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ASSISTANCE TO ENERGY PRODUCTION

FROM BIOMASS WASTE MATERIALS

DP/PHI/78/022

PHILIPPINES

Technical Report*

Mission from 25 November 1984 to 3 March 1985

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

Based on the work of Prem D. Grover

Consultant in Biomass Conversion System

United Nations Industrial Development Organization

Vienna

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The consultant is thankful to UNIDO for giving him this opportunity to work on the development of Thermochemical Biomass Conversion Systems. Profound thanks are due to Dr. Ibarra E. Cruz of ERDC and his team of Engineers for their active cooperation and help rendered to make the present mission a success. Mr. Mario R. Carlos and his team of Engineers and Technicians deserve special thanks for working endlessly under difficult and sometimes polluted conditions for operating the plants and generated useful data.

Special thanks are also due to the staff of the Conventional Fuels Department, specially to Ms. Liza F. Vidal for doing an excellent job of typing this report.

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1.0 INTRODUCTION

The need for efficient utilization of biomass waste materials like rice hulls as an alternate source of energy for the Philippines is now even greater than it was when the present project was initiated in 1980. This can be judged from the exponential increase in the prices of petroleum products and even that of basic domestic fuel like charcoal. During the period of this project, the retail price of charcoal has undergone seven-fold increase, that is, from P0.50 to P3.50.

In the context of national energy scenario, the contribution of the present indigonized developmental work and the dissemination of biomass utilization technologies may seem modest yet within the preview of this project significant contributions have been made. Five small and medium range units have already been transferred to various recipients in the field from the Centre and the sixth one on Steam Pyrolysis Gasification System (SPGS) is at the advanced stage of its development.

The operating performance of these projects, under actual field conditions is being monitored. But non-availability of additional funds and/or any curtailment of sanctioned funds either from the national resources or from UNIDO shall be detrimental to the achievement of the project's objectives envisaged at its inception. The current stage of this project appears to be the important and critical, and needs the maximum financial and manpower inputs. Therefore, it is strongly recommended that the progress of this project should be thoroughly and immediately reviewed by the appropriate authority and necessary inputs assessed and provided expeditiously. Any delay in its implementation may result in wastage of all the efforts that have been put in this important area of biomass utilization.

The projects that qualify for inputs which are either in the final stage of development or require performance monitoring in actual field conditions are given in Table 1.1.

The present report is basically a technical report and continuation of work already detailed in earlier two reports (2), (3). It covers the period of the present mission from 25th November 1984 to 3rd March 1985. This is also prepared by Professor Prem D. Grover, UNIDO Consultant, about his assignment under this project with the Energy Research and Development Center of the Philippine National Oil Company (PNOC-ERDC).

The major objectives of the present assignment were to test and suggest modifications for the smooth operations for two systems, that is, Steam Pyrolysis Gasification System for rice hulls, and Air Pyrolysis Gasification System for coconut shells. While steam pyrolysis system is installed at ERDC, the latter is being installed at MSU-Iligan Institute of Technology. In addition, the consultant was expected to render technical assistance for other on-going projects on gasification and biomass stove development as and when required by staff at ERDC.

About 146 trial runs were carried out with the Steam Pyrolysis Gasification System and the results obtained had been very encouraging. The system has proved its utility as one of the world's best systems for partial/complete pyrolysis of rice

UNITS	CAPACITY	RAW MATERIALS *	SITE	INTENDED USAGE	RECIPIENT
1) Mobile Charcoal Retort I (MCR I)	150-200 kg/hr	- coconut shell ipil-ipil wood blocks	Pinamuk-an Island Washington Aklan	- produce charcoal	Pinamuk-an Sumalang Mayor
2) Mobile Charcoal Retort II (MCR II)	150-200 kg/hr	-- do --	Ormoc, Leyte	- produce charcoal recover tar	Tan Martinez Corporation
3) Air Pyrolysis Gasification System I (APGS I)	25 kg/hr	- rice hulls	Plaridel, Bulacan	- run an engine to power the ricemill	Glessie Ricemill
4) Air Pyrolysis Gasification System II (APGS II)	92 kg/hr	- rice hulls	Guimba, Nueva Ecija	- burn the gas in an aluminum smelting plant	Milmore Corporation
5) Coconut Pyrolytic Converter System (CPCS)	200-250 kg/hr	- coconut shell - ipil-ipil wood blocks	MSU - IIT Iligan City	- produce charcoal recover oil-tar mixture burn gas in a boiler	MSU - IIT Mindanao State University
6) Steam Pyrolysis Gasification System (SPGS)	25 kg/hr	- rice hulls - saw dust	ERDC Complex	- produce medium BTU gas - recover reactive silica from rice hull	FMDC ERDC

hulls. Process wise and also in mechanical operational reliability, this system has proved to be far superior to the similar systems already developed and commercialized by the consultant in India and Nepal where 36 plants have already been installed. Any degree of controlled and uniform pyrolysis of rice hulls can be achieved in this unit, hither to not possible in directly fired vertical partial oxidation units.

As a pyrolytic gasifier, the units have given excellent results. About 85-93% of the combustible material in rice husk, that is, carbon and volatiles could be devolatized with a residence time of about 5 minutes. Further extensive data on the flow characteristics of rice hulls and rice hull char, in terms of hold-up and residence time studies, have been obtained. Such data are not available in any published literature and are extremely useful for scaling-up and designing commercial units.

However, the tests on steam gasification envisaged to get medium BTU gas (HHV 350-500 Btu/ft3) and direct recovery of silica from the gasifier could not be carried out. For this certain modifications have to be carried out. Although these were detailed while designing the system yet somehow these were not incorporated. With extensive experience gained with its operation, many of these have now been modified and explicitly detailed in this report. It may take about two months to incorporate these modifications and tests on steam gasification can be started again in May, 1985.

Since the units on Air Pyrolysis Gasification of coconut shells is being installed, the visit to Iligan has to be postponed to coincide with the next testing of steam gasification system at ERDC.

A satisfactory performance report about the production of charcoal from coconut shells and ipil-ipil wood blocks have been received from the recipient of mobile kiln unit installed at Ormoc, Leyte.

Suggestions on further development of rice hull stoves have been given and incorporated as recommendations in Annexure-VI.

During the mission, a lecture mainly dealing with cracking of tar in gasifier, gas clean up system and analytic techniques for analysis of gas, was delivered to the engineers from ERDC.

2.0 STEAM PYROLYSIS GASIFICATION SYSTEM (SPGS)

2.1 Introduction

Steam pyrolysis is characterized by the fact that the substrate such as biomass is subjected to thermal degradation under the atmosphere of superheated steam. The steam, not only acts as a carrier of pyro-gases as produced, but also reacts with reactive char at relatively lower temperatures (650-800 C) thereby enriching the resulting gases with such combustible constituents as CO and H2. These findings have been well established by thermogravimetric analysis (TGA) by research workers (1) at Royal Institute of Technology Stockholm on biomass such as straw and on rice hulls at Indian Institute of Technology, Delhi.

The reasons for selecting a rotary gasifier, its advantages and basis for the design of the present Steam Pyrolysis Gasification System (SPGS) have been presented in an earlier report (2). The layout of the pilot plant, and procedure for evaluating its performance have been detailed in the subsequent report (3) prepared by the Consultant during the last mission in January 1984. It is therefore essential that this report should be studied in conjunction with the earlier two reports (2), (3).

2.2 Pre-operational Status of SPGS

Before the testing of the unit could be commenced in late November 1984, it is pertinent to describe the physical status of the plant as installed and existed, ready for pre-trial operation. The credit for having installed it as per the layout given in second report (3) (pp. 22-25) must be given to the engineers from EPDC. However, the following components and facilities had yet to be incorporated. These were:

(a) Provision of oil/gas burner to heat up the gasifier;

(b) Provision of either a chimney of sufficient height and/or induced draft fan to provide sufficient suction for efficient exit of flue gas;

(c) Provision of an adequate speed reduction system for the feeder motor to facilitate its rotation at low rpm for the control of feed rate of rice hulls;

(d) Proper insulation of gas outlet pipe and provision of locating the first cyclone separator as given on page 30 of second report (3);

[illegible] Proper ash collection system as per specifications.

The absence of above facilities could not prevent the initiation of pre-trial testing operation as these could be incorporated during the progress of testing operation. The physical status of the unit as it existed before the commencement of pre-trial operation is given in Figure 2.1.

2.3 Strategy of Testing

This system consists of four major components. These are:

(a) The rotary gasifier with furnace;

(b) Ash collection system;

(c) Gas cleaning and steam raising system;

(d) Gas monitoring and its subsequent disposal utilization.

Before the system is operated as composite unit, it is imperative that each of the above components is tested and modified if necessary for its smooth operation. Of all the above components, the gasifier is the key component and its testing and operation involves more than 80% of the total workload required for overall testing operation. The other components are of rather conventional type and their testing should not involve any major problems.

Further the gasifier itself should be subdivided into its major sub-components and each of these is required to be tested before the gasifier itself can be tested as a composite unit. As unit of this type is being operated for the first time in the world on gasification of rice hulls, all possible data on flow characteristics, residence time, heat transfer rates, [illegible]

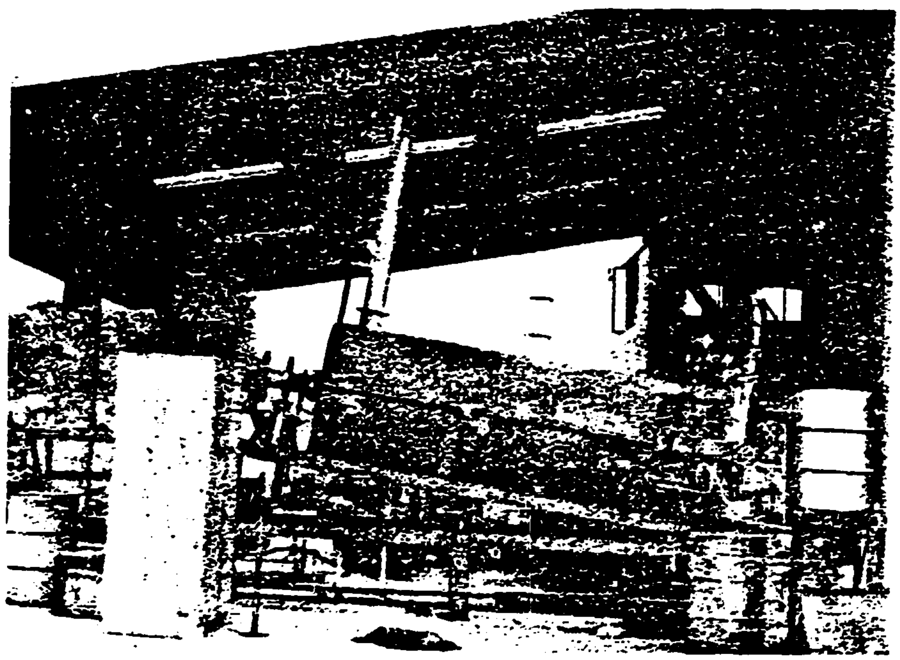

Fig. 2.1 General view of Steam Gasifier before the commencement of operation trials.

[illegible] and quantum of gasification are required to obtained. To achieve these objectives, the gasifier is required to be operated extensively, under both cold (without heating) and hot (with heating) conditions. Systematically, the above operational strategy was followed and the results of these operations are presented in subsequent chapters.

3.0 COLD TESTING OF THE GASIFIER (SPGS)

3.1 Introduction

The operational testing of SPG System forms one of the major objectives of the present mission. Before the unit is tested at higher temperatures for gasification studies, it is imperative that the unit be first tested under ambient conditions to check its mechanical functions and also generate data on the flow characteristics of rice hulls such as hold-up, residence time and the discharge rate as function of (a) slope of the gasifiers; (b) rotational speed of the gasifier; and (c) the rotational speed of the feeder. In addition, the purpose of cold testing was to identify and experience operational problems so that these could be first rectified. If those problems are not detected during the cold testing, these could appear in their aggravative forms during the subsequent hot testing of the gasifier.

The cold testing of the gasifier was also conducted by initially checking the individual components of the Gasifier.

The major components of the gasifiers are:

(a) Feed Hopper (HI)*

(b) Screw Feeder and its Drive (FI)

(c) Rotary Gasifier Pipe and its Drive (GG-1)

(d) Furnace (F2)

(e) Burner (G1)

(f) Ash and Gas Outlet Separator (A-I)

3.2 Feeder Hopper and Screw Feeder

No problems were experienced with the flow of material in the feed hopper. The rice hulls moved smoothly and no choking or bridging of material could be noticed.

