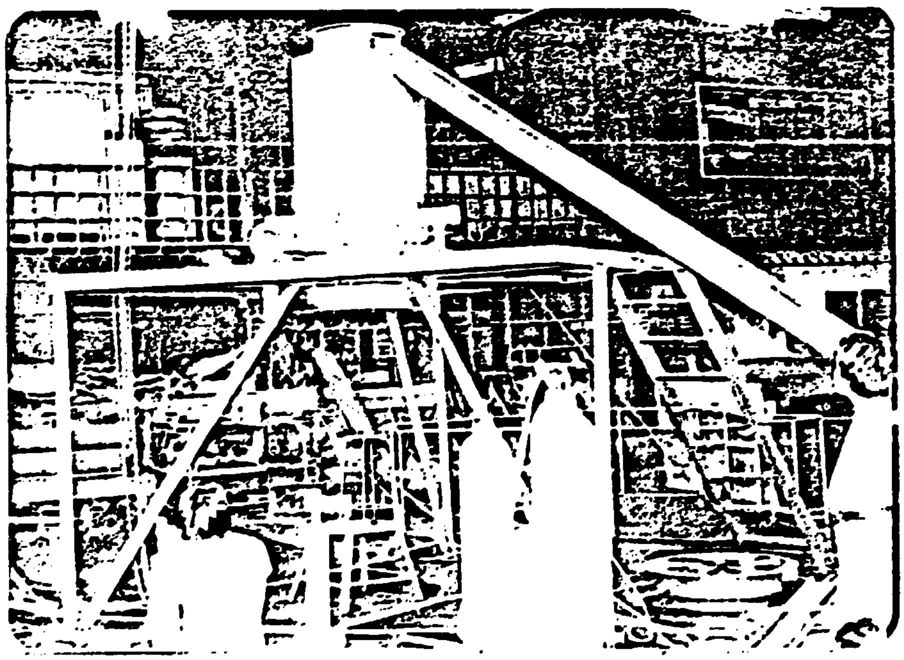


FIGURE 13. Reactor Vessel for Prototype Pyrolytic Conversion System.

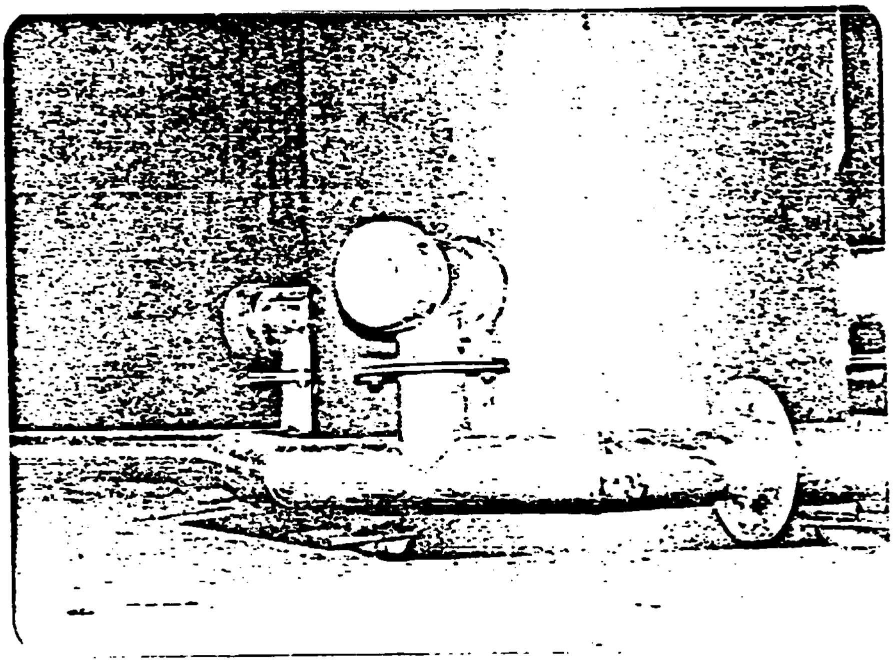


FIGURE 14. Off-Gas System for Prototype Pyrolytic Conversion System.

