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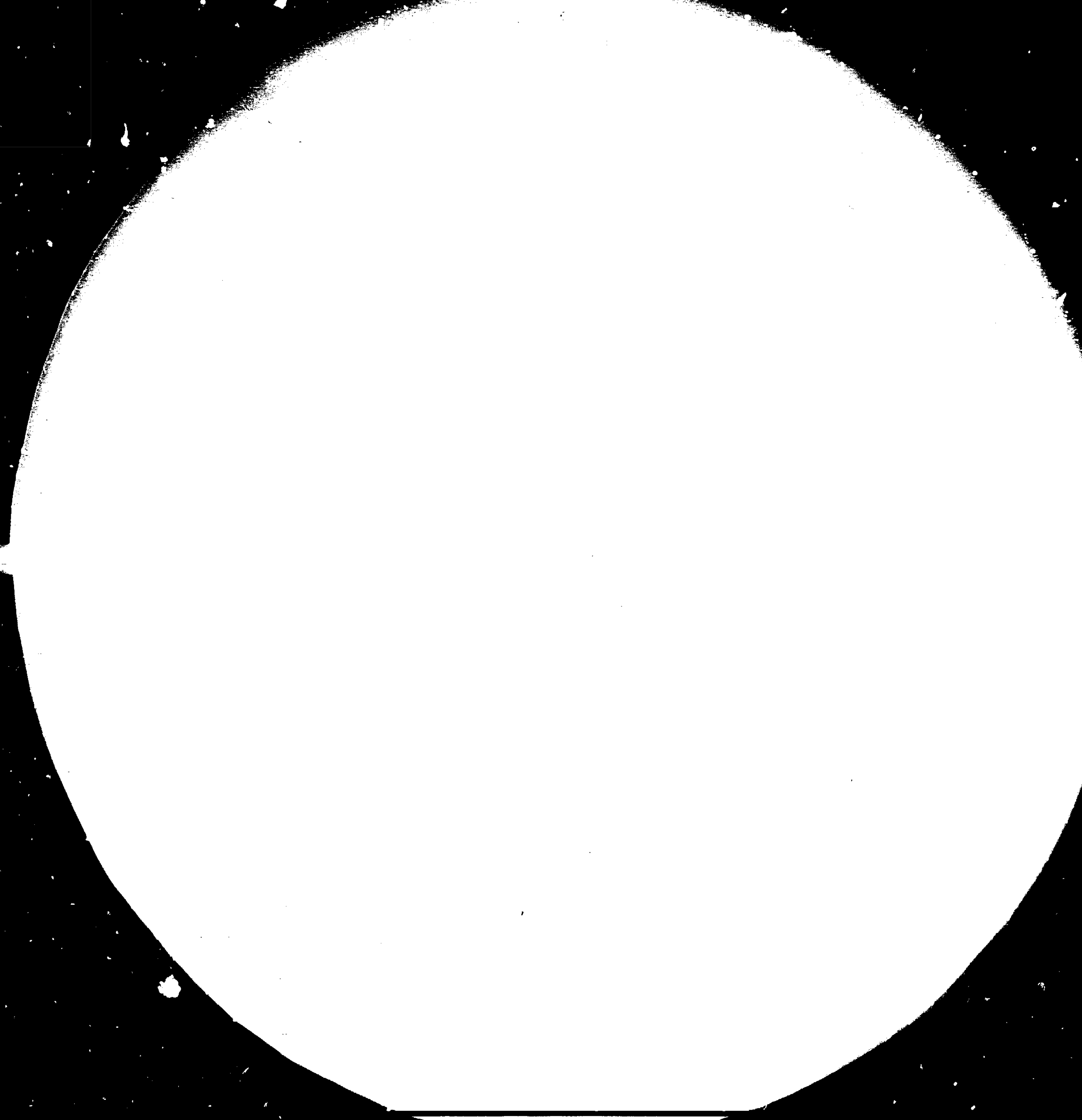

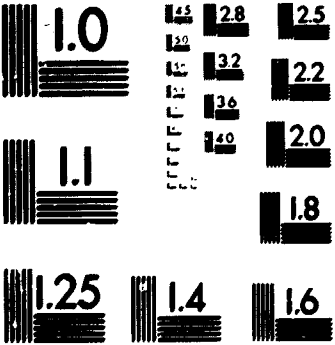

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Philippines.

ASSISTANCE TO ENERGY PRODUCTION FROM BIOMASS WASTE MATERIALS

DP/PHI/78/022

PHILIPPINES

Technical Report:
Return mission December 1983/January 1984*

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 Prem D. Grover,
consultant in biomass conversion systems

United Nations Industrial Development Organization
Vienna

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The return visit of the consultant was implemented mainly to provide technical inputs for the development of the following pyrolytic and gasification conversion systems.

a) Rice Hull Gas Stove
b) Mobile Charcoal Retorts
c) 200 kg/hr. Pyrolytic Converter
d) Rice Hull Steam-Pyrolytic Gasifier

In addition, technical suggestions were also provided for rice hull gasifier (Dr. Cruz's design), in particular for the cleaning of gases by thermal cracking of tar in the furnace before these gases are used for clean combustion in the same furnace:

Rice Hull Gas Stove

The necessary modifications to the existing prototype unit are suggested. The scientific testing procedure to get performance data have been incorporated. The scheme to utilize these rice hull stoves as small scale industrial and agricultural drier have been recommended. Because of clean combustion of gases produced by rice hulls, these units should be well accepted as domestic and community kitchen stoves in the rice producing provinces of the Philippines.

Mobile Charcoal Kiln

Based on the operational problems experienced during the earlier testing of one of these kilns, certain minor modifications for its smooth functioning have been incorporated. The recovery of tar and its re-use to protect the kiln from corrosion form one of the major recommendations.

200 kg/hr. Pyrolytic Converter

The main items of this unit have been procured but are yet to be installed. Unless installed and tested one would not suggest major modifications. The partial blocking of some of the tuyeres with clay should be one major parameter to control its operation, enhance recovery and quality of the products.

Rice Hull Steam-Pyrolytic Gasifier (Steam Gasifier)

This unit was designed and fabricated drawings were provided during the previous trip of the consultant. The order for the fabrication of the main rotary gasifier was placed during the earlier period of the present trip. The fabrication work by the contractor was constantly monitored and many suggestions got incorporated. Due to the non-availability of 8" diameter A1S1-310 stainless steel in the Philippines, recommended earlier as material of construction for rotary section, substitution by 6" diameter A1S1-316 stainless steel had to be incorporated. Accordingly, the drawings had to be modified. It is unlikely that the complete unit will be tested before the end of the present trip. However, efforts are being made to manually check the smooth rotation of the gasifier rotary system fitted with supports and gland seals. Due to non-availability of expansion joints for each end of the rotary system, gland type seals have to be substituted in its modified design.

Both during each stage of fabrication and after complete fabrication of the gasifier, its smooth rotation without any eccentric movement whatsoever, should be checked by ERDC engineers prior to its effective delivery. This is one of the most important requirements and should not be compromised.

The consultant's major efforts were directed for the development of this steam gasifier system. Accordingly, the following aspects, essential for its smooth operation and expeditious installation have been discussed with engineers at ERDC and incorporated in this report.

a) Operating and Maintenance Procedures including pre-operational testing, start up, shutdown and trouble shooting.

b) Two dimensional and perspective three dimensional layout plans to facilitate its installation.

c) Identifying the types and locations of various valves and fittings for piping network.

d) Locations and types of instruments for measurements of temperatures, pressures and pressure drops, and flow of fluids.

e) Methodology of data generation inclusive of data logging sheet.

f) List of modifications to be incorporated on the auxilliary equipment already procured.

g) List of auxiliary equipment yet to be procured.

h) Preliminary Preinvestment economic evaluation of the system and its methodology.

In conclusion, as a continuation of the previous report, the photographs of the modified drum charring unit (Annexure IV) and twin hearth rice hulls gas stove fabricated at the Indian Institute of Technology, New Delhi have also been included.

1.0 INTRODUCTION

The efficient utilization of biomass waste materials as an alternate source of energy for the Philippines needs neither introduction nor any justification. It is now an established necessity.

In addition to many benefits, the necessity to expedite the dissemination of biomass conversion technologies arises out of the two main considerations. Firstly, the nature has endowed to the Philippines an abundance of these materials and secondly, these technologies will directly benefit the agrarian rural communities. Therefore, it becomes imperative that immediate and timebound steps should be undertaken to transfer some of the technologies developed under the UNDP/UNIDO Project DP/PHI/78/022.

The present report is basically a technical report and continuation of the previous report "DP/ID/SER-A/453; 2nd August, 1983" covering the period from 24th March to 16th May, 1983. This report is prepared by 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) for the period 5th December, 1983 to 26th January, 1984.

In the previous report, based on availability of biomass waste materials namely, coconut shells and husk, rice hulls and rice straw, bagasse and wastes from wood processing; a number of appropriate technologies and their modes of transfer and dissemination have been identified. Since then steps have been initiated by ERDC to put up commercial and demonstration units in the field.

During the previous trip, a steam pyrolysis rice hull gasifier pilot plant unit was also designed and fabrication drawings prepared. This unit is now being fabricated and likely to go on stream in 3-4 months.

The return trip of the consultant was basically one of technical trouble shooting and meant to appraise and argument the proposed technologies envisaged to be developed under this project. The duties assigned by ERDC to the consultant are given in Annexure-I. To summarize, these relate to the development of:

a) Rice Hull Gas Stove
b) Mobile Charcoal Kilns
c) Steam-Pyrolysis-Rice Hulls Gasifier
d) 200 kg/hr. Coconut Shell Pyrolytic Converter

The requisite details of units (a), (b), and (c) have been incorporated. The comments and suggestion regarding the design of item (d) have been discussed with ERDC engineers.

According to the ERDC engineers, the outputs of the project in Phase-2 have been met to the extent of about 40%. While equipment like mobile kilns, rice hull gas stove and rice hull gasifier (Dr. Cruz's design), with minor modifications, are ready for transfer, the rice hull steam pyrolysis gasifier, which is being fabricated, would need extensive testing and possibly minor modifications, at ERDC test facility. To accomplish this, a period of 16 months would be required. This also includes the jobs such as: Analysis of data for scale-up, the design of a commercial unit and carrying out its techno-economic evaluation. It is, therefore, recommended that starting from June 1984, the period of the present project should be extended by one year.