The screw feeder was found to have the tendencies to get choked and ceased to function. This was mainly attributed to the relatively small opening at the outlet of the feeder and small clearance between the feeder outlet pipe and the inner diameter of the gasifier. To solve this problem, the following modifications were carried out:

(a) The discharge end bush bearing was removed so that the obstruction to flow of rice hulls was eliminated. Figures 3.1 and 3.2 give the details of rice hull feeder before and after modifications, respectively. It may be mentioned that because of interlinking tendencies of rice hulls, special attention is required for the design of rice hull feeder. The conventional design methods for screw feeders for other materials do not work properly with the feeding of rice

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* These refer to nomenclature given in report (I)

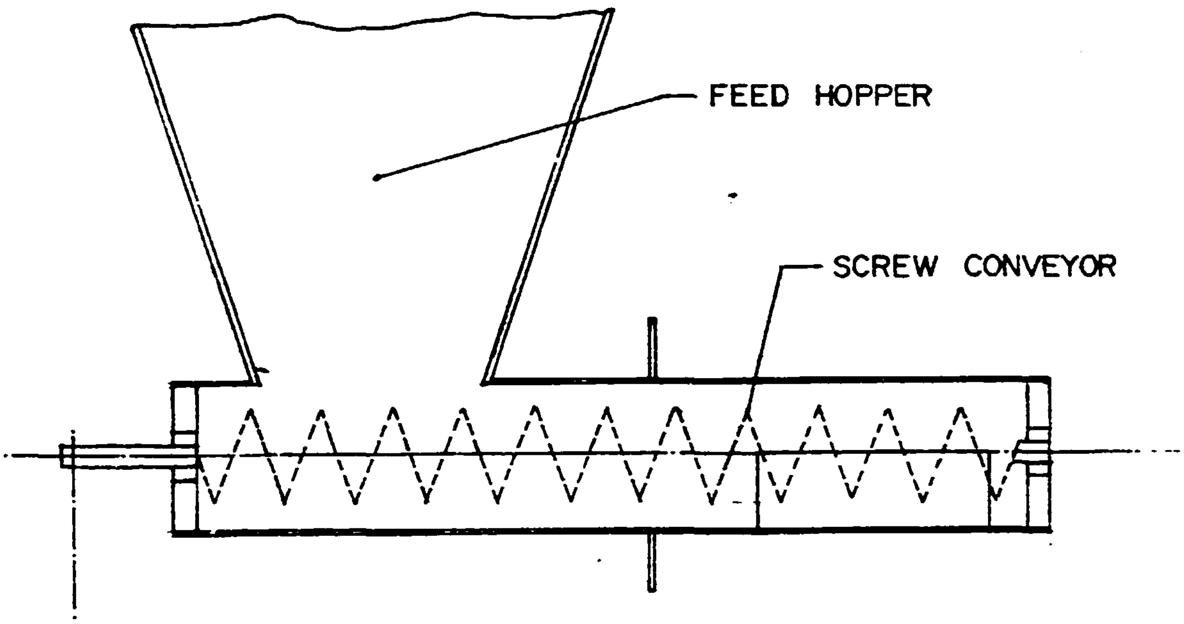


FIG. 3.1 OLD DESIGN

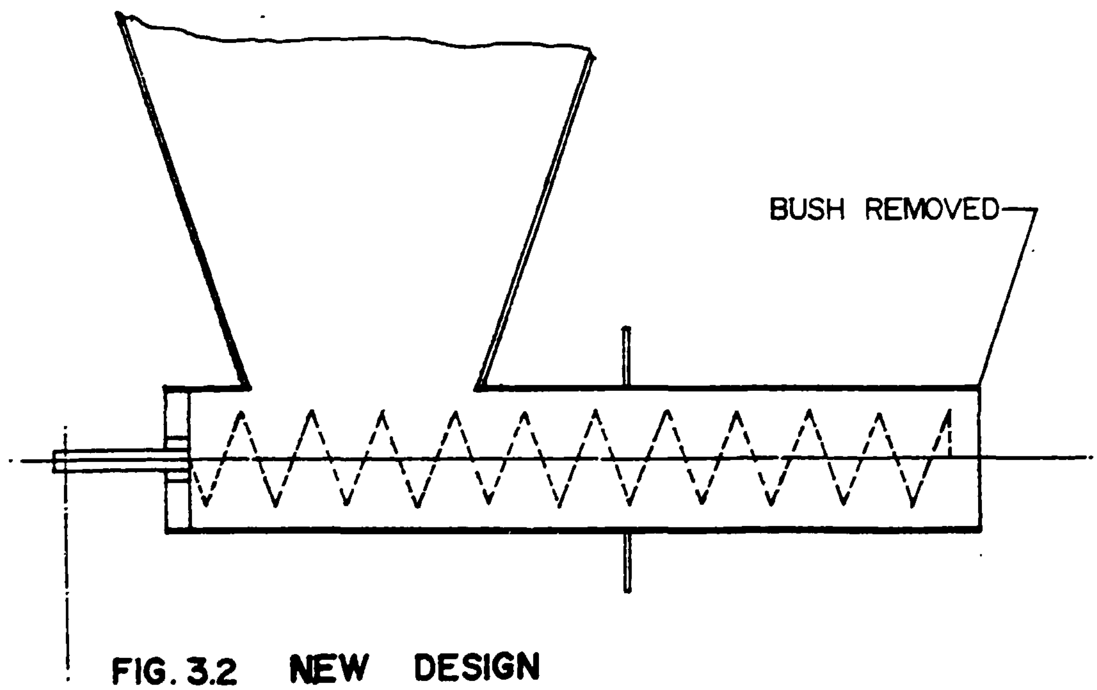


FIG. 3.2 NEW DESIGN

boils. With this modification and having kept proper clearance between the outside diameter of screw and inside diameter of pipe, no operational problems were later experienced.

(b) Initially, the feeder drive was fitted with chain drive from 0.75 hp. 1740 rpm motor and variable hydraulic reduction gear of reduction ratio 400:1. This implied that the theoretically minimum rpm obtainable for feeder could be 4.37. Normally, these hydraulic drives do not function properly at extreme reduction limits. So in its present form the feeder could not be operated at very low speeds. The low speeds of the feeder were rather essential to test the gasifier at different capacities. It was experimentally found that the feeder delivered about 30-35 grams of materials per revolution. This means that even at 2 rpm, material at the rate of 3.6 - 4.2 kg/hr was being delivered to the gasifier.

In order to attain variable speeds for low rpm, the drive had to be modified by incorporating fixed reduction gear of 1:40 coupled with original variable hydraulic reduction gear system and also providing idlers to take care of tension for chain drive. This modified system worked without any trouble and speeds as low as 1 rpm for feeder could be obtained. The photograph depicting final arrangement of drive for feeder is given in Figure 3.3.

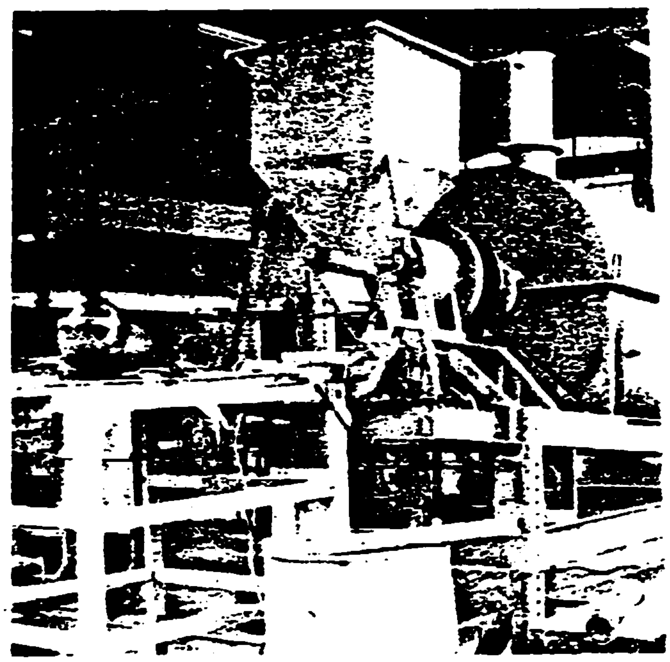


Fig. 3.3 Arrangement of feeder drive.

3.3 Feeder Characteristics

The screw feeder was tested at various rpm and the feed rates of rice hulls were monitored after a number of experimental trials with fresh and re-used rice hulls. The feeding characteristics were obtained which are presented in Figure 3.4. Within the limits prescribed in the Figure 3.4, the rate of feeding as a function of rpm is basically linear with the relation as:

$$\text{Feeder rate (kg/hr)} = \frac{100}{44} \times \text{(rpm)}$$

3.4 Rotary Gasifier

The rotary gasifier is at present being driven by 1 hp eddy current controlled variable speed motor coupled with [illegible] variable hydraulic drive. The hydraulic drive is coupled to the gasifier through chain drive. As no idlers for chain drive were provided, the chain used to get misaligned and gave transmission problems. This happened occasionally though most of the runs could be taken at constant speed of the gasifier which could be varied from 2 to 30 rpm.

The fabricator had not provided any packing in the gland seals meant to seal the rotary gasifier from stationary parts at both its end. According to the engineers at ERDC when the graphatic asbestos packing was fitted into the seals, the motor installed could not take the load and due to additional frictional forces, the gasifier ceased to rotate. To overcome this problem, it was decided to replace the present 1 hp motor

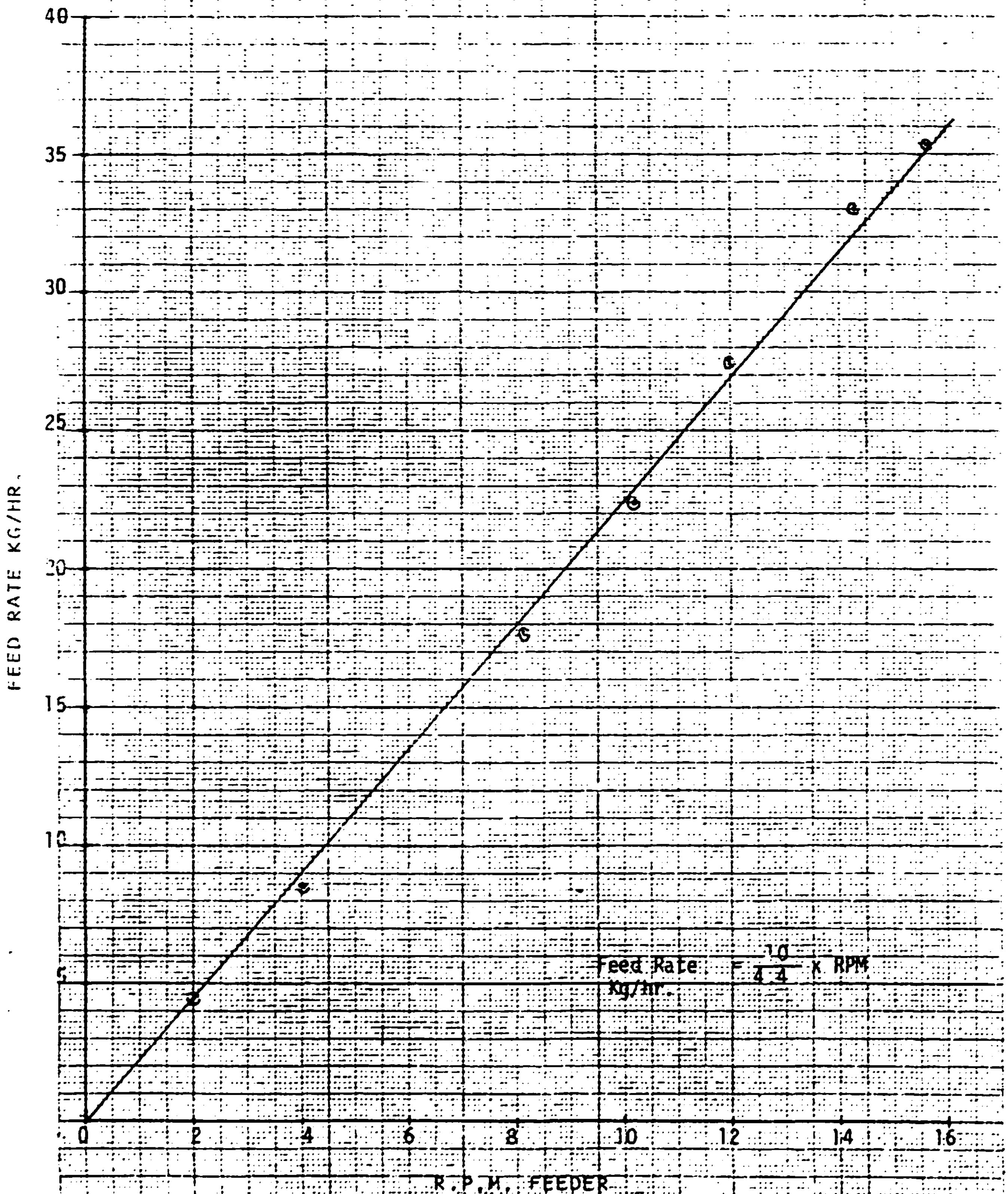


Fig. 3.4 Performance of Ricehull Feeder

with [illegible] hp variable speed motor which has just been delivered but yet to be installed. Except for the above limitation, the gasifier rotated smoothly and data for about 14 cold and hot test runs could be obtained.

7.5 Furnace and Burner

The original programme envisaged was to heat the gasifier for testing purposes with LPG gas. However, because of excessive operating costs, the engineers at ERDC decided to use kerosene oil and tried to device a burning system which was later found to be impracticable. So, as mentioned earlier, no heating arrangement was provided at the start of the present mission.

For the purpose of testing the gasifier, it was ultimately decided to use diesel oil and an old manually operated oil burner was obtained on loan from the Mechanical Engineering Department of the University of the Philippines. In order to improve the draught, a 3 hp induce draft fan was also fitted at the outlet of the flue gases mounted on top of furnace shell of the gasifier. The position of the oil burner was also changed to have smooth flow of flue gases through the five compartments of the furnace.

The oil was fired incombination with wood to make sure that the burner flame was not extinguished due to the presence of hot charcoal amber inside the furnace. With manually operated burner, there is always a danger of getting explosive gases mixture of unburnt vaporized fuel when the flame accidentally goes off and fuel supply is not shut off immediately. It is therefore desirable to procure a semi automatic oil burner with flame detector operated in conjunction with solenoid valve to stop the fuel supply once the flame goes off.

The furnace as designed worked satisfactorily and the alumina refractory withstood the high temperatures attained in the furnace. With initial slow heating adopted during hot trial runs, and refractory materials properly dried no serious cracks in the furnace lining were noticed.