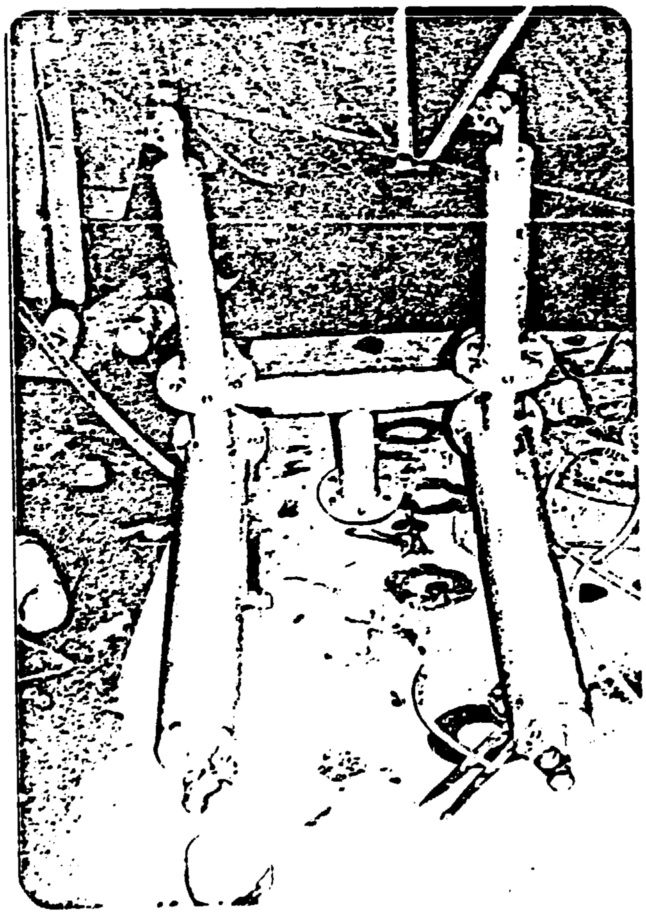


FIGURE 15. Condenser for Prototype Pyrolytic Conversion System.

and construction work started. Presented in Figure 16 are elevation and plan views of this facility. Because of the onset of the rainly season and other contractual and administrative problems, work on this building has been slow, and the current estimate of its completion date is October 1, 1982. Recognizing that considerable time will then be required to install and to checkout the equipment, it is unlikely that any serious testing of the system can be conducted before the year's end.

While the cost of the overall system is not known exactly at this time, since it is not yet completed, enough information is available to estimate these costs, and Table 2 is presented to provide this information. Study of the table shows that the total bought-out equipment costs are estimated to be $8,120, the fabricated component costs are estimated to be $7,091, and the facility costs estimated at $12,000, with an overall system costs total estimated at $27,210. In a later report a more accurate accounting of these costs will be made, and estimates of cost savings that may be realized; for example through local fabrication of some of the manufactured components purchased in the U.S., will be presented.