To expedite this project and also to eliminate the possibility of any manufacturing defects, the fabrication of the gasifier was periodically monitored and some modifications got incorporated.

Regarding 200 kg/hr. coconut shell pyrolytic converter, its main components, such as: Feeding system, pyrolysis chamber, gas manifold, tar condenser, charcoal removal system and the converter plateform have been procured. The mechanical feed conveyors are yet to be obtained. Considering its size and capacity, extensive testing of the unit shall have to be undertaken in the field before it could be considered as a developed system. These objectives are likely to be achieved by the end of 1984.

During the present assignment, a one day visit was arranged to Iligan Institute of Technology (Mindanao University) Iligan, to see the commercial charcoal kiln integrated with copra drying system installed at the Institute Campus test facility. Although, the kiln is not operating since 1981, yet considerable, experience and infrastructure do exist there to justify an immediate transferring of one of the mobile kilns. This could be followed up by the possible transfer of the 200 kg/hr. pyrolytic converter.

During this period, two seminars, one each at ERDC and Chemical Engineering Department, University of the Philippines, were also delivered on the subject of latest progress in pyrolysis and biomass conversion technologies.

2.0 MOBILE CHARCOAL KILN

In the earlier report[1], the reference about its utility has been mentioned. Two such kilns have since been brought by ERDC. The internal dimensions of these kilns are shown in the Figure 2.1.

2.1 Preliminary Trials and Operation Problems

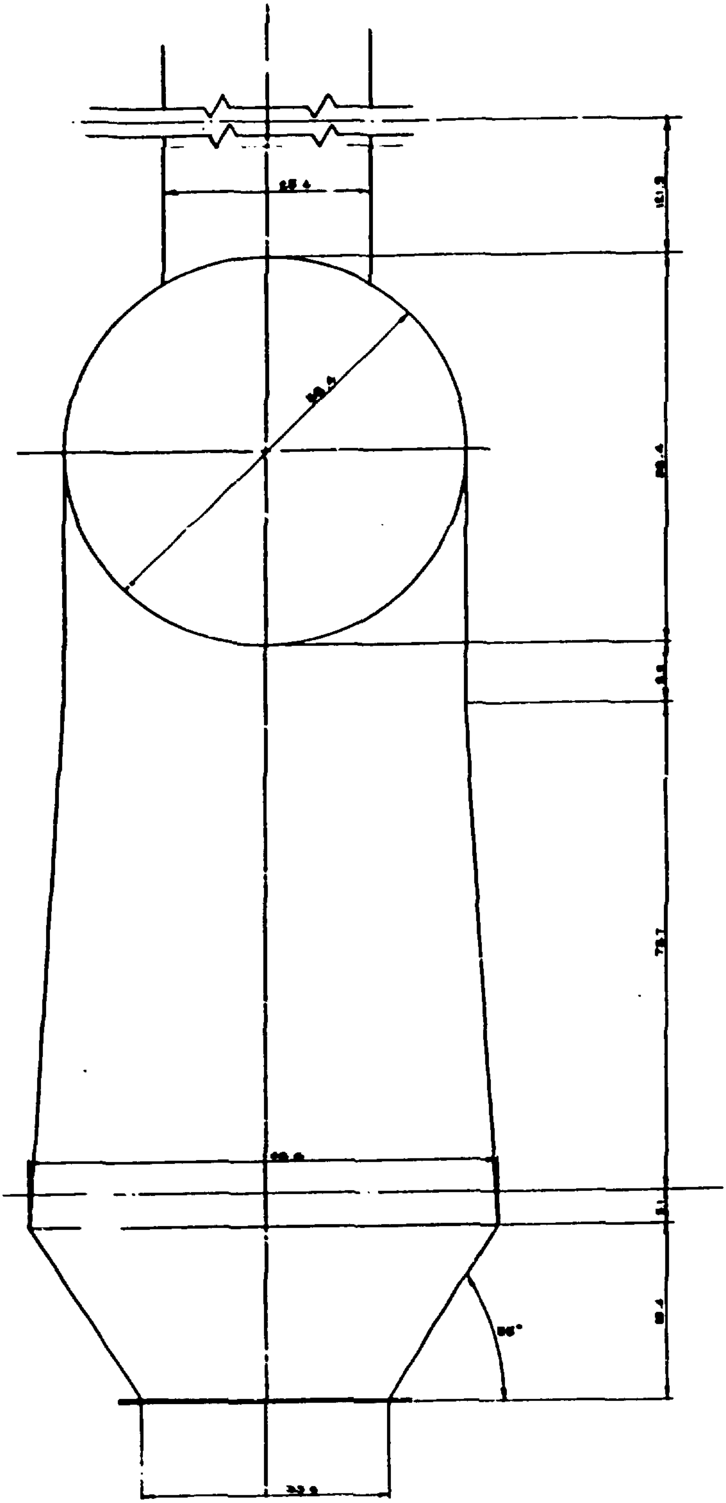
The preliminary test trials on one of these kilns have been carried out by ERDC engineers and these have brought out certain operational problems. These are:

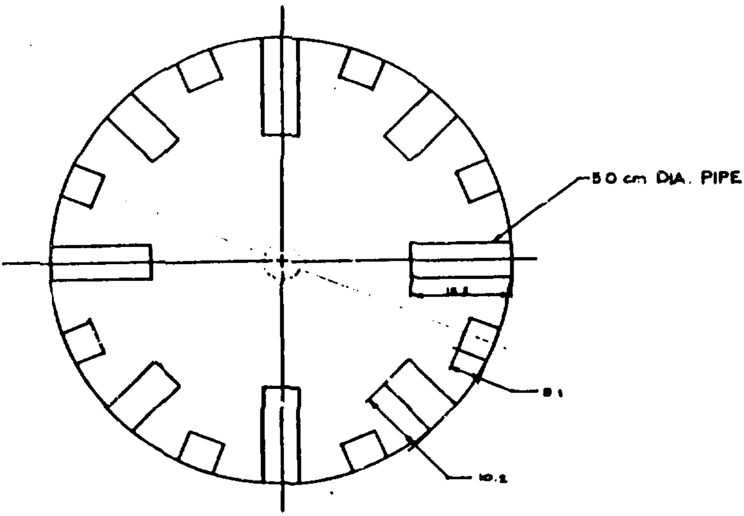
1. The capacity to process coconut shells found out of the order of 250 kg. per hour of feed was much higher than the envisaged design capacity of 150 kg. per hour. This capacity was obtained even when the tuyeres diameter was reduced from 2" to 1" diameter standard pipe. To feed manually so much material and take out periodically 50 kg. per hour of charcoal was found impractical. This capacity is feasible if the feeding system is mechanized. Since the kiln is required to operate in the remote areas without any grid power, it is imperative to reduce its capacity to about 100 kg. per hour with a provision to increase its capacity as and when feasible with the availability of suitable manpower and raw materials.

2. When the feed door is opened for charging, an excessive amount of pyrolytic gases escape through this opening invariably accompanied by flame making the manual loading dangerous and more difficult.

3. The charcoal discharge gate was found to be rather difficult to close properly. Being a push type operation, more power was required as the gate had to physically push the material for proper air tight closure.

4. Excessive oxidative corrosion on the outside surface of the mild steel kiln was noticed especially in the surface area exposed to higher temperature, thereby reducing the expected life of the kiln.





NOTE:
ALL DIMENSIONS IN CENTIMETERS.

FIG. 2.1 MOBILE KILN

5. The hot tar condenser designed by ERDC engineers and placed on the chimney was of sound concept and found operational but it collected very small quantity of tar. Its capacity needs to be increased.

6. The inside surface of the kiln's combustion zone near the tuyeres needs high temperature protective coating to increase the working life of the kiln. The relatively cooler zones seemed well protective by the deposition of thermally cracked tar.

2.2 Recommendations

Suggestions are included in this section to improve the performance of the mobile kiln and also minimize the operational problems and hazards to the operating personnels. Care has been taken to suggest only minimal and inexpensive modifications so as not to make the mobile kiln rather too heavy making it difficult to transport.

1 Capacity of the Kiln

To have operational flexibility, it is envisaged to operate it between 250 and 100 kg. of coconut shell feed per hour, preferably at the latter loading. This implies that the residence time of the material in the kiln should be increased with corresponding decrease in the flow rate of air introduced through the tuyeres.

Taking the bulk density of unbroken coconut shell of 164 kg. per cu.meter (10.25 pounds/cu.ft.) as carried out in the ERDC with the available feedstock, the residence time with capacity of 250 kg. per hour of feed amounts to about 24 minutes. Taking feeding cycle of 5 minutes at this capacity of 250 kg. per hour, the level of material in the kiln can drop by about 51 cm. (20 inches) compared with overall height of the kiln of the order of 108 cm. (42.5 inches). This also amounts to adding 21 kg. of feed in 5 minutes.

The capacity of 100 kg/hr. can be achieved by adding 8.3 kg. (50 liters) of coconut shell after every five minutes as the feed recycle time. The average residence time at this capacity, amounts to about 1 hour based on raw feed. Further, the air intake rate can be reduced in the following manner.

The diameter for each of the tuyeres should be reduced to 1.0-1.25 cm. (0.4-0.5 inches). This could be easily done by blocking the unwanted area with wet clay. This technique of blocking the holes with clay has the inbuilt flexibility to get it removed as and when wanted for higher capacity. Performance tests can also be carried out by completely blocking some of the holes and keeping larger diameters for other holes so that these can also be used as poke holes for breaking the occasional bridging of the materials inside the kiln.

2. Method for Charging the Feed

In order to avoid the escape of smoke, pyrolytic gases and flame through the charging door, a detachable hopper having the total capacity of 0.14 cu.meter (5 cu.ft.) with chute bolted to the charging door should be provided. The bottom of the hopper can be closed by a hinged plate. The hinged plate can be used to close the hopper operatable by the rope and pulley arrangement, when feeding the material in the hopper. For charging the material from hopper to the kiln, the door is opened by releasing the rope or the flexible wire. The dimensions and arrangement of this hopper is given in Figure 2.2.