3.6 Ash and Gas Outlet Separator

The function of this unit is to separate the gases from the ash/char. The gas being lighter is allowed to go up from the top outlet pipe and ash being heavier drops through the bottom outlet. The ash drum provided had to be removed as the ash outlet pipe had a small diameter (2 inches) and thus prone to choking. At the time of writing this report, the modified ash collection drum is being fabricated. However, during the cold and hot test runs, the solid discharge was being collected in small containers and discharge rates monitored to get the operational performance of the gasifier.

For all the tests carried out during the present mission, the gas produced was vented as a makeshift arrangement through a long pipe having outlet above the roof of the pyrolysis shed. This had to be done as the gas cleaning system was yet to be tested but more specifically, the gasifier's gland seals did not have any packing. Absence of packing could have resulted in intrusion of air into the combustible gases thereby forming a possible explosive mixture. Till the glands are properly packed, it is advisable not to introduce the gases through the gas cleaning system being operated under slight vacuum.

3.7 Operational Procedure

For cold runs, the pilot plant was operated with rice hulls having the following proximate composition (Table 3.1) which was periodically recycled through the gasifier. Because of reusage, its physical structure slightly changed which was indicated by the change in bulk density from 0.12 kg/litre for fresh rice hulls to 0.13 kg/litre for that reused for about 20 cycles.

Table 3.1
Proximate Analysis of Rice Hulls
(as per ASTM D-1762)

Moisture	5.95
Volatile Matter	68.10
Fixed Carbon	7.34
Ash	24.56

Heating Value = 6,205 Btu/lb (ASTM D-2015)
= 3,477 Kcal/kg

The above analysis results are averaged of two trials and are on dry basis.

In order to generate data on the flow characteristics of rice hulls through the gasifier, the following procedure was adopted:

(1) The inclination of the gasifier was adjusted by raising or lowering the feeding end of the gasifier and by fixing it in the specific holes provided in the adjustable support of the gasifier. The holes were numbered from the bottom of the

adjustable support. The hole number indicated in the data represents the angle of inclination as given in Table 3.2.

Table 3.2
Representation of Number of Hole
with Angle of Inclination

Hole No.	Angle of Inclination (degree)
6	4.48
4	5.80
2	7.10
0	8.34

(2) The feeder hopper was manually filled with rice hulls.

(3) The rotational speed of the gasifier was fixed at predetermined position by adjusting the speed of the motor.

(5) The discharge rate was later measured by collecting materials in a weighted container for specified time. Once consistent discharge rates were obtained, the feeder and the gasifier were stopped simultaneously.

(6) The cross sectional area occupied by the husk was measured by taking dimensions of the maximum width and height of husk columns at the discharge outlet. This was essential for determining the maximum possible loading of the gasifier in terms of the maximum volume that can be occupied by husk as a fraction of the physical volume of the gasifier without reaching the choking point.

(7) Keeping the feeder stopped, the gasifier was restarted and material allowed to discharge and collected. The entire

amount of material discharged from gasifier was weighed and the time taken to get this amount. The amount of material obtained directly gave the apprent hold-up of the material in the gasifier under specific feed rate, rotational speed of gasifier and the inclination of the gasifier.

(8) The apparent residence time of rice hull was then calculated by dividing the hold-up in kilograms by the discharge rate in terms of kg/min. Although, the intrinsic residence time will be different when rice hulls is subjected to gasification/pyrolysis, but this parameter gives the common denominator for comparison of resident time, an important factor for gasification as a function of various operating parameters.

7.0 Data Generated

By adopting the procedure outlined in the previous section, 83 cold test runs were conducted and data on hold-up, residence time and flow rate of rice hulls in the gasifier were generated, as a function of inclination of the gasifier its speed and rotation of the feeder. This is presented in Annexure-I.

The first column indicates the test number and the date and month on which the specific run was conducted. For example, 10/1812 represents test no. 10 conducted on 18th December 1984. Similarly, 61/0401 represents test no. 61 conducted on 4th of January 1985.

The second column indicates the level of inclination of the gasifier. The hole number represents the angle of inclination as given in Table [illegible]. The dimensions in column no. VII represents the maximum height and width of the cross sectional area occupied by the rice husk. The rest of the data is self explanatory.

The discharge rate was varied from 3.73 to 36.8 kg/hr with corresponding feeder speed from 1.93 to 16.72 rpm. Accordingly, the gasifier speed was varied from 4 to 31.3 rpm with its angle from 4.48 to 8.34 degrees.

The hold-up in the gasifier could be as low as 0.2 kg (39/2712) and increased to 2.9 kg and residence time from 2.5 to 25.6 min., an increase by an order of magnitude.

3.9 Analysis of Data

As mentioned in previous section, the feeder was calibrated and gave the following linear relationship.

$$\text{Feed Rate (kg/hr)} = \frac{100}{44} \text{(rpm)}$$

Analysis of data as given in Annexure-II, indicates an interesting trend for residence time. Except for 2 rpm of the feeder (i.e. feed rate = 4.54 kg/hr), the residence time of the material remained constant for particular rpm of the gasifier and independent of feeding rate from 8 kg/hr to 36.8 kg/hr. Even at low feeding rate at 2 rpm, the upward trend was not noticed for all the trial runs. This constancy of resident time is attributed to the fact that when the feed rate is increased at specific rpm of gasifier, the hold-up also got increased so that the ratios of hold-up to feed rate gave constant values. In actual operation, this can be concluded that provided the temperature profile in the gasifier and rate of heating remain constant, same degree of pyrolysis/gasification can be obtained at different capacities. However, for a particular inclination, the residence time was a direct function of the rotational speed of the gasifier and dropped remarkably from 19.34 min. at 4 rpm to about 2.5 min. at 29 rpm.

The substantial change in residence time is advantageous for operation that any degree of pyrolysis can be achieved just by changing the rpm of the rotary gasifier. However, the maximum throughput obtainable in this gasifier is limited by the fractional volume occupied by the material. These limits at different rpm of the gasifier have been clearly identified.

As a function of increase in inclination, the residence time drops substantially. As an instance, for 10 rpm of gasifier speed, it varies from 12 to 7.3 and 6.6 min. when inclination angle is increased from 4.48 to 5.8 and 7.10 degrees, respectively. This implies that the angle of inclination should be kept as low as desired for smooth flow of materials. Low angle will also have less mechanical problems of supporting the gasifier to take account of its sliding tendency in the inclined position.

4.0 HOT OPERATIONAL TESTING OF CPGS

4.1 Introduction

The heating of the SPG System could proceed only when the unit, as described in Chapter 3, was thoroughly tested for its smooth operation under ambient conditions. All possible modifications were carried out to ensure smooth mechanical operation when the unit was required to be operated under thermal duty. Satisfactory operation was achieved and requisite operational data could be obtained.

Initially, the heating of the gasifier was done with wood and later supplemented by using diesel oil. The gasifier was operated at various rpm at varying feed rates and data on the extent of pyrolysis/gasification were obtained. By no means, the work is complete and certain modifications, especially on steam injection and sealing of the gasifier have to be carried out before further testing of the system can be done to study its performance as Steam Pyrolysis System.

For partial and complete pyrolysis of rice hulls, the unit has demonstrated its characteristics as one of the best systems and by far the most superior in performance and costs than the well established system already commercialized in India for making carbonized briquetted fuel known as "PARU" (4).

4.2 Operational Procedure

The hot testing of the unit was carried out by adopting the following procedure:

(1) The hopper was filled with rice hulls.

(2) The rotary gasifier was started at the predetermined speed.

(3) The gasifier was ignited by burning wood logs in the first section of the furnace. As mentioned earlier, the furnace is divided into five sections with intersecting baffles for the flue gas to have five passes before escaping through the

chimney. These sections are numbered starting from the discharge end of the gasifier whereat the maximum temperature is attained in the first section and the chimney is placed on the top of the last and fifth section.

For reasons given in subsequent sections of this report, the wood was also later fired in section four of the furnace of the gasifier.

(4) Once the temperature in the fifth section of the gasifier had reached beyond 200 C, the rice hull feeder was started at predetermined speed.

(5) The temperature inside the gasifier was measured only near the discharge portion, limited by the length of the stainless steel pipe meant to inject steam. This temperature designated as T6 indicated the gas temperature near the hottest portion of the gasifier. This temperature was fixed during the hot trials and controlled by adjusting the firing of wood and diesel oil.

(6) Once the temperatures for gasification were attaied, the discharge rates of char were measured under steady state conditions.

(7) Simultaneously, the temperature in each section of the furnace designated as T1, T2, T3, T4 and T5 for sections 1-5 respectively were noted.

(8) Temperature T1 and later on Temperature T4 were measured by infrared operated pyrometer "Omegascope" Series 3000 manufactured by Omega Engineering, Inc., Stamford CT 06907, U.S.A., which gave the outside surface temperatures of the

gasifier. Other temperatures were measured by K type thermocouples coupled to digital temperature indicator through multipoint switch.

4.3 Data Generated

As mentioned earlier, the unit performed well as rice hull pyrolysis system where degree of pyrolysis could be easily controlled.

Because of essentially plug-flow pattern of rice hulls, the uniformity of char obtained was assured. This was confirmed both by appearance as well as by laboratory analysis test results given in Annexure-V. Due to excessive production of gases, most of the data was taken at low feed rates. Although gas was allowed to escape through a long pipe, yet invariably gases did come out through the char outlet making it difficult and dangerous for the workers to take performance data. Occasionally, these gases got self ignited near the char outlet.

Neither the quality nor the quantity of these gases could be measured. The gas analysis unit GLC available in the Center was out of order for want of spare parts. Therefore, the rates were obtained indirectly by taking overall material balance. Once the clean up system is operated and gas analysis unit perfected, these important parameters can be evaluated.

In all, 59 test trial runs carried out numbered as 84/0901 to 146/0802 for which some meaningful results could be obtained. In fact, total trial runs were conducted should have been almost twice in number. Data presented in Annexure-III include such parameters as discharge rates of char as a function of feed rate, rpm of the gasifier, temperatures of the furnace and gasifier, and residence time. The residence time was based on the feed rates and the hold-up of rice hulls as the feed. This has to be the only basis as the physical structure of char and its bulk density change continuously during pyrolysis.

Extensive tests were carried out on grindability of the char by having trials with rods of various sizes and lengths. Partial success on grinding of char was obtained and modifications as suggested in the proceeding sections have to be carried out before further testing of this aspect is recommended.

4.4 Analysis of Data

The quantum of pyrolysis/gasification is dependent on three parameters. These are temperature of pyrolysis, rate of heating, and residence time. Analysis of data obtained indicates that a residence time of about 5 minutes was sufficient to give 93% conversion of volatiles and carbon into gas from rice hulls (92/1601) provided the temperature T6 was kept above 700 C. This implies that char with 82% ash and 17% carbon could be obtained (based on rice hull analysis given in Table 3.1).

The above analysis is one of the best results obtained with feed rate of 4.54 kg/hr. However, the capacity of the gasifier could be increased and gasification tested at about 30 kg/hr with similar results.

Initially, the trial runs were carried out by firing of wood and oil in section one of the furnace, with the results that the temperatures obtained in sections 4 and 5 of the furnace were of the order of about 300 C. Considering the temperature drops through the gasifier wall, low heat capacity and extremely low thermal conductivity of rice hulls, the temperatures inside the gasifier in first two sections were low enough to give any effective charring of rice hulls. As already mentioned in the reports (2) and (3), the gasifier is divided into four zones/sections, each separated by circular rings/baffles to give effective hold-up of the material. Starting from feed end, these sections are (a) drying zone, (b) carbonizing or charring section, (c) carbonizing and grinding section, and (d) the thermal cracking of tar and gaseous products.

Relatively, low temperatures in sections (a) and (b) above basically meant only effective drying with little or no charring in these zones. Unless, the rice hulls is properly charred, it is not brittle enough to get its effective grinding in zone (c). This was proved by virtually no grinding of the char during initial grindability tests. Therefore, it was decided to increase the temperature in zones (a) and (b) of the gasifier by firing wood in section (4) of the gasifier furnace.

By incorporating this important modification, starting from run no. 106/3101, temperatures in section (4) of the furnace could be increased to as high as 760 C and accordingly, the pyrolysis characteristics of gasifier improved as indicated by percentage of char yield obtained ranging from 26% to 30% compared to 35% to 40% in earlier trials.

4.5 Grindability Test Results

As described earlier, partial success was obtained in getting the char ground in the rotary gasifier. MS and stainless steel rods varying in diameter from 3/8" to 3/4" and in length from 6" to 27.5" were used in combination with sets of 2, 3, 4, and 6. However, best results were obtained with 3/4 Ø s.s. rods when the lengths were kept more than 23.4". Very good grinding results were obtained only for 1 – 2 hrs after which partially and/or completely unground char was observed at the discharge end of the gasifier. Ultimately in many cases, the flow of material got blocked in zone (b) of the gasifier and the tests had to be stopped. Finally, the rods automatically came out of the gasifier.

This phenomenon was attributed to the fact that once the material started to grind, it had tendency to build up in the grinding zone. Since no lifter baffles are provided in this section, the material could not move forward only with the influence of gravity and rotational speed of the gasifier. The built-up of the ground material below and around the rods embedded the rods thereby stopping their rotation. Once rotation of rods is impaired, the grinding action stops, and the char then flows over the rods without any effective grinding. Further, due to accumulation of ground materials below the rods, the front portion of rods gets lifted above the outer edge of the circular baffles and these tend to come out of the grinding zone and finally land up at the discharge end of the gasifier. Due to obstruction provided by the raising of the rods, the material tends to built up in zone (b) of the gasifier and ultimately grinding does occur.