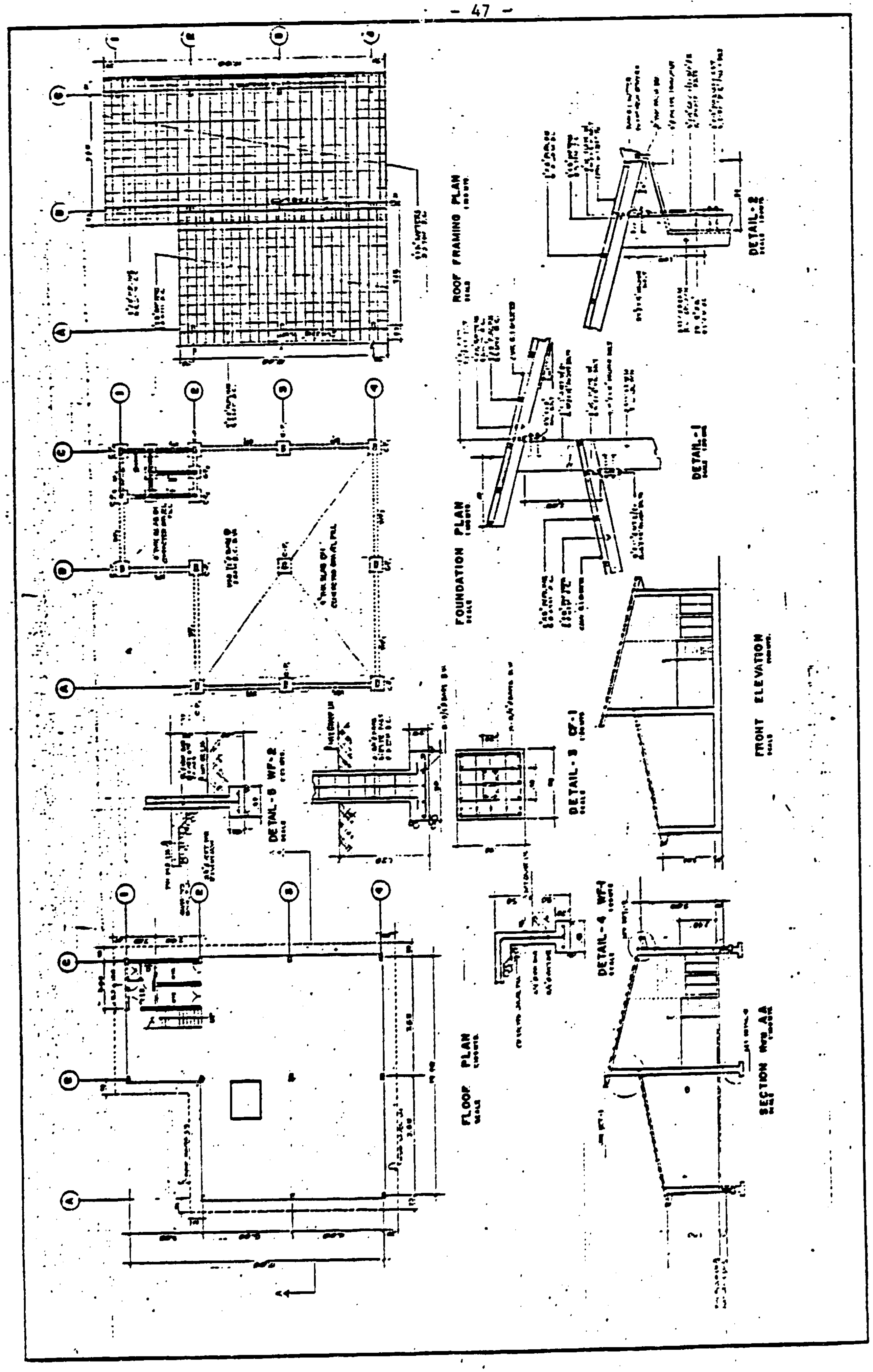
TABLE 2

PYROLYTIC CONVERTOR SYSTEM
COST BREAKDOWN

ITEM	COST	
I. FABRICATION & INSTALLATION (LOCAL)		
1. Off gas collecting ring	$ 394.59	₱ 3,354.00
2. Agitator (using hollow bar - 7/16" thick approx.)	176.47	1,500.00
3. Grate Assembly	517.65	4,400.00
4. Char Drum Carriage & Lifting Mecha Mechanism	105.30	895.00
5. Reactor shell	341.18	2,900.00
6. Char drum clamps and off-gal filters	210.59	1,790.00
7. Jet condenser	362.35	3,080.00
8. Pyrolysis gas burner	297.10	2,525.00
9. Ducting (excluding motor & blower)	1,164.70	9,900.00
10. Service platform	705.90	6,000.00
11. Secadora de Aserrin (bearing incl.)	2,052.95	17,450.00
12. Inclined screw conveyor; 30° x 20' long	397.10	3,375.00
13. Air lock	364.70	3,100.00
	$ 7,090.58	₱ 60,269.00
II. EQUIPMENT FROM FOREIGN PURCHASE		
1. 1,000:1 speed reducer w/ motor	$ 1,148.10	₱ 9,758.85
2. 4,130 steel tube; 15 ft Lct, 2"OD, 1" ID	400.00	3,400.00
3. Orifice meter system	102.18	868.53
4. Pressure gage (0-5" H_2O)	46.00	391.00
5. 1 pc. Ametek lamb vacuum motors	159.00	1,351.50
6. Mechanical timer; model 2E356	74.80	635.80
7. Pneumatic components w/ 4" cyl. including rotating union	481.21	4,090.29
8. Chaindrive 8OSK 19 Sprocket OSD 493-D x 1 5/8 Slip Clutch 8OP 19G Srocket for OSD 493-D SK Bushing	244.68	2,079.78
9. Total Freight Cost	1,121.80	9,535.30
	$ 3,777.77	₱ 32,111.05