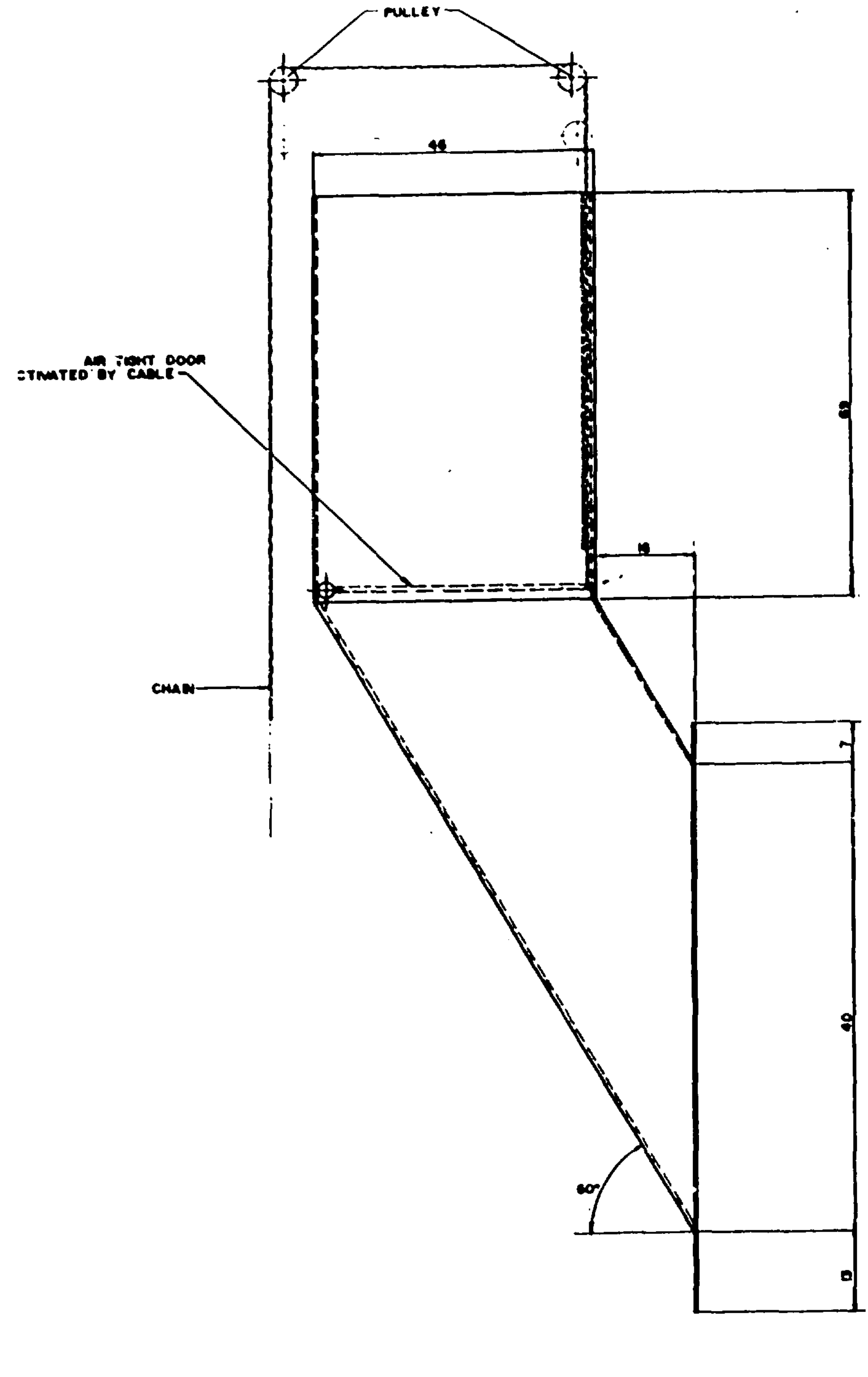
In order to attain slight suction at the charging door, the height of the chimney should be increased, built in sections.

3. Discharge Gate for Charcoal

The present discharge gate should be modified from push type to a slide gate. The movement of the slide gate within the two guides can be achieved by a lever handle attached to the support of the present kiln. This will significantly improve its working as the slide door does not have to push the weight of the material inside the kiln.

4. Prevention of Corrosion

As mentioned in the report(1), the outside surface of the kiln should be coated periodically with washed tar immediately before firing the kiln. During the firing, the tar will thermally crack leaving the coating of carbon on the surface of the kiln. Therefore, it is important to coat


PULLEY
46
AIR TIGHT DOOR
CTIVATED BY CABLE
16
CHAIN
7
40
60°

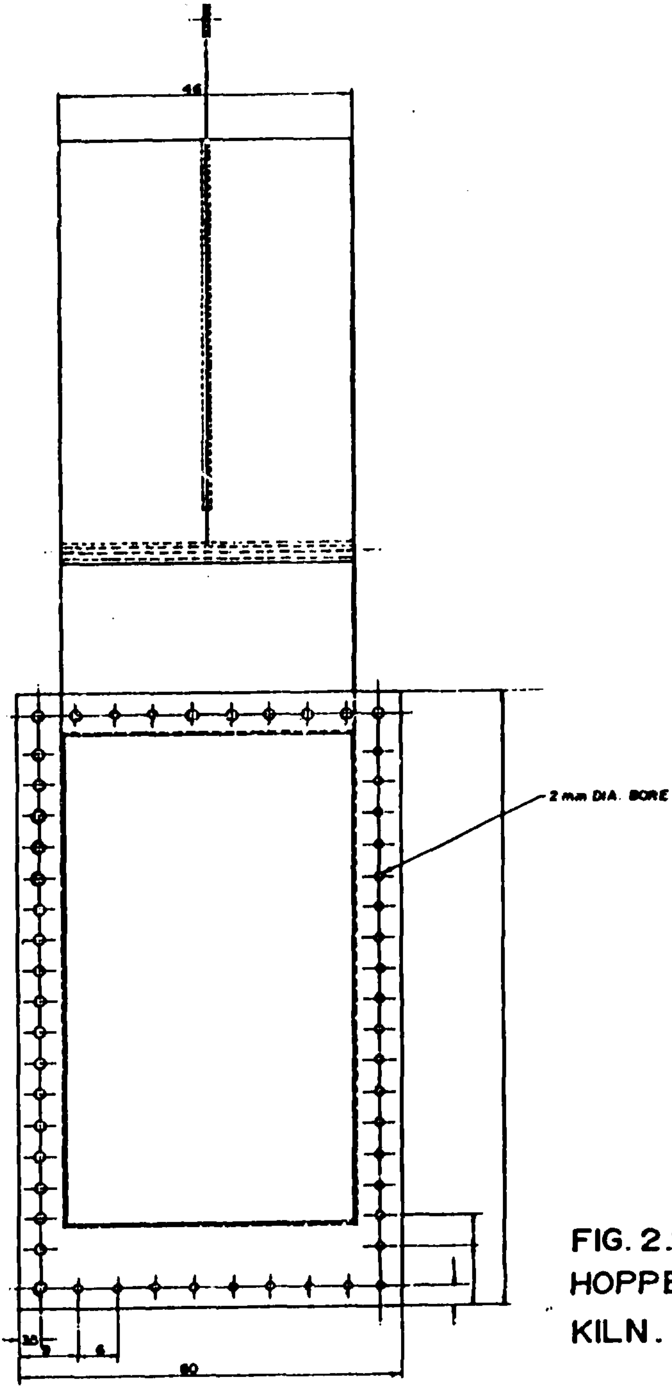


FIG. 2.2 CHARGING HOPPER FOR MOBILE KILN.

the tar just prior to the firing. In no case, the virgin coating of the tar should be done if the kiln is not immediately used. Being acidic in nature, the tar, if left as such on the surface, will tend to corrode the metallic surface.

5. Hot Tar Condenser

The tar condenser designed by ERDC engineers is suitable. Its size should be increased so as to double the surface area of the condensing section. Further, the condensing section should be provided with longitudinal heat transfer fins to facilitate rates of heat transfer.

Only, thick tar is required to be condensed. The condensation of moisture with pyrolytic oils should be avoided in any part of the chimney so as not to encounter any corrosion problems.

6. Protection of Material in Combustion Zone

The inside area of the kiln near the tuyeres and the tuyere outside surface should be cladded with 2.5 cm. thick (1 inch) high alumina castable refractory cement. All possible edges and bends should be smoothened to facilitate easy flow of material during processing.

3.0 RICE HULLS GAS STOVE

In the previous report[1], the concept of rice hull gas stove and the working drawings of the prototype were included. Accordingly, a unit was obtained and two preliminary tests were conducted at ERDC.

These tests showed promising results similar to those obtained on a prototype unit fabricated and tested at Indian Institute of Technology New Delhi[6] (I.I.T.D.).

The stove is simple in construction, with charcoal or briquetted charred rice hulls in the central hearth and rice hulls filled in an air tight concentric jacket. On burning charcoal or coke, the rice hulls get pyrolyzed and the pyrolysis gases are directed to pass through hot bed of charcoal. These tar laden dirty and odorous gases thermally crack and burn with a smokeless flame like that of LPG on the top of the charcoal bed without any characteristic smell normally associated with direct combustion of rice hulls. This simple stove can replace 60% consumption of charcoal by rice hulls. With modifications and re-use of charred rice hulls, the rice hulls can replace 80-85% consumption of traditional solid fuels. These stove are shown in Figs. 3.1 and 3.2. Another stove with two hearths fabricated at I.I.T.D. is shown in Fig. 3.3. The prototype unit needs minor modification and systematic testing before releasing it for the use of the general public.

3.1 Modifications

a) To replace the existing grate in the present unit for which the design has already been supplied.

b) To fix four (4) supports 40 mm high on the top cover to accommodate larger diameter pan.

c) In future models, the bottom portion of the shell (below the jacket) can be removed. A tripod stand can be used instead for supporting the stove.

d) Ash chamber bottom plate to be installed.

e) Swing (hinged) door to be provided at the bottom air entry port to control the draught.

3.2 Procedure for Testing the Rice Hull Stove

a) <u>Analysis of Fuels</u>

Rice hulls and charcoal should be analyzed to get data on:

1) Proximate Analysis

a) Moisture Content*
b) Ash Content
c) Combustible Materials - i.e., carbon + volatiles

2) Calorific Values

* Rice hulls should be dried in sun so as to have moisture content less than 10% on wet basis.