To overcome this problem, it has been decided to provide openings close to inner surface of the gasifier such that as soon as the material is ground, it should not built up in the grinding zone of the gasifier. These segmental openings should be made about 13 cm in width, to facilitate the movement of material but restricting the longitudinal movement of the rods. Further rods with diameter greater than 13 cm and having maximum possible length but capable of having movement should be employed. The openings in the baffle and ends of the rods should have smooth edges so that the rotational movement of the rods are not restricted. This aspect has been thoroughly discussed with engineers at SPDC.

5.0 CONCLUSIONS AND RECOMMENDATION FOR FUTURE WORK

5.1 Introduction

The extensive testing of SPG System, extended over a period of three months, has brought out many factual information hither to not available. regarding its usefulness as an effective and reliable rice hulls gasification/pyrolysis unit. The operational testing of the unit is not yet complete and many aspects originally envisaged in earlier reports (2), (3), especially on steam gasification have still to be verified.

The objective of this section is to highlight the improvements so far obtained and further extension of work that can be carried out to enhance its scope of utilization. In order to carry out the latter activities and also to test it as steam gasifier, certain modifications based on experience gained during present testing spell, have to be incorporated. These have been detailed and enumerated in the proceeding section of this report.

While carrying out the testing of any such system, the emphasis should be to try, identify, and experience possible problems. These should be properly diagonized and then corrective measures should be taken. Such problems should never be supressed or underestimated as those can prove later detrimental to the reliable operation of the plant.

No published data are available regarding the flow characteristics of rice hulls and char in a rotary system of this type. Such basic data which have been generated about the capacity of this gasifier in relation to its diameter and function of rotational speed, inclination of gasifier, residence time, and hold up are extremely useful for designing large system. This, itself has been the major achievement. The above data along with extent of charring gasification obtained constitutes about 80 percent of this overall success for which the present system was conceived, designed, and installed.

Based on experience gained with the operation of the plant and analysis of the data generated, the following conclusions can be drawn.

(1) By achieving plug flow movement of rice hulls, controlled and uniform pyrolysis of rice hulls have been obtained. Further with proper control of temperatures, any degree of

pyrolysis can be obtained with controlled amount of volatiles in the resulting char. The char so produced can be utilized for making smokeless briquetted fuel and the resulting associated gases can be recycled and burnt in the furnace to provide heat required for pyrolysis, thereby making the system self sustaining. This is only possible in this type of system where the material is heated indirectly. In directly heated, partial oxidation system, such rigid controls on the quality of char are not possible to achieve. One such system had been unsuccessfully tried under the present project.

The briquetted fuel so produced can replaced the use of wood and charcoal for domestic purposes. The briquetted fuels from rice husk, coffee husk, coconut husk and jute wastes are being produced commercially in similar methods but in different type of systems.

(2) Because of circular shape of the gasifier, hot spotting and hence unequal expansion of gasifier leading to accumulation of thermal stresses are prevented. With the result that the unit, even under high temperatures gave no serious mechanical problems. In this respect, the present system is far superior to the 'PARU' (4) fuel plants being commercially operated in India and other countries. An appreciable expansion of about 1 1/2" was noticed which was accomodated in the gland seals provided at the discharge end of the gasifier.

(3) Because of the satisfactory performance with controlled

pyrolysis of rice hulls, the unit can easily be used for pyrolysis of such materials as sawdust, coffee husk, ground nut shells, coir pith and dried bagasse. Some of these materials, because of their low ash content give far superior char to that of rice hulls and make excellent carbonized triquetted fuels.

Since a briquetting machine is being procured by the Centre, extension of work in this area is a logical conclusion.

(4) As temperatures of the order of 850 C have been obtained inside the gasifier, this, in addition to its use as a pyrolytic converter can be an ideal gasifier for such like agro-wastes.

(5) Another area in which the work can be further extended is to dose the biomass feed with slaked line. Addition of requisite quantity of calcium oxide has the following additional advantages:

(a) Alkali salts are known to act as catalyst for enhancing the rates of gasification.

(b) Calcium oxide will react with steam in the gasifier to form calcium hydroxide. This, being highly exothermic reaction, will produce additional heat thereby reducing the heat duty for the gasifier furnace.

(c) The presence of calcium hydroxide shall tend to absorb CO_2 from the gases thereby moderately enriching the gases produced in the gasifier.

(d) In case the char is required for making briquetted [illegible] al. the presence of [illegible] harder and [illegible] and if sufficient quantity of CaCO3 is formed, thus also act as [illegible] [illegible] i.e. increases the burning time.

(e) The presence of dense material such as lime in the gasifier shall increase the heat capacity and thermal conductivity of the biomass mixture. This should result in better heat transfer characteristics.

The above advantages are logical but the quantum of their individual beneficial effects on gasification kinetics cannot be theoretically ascertained either technically or in terms of cost benefits unless trial runs are carried out.

(f) No accurate cost analysis of the plant can be carried out till further tests, especially on steam gasification, are completed. However, as a pyrolytic converter, because of its simplicity and comparatively having less moving parts, the unit should be more economical than the existing plants.

6.0 RECOMMENDATIONS FOR MODIFICATIONS

6.1 Introduction

As described earlier, the utility of the present rotary system as pyrolytic convertor and gasifier has been established. This itself is a major achievement accomplished during the present mission. However, gasification with the presence of high [illegible] of steam could not be carried out along with the [illegible] gas cleaning system. Further, the quality of gas [illegible] realised due to non-availability of the facilities. Certain minor and other modifications have to be carried out before the abovementioned aspects of the unit can be further tested. The essential modifications are detailed in the following sections.

5.2 Gasifier Drive and Gland Packing

The gland seals provided at both ends of the rotary gasifier should be packed with graphite coated asbestos rope having square cross section of the same size as the clearance provided in the glands. Three to four rings should be sufficient to effectively seal these glands.

The present 1 hp motor should be replaced by 3 hp variable speed motor which has already been procured. The chain drive of the gasifier should be fitted with idlers similar to the arrangement already done for feeder drive.

5.3 Gasifier Grinding Zone

To avoid the accumulation of ground char inside the grinding zone of the gasifier, four segmental openings of the size 13 mm wide with peripheral length of 95 mm should be provided. This can be done by cutting the outer edges of the radial baffle already provided at the outer end of the grinding zone. All cutting edges of the baffles and grinding rods should be made smooth to avoid any hindrance either to the flow of material or rotation of the rods. This implies that the structure of baffles and lifters provided inside the gasifier has to be taken out and placed back after cutting the grooves.

[illegible] Steam Injection Pipe

The length and size of the pipe presently provided are not [illegible]. This should be replaced by 1/2" (12 mm) O.D. pipe having sufficient length so as to reach the end of the second zone (charring section) of the gasifier. The holes of 5 mm should be provided in the pipe covering only the charring and grinding zones of the gasifier. Further instead of providing radial holes, inclind holes should be provided so that steam jetting out of these holes has a horizontal component directed towards the discharge end of the gasifier. This would facilitate the movement of the material inside the gasifier by directing it towards the outlet. Four radial holes at a distance 5 cm should be adequate. The pipe should be rigidly fixed on the gas-ash separator to avoid its vibration inside the gasifier. Further the pipe itself should be rigid and for this 1/2" O.D. pipe [illegible] is recommended. The outer end of this pipe should be connected with removable steam hose pipe so that a long s.s. sheathed thermocouple can be inserted to measure the temperature profile inside the gasifier.

[illegible].5 Ash Removal System

The ash is being removed in the system at two stages. At first stage, one ash drum is placed below the gas/char separator and another one below the cyclone separator. Both these units should be airtight. The first one has already been modified but [illegible]

[illegible] drum should be fabricated and fixed [illegible] below the cyclone separator. The conical portion of [illegible] with [illegible] The separator should [illegible] to match the dimensions of inlet opening of the ash drum. The present size of the ash outlet pipe is rather small and prone to choking.

4.6 Lagging of Gas Pipe and Cyclone

As described in previous report (3), the gas pipe connecting the ash-gas separator and the cyclone and also cyclone itself should be thermally insulated. Further this unit should be covered with heating tapes. The objective is that these should be first heated before the gas is introduced to avoid any condensation of steam and tar. After this is hot enough due to flow of hot gases, the electrical heating can be switched off.

4.7 Water Seal

At the outlet of the blower, the water seal should be provided just before the burner. Apart from its use as a safety device, it can also measure the outside discharge pressure of the blower.

4.8 Refractory Lining of Furnace

Refractory lining on the outside of rotary gasifier and on the intersecting baffles have been provided without proper supporting structure. With the result that at many places, it has cracked and come off. This should be repaired by providing proper supporting [illegible] or loops. The [illegible] of this loops should [illegible] push the refractory out due to their expansion during heating. Further refractory lining should also be provided on the outside of the rotary gasifier exposed to section four of the furnace. This is necessary as heating is also being carried out in this section. High quality castable refractory cement with about 90% alumina should only be used.

5.9 Flow Meter

On the gas line connecting the demistor and the blower, a calibrated orifice plate or a similar flow meter should be installed. The range of the flow meter should be from 30-300 liters/min.

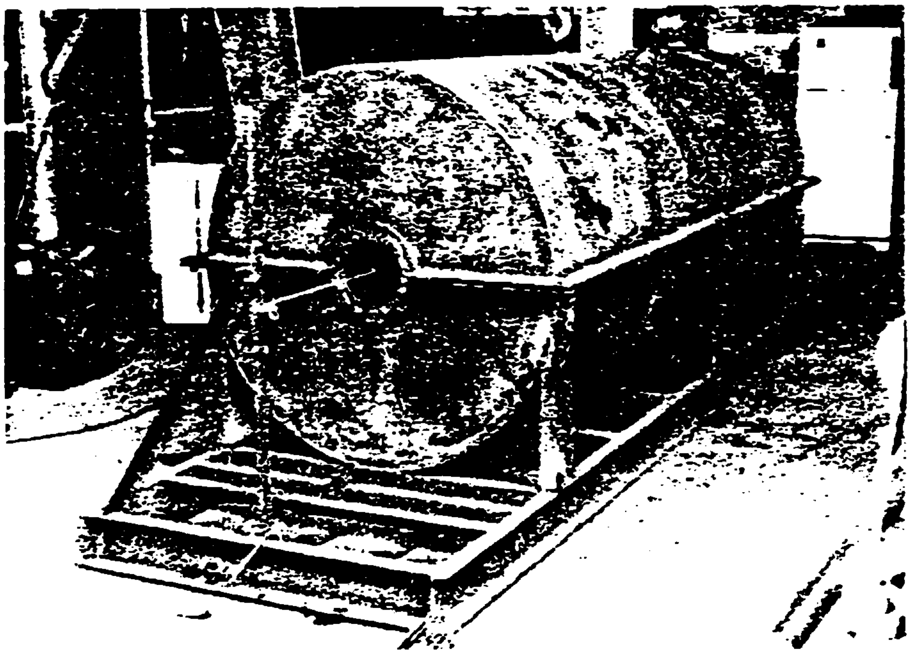
REFERENCES

1. RENSFELT E. and et al. Basic Gasification Studies for Development of Biomass Medium - BTU gasification processes. The Royal Institute of Technology, Stockholm, Sweden. Symposium papers Energy from Biomass and wastes, August 14 to 18, 1978, Washington, D.C.

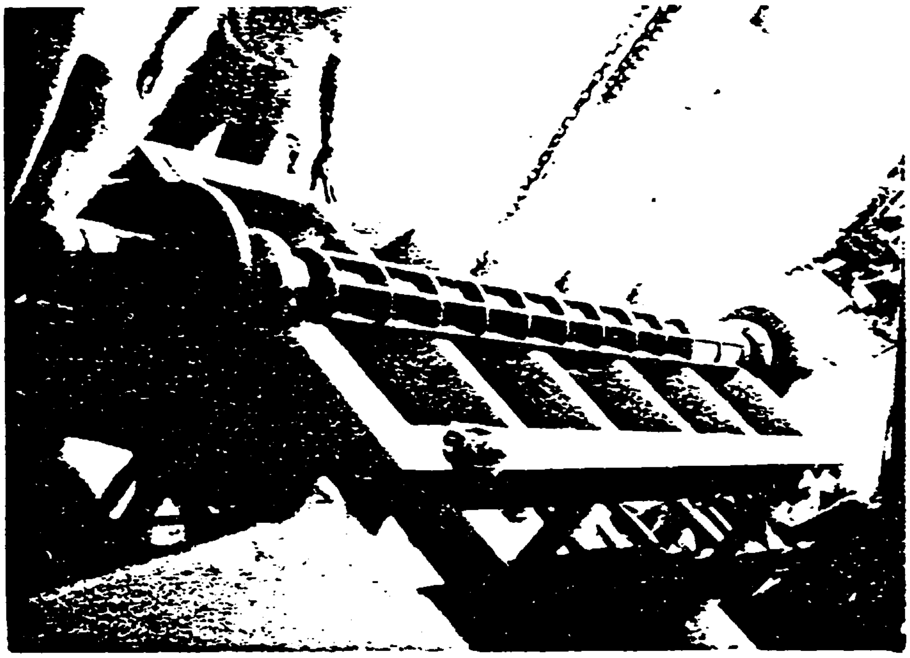
2. GROVER, P. D. Technical Report, UNIDO DP/ID/SER A 463, 2nd August, 1983