ITEM		COST
III. EQUIPMENT FROM LOCAL PURCHASE		
1. Dial Thermometer (0-1000F) 2 pcs.	$ 105.88	₱ 900.00
2. Dial Thermometer (0-500F) 4 pcs.	141.18	1,200.00
3. 3/4 Hp motor, 3 phase, 220 V 2 units	265.88	2,260.00
4. 1/2 Hp motor, 3 phase, 220 V 1 unit	112.94	960.00
5. Magnetic starter 15 Hp size 2, 220 V, 3 Ø	135.47	1,151.50
6. Push botton, start-stop, 15 Hp	15.89	135.00
7. Magnetic starter reversing, 3/4 hp 3 Ø, 220 V, 2 sets	238.31	2,025.60
8. Push button, forward-reverse-stop, 3/4 Hp, 2 sets	93.65	796.00
9. 5,000 CFM Air blower	1,987.47	16,893.45
10. 60:1 speed reducer, 3 Hp, 1 set 1	329.41	2,800.00
11. 40:1 speed reducer, 1/2 Hp, 3 sets	298.82	2,540.00
12. 2 CFM, 120 psi air compressor	329.41	2,800.00
13. Bevel gear for 60:1 reducer	105.89	900.00
14. Sprockets 1/2" pitch, 16T; 2 pcs.	7.77	66.00
15. Sprockets 3/4" pitch, 10T; 2 pcs.	8.07	68.60
16. Sprockets 3/4" pitch, 30T; 5 pcs.	84.65	719.50
17. Roller chain 1/2 " pitch; 3 ft..	3.87	32.85
18. Roller chain 3/4" pitch ; 13 ft.	30.20	256.75
19. Idler shaft 1"Ø, 6" 1C	17.65	150.00
20. Wires for motors (royal chords)	29.41	250.00
	$ 4,341.82	₱ 36,905.25
IV. FACILITY		
MATERIALS	$ 9,058,85	₱ 77,000.00
LABOR	$ 2,941.18	₱ 25,000.00
	$12,000.03	₱102,000.00
T O T A L	$27,210.20[1]	₱231,285.30

*Exchange Rate: 8.5 ₱/$


ROOF FRAMING PLAN
FOUNDATION PLAN
FLOOR PLAN
DETAIL-1
DETAIL-2
DETAIL-3 CF-1
DETAIL-4 WF-1
DETAIL-5 WF-2
FRONT ELEVATION
SECTION AA

CONCLUSIONS AND RECOMMENDATIONS

As a result of this study, there is no question that the quantities of agricultural and silvicultural process wastes produced in the Philippines are extremely significant in terms of the national energy needs. Moreover, there can be little doubt of the potentially important role of pyrolysis of these wastes to produce valuable, easily transportable, storable, and utilizable alternative fuels and other products. The greater emphasis on mechanization of the pyrolysis system appears as a valid approach, especially in light of previous experience in other LDC's and also here in the Philippines, and it should be cautiously pursued. Particular emphasis should be given to coconut shells as a feed stock because of their quantity and their high value. Also, rice husk charcoal may make an excellent fuel for cement kilns, and further investigation of this application should be made. A more thorough study of the application of pyrolysis to sawmill residues should be conducted, and site visits to a number of sawmills planned.

Regarding the charcoal from wood wastes the potential of mechanical briqueting should be more closely reviewed and appropriate technology briqueting machines, such as available in India, should be purchased for evaluation. Also the practical possibilities of development of a modification kit to convert diesel engines to gas powered spark ignition operation should be given careful attention. Moreover, on-going research into the use of the pyrolytic oils as a wood preservative should be pursued.

Of special importance is a need to continuously review the planned 100 kg/hr, 400 kg/hr and 1,000 kg/hr production capacities for the pyrolytic convertors, to insure that these sizes do indeed reflect the real needs of Philippine industry. In addition, a study of the level of pyrolysis technology applicable to local industry must be constantly made, with the recognition that perhaps simpler methods, especially applicable to coconut shells, can be developed.

Finally, it is of fundamental importance that the prototype plant be put into operation at the earliest possible time, and the highest priority should be given to this effort.

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