(a) Upright position with lid

(b) Horizontal position showing grate and fins

FIG. 3.1 RICE HULL GAS STOVE AT ERDC

FIG. 3.2 RICE HUSK GAS STOVE AT I.I.T. NEW DELHI

FIG. 3.3 TWIN HEARTH RICE HUSK GAS STOVE AT I.I.T. NEW DELHI

b) Charging of Stove

The weighed dry rice hulls should be added into the jacket enough to cover the top ends of the heat transfer fins. The top jacket should be replaced and the joints should be sealed with clay mortar to prevent any leakage of gases produced during pyrolysis.

4 kg. of charcoal should be kept separately for each firing. Initially, out of this amount, about 2 kg. may be added along with broken fire clay brick pieces of 30-50 mm size in the following order.

a) Charcoal to cover the top end of the grate.

b) One layer of broken refractory pieces.

c) About 50 mm layer of charcoal.

d) One more layer of broken refractory pieces.

e) 20-30 mm layer of charcoal.

The weight of refractory added should be known so that the same amount can be added in subsequent tests.

The stove should be lighted by burning paper or rags below the grate.

c) Operating Procedure (Rice Hull Stove)

Once the stove is ignited and production of smoke ceases, a pan having a minimum botton diameter of 240 mm and three quarter of its volume filled with known volume of water is placed on the stove.

Pans with larger diameter for subsequent experiments say, 300 mm, 400 mm and 500 mm, should be tried. To enable the larger diameter pans, the top cover handles may have to be removed and refixed on the sides of the cover.

The time of placing the pan and the temperature of water should be noted. Temperature of water at regular intervals should be noted to calculate the rate of heat transfer. Once the water starts to boil, periodically, the weight of pan with water should be noted to calculate the rate of evaporation. In case, the quantity of water is reduced, additional known quantity of water may be added.

The grate of the stove should be periodically poked to remove accumulated ash. Once the level of the solid fuels comes down, a known quantity of charcoal (about ½ kg.) should be added periodically. The timings of such addition should also be noted. These charcoal additions should be continued till the gases produced by pyrolysis are stopped, gas flame is extinguished and water ceases to boil, the water pan should be removed. Time of removal of pan and the pan weight are noted.

The top cover is removed and the remainder char is immediately extinguished by sprinkling adequate quantity of water. The char is weighed and analyzed for moisture, ash and combustible matter. Its calorific value is also determined.

d) Operation Without Rice Hulls

The same stove should be operated as per procedure given in Section 3.2.c but without any addition of rice hulls. The amount of refractory pieces and charcoal initially charged and subsequent additions should be at the same interval of time and quantity as carried out in the test run with rice hulls.

e) Analysis of Data

For both the tests with and without rice hulls, data should be analyzed and the following parameters are evaluated:

a) Duration of combustion.

b) Amount of water evaporated.

c) Performance plots - rate of energy recovered as a function of time for a particular size and shape of pan.

d) Average heat recovery rates -

. During start up
. During boiling of water
. Just before shutting down

e) Overall thermal efficiency - this can be computed by the total heat utilized for heating and evaporating the known quantity of water divided by the net heat content of the rice hulls used and the charcoal.

f) Percentage of total heat released by the rice hulls.

g) Improvement factor - defined as total heat recovered by water with rice hulls divided by the heat recovered without having rice hulls in the same stove.

3.3 Further Work with Present Unit

The prototype unit can be tested with various sizes of pans and energy released as a function of pan diameter can be computed. The convective heat transfer enhancement factor can also be computed. This should normally increase with diameter up to a limit and then decrease due to radiation losses through the sides of the pan. In this way, the optimum size of the pan for this unit can be evaluated.

The prototype unit can also be tested on various other biomass materials which are similar in size to rice hulls. Some of these are sawdust, shredded straw and leaves, coconut husks, erc.

3.4 Recommendations for Further Development of Rice Husk Stove

The prototype unit built at ERDC gives good performance and testify the working of the concept of pyrolysis - gasification of rice husk, cracking of gases and their smokeless combustion in a simple single unit. However, it is not the most efficient unit and has a scope of improving its overall thermal efficiency. To achieve this goal, the recommendations for its further development are given below.

a) <u>Hardware Development</u>

a) Orientation of heat transfer fins - The sizes and number of these fins can be changed and its performance tested. The number of fins should not be less than eight which seems the minimum requirement considering the low effective thermal conductivity of rice hulls.

b) The size of the solid fuel burner may be reduced and the optimum ratio between the diameter of the charcoal bed to overall diameter of the stove can be established.

c) A cast iron perforated burner similar to one used as LPG burner can be incorporated on the top of the charcoal bed to get proper distribution of gas flame.

d) Prototype units having more than one charcoal hearth can be fabricated which can be used as stoves for restaurants or as industrial driers as per scheme in the Sketch-3.4.

e) It has been observed that introduction of a small amount of air in the rice hulls jacket improves th rate of pyrolysis/gasification and combustion. This should be tried.

b) Analytical Approach

Heat transfer and mathematical modelling of the stove can be carried out to predict its performance. With various configuration of fins, the temperature profiles in the rice hulls beds and hence, the rate and amount of devolatilization can be predicted. The theoretical studies can be verified by measuring the temperature of various points in the charcoal and rice hulls beds. These studies may be sponsored to the universities as a part of undergraduate and graduate studies project work.

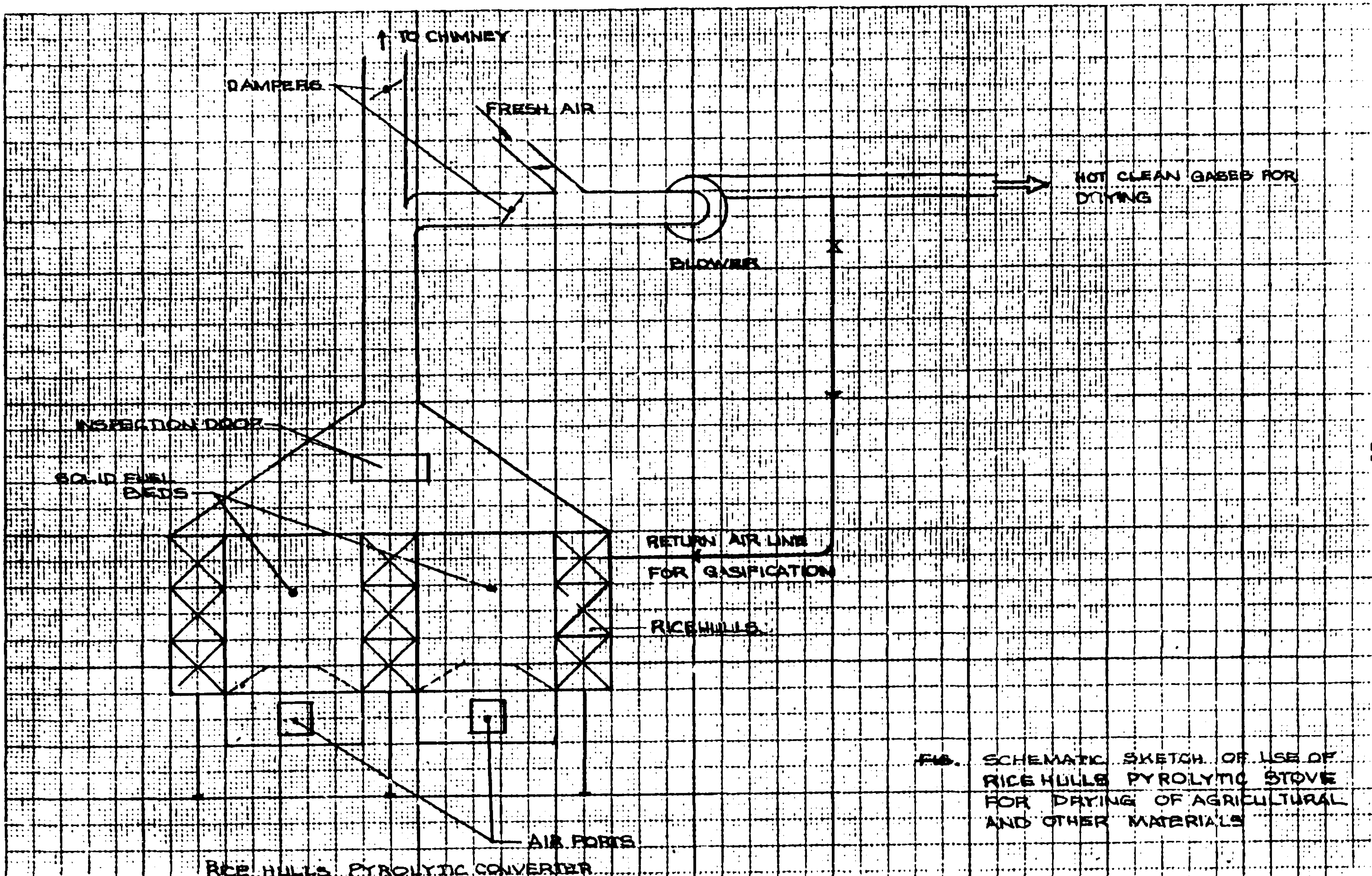


FIG. SCHEMATIC SKETCH OF USE OF RICE HULLS PYROLYTIC STOVE FOR DRYING OF AGRICULTURAL AND OTHER MATERIALS

FIG 3.4 STOVE AS DRYER

4.0 OPERATING AND MAINTENANCE PROCEDURES FOR STEAM GASIFIER

In this chapter, the operating and maintenance procedures for the smooth running of the rotary steam gasifier are included. Following of these instructions should result in generation of meaningful data suitable for scaling up and design of commercial size units. The unit consists of four major sections:

a) Rotary Gasifier
b) Ash Removal System
c) Gas Clean up System
d) Gas Storage and Combustion.

The relative heights of these units and the layout of the equipment and machinery are shown in Fig. 4.1. The three dimensional-prospective plan of the gasifier is shown in Fig. 4.2.

4.1 The Pre-Operational Testing

Before carrying out gasification, the rotary gasifier and other auxiliary equipment and piping work should be thoroughly tested for fabrication and erection defects.