3. GROVER, P. D. Technical Report, UNIDO, 25 January 1984.

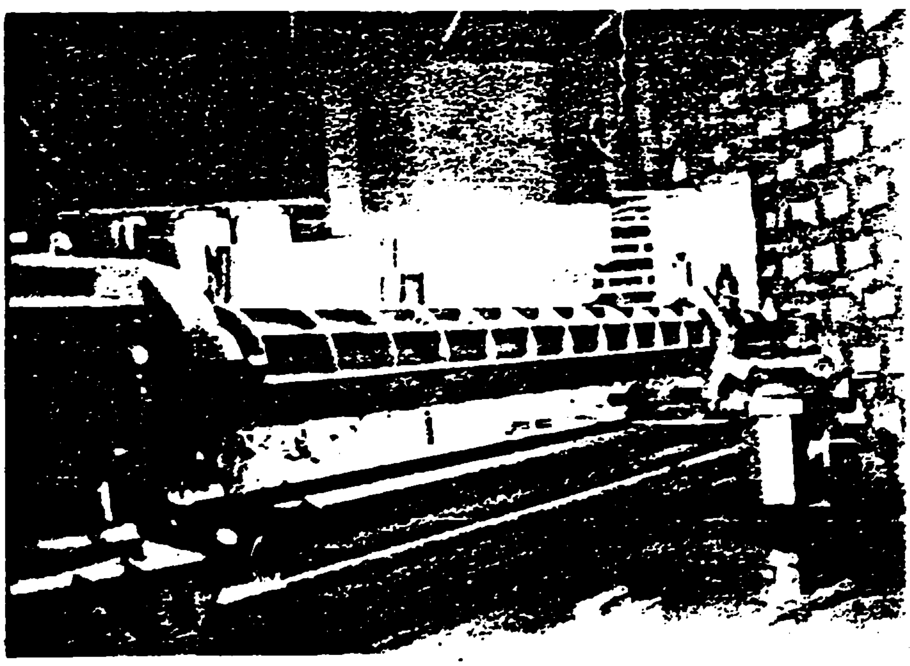
4. GROVER, P. D. Briquetted Fuel (PARU), Mechanized Plant - Feasibility Report, Indian Institute of Technology, New Delhi 110016, India



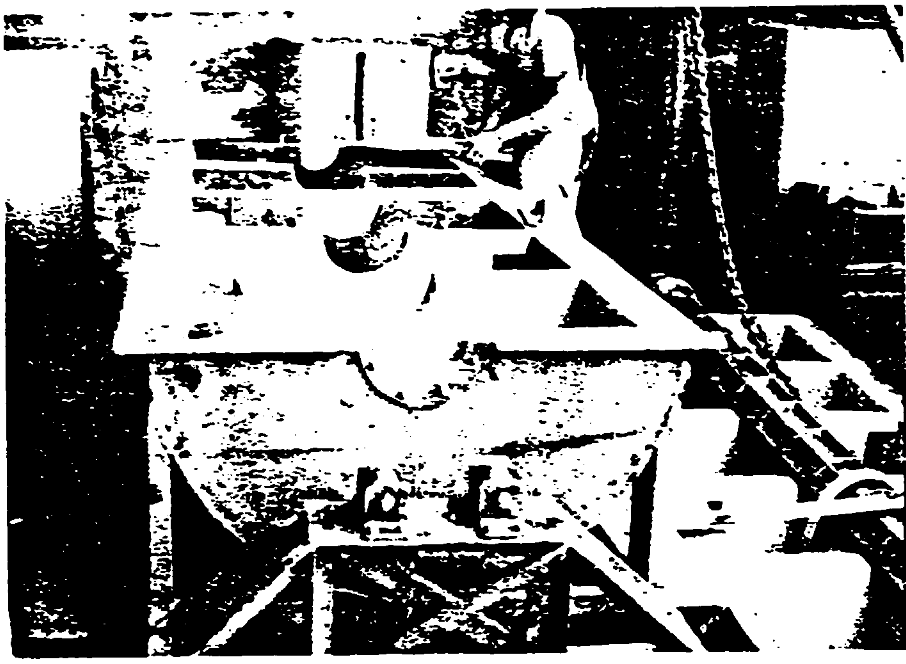
Furnace under assembly.



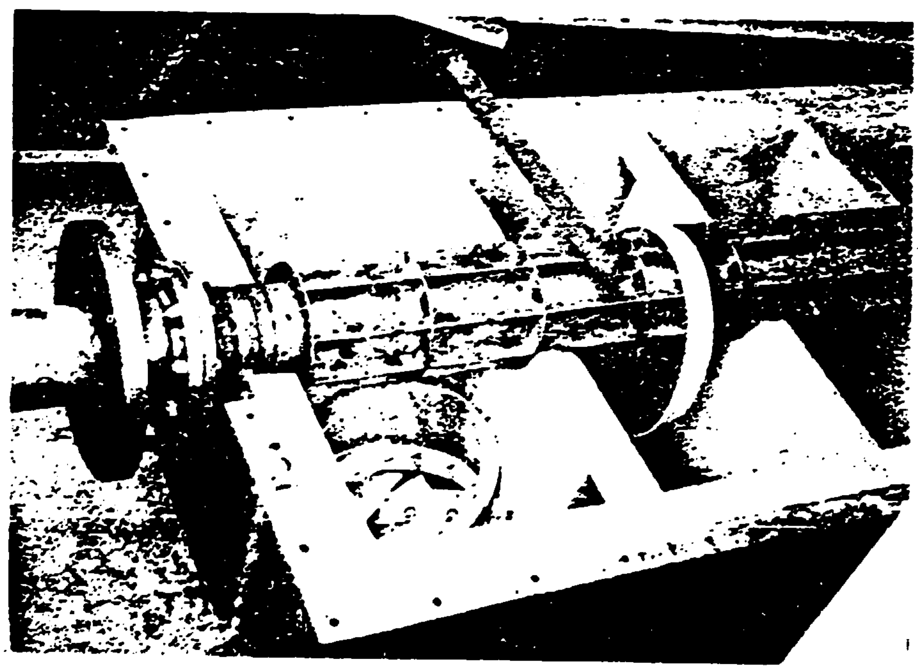
Gasifier being placed in the furnace.



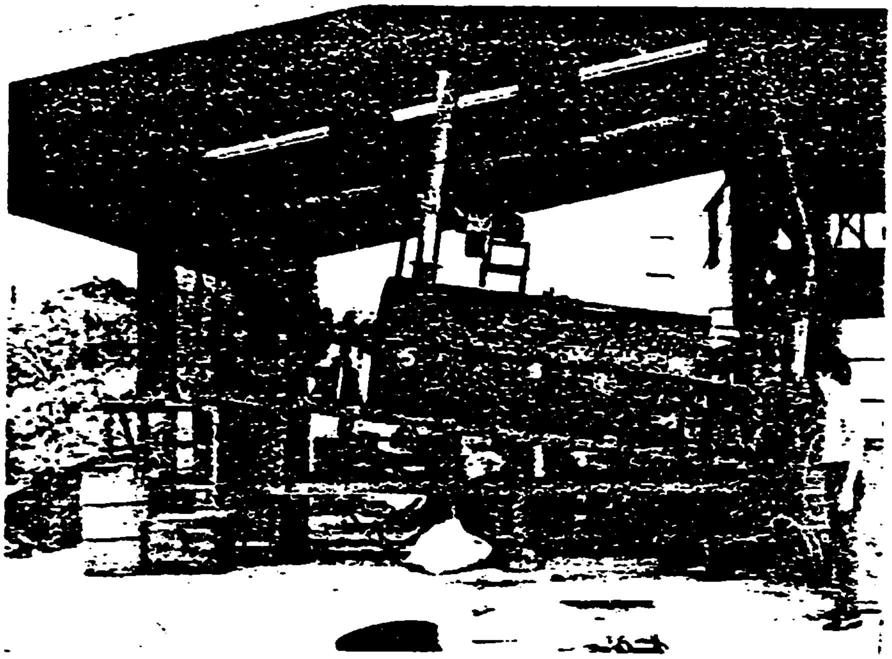
View of the outside shell of the
Gasifier being machined.



Horizontal sectional view of the Gasifier showing five (5) passes for flue gases.



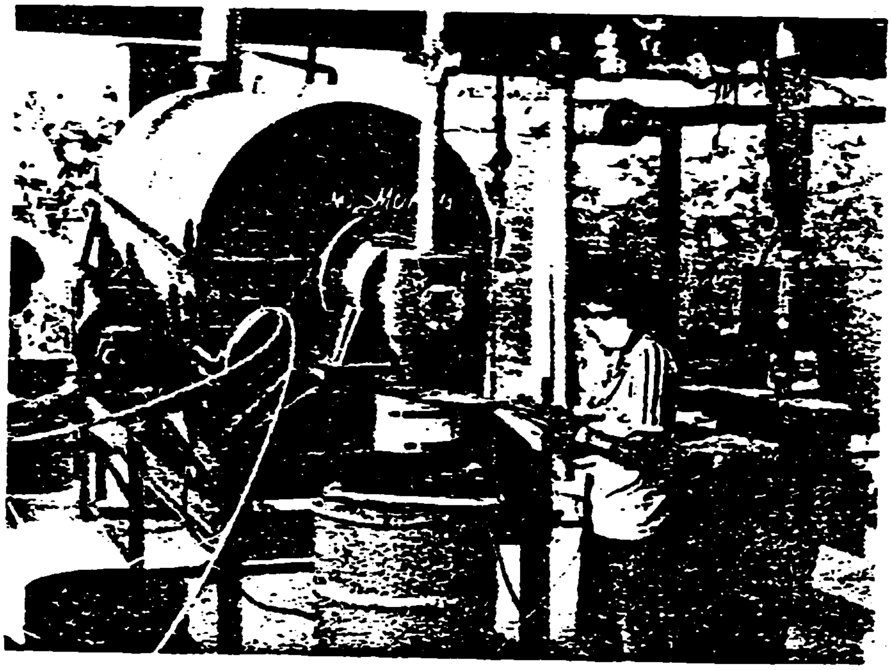
Close-up of the furnace showing intersecting baffles



General view of Gasifier with I:D. fan.

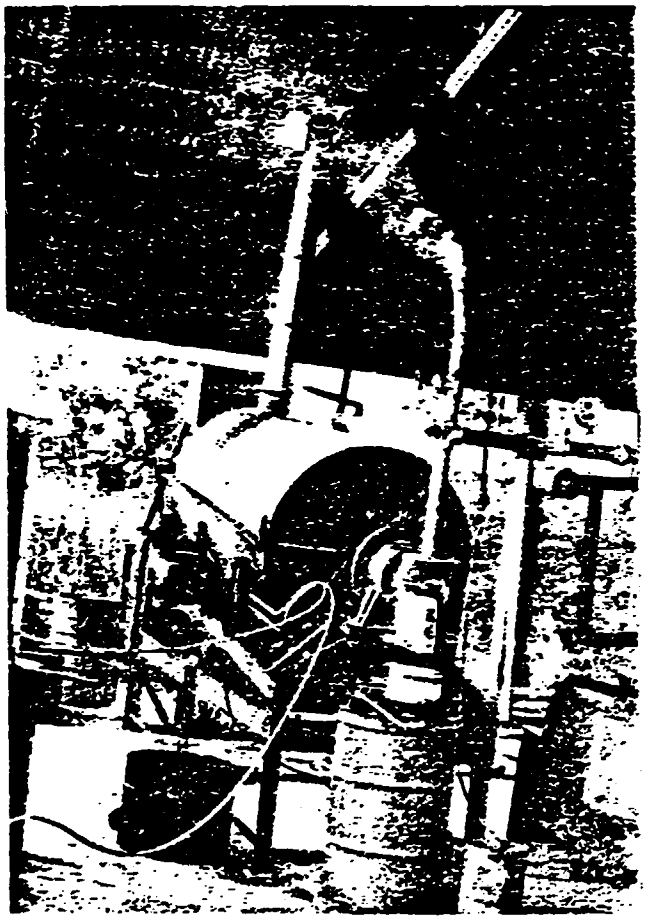
I.D. Fan Assembly

View of the Discharge



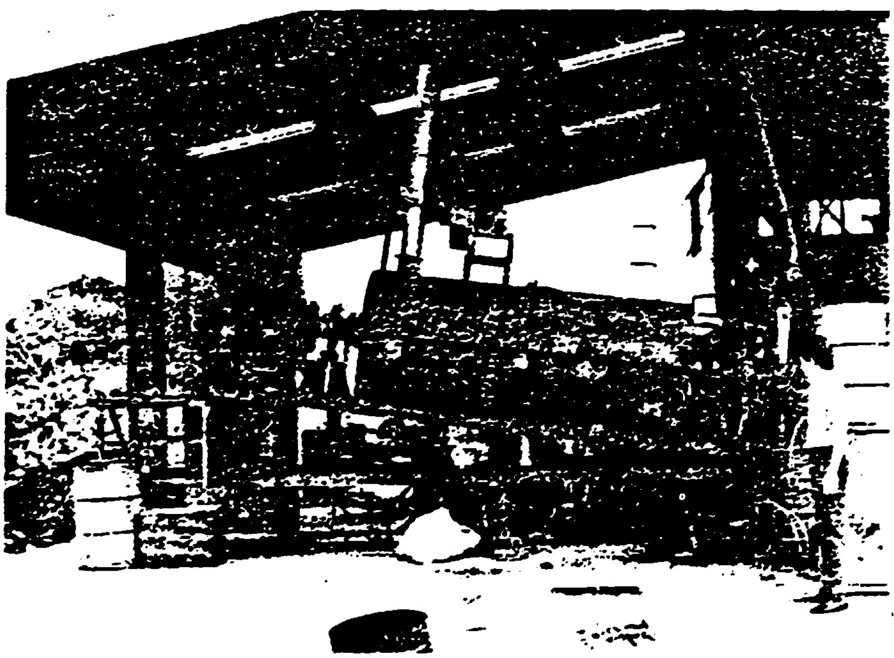
With cover

Without cover



Gasifier in hot operation.