4.1.1 Calibration and Cold Testing of Gasifier

a) Rotation Checks

Before switching on the rotation, check that the gasifier is properly levelled, gland seats are adjusted and rotating parts are well lubricated.

The gasifier should be switched on at the minimum rotational speed speed of 1 rpm without adding feed and checks for any vibrations and eccentricity are made. Slowly, the speed is increased in steps and the abovementioned checks are carried out. Any undesirable noise should be investigated and rectified. Accordingly, the maximum rpm should be determined.

Similarly, the feed screw should also be tested and its maximum rpm is accordingly determined.

b) Grindability Checks

The rotary part is divided into four zones. The third zone from the feed end is meant to crush the charred rice hulls to liberate entrapped carbon in the carbon-ash matrix. To check the

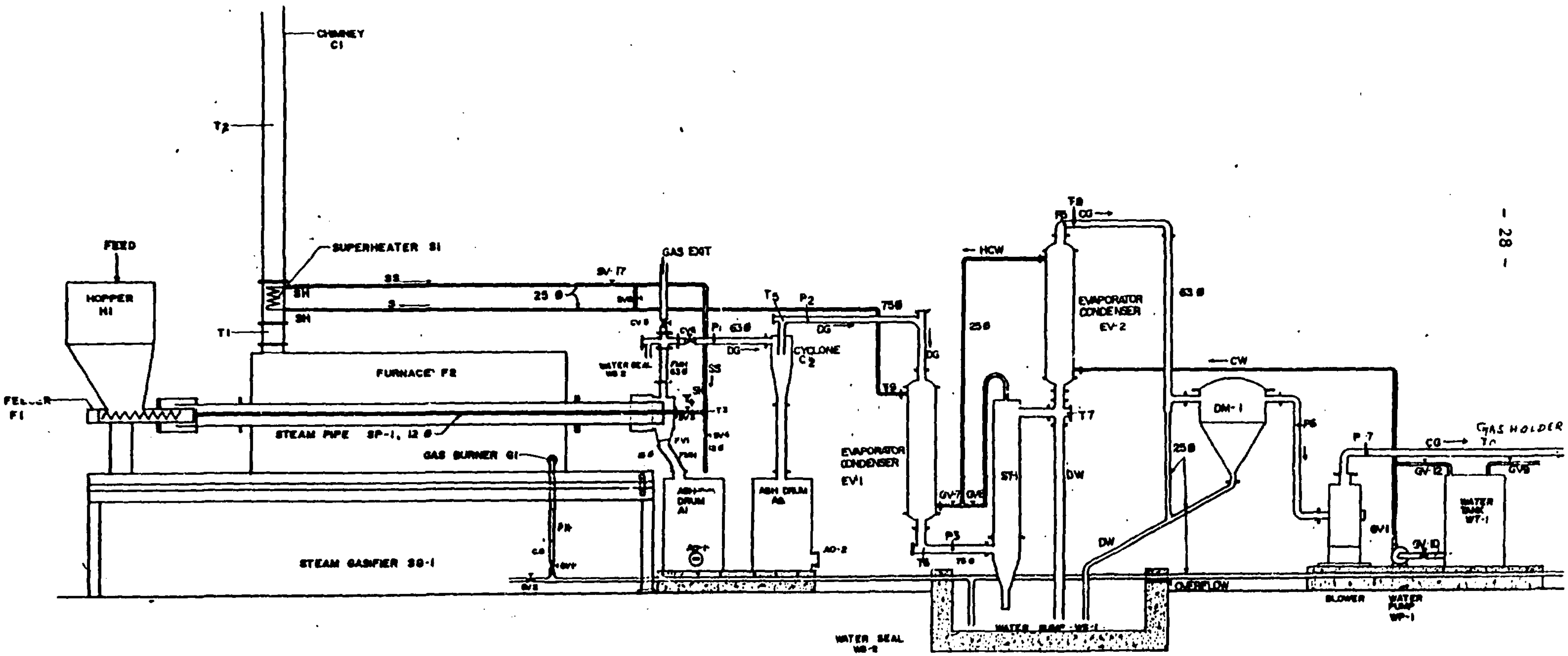


FIG 4.1 RELATIVE HEIGHTS OF EQUIPMENTS

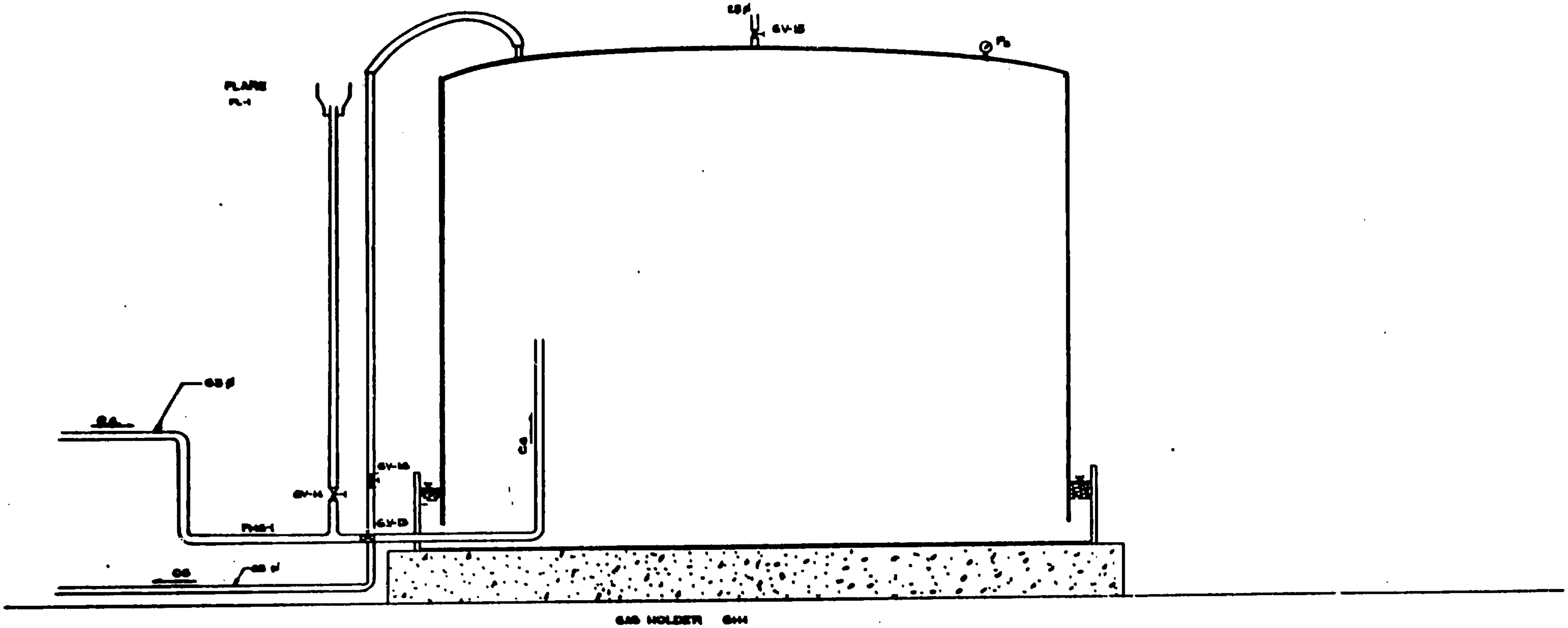


FIG. 4.1 GAS HOLDER

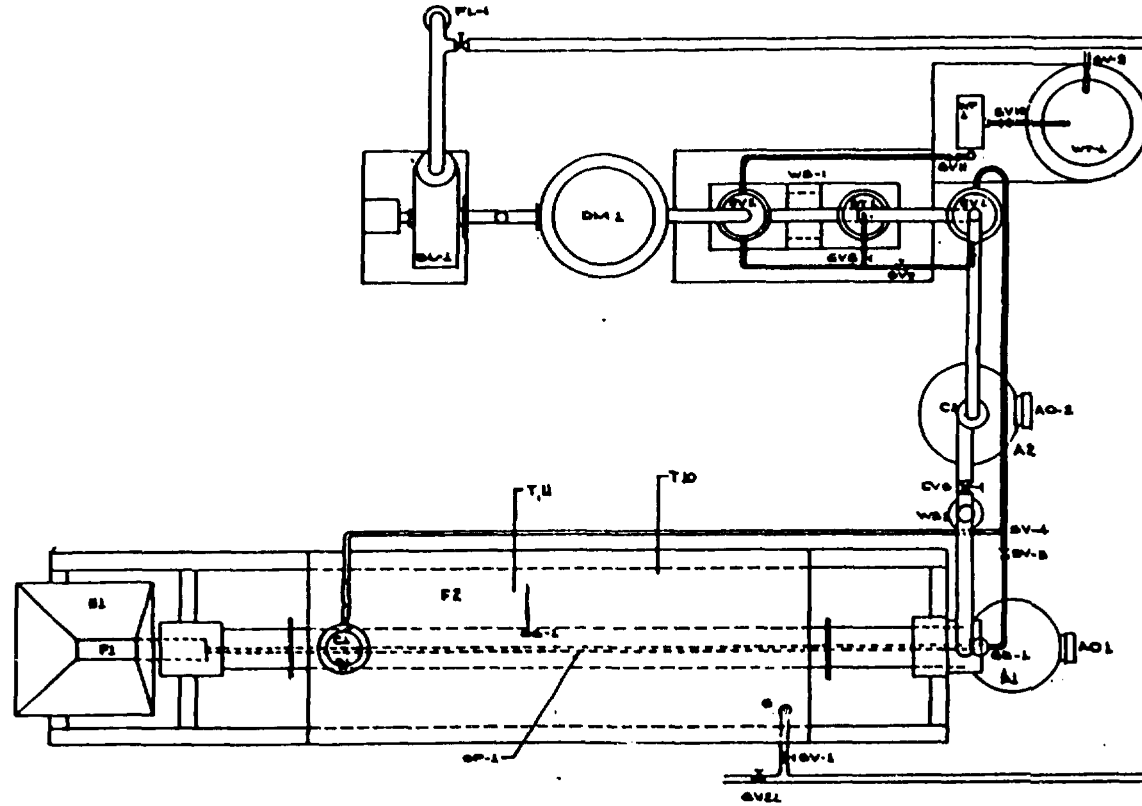
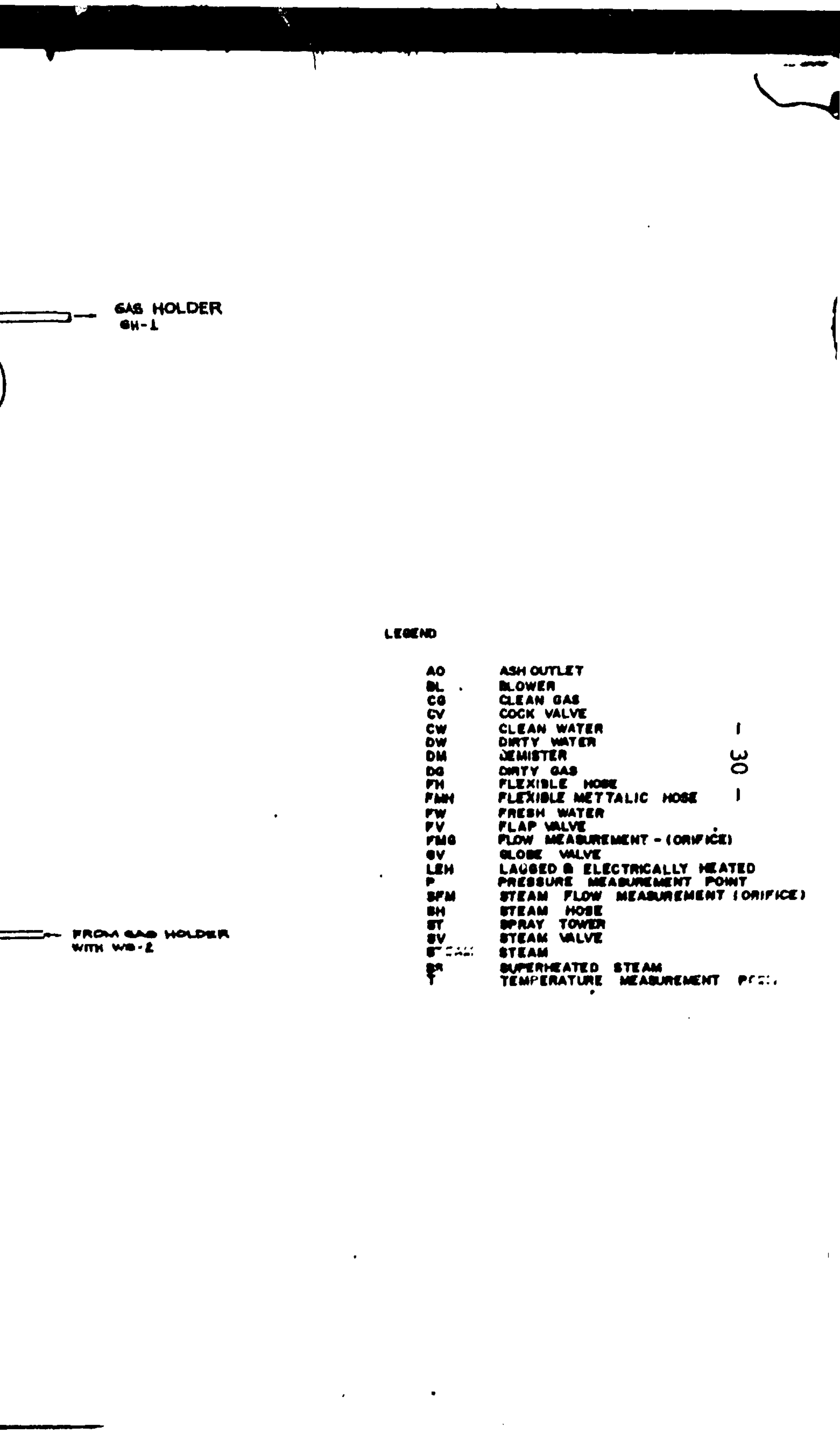


FIG. 1 LAYOUT



LEGEND

AO	ASH OUTLET
BL	BLOWER
CG	CLEAN GAS
CV	COCK VALVE
CW	CLEAN WATER
DW	DIRTY WATER
DM	DEMISTER
DG	DIRTY GAS
FH	FLEXIBLE HOSE
FMH	FLEXIBLE METTALIC HOSE
FW	FRESH WATER
FV	FLAP VALVE
FMG	FLOW MEASUREMENT - (ORIFICE)
GV	GLOBE VALVE
LEH	LAGGED & ELECTRICALLY HEATED
P	PRESSURE MEASUREMENT POINT
SFM	STEAM FLOW MEASUREMENT (ORIFICE)
SH	STEAM HOSE
ST	SPRAY TOWER
SV	STEAM VALVE
S[illegible]	STEAM
SS	SUPERHEATED STEAM
T	TEMPERATURE MEASUREMENT P[illegible]

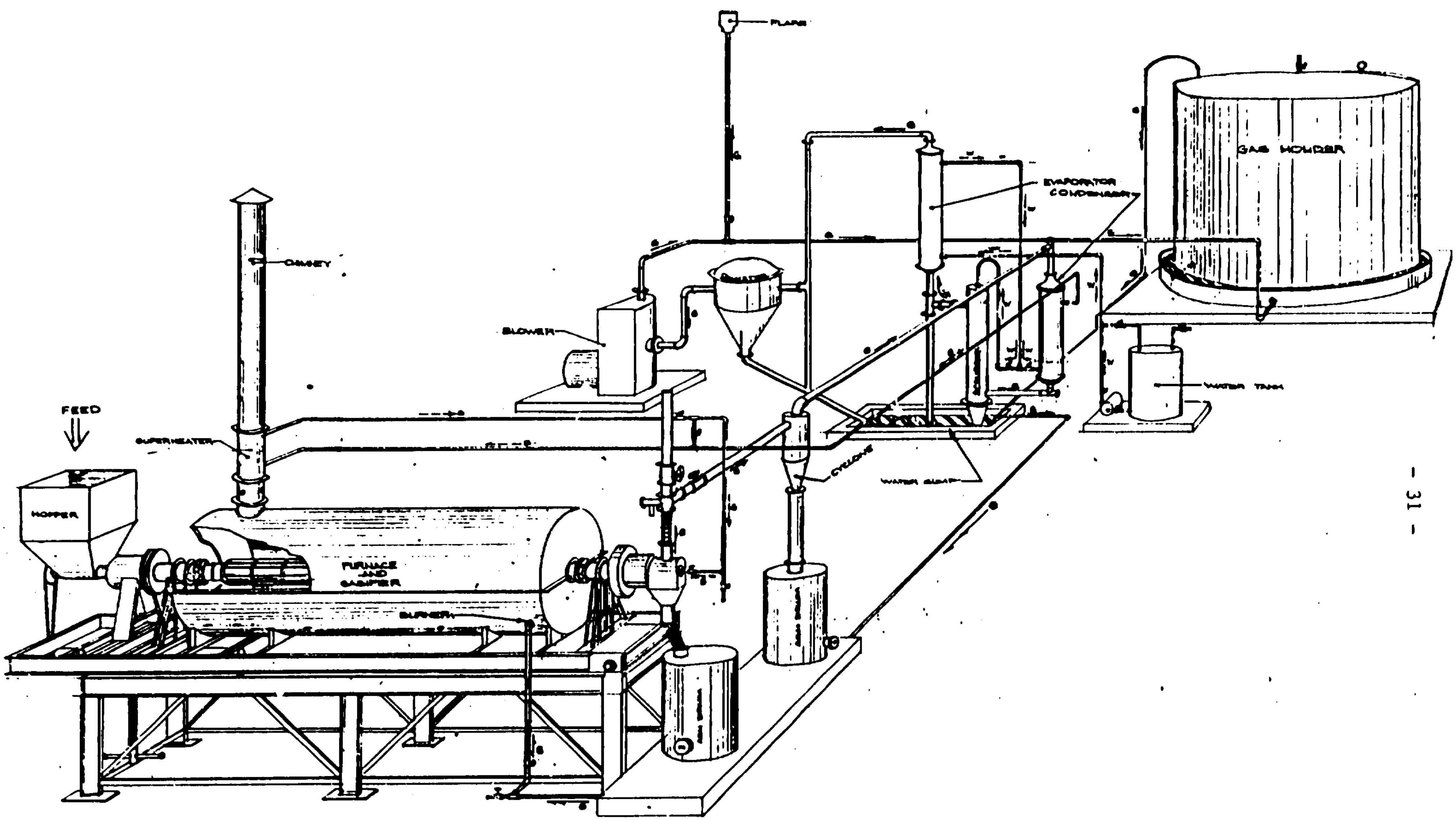


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FIG. 4.2 PERSPECTIVE PLAN
STEAM GASIFIER