Team of engineers who operated the Gasifier
(L - R, Mario Carlos, Cris German, Romy Bernel,
Joy Zumarraga and Mike Dalida)



General layout of the Gasifier.

Visit of Dr. Pluhar and Mr. Boss of UNIDO.

Inspecting the Gasifier
(L-R Dr. Cruz, Dr. Pluhar, Mr. Boss and Dr. Grover)

ANNEXURE-I

OPERATIONAL DATA OBTAINED COLD TESTING

I	II	III	IV	V	VI	VII		VIII	IX	X
READING	SLOPE (hole)	FEEDER (rpm)	GASIFIER (rpm)	GASIFIER (reading)	DISCHARGE RATE (kg/hr)	DISCHARGE DIMENSIONS H (mm)	W	HOLD-UP (kg)	TIME (min)	REMARKS
1/1812	6	2.0	16	1760	3.73	9	50	0.57	35	* weighing with 80 kg. scale
2/1312	6	4.0	16	1750	7.2*	15	55	1.0	-	
3/1312	6	6.0	16	1750	10.8*	20	65	1.6	-	
4/1312	6	8.0	16	1750	15.6*	25	70	2.1	-	
5/1312	6	10.0	16	1750	20.4*	30	75	3.0	-	
6/1812	6	2.0	10	1200	3.86	15	55	0.74	35	
7/1412	6	4.0	10	1200	8.40	20	60	1.5	-	
8/1412	6	6.0	10	1200	10.90	25	75	2.25	-	
9/1412	6	8.0	10	1200	13.61	30	80	2.64	-	
10/1812	6	2.0	5.5	600	3.85	20	65	1.31	35	
11/1712	6	4.0	5.5	600	7.46	30	80	3.19	35	
12/1812	6	6.0	5.5	600		FEEDER GETS CHOKED				
13/1912	4	2.0	10	1750	4.1	10	50	0.50	30	
14/1912	4	4.0	13.5	1750	7.8	15	55	0.86	20	
15/1912	4	6.0	14	1750	12.52	20	60	1.24	12	
16/2012	4	8.2	15	1100	16.93	20	70	1.55	15	

OPERATIONAL DATA OBTAINED COLD TESTING

I	II	III	IV	V	VI	VII		VIII	IX	X
READING	SLOPE (hole)	FEEDER (rpm)	GASIFIER (rpm)	GASIFIER (reading)	DISCHARGE RATE (kg/hr)	DISCHARGE DIMENSIONS H (mm)	W	HOLD-UP (kg)	TIME (min)	REMARKS
17/2012	4	10.0	15	1000	21.4	25	75	2.11	11	
18/2012	4	12.0	15	950	25.2	25	75	2.57	11	
19/2012	4	14.00	15	950	27.06	25	80	4.16	14	
20/2012	4	15.2	15	9500	27.25	30	85	3.80	11	Feeder Choked
21/2612	4	4.026	12	750	8.43	15	60	1.03	13	
22/2612	4	4.026	9.8	600	8.50	18	65	1.38	15	
23/2612	4	4.026	19.8	1250	8.42	10	50	0.66	8	
24/2612	4	4.026	23.4	1580	8.46	10	45	0.57	7	
25/2612	4	4.026	8.57	550	8.74	20	65	1.39	18	
26/2612	4	4.00	5.36	350	8.64	25	75	2.36	40	
27/2612	2	4.03	25	1575	8.47	9	50	0.44	10	
28/2612	2	4.05	20	1320	8.40	10	50	0.53	12	
29/2612	2	4.05	15	975	8.37	11	50	0.64	12.5	
30/2712	2	4.02	10	600	8.7	18	60	0.97	12	
31/2712	2	4.05	6.6	400	8.59	20	65	1.50	19	
32/2712	2	4.05	4.0	200	8.44	30	85	2.72	30	

OPERATIONAL DATA OBTAINED COLD TESTING

I	II	III	IV	V	VI	VII		VIII	IX	X
READING	SLOPE (hole)	FEEDER (rpm)	GASIFIER (rpm)	GASIFIER (reading)	DISCHARGE RATE (kg/hr)	DISCHARGE DIMENSIONS H (mm)	W	HOLD-UP (kg)	TIME (min)	REMARKS
33/2712	2	4.05	29	1800	8.86	8	40	0.45	7	Gasifier coupling rubber changed.
34/2712	2	8.0	30	1800	17.13	12	50	0.74	6	
35/2712	2	10	30	1800	22.12	15	60	0.71	7	
36/2712	2	12	30	1800	26.18	15	60	1.12	8	
37/2712	2	14	30	1800	31.6	19	65	1.33	10	
38/2712	2	15.36	30.2	1800	34.21	20	70	1.456	8	
39/2712	2	2.031	31.3	1800	4.61	5	30	0.202	7	
40/2712		2.04	25.0	1550	4.6	7	35	0.23	8	
41/2712	2	2.04	20.2	1260	4.39	8	38	0.29	10	
42/2712	2	2.03	14.9	940	4.47	10	40	0.36	14	
43/2812	2	2.01	10	na	4.45	10	50	0.52	14	
44/2812	2	2.03	6.09	3.99	4.38	15	55	0.75	17	
45/2812	2	5.94	25.3	1620	12.82	15	50	0.14	7	
46/2812	2	6.0	21.3	1350	12.97	11	55	0.73	9	
47/2812	2	6.0	14.9	920	13.02	15	55	1.02	12	
48/2812	2	6.0	12.0	740	13.2	17	65	1.23	11	

OPERATIONAL DATA OBTAINED COLD TESTING

I	II	III	IV	V	VI	VII		VIII	IX	X
READING	SLOPE (hole)	FEEDER (rpm)	GASIFIER (rpm)	GASIFIER (reading)	DISCHARGE RATE (kg/hr)	DISCHARGE DIMENSIONS H (mm)	W (mm)	HOLD-UP (kg)	TIME (min)	REMARKS
49/2812	2	5.94	10.0	600	12.90	20	70	1.42	12	
50/2812	2	6.0	8.1	500	13.16	25	80	1.82	15	
51/2912	2	8.20	9.9	600	17.82	23	75	2.02	17	
52/2912	2	8.13	12.1	74[illegible]	18.21	20	75	1.76	14	
53/2912	2	8.09	15.1	960	17.56	18	68	1.44	16	
54/2912	2	8.09	20.3	1300	17.95	15	58	1.10	11	
55/2912	2	8.13	24.8	1620	18.12	15	55	0.87	10	
56/0201	2	10.29	23.4	1620	21.95	15	55	1.10	7	
57/0201	2	10.23	19.81	1300	22.41	20	65	1.41	8	
58/0201	2	10.23	16	1050	22.76	20	75	1.71	8	
59/0201	2	10.29	13.8	880	22.86	20	75	2.05	9	
60/0201	2	10.0	12.0	760	22.32	20	80	2.44	14	
61/0201	2	10.25	25.0	1600	22.28	15	65	1.21	8	
61/0301R	2	12.20	24.6	1120	28.92	17	67	1.42	12	
62/0201	2	11.80	20.1	925	26.60	15	70	2.91	13	
62/0301R	2	12.20	20.0	900	29.60	18	70	1.64		

OPERATIONAL DATA OBTAINED COLD TESTING

I	II	III	IV	V	VI	VII		VIII	IX	X
READING	SLOPE (hole)	FEEDER (rpm)	GASIFIER (rpm)	GASIFIER (reading)	DISCHARGE RATE (kg/hr)	DISCHARGE DIMENSIONS (mm) H	W	HOLD-UP (kg)	TIME (min)	REMARKS
63/0201	2	11.80	18.0	815	26.75	20	75	1.70	12	
64/0201	2	11.80	15.7	700	27.34	20	80	2.12	13	
65/0201	2	11.74	14.1	675	27.4	23	83	2.41	16	
66/0301	2	14.33	25.0	1160	32.9	18	70	1.78	8	
67/0301	2	14.31	23.1	1040	33.2	20	70	1.85	10	
68/0301	2	14.09	16.5	850	33.4	25	80	2.67	10	
69/0301	2	14.24	16.4	760	34.0	28	80	2.72	12	
70/0301	2	14.26	15.1	700	33.1	20	80	2.85	12	
71/0301	2	15.94	25.2	1120	35.8	20	70	1.87	10	
72/0301	2	15.94	22.6	1000	36.4	21	75	2.0	8	
73/0301	2	15.45	19.4	850	36.2	22	77	2.48	10	
74/0301	2	16.72	16.3	760	36.8	24	80	2.91	11.5	
75/0401	2	1.95	25.1	1150	4.48	5	85	0.32	10	
76/0401	2	1.97	20.3	900	4.51	4	35	0.35	-	
77/0401	2	1.95	15.2	660	4.52	7	40	0.36	-	
78/0401	2	1.93	9.8	450	4.30	10	50	0.60	16	

OPERATIONAL DATA OBTAINED COLD TESTING

I	II	III	IV	V	VI	VII		VIII	IX	X
READING	SLOPE (hole)	FEEDER (rpm)	GASIFIER (rpm)	GASIFIER (reading)	DISCHARGE RATE (kg/hr)	DISCHARGE DIMENSIONS H (mm)	W	HOLD-UP (kg)	TIME (min)	REMARKS
79/0401	2	1.96	4.7	200	4.03	25	60	1.19	22	
80/0501	2	4.14	5.9	250	8.71	22	70	1.7	25	
81/0501	2	4.03	25.4	1130	8.83	8	43	0.42	9	
82/0501	2	7.97	10.0	440	17.28	22	80	2.02	15	
83/0501	2	14.88	25.4	1140	33.4	20	72	1.71	10	

OPERATIONAL DATA OBTAINED HOT TESTING

I	II	III	IV	V	VI								VII	VIII	IX
RUN NO.	RPM GASIFIER	RPM FEEDER	METER READING	DISCHARGE RATE (kg/hr)	TEMPERATURE C T1	T2	T3	T4	T5	T6	T7	T8	HOLD-UP (kg)	TIME (min)	REMARKS
84/0901	6.07	1.99	-	1.41	457	237	147	74	83	402	-	-	-	-	
85/0901	6.08	1.99	-	1.53	618	292	89	127	79	495	-	-	-	-	after 30 meters
86/0901	6.17	1.99	-	1.41	605	250	89	114	83	553	56	45	-	-	after 30 meters
87/0901	6.2	1.99	-	1.39	532	233	195	122	88	549	72	58	-	-	after 30 meters
88/0901	6.12	1.99	-	1.30	697	227	214	87	79	-	79	54	-	-	after 30 meters
89/1101	6	2.0	-	4.2	-	-	-	-	-	-	-	-	1.063	26	L = 70 : W = 25
90/1101	6	4	-	9.30	-	-	-	-	-	-	-	-	1.764	33	L = 75 : W = 30
91/1101	8	6	-	13.12	-	-	-	-	-	-	-	-	2.306	22	L = 75 : W = 25
92/1601	16	2	-	1.28	716	490	329	172	130	700	-	44	-	-	wood firing
93/1601	16	3	-	1.78	485	400	230	174	126	752	-	-	-	-	
94/1601	16	3.97	-	4.37	803	366	226	160	116	508	-	-	-	..	
95/1601	16	4.521	-	3.59	946	521	310	174	126	753	-	94	-	-	
96/1601	16	4.853	-	4.38	-	528	349	197	167	-	-	65	-	-	
97/2101	6.13	2.05	-	1.63	1042*	433	320	280	240	619	-	30	-	-	wood w/ I.D. Fan
98/2101	7.87	2.06	-	1.63	1140*	556	490	347	220	678	-	30	-	-	after 45 meters
99/2101	9.37	2.06	-	1.54	1156*	686	528	396	280	876	-	40	-	-	after 1 hr.
100/2101	10	2.06	-	1.63	1292*	762	552	434	295	812	-	75	-	-	after 35 meters

OPERATIONAL DATA OBTAINED HOT TESTING

I RUN NO.	II RPM GASIFIER	III RPM FEEDER	IV METER READING	V DISCHARGE RATE (kg/hr)	VI T1	T2	T3	T4	T5	T6	T7	T8	VII HOLD-UP (kg)	VIII TIME (min)	IX REMARKS
					TEMPERATURE °C										
101/2201	16.34	2.06	-	1.92	1126*	620	458	390	265	697	-	50	-	-	4:00 p.m.
102/2401	19.8	2.07	-	1.13	745	328	274	185	160	0	-	35	-	-	burner + wood
103/2401	19.04	2.08	-	1.06	-	348	308	195	-	-	-	-	-	-	with rods
104/2401	20	2	-	1.56 0.7	-	-	-	-	-	-	-	-	-	-	with steam injection
105/2401	20	2	-	0.7 1.1 1.8	-	-	-	-	-	-	-	-	-	-	2nd hole
106/3101	19.35	2.06	-	0.24	927	528	354	580	336	820	-	-	-	-	2 1/2" x 55 cm rc 70% ground gas burning
107/3101	19.35	2.06	-	0.36	936	515	343	624	300	826	-	-	-	-	20% ground
108/3101	19.7	2.02	-	0.58	927	536	384	640	367	832	-	-	-	-	unground
109/3101	19.7	2.02	-	0.64	980	578	386	623	341	843	-	-	-	-	- do -
110/3101	25.6	2.03	-	0.94	927	542	392	632	354	828	-	-	-	-	unground char - 120°C
111/3101	25.6	2.03	-	0.97	882	557	396	653	364	800	-	-	-	-	- do -
112/3101	29.5	2.04	-	1.16	915	568	390	657	329	798	-	-	-	-	- do -
113/3101	29.5	2.04	-	1.39	971	580	414	674	346	813	-	-	-	-	unground and choking noticed

*charcoal in furnace

OPERATIONAL DATA OBTAINED HOT TESTING

I	II	III	IV	V	VI								VII	VIII	IX
RUN NO.	RPM GASIFIER	RPM FEEDER	METER READING	DISCHARGE RATE (kg/hr)	TEMPERATURE C T1	T2	T3	T4	T5	T6	T7	T8	HOLD-UP (kg)	TIME (min)	REMARKS
114/0102	20	2	-	-	Trials with 4 rods - 1/2" ø and 4 rods of 3/8" ø. In both cases, rods came out.								-	-	-
115/0402	20	2	-	-	Trials with 4 rods - 1/2" ø and 2 rods of 3/8" ø. Two rods came out. Choking occured - unground char.								-	-	-
116/0502	20	2	-	-	Trial with 4 rods - 1/2" ø - 30 cm in length. All rods came out.								-	-	-
117/0602	20	2	-	-	Repeated as 116 similar observations - plus choking noticed.										
118/0702	20	2	-	1.72	-	350	262	-	255	-	-	-	-	-	-
119/0702	25	2	-	1.65	-	384	277	-	308	-	-	-	-	-	-
120/0702	30	2	-	1.66	-	382	294	-	260	-	-	-	-	-	-
121/0802	15	2	-	-	Trial with 4 - 1/2" ø 15 cm long rods. After 8 minutes the rods came out.										
122/0802	20	2	-	-	Same as 121. After 10 minutes, the rods came out.										
123/0802	20	2	-	3.0	791	426	271	557	413	-	-	-	-	-	no rods
124/0802	20	4	-	4.05	705	410	283	518	530	-	-	-	-	-	-
125/0802	20	6	-	3.43	701	422	304	576	516	-	-	-	-	-	-

OPERATIONAL DATA OBTAINED HOT TESTING

I	II	III	IV	V	VI								VII	VIII	IX
RUN NO.	RPM GASIFIER	RPM FEEDER	METER READING	DISCHARGE RATE (kg/hr)	TEMPERATURE C								HOLD-UP (kg)	TIME (min)	REMARKS
					T1	T2	T3	T4	T5	T6	T7	T8			
126/0802	20	6	-	3.05	677	425	317	568	461	-	-	-	-	-	-
127/0802	20	8	-	5.44	633	434	336	523	487	-	-	-	-	-	-
128/0802	20	8	-	5.08	744	454	353	583	420	-	-	-	-	-	-
129/0802	20	10	-	7.31	804	493	360	587	414	-	-	-	-	-	-
130/0802	20	10	-	6.97	780	477	362	618	395	-	-	-	-	-	-
131/0802	20	12	-	8.14	708	455	360	608	382	-	-	-	-	-	-
132/0802	20	12	-	6.48	650	431	354	561	356	-	-	-	-	-	-
133/0802	20	14	-	11.39	614	397	341	574	323	-	-	-	-	-	-
134/0802	20	14	-	11.74	557	388	337	528	314	-	-	-	-	-	-
135/1802	4	2	-	1.40	839	510	-	664	357	-	-	-	-	-	-
136/1802	6	2	-	1.40	801	479	-	692	365	-	-	-	-	-	-
137/1802	8	2	-	1.67	833	495	-	767	400	-	-	-	-	-	-
138/1802	10	2	-	1.56	883	454	-	533	292	740	-	-	-	-	-
139/1802	12	2	-	1.37	900	517	-	626	356	741	-	-	-	-	-
140/1802	14	2	-	1.18	869	530	-	648	392	764	-	-	-	-	-
141/1802	16	2	-	1.23	860	568	-	648	420	763	-	-	-	-	-
142/1802	18	2	-	1.25	904	597	-	691	450	769	-	-	-	-	-

Annexure-III

CALCULATED DATA - COLD TESTING

NO.	HOLD UP (kg)	DISCHARGE RATE (kg/hr)	RESIDENCE TIME (min)	RPM FEEDER	RPM GASIFIER	DISCHARGE (kg/rev)
1/1812	0.57	3.73	9.3	2	15/16	31
2/1312	1.0	7.2	8.3	4	16	30
3/1312	1.6	10.8	8.8	6	16	30
4/1312	2.1	15.6	8.1	8	16	32
5/1312	3.0	20.4	8.8	10	16	34
6/1812	0.74	3.86	11.50	2	10/11	32
7/1412	1.5	8.4	10.7	4	10	35
8/1412	2.25	10.4	12.3	6	10	30
9/1412	2.64	13.61	11.6	8	10	28.3
10/1812	1.313	3.85	20.4	2	5.5	32.0
11/1712	3.19	7.46	25.6	4	5.5	31.0
12/1812	-	-	-	-	-	-
13/1912	0.5	4.1	7.3	2	10	34
14/1912	0.86	7.8	6.6	4	13.5	32.5
15/1912	1.24	12.52	5.94	6	14	34.7
16/1912	1.55	16.93	9.1	8.2	15	34.4
17/2012	2.11	21.4	5.9	10	15	35.6
18/2012	2.57	25.2	6.1	12	15	35
19/2012	4.17	27.06	9.2	14	15	32.2

CALCULATED DATA - COLD TESTING

NO.	HOLD UP (kg)	DISCHARGE RATE (kg/hr)	RESIDENCE TIME (min)	RPM FEEDER	RPM GASIFIER	DISCHARGE (kg/rev)
20/2012	3.804	27.25	8.3	15.6	15	29.8
21/2612	1.029	8.426	7.33	4.026	12	34.9
22/2612	1.381	8.50	9.75	4.026	9.83	35.2
23/2612	0.669	8.426	4.76	4.026	19.89	34.8
24/2612	0.574	8.46	4.07	4.026	23.4	35
25/2612	1.394	8.57	9.76	4.026	8.57	35.5
26/2612	2.366	8.64	16.4	4.00	5.36	36.0
27/2612	0.444	8.47	3.14	4.026	25	35.06
28/2612	0.536	8.4	3.83	4.054	20	34.5
29/2612	0.647	8.37	4.64	4.054	15	34.4
30/2712	0.974	8.7	6.71	4.017	10	34.8
31/2712	1.506	8.59	10.52	4.054	6.62	35.3
32/2712	2.721	8.44	19.34	4.054	4.0	34.6
33/2712	0.453	8.86	3.06	4.054	29.03	36.42
34/2712	0.749	17.13	2.62	7.97	30.5	35.8
35/2712	0.717	22.12	1.94	10	30.5	36.87
36/2712	1.123	26.18	2.57	12	30.25	36.36
37/2712	1.334	31.6	2.53	14	30.0	37.6
38/2712	1.456	34.21	2.55	15.36	30.25	37.1

CALCULATED DATA - COLD TESTING

NO.	HOLD UP (kg)	DISCHARGE RATE (kg/hr)	RESIDENCE TIME (min)	RPM FEEDER	RPM GASIFIER	DISCHARGE (kg/rev)
39/2712	0.202	4.61	2.63	2.027	31.3	37.90
40/2712	0.235	4.60	3.065	2.04	25	37.6
41/2712	0.288	4.39	3.94	2.04	20.22	35.9
42/2712	0.361	4.47	4.85	2.03	14.94	36.7
43/2812	0.519	4.45	7.00	2.01	10.06	36.9
44/2812	0.754	4.38	10.33	2.03	6.09	35.96
45/2812	0.143 0.243	12.82	0.67 1.14	5.94	25.35	35.97
46/2812	0.727	12.97	3.36	6.0	21.3	36.03
47/2812	1.023	13.02	4.71	6.0	14.88	36.17
48/2812	1.228	13.2	5.58	6.0	12.04	36.67
49/2812	1.422	12.90	6.61	5.94	10.03	36.20
50/2812	1.822	13.16	8.31	6.0	8.13	36.55
51/2912	2.025	17.82	6.82	8.205	9.92	36.2
52/2912	1.760	18.21	5.80	8.136	12.135	37.3
53/2912	1.445	17.56	4.94	8.09	15.08	36.2
54/2912	1.108	17.95	3.70	8.09	20.34	37.0
55/2912	0.875	18.12	2.90	8.136	24.86	37.1
56/0201	1.104	21.95	3.02	10.29	23.44	35.5

CALCULATED DATA - COLD TESTING

NO.	HOLD UP (kg)	DISCHARGE RATE (kg/hr)	RESIDENCE TIME (min)	RPM FEEDER	RPM GASIFIER	DISCHARGE (kg/rev)
57/0201	1.409	22.41	3.71	10.23	19.78	36.5
58/0201	1.719	22.76	4.53	10.23	15.96	37.1
59/0201	2.058	22.86	5.40	10.29	13.80	37.0
60/0201	2.44	22.32	6.56	10.00	12.03	37.2
61/0201	1.210	22.28	3.26	10.25	25.0	36.3
61/0401R	1.420	28.92	2.95	12.2	24.59	39.5
62/0201	2.915	26.60	6.58	11.80	20.11	37.5
62/0401	1.637	29.60	3.32	12.2	20.03	40.4
63/0201	1.705	26.75	3.82	11.8	18.0	37.8
64/0201	2.123	27.34	4.66	11.8	15.74	38.6
65/0201	2.412	27.4	5.28	11.74	14.12	38.9
66/0301	1.783	32.9	3.25	14.33	25.05	38.26
67/0301	1.855	33.2	3.35	14.31	23.12	38.66
68/0301	2.675	33.4	4.80	14.09	16.52	39.50
69/0301	2.717	34.0	4.80	14.24	16.45	39.70
70/0301	2.853	33.1	5.17	14.26	15.09	38.68
71/0301	1.874	35.8	3.14	15.94	25.17	37.40
72/0301	2.005	36.4	3.30	15.94	22.63	38.05
73/0301	2.479	36.2	4.11	15.45	19.38	39.05

CALCULATED DATA - COLD TESTING

NO.	HOLD UP (kg)	DISCHARGE RATE (kg/hr)	RESIDENCE TIME (min)	RPM FEEDER	RPM GASIFIER	DISCHARGE (kg/rev)
74/0301	2.912	36.8	4.75	16.72	16.32	36.68
75/0401	0.321	4.48	4.30	1.95	25.08	38.3
76/0401	0.351	4.51	4.67	1.97	20.33	38.15
77/0401	0.364	4.52	4.83	1.95	15.25	36.60
78/0401	0.601	4.3	8.39	1.93	9.84	37.13
79/0401	1.187	4.03	17.67	1.96	4.69	34.26
80/0501	1.697	8.71	11.69	4.14	5.95	35.06
81/0501	0.425	8.83	2.89	4.03	25.42	36.5
82/0501	2.015	17.28	7.0	7.97	10	36.13
83/0501	1.710	33.4	3.07	14.88	25.42	37.4

CALCULATED DATA - HOT TESTING

ANNEXURE-IV

RUN NO.	RPM G	RPM F	HOLD-UP (kg)	DISCHARGE RATE	RESIDENCE TIME	FEED RATE	% CHAR YIELD	TEMPERATURE F	TEMPERATURE G	FEED/REV
84/0901	6.07	1.99	-	1.4	10.33	4.523	30.9	457	402	
85/0901	6.08	1.99	-	1.527	10.33	4.523	33.8	618	495	
86/0901	6.17	1.99	-	1.413	10.33	4.523	31.2	605	553	
87/0901	6.2	1.99	-	1.392	10.33	4.523	30.8	532	549	
88/0901	6.12	1.99	-	1.305	10.33	4.523	28.85	697	-	
			CHAR AS FEED							
89/1101	6	2	1.063	4.21	15.15	4.21	-	-	-	35.0
90/1101	6	4	1.764	9.30	11.38	9.30	-	-	-	38.75
91/1101	8	6	2.306	13.12	10.54	13.12	-	-	-	36.4
92/1601	16	2	0.364	1.28	4.83	4.54	28.20	716	700	-
93/1601	16	3	0.364	1.786	4.83	6.82	26.18	485	752	
94/1601	16	3.97	0.647	4.37	4.64	9.02	48.44	803	508	
95/1601	16	4.521	0.647	3.59	4.64	10.27	34.9	946	753	
96/1601	16	4.853	0.647	4.38	4.64	11.03	44.0	-	-	
97/2101**	6.13	2.05	.754	1.63	10.33	4.66	35	1042*	619	
98/2101**	7.87	2.06	.754	1.63	10.33	4.68	34.8	1140*	678	
99/2101**	9.37	2.06	.519/ .601	1.54	7.0/ 8.39	4.68	32.9	1156*	876	
100/2101	10	2.06	.519	1.63	7.0	4.68	34.8	1292*	812	