performance of this zone, charred rice hulls should be added into the feed hopper. At various feed rates, the grinding characteristics of the rods on the char are observed. Accordingly, the number of rods required at a particular rpm of the gasifier can be determined. The output criterion should be that the char is just crushed and not ground to a fine powder at the minimum possible rpm. Prolonged operation of the gasifier at higher rpm should be avoided to cause excessive wear and tear.

4.2 Calibration of Feeder

The feed hopper full with rice hulls, the gasifier body adjusted at an overall minimum inclination of 10 cm. and running at minimum of 2 rpm, the feed screw screw is started at 2 rpm. The output rate of rice hull from the gasifier is measured at steady state. The holdup of rice hulls in the gasifier is also computed by finding the difference between the weight of rice hulls added in the hopper and the total weight of rice hulls collected at the gasifier outlet. For this purpose, the plant is allowed to run till the hopper and the feed screw are empty.

The average residence time (min.) of the rice hull in the gasifier can be calculated by dividing the holdup (kg.) by the feed rate (kg/min.).

The about test runs are repeated at various speeds of the feeder. The relationship should then be established for feed rate and its corresponding residence time as a function of screw speed at various speeds of the feeder. The relationship should then be established for feed rate and its corresponding residence time as a function of screw speed at various inclinations and rpm of the gasifier.

Taking rice hull bulk density of 0.12 kg/liter, the volume occupied by rice hull in the gasifier should be calculated. It is imperative that only those combinations of feed rate, inclination and rpm should be selected for subsequent gasification runs which give more than 60% free volume in the gasifier. This implies that the hold up in the gasifier should not be more than 3.5 kg.

4.3 Hot Testing of the Gasifier

Before connecting the gasifier to the down stream gas cleaning system, isolated by valve C.V-6*, (Fig. 4.1), it should be tested independently. These tests will be essential to find out any mechanical problems not encountered during cold testing runs. Also, the range of operating parameters such as temperature, feed rate, inclination and rotational speed of the gasifier, most suitable for subsequent steam gasification runs can be identified.

The gasifier is envisaged to be heated by the recirculation of a portion of gas produced during gasification. Till such times, the facilities for storage of gas, as shown in Fig. 4.1, are completed, L.P.G. with suitable burner can be used for the initial hot runs.

The procedural steps involved in hot testing of gasifier are as follows:

1) Fill up the hopper (H1) with dried rice hulls.

2) For particular inclination and rpm of gasifier (determined as most suitable from previous tests given in section 4.1), the unit is switched on for rotation.

3) The feeder speed is adjusted at predetermined value and is started for a period till the rice hulls starts to come out at the discharge end. Then, only the feeder is stopped. This is done to accomplish a sufficient rice hull holdup in the gasifier.

4) Ash drum (A1) is cleaned and ash outlet A.O-1 closed. Flap valve F.V-1 should be opened for ash to fall into the drum. Valve C.V-6 kept closed and valve C.V-5 should be fully open.

5) With gasifier rotating and feed screw stopped, the L.P.G. burner is lighted and the gasifier is heated slowly. The firing specially the first one should be done very carefully and temperature rise of the gasifier carried out slowly to avoid any excessive thermal shocks to the inside refractory and the gasifier. The rate of heating should be below $5^{o}C$/min. specially above $300^{o}C$.

* for identification of the nomenclature, refer to Fig. 4.1

While the gasifier is being slowly heated, checks should be made for smooth rotation without any undesirable noise. An ampere load meter connected to the motor rotating the gasifier will indicate any excessive load caused by maloperation. In case, any defect is noticed, the heating should be stopped and the defect rectified. It is imperative that during heating, the gasifier rotation should not be stopped. The heating should be first stopped and then after a few minutes, gasifier motor is switched off.

The temperatures at points T1 or T2, T4 and T10 are recorded at regular intervals. During heating, the feeder should be started periodically for a few seconds to avoid the blockage at the outlet of the feeder. This blockage can occur if tar produced during the heating of ricehulls gets deposited on the feeder outlet openings.

Because of high heat capacity of the furnace, the heating of the gasifier to the temperature (T4) of 500°C, may take 3-4 hours. During the heating, if required, the gland seals of the gasifier should be adjusted.

6) Once the temperature T4 reaches 500°C, the feeder F1 should be started and operation continued till steady state is reached. Steady state will be indicated by the constant temperatures with time.

7) The gases produced during heating should be burnt in a separate flare away from the gasifier, making sure that the water seal WS-2 is fitted and the dip pipe is not blocked.

8) Once the steady state is reached, flap valve F.V-1 is closed and the ash drum is emptied of charred and uncharred rice hulls in the shortest possible time. Alternately, two ash drums may be incorporated with a dividing flap plate so that when one is under operation, the other can be emptied out.

9) During the steady state, the amount of feed added and char collected should be ascertained in a definite period of time. The proximate analysis of char and rice hulls should give the material balance, and degree of devolatization.

10) Weight of the L.P.G. used during steady state and percentage excess air used (by analyzing the flue gases) should generate data on heat

balance and fuel required for gasification and hence the thermal efficiency of the gasifier.

In case the radiation and other heat losses are excessive, steps may be taken to provide additional insulation on the furnace wall and other necessary exposed hot zones.

4.4 Preliminary Pyrolysis Tests

Before the steam gasification tests are undertaken some simple pyrolysis tests should be carried out to determine the operating ranges of the gasifier.

Due to non-availability of the recommended(1) stainless steel AlSl-310 as material of construction, the present unit has been fabricated out of AlSl-316 stainless steel. This imposes the constraints of not running its beyond 800°C compared to about 1050°C for AlSl-310. This implies that the temperature T_4 should not be exceeded beyond 700°C. Further, at anytime, the gasifier should not be run at high temperature without the feed in the gasifier to avoid hot spotting on the gasifier shell.

For pyrolysis tests, the operating variables are:

(1) Temperature of pyrolysis,
(2) Feed rate,
(3) Overall inclination of the gasifier, and
(4) The rotational speed of the gasifier.

The desired output variable is the degree of pyrolysis which in other words can be the minimum fraction of char obtained at maximum possible feed rate.

By following the steps mentioned in Section 4.3, tests can be conducted by varying the abovementioned operating parameters. Their combinations, which result in giving the most desired outputs both in terms of yields of gaseous products and output rates should be identified for subsequent tests to be carried out with steam.

4.5 Testing of Gas Cleaning System

The downstream gas cleaning system commences at Valve C.V-6 and terminates at Valve G.V-13 (Fig. 4.1). The gas cleaning system sequentially comprises of

Cyclone C-2, evaporator-condenser E.V-1, spray tower S.T-1, evaporator-condenser E.V-2, demister D.M-1 and blower G.L-1 before the gases are flared or stored.

The auxilliary water system required for scrubbing the gas and for raising steam similarly comprises of (in sequence) water tank W.T-1, water pump W.P-1 and shell side of E.V-2. The hot water from the outlet of E.V-2 then gets divided into two streams, one for scrubber and the other for raising steam. The water for steam raising then passes through the shell side of E.V-1. The steam raised in E.V-1 is superheated in the superheater S-1 before it enters the gasifier, controlled by steam valves, S.V-3 and S.V-4. All the steam and hot water pipes and evaporator-condensers are properly insulated.

To avoid the condensation of steam, the pipe connecting valve C.V-6 and cyclone C2, cyclone itself and connecting pipe between cyclone C1 and E.V-1 are not only insulated but have inbuilt provisions to be electrically heated by a wound nichrome wire heating tapes.

A water sump W.S-1 is provided to act as water seals. These water seals not only collect water but also act as safety devices.

Testing of these equipment involves checking for possible leakages once the various units and interconnecting pipings are assembled.

To test leakages in the water and steam lines, these lines should be filled with water and checking is carried out. The leakages, if found, are rectified. Similarly, the gas line is tested by pumping water after all the outlets have been closed. Only one outlet at the highest elevation should be initially left opened to purge out the air. Testing up to 1 atmospheric pressure gauge is adequate. Since these gas lines are to operate under slight vacuum, utmost attention should be paid for any leaks as during operation air may get into gas system and form an explosive mixture.

4.6 Testing of Gas Holder

After the gas holder is installed, and water seal maintained, it is filled with compressed air. The tests for leakages are made. Further the free movement of gas holder, by releasing the air from the holder and filling in more air should be checked.

Before the gas holder is brought into service, it should be thoroughly purged of air with inert gas if available or the pyro-gas with great precautions. The procedure outlined on page 14/20 of Gas Engineers Handbook[2] should be followed.

4.7 Steam Gasification Tests

After the complete integrated unit is installed and tested, extended steam gasification tests should be conducted. The unit is likely take 5-6 hours from cold start before the steady state conditions are obtained. Therefore, to obtain reliable data at least two shift operation should be programmed.

The unit was designed to handle 25 kg. of ricehulls per hour. Since the size of the gasifier has been reduced from 8" to 6" dia. pipe, the capacity may also be reduced. Accordingly, sufficient quantity of raw material should be made available.

4.7.1 Start Up Procedure and Steady State Operation

The following procedure should be adopted to start the gasifier and bring it to the steady state operation:

1. The valve C.V-6 (Fig. 4.1) should be closed and valve C.V-5 should be fully opened. This would isolate the gas cleaning system from the gasifier and allow the gases to go to gas exit pipe G.E-1.

2. With hopper, H-1 full with rice hulls and at predetermined inclination and rpm, the gasifier shell is started.

3. The screw feeder F1 is started for a short duration till adequate amount of rice hull is filled into the gasifier as a hold up. At any stage of heating, the gasifier should not be empty of raw material.

4. The burner is now lighted either with LPG or gas from the gas holder by opening valve G.V-1 and G.V-16. Valve G.V-2 should be fully closed.

5. When the temperature T4 reaches about 300°C, screw feeder is started at the lowest possible rpm. As the temperature T4 increases, the screw feeder rpm can be increased till it reaches the predetermined speed. By this time, the temperature T4 should also reach the desired value.

6. Before allowing the gas to go into the gas cleaning system, the following operations should be completed:

   a) All steam and water valves such as S.V-4, S.V-16, S.V-17, G.V-7, G.V-8, G.V-10, G.V-11, G.V-12 should be in fully open position. Only valve S.V-3 and G.V-17 should be kept closed.

   b) The electrical heaters warming up the pipelines before and after cyclone C2 and cyclone itself should be switched on till the temperature of 120°C as indicated by T5 is attained.

   c) Pump, W.P-1 is started and G.V-12 is partially closed till water starts coming out of the scrubber S.T-1.

   d) Valve G-13 to gas holder is closed and valve G-14 is fully opened so that the gas once released into the cleaning system escapes through the flare pipe rather than getting into the gas holder.

   e) Make sure that the ash outlet ports A.O-1 and A.O-2 are fully closed.

7. The gas blower is B.L-1 is started and immediately after gas is released to the gas cleaning system by simultaneously closing valve C.V-5 and opening valve C.V-6.

   (NOTE: In case a positive displacement type blower is used, its by-pass valve should be initially open during the start of the blower and then closed after valve C.V-6 is opened and C.V-5 is closed).

8. The electrical heaters heating the cyclone and piping are switched off.

9. The flow rate of water is adjusted into the evaporator condenser E.V-1 by operating valves G.V-7, G.V-8 and G.V-12 in such a way that the temperature T9 should be about 100°C. Further, the level of the water as indicated by level gauge is maintained constant in the upper quarter zone.

10. Once the steam starts ejecting out of valve S.V-4, valve S.V-16 is closed and S.V-3 is opened to inject-steam into the gasifier simultaneously partially closing valve S.V-4.

11. By manipulating valve S.V-3 and S.V-4, a certain amount of steam can be injected into the gasifier so as to obtain steady state operation.