*charcoal in furnace
**1st hole
***2nd hole

CALCULATED DATA - HOT TESTING

RUN NO.	RPM G	RPM F	HOLD-UP (kg)	DISCHARGE RATE	RESIDENCE TIME	FEED RATE	% CHAR YIELD	TEMPERATURE F	TEMPERATURE G	FEED/REV
101/2201***	16.34	2.06	.361	1.92	4.85	4.68	41.0	1126*	697	
102/2401***	19.8	2.07	.288/ .351	1.13	3.94/ 4.67	4.70	24.0	745	-	
103/2401**	19.04	2.08	.288	1.06	3.94	4.73	22.4	-	-	
104/2401***	20	2	.288	1.56		4.54	34.3			
105/2401***	20	2	.288	.7	3.94	4.54	15.4			
				1.1		4.54	24.1	-	849	
				1.8		4.54	39.6			
106/3101**	19.35	2.06		.24		4.68	5	927	820	
107/3101	19.35	2.06		.36		4.68	7	936	826	
108/3101	19.7	2.02		.58		4.59	.12.6	927	832	
109/3101	19.7	2.02		.64		4.59	13.9	980	843	
110/3101	25.6	2.03		.94		4.61	20.4	927	828	
111/3101	25.6	2.03		.97		4.61	21.0	882	800	
112/3101	29.5	2.04		1.16		4.64	25	915	798	
113/3101	29.5	2.04		1.39		4.64	29.9	971	813	
114/0102	20	2	Trials with 4 rods - 1/2" ø and 4 rods of 3/8" ø. In both cases, rods came out.							
115/0402	20	2	Trials with 4 rods - 1/2" ø + 2 rods - 3/8" ø. Two rods came out; choking occured; unground char							
116/0502	20	2	Trials with 4 rods - 1/2" ø - 30 cm in length. All rods came out.							
117/0602	20	2	Repeated as 116, similar observations plus choking noticed.							
118/0702	20	2		1.72		4.54	37.8	-	-	
119/0702	25	2		1.65		4.54	36.3	-	-	

CALCULATED DATA - HOT TESTING

RUN NO.	RPM G	RPM F	HOLD-UP (kg)	DISCHARGE RATE	RESIDENCE TIME	FEED RATE	% CHAR YIELD	TEMPERATURE F	TEMPERATURE G	FEED/REV
120/0702	30	2		1.66		4.54	36.5	-	-	
121/0802	15	2	Trial with 4 - 1/2" ø. 15 cm long rods. After 8 min., the rods came out.							
122/0802	15	2	Same as 121. After 10 min., the rods came out.							
123/0802	20	2		3.0		4.54	65.6	791	-	
124/0802	20	4		4.05		9.09	44.6	705	-	
125/0802	20	6		3.43		13.64	25.1	701	-	
126/0802	20	6		3.05		13.64	22.4	677	-	
127/0802	20	8		5.44		18.18	29.9	633	-	
128/0802	20	8		5.08		18.18	27.9	744	-	
129/0802	20	10		7.31		22.73	32.2	804	-	
130/0802	20	10		6.97		22.73	30.7	780	-	
131/0802	20	12		8.14		27.27	29.9	708	-	
132/0802	20	12		6.48		27.27	23.8	650	-	
133/0802	20	14		11.39		31.82	35.8	614	-	
134/0802	20	14		11.74		31.82	30.8	557	-	
135/0802	4	2		1.40		4.54	30.8	839	-	
136/0802	6	2		1.40		4.54	30.8	801	-	
137/0802	8	2		1.67		4.54	36.8	833	-	
138/0802	10	2		1.56		4.54	34.4	883	740	
139/0802	12	2		1.37		4.54	30.2	900	741	
140/0802	14	2		1.18		4.54	26.00	869	764	

CALCULATED DATA - HOT TESTING

RUN NO.	RPM G	RPM F	HOLD-UP (kg)	DISCHARGE RATE	RESIDENCE TIME	FEED RATE	% CHAR YIELD	TEMPERATURE F	TEMPERATURE G	FEED/REV
141/0802	16	2		1.23		4.54	27.1	860	763	
142/0802	18	2		1.25		4.54	27.5	904	769	

PNOC-ENERGY RESEARCH & DEVELOPMENT CENTER
DON MARIANO MARCOS AVENUE
DILIMAN, QUEZON CITY
TEL. NOS. 97-76-11 TO 19

LABORATORY SERVICE REPORT
BIOFUELS SECTION

CLIENT: CONVENTIONAL FUELS DEPT. C/O M. CARLOS　　DATE: Jan. 18, 1985

REPORT ON: Rice Hull and Rice Hull Ash　　REF. NO.: 1A-CL-85

SAMPLE	ANALYZED FOR	RESULT	METHOD
1. Rice hulls 1-15-85	Moisture, %	5.95% ✓	ASTM D-1762
	Ash, %	20.92% ✓	-do-
2. Rice hull Ash 1-15-85	Moisture, %	2.97% ✓	-do-
	Ash, %	39.33%	-do-
3. Rice hull Ash 1-17-85	Moisture, %	0.61% ✓	-do-
		*43.61%	

* Ash with clay-like particles

Ash content is in dry weight basis. Test Results are average of two trials.

F. B. STA. ANA
HEAD BIOFUELS SECTION

ANALYZED BY: MA. ARIEL S. PARAISO

PNOC DECADE OF ACCOMPLISHMENT 1973-1983 TOWARD ENERGY SELF RELIANCE

PNOC-ENERGY RESEARCH & DEVELOPMENT CENTER
DON MARIANO MARCOS AVENUE
DILIMAN, QUEZON CITY
TEL. NOS. 97-76-11 TO 19

LABORATORY SERVICE REPORT
BIOFUELS SECTION

CLIENT: Conventional Fuels Dept. c/o M. Carlos   DATE: Jan. 30, 1985

REPORT ON: Rice hulls and Rice hull Ash   REF. NO.: 1B-CL-85

SAMPLE	ANALYZED FOR	RESULT	METHOD
Rice Hull Ash #93	Moisture,%	3.01%	ASTM D-1762
	Volatile Matter,%	18.54%	-do-
	Ash, %	44.76%	-do-
	Fixed Carbon, %	36.70%	-do-
	Heating Value, Btu/lb.	7,070	ASTM D-2015
Rice hull Ash # 94	Moisture,%	3.49%	ASTM D-1762
	Volatile Matter,%	23.03%	-do-
	Ash,%	42.89%	-do-
	Fixed Carbon,%	34.08%	-do-
	Heating Value, Btu/lb.	6,811	ASTM D-2015
Rice hull Ash #95	Moisture,%	1.29%	ASTM D-1762
	Volatile Matter,%	12.53%	-do-
	Ash,%	35.95%	-do-
	Fixed Carbon,%	51.52%	-do-
	Heating Value, Btu/lb.	6,486	ASTM D-2015
Rice hull ash #96	Moisture,%	1.13%	ASTM D-1762
	Volatile Matter,%	18.91%	-do
	Ash,%	51.67%	-do-
	Fixed Carbon,%	29.42%	-do-
	Heating Value, Btu/lb.	6,712	ASTM D-2015
Rice hull ash -15-85	Moisture,%	2.97%	ASTM D-1762
	Volatile Matter,%	18.59%	-do-

ANALYZED BY: MA. A. S. PARAISO
B. B. BRAGANZA

F. B. STA. ANA
HEAD BIOFUELS SECTION

PNOC DECADE OF ACCOMPLISHMENT 1973-1983 TOWARD ENERGY SELF RELIANCE

PNOC ENERGY RESEARCH & DEVELOPMENT CENTER
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LABORATORY SERVICE REPORT
BIOFUELS SECTION

CLIENT: Conventional Fuels Dept. c/o M. Carlos DATE: Jan. 30, 1985

REPORT ON: Rice hulls and Rice hull Ash REF. NO.: 1B-CL-85

SAMPLE	ANALYZED FOR	RESULT	METHOD
	Ash, %	40.12%	ASTM D-1762
	Fixed Carbon, %	41.29%	-do-
	Heating Value, Btu/lb.	7,099	ASTM D-2015
Rice hull 1-15-85	Moisture, %	5.95%	ASTM D-1762
	Volatile Matter, %	68.10%	-do-
	Ash, %	24.56%	-do-
	Fixed Carbon, %	7.34%	-do-
	Heating Value, Btu/lb.	6,205	ASTM D-2015

Note: Results are averaged of two trials and on dry basis.

ANALYZED BY MA. A. S. PARAISO
...AGANZA

E. B. STA. ANA
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PNOC DECADE OF ACCOMPLISHMENT 1973-1983 TOWARD ENERGY SELF RELIANCE

PNOC-ENERGY RESEARCH & DEVELOPMENT CENTER
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LABORATORY SERVICE REPORT
BIOFUELS SECTION

CLIE T: c/o Marc Carlos DATE: 02-19-85

REPORT ON: Proximate Analysis and Heating Value Detn. REF. NO.: B-11-CL-85

SAMPLE	ANALYZED FOR	RESULT	METHOD
Rice Hull Ash #97	% Moisture	3.11	ASTM D-1762
	% Volatile Matter	8.67	-do-
	% Ash	48.50	-do-
	% Fixed Carbon	42.83	-do-
	Heating Value, Btu/lb.	7,051	ASTM D-2015
#98	% Moisture	5.37	ASTM D-1762
	% Volatile Matter	5.20	-do-
	% Ash	51.47	-do-
	% Fixed Carbon	43.33	-do-
	Heating Value, Btu/lb.	6,455	ASTM D-2015
#99	% Moisture	1.87	ASTM D-1762
	% Volatile Matter	2.51	-do-
	% Ash	51.99	-do-
	% Fixed Carbon	45.50	-dO-
	Heating Value, Btu/lb.	6,217	ASTM D-2015
#100	% Moisture	2.07	ASTM D-1762
	% Volatile Matter	7.73	-do-

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ANALYZED BY: MA. A. S. PARAISO

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PNOC DECADE OF ACCOMPLISHMENT
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BIOFUELS SECTION

CLIENT: c/o Marc Carlos DATE: 02-19-85

REPORT ON: Proximate Analysis and Heating Value DEtn. REF. NO.: B-11-CL-85

SAMPLE	ANALYZED FOR	RESULT	METHOD
	% Ash	54.46	ASTM D-1762
	% Fixed Carbon	37.81	-do-
	Heating Value, Btu/lb.	5,978	ASTM D-2015
Rice Hull Ash #101	% Moisture	3.03	ASTM D-1762
	% Volatile Matter	14.14	-do-
	% Ash	50.30	-do-
	% Fixed Carbon	35.56	-do-
	Heating Value, Btu/lb.	7.243	ASTM D-2015

* Results are average of two trials and on dry basis.

ANALYZED BY: MA. A. S. PARAISO

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F. B. STA. ANA
HEAD BIOFUELS SECTION

PNOC DECADE OF ACCOMPLISHMENT
1973-1983
TOWARD ENERGY SELF RELIANCE

Annexure-VI

MEMORANDUM

19 December 1984

To: Mr. M. T. Cruz
Mr. M. R. Carlos

cc: Dr. I. E. Cruz

Ref:

Code:

Gist of discussions with Mr. M. T. Cruz, Mr. M. R. Carlos and the undersigned

With reference to the memo of 13 December 1984 by Mr. Cruz, a meeting was held on 17th December 1984 at 2:00 p.m. in the office of Mr. Cruz and the following decisions were arrived at:

1. In view of the marginal improvement that can possibly be obtained over the existing efficient charcoal stoves already available, it was not considered worthwhile to initiate at this stage the developmental work for such stoves. Instead, efforts should be expeditiously directed towards the development of rice hulls and other biomass stoves and driers both for domestic and industrial applications. It is appropriate because under the pyrolysis project an extensive lead in developmental work for such units has already been achieved.

   The units identified for demonstration with and without modifications of the existing designs are as follows:

   a) Existing "PARU" Rice Hull Gas Stove

      In the first phase, this should be fitted with air injection system in the jacket of rice hulls and demonstrated for a possible application as hot air generator for drying of paddy and other thermal applications. Further in the second phase, this should be converted into a drier by providing blower and prototype unit built for actual demonstration and commercialization.

      Duration : 1st phase - 2 weeks
      2nd phase - 5 weeks
      Officer-in-charge: Mr. M. R. Carlos

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b) Restaurant Level Biomass Gas Stove

This is similar to the existing model as in (a) except that this should be tried on such biomass materials which have low ash content such as sawdust, bagasse, leaves and coir pith. The advantage of using such materials is that these materials after pyrolysis in the existing stove can be briquetted and re-used as fuels.

Duration : 4 weeks
Officer-in-charge: To be nominated by the dept.

c) Domestic Stove for Rice Hulls

This is similar in principle to stove (b) except that it has the following additional features:

i) Its size is reduced and heat transfer fins are excluded to save on cost.
ii) The top cover is permanently fixed to avoid gas leakage and sealing problems.

The principle has already been tested and the development work now includes building the prototype and testing it for its performance.

Duration : 6 weeks
Officer-in-charge: To be nominated by the dept.

d) Continuous Rice Hulls Brick Pile Stove

To overcome the only disadvantage in the aforesaid stoves (a) or (b) of being batch operation, a continuous rice hull brick pile stove already demonstrated by Herman Johannes[1] can be installed. This has the advantage that husk can be fired continuously. However, it employs the concept of trying to burn voltalies by providing only secondary combustion air. This can be easily modified to introduce the principles of thermal cracking of tar and other high molecular volatiles as incorporated in other stoves developed by us. This should give better and cleaner combustion.

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(1) H. Johannes Flower Pot and Brick-Pile Stoves burning Rice hulls, fine leaves and coarse biomass.

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MEMO

Mr. M. T. Cruz
19 December 1984
Page 3

In addition to thermal energy this could also provide white ash (though not in very reactive form) which has many uses and great potentials for export. According to some information, Malaysia is exporting this ash containing 95% silica at the present rate of ¢5 per kg.

Duration : 6-8 weeks
Officer-in-charge: To be nominated by the dept.

In order to expedite these developments for favour of commercialization, the work on items (a), (b), (c) and (d) above should be initiated simultaneously.

Regarding the design fabrication and development of charcoal retort, it was decided to get the operational feedback of the retort already installed at Ormoc City. Tentatively, a visit to the site is also being scheduled during the last week of December 1984.

Based on this information and design and operational experience available in the department, the schedule of developing a prototype, ERDC model kiln can be formulated.

Submitted for any comments and implementation.

PREM D. GROVER

/lrv