    The steady state operation is attained when the various temperatures remain constant with time.

12. When the steady state is attained, the ash and char collected in ash drums A1 and A2 are taken out after closing the flap valves F.V-1 and F.V-2. The time at the point of closing the flap is noted and hereafter, the amounts of ash collected and the raw feed added into the gasifier at regular intervals are recorded.

13. After logging the operational data as given in the proceeding section 5.2, at least, for 2-3 hours, the operating conditions should not be changed. One of the most important parameters is the amount of steam added into the gasifier. Initially, a fraction of steam generated is allowed to go into the gasifier through valve S.V-3 and remainder steam is allowed to escape through S.V-4 and condensed and the volume of the condensate noted. Later, the amount of steam in the gasifier is increased in steps and data obtained at steady state.

4.7.2 Shut Down Procedure

The following sequence should be adopted for shutting down the steam gasifier:

1. In case the gas is being released into the gas holder, the gas holder should be isolated by closing valve G.V-13 and gas put into the flare by simultaneously opening valve G.V-14.

2. The burner is stopped by closing the valve G.V-1.

3. The blower is switched off and simultaneously, the gas cleaning system is isolated by closing valve C.V-6 and at the same time opening the valve C.V-5.

4. The water pump is stopped and also the screw feeder F1. The steam is stopped by opening valve S.V-4 and closing valve S.V-3. The water in the system is drained off by opening valve G.V-17.

5. The screw feeder is periodically switched on for short duration to avoid its choking due to deposition of tar at its outlet.

6. The rotation of the gasifier is continued till the temperature T4 drops below 200°C. At this stage, the feeder is again started to maintain certain hold up of material. Once T4 drops below 100°C, the feeder and the rotary gasifier are switched off.

4.8 Maintenance Procedure

The major problem likely to be encountered during the operation of the gasifier is the choking of the pipelines and gas cleaning equipment with tar and ash particles, specially, the horizontal pipes are more prone to choking. Periodical cleaning and having good house-keeping are most important.

All the pipes leading to evaporator-condenser E.V-2 have been provided with extra flanges for cleaning purposes. The pressure drops across various equipment is periodically checked. An excessive pressure drop will indicate possible choking. Once detected, the equipment should be cleaned with hard steel brushes with detergents dissolved in hot water. If need be, acetone or methanol may be used to dissolve tar followed by detergent wash.

Periodically, the inside surface of the rotary gasifier should be checked and cleaned. For cleaning, dry sand may be added into the cold gasifier, chamber and gasifier rotated till such time the surface become smooth and clean. Abovementioned solvents may be used if required, when the tar does not come off only with sand treatment. The quantum of abrasion in the grinding zone of gasifier should be checked.

Periodically, the furnace should be opened for general cleaning and inspection of refractory and baffles. A crack in the refractory lining should be repaired with castable refractory cement. The baffles may be replaced if found damaged. The outside surface of the gasifier pipe should also be inspected for possible corrosion and weld-cracks due to thermal stresses. If need be, these cracks should be rewelded with 316 ss electrodes only.

Lubrication

The drives should be well lubricated and protected from dust and heat. The expansion gland seals on the gasifier need regular maintenance of lubrication with high temperature grease. Once the packing starts eroding, it should be replaced.

The instruments should be kept clean, free from tar and dust. Thermocouples placed in the dirty gas pipeline should be periodically cleaned with acetone or methanol to avoid giving wrong readings. The port holes for manometer tappings should be checked periodically for choking, etc. Manometeric fluids should be replaced after 14 days or earlier if these get contaminated. The list of instruments and their specific purpose is given in the next section.

5.0 INSTRUMENTATION AND DATA GENERATION

The type and number of instruments required to generate requisite data suitable for the design of commercial steam gasifier have been incorporated in this section. The necessity care has been taken to include only simple and minimum number of these instruments so as to minimize their costs and that these are also indigenously available in the Philippines. To stress their necessity, the function and importance of these instruments are also incorporated.

5.1 Temperature Measurements

The type of these instruments and their locations in the plant have been identified and shown in Fig. 4-1. These could be either standard stainless steel sheathed iron constanten or chromel-alumel thermocouples connected to a multipoint strip chart recorder with or without selector switches. Depending upon their criticality, whereever possible, respective substitution by indicating dial type thermometers have been suggested. These are:

T1 and T2. These are meant to measure temperatures of flue gases before and after superheater, so as to compute the performance of superheater and the furnace. The expected range is from 50 to 500°C.

T3. Its function is to measure the temperature of steam entering the gasifier. The expected range is from 100 to 300 C, and should be recorded continuously.

T4. This indicates the temperature of the gases just leaving the gasifier. This thermocouple should be strong and long enough, so as, when adjusted, can measure the temperature in the fourth zone of the gasifier and should be continuously recorded. Expected range is 25°C to 800°C.

T5. This thermocouple or dial thermometer has dual functions. Firstly, to measure the temperature of the empty outlet pipe of the cyclone separation, when the electrical heaters are switched on before gas is introduced and secondly, to measure the temperature of gases when these are introduced and heaters switched off. Expected range is from 100°C to 700°C.

T6. This could be either dial type or thermocouple to measure the temperature of gases leaving the evaporator condenser. This, together with T5, can be useful to compute the performance of evaporator-condenser E.V-1. Expected temperature range is 0-500°C.

T7 and T8. These can be either dial thermometers or thermocouples meant to give the performance of E.V-2. Range 0-150°C.

T9. This should be measured by a thermocouple with continuously recorded and gives the indication when steam is formed in E.V-1. Range is 0-150°C.

T10. This is meant to record the temperature of the furnace in its hottest zone. A refractory protected, calibrated pyrometer range. 500-1400°C should be used. Further, this could also be measured by either optical or radiation pyrometer.

T11. This is similar to T10 but meant to measure temperature in the middle of the furnace. Range: 400-1200°C.

5.2 Pressure and Pressure Drop Measurements

The gasifier is expected to operate at a pressure slightly above atmospheric pressure to avoid the suction of air into the gasifier. The gas cleaning system is under slight vacuum while gas storage is under slight pressure. Manometers filled with colored water as manometric fluids should be used for measuring pressures or pressure drops. Excessive pressure drops will indicate the possibility of choking in respective piping and or equipment hence these are important parameters to be measured for smooth operation.

The locations for pressure drops and pressure measurements are described below:

P1-P2. The tapping P1 is used for measurement of pressure in the gasifier and pressure drop (P1-P2) across the cyclone.

P2-P3. Pressure drop across the evaporator-condenser E.V-1 can be measured from these tappings.

P3-P4. These are meant to measure the pressure drop across the scrubber S.T-1.

P4-P5. These are used for pressure drop across the E.V-2.

P5-P6. These are used to measure pressure drop across the demister D.M-1. P6 should also be used for the measurement of pressure. The difference between P1 and P6 will give pressure drop across the complete gas cleaning system.

P6-P7. These are used to indicate pressure developed by the blower.

P8. This is connected to a mercury manometer to indicate the pressure in the gas holder. The expected range is 0-8 inches Hg.

5.3 Level Measurement

Only one level gauge is fitted on E.V-1 to indicate the level of water on its shell side. A leak proof thick glass tube should be used, capable of withstanding a temperature of 120°C.

5.4 Flow Measurement

Provisions have been incorporated to measure flow-rates of superheated steam being produced in the superheater S-1 and the clean pyro-gas. Suitable calibrated orifice flow meter with manometers with compensating legs (specially for steam) should be used at the sites given in Fig. 4.1. These could be either purchased as standard units or got fabricated as per designs given in any standard handbook or Perry and Chilton, Chemical Engineering Handbook[3].

The range of measurement for steam is 0-15 cu.ft. per minute at 1 atm and 300°C and that of gas is 0-15 scf.m.

6.0 STEAM GASIFIER (Equipment to be procured/installed.)

This section deals with the quantum of work yet to be completed in terms of procurement of Equipment, Instruments, and Installation work before the unit of steam gasifier becomes fully operational.

6.1 Major Equipment

A. Steam Gasifier Rotary Section

The rotary gasifier complete with hopper and furnace is under fabrication and is being periodically inspected in order to avoid any fabrication defects. As promised by the fabrication contractor, major parts are likely to be completed before the termination of the present trip, so that it can be physically tested for smooth rotation.

6.2 Auxiliary Equipment

A. Burner. It is yet to be procured. For initial tests and for tests when pyro-gas is not available, L. P. Gas has to be burnt. L. P. G. burner capable of generating a maximum rating of 1.5 Million BTU/hr. (0.378 x 10^6 KCal/hr.) should be procured. This rating is required to initially heat the furnace to the desired temperature of 1000°C in approximately 3 hour consuming on an average 0.5 kg. of L. P. Gas per minute of average heating value of 21,300 BTU/lb (11,833 KCal/kg.).

The burner should have the flexibility to decrease the rating to 0.1 Million BTU/hr. or 25,200 KCal/hr. This rating is required to maintain steady state operation for gasification after the furnace has been heated to about 1000°C.

The gas burner of the abovementioned ratings should also have the utility to burn pyro-gas being produced during gasification. The heating value of these gases is 350-400 BTU/ft^3 or 3,262 KCal/kg. or 5,871 BTU/lb. (specific volume 0.85 m^3/kg.).

The burner should be provided with an air blower, non-return valve and regulator on the gas inlet line. In case the same burner capable of handling both the types of gases is not available, two separate burners may have to be provided.

B. Evaporator Condenser E.V-1

The evaporator condenser units E.V-1 and E.V-2 are similar. While E.V-2 has been procured, E.V-2 is still to be got fabricated. As mentioned earlier, these units have to be slightly modified.

The unit E.V-2, should be got fabricated. As mentioned in earlier section, it should be provided with a level indicator.

C. Gas Blower

As per specifications given in earlier report[1], section 5.8-D, a suitable blower is yet to be procured. It could be either a positive displacement rotary blower or a suitable centrifugal blower of similar specifications.

D. Ash Collecting Drums and Water Drums

These could be fabricated out of 200 liters barrels and can be carried out departmentally as per connections given in Fig. 4.1.

E. Water Pump

A centrifugal pump capable of delivering 500 liters per hour of water against a head of 6 meters should be procured and connected as per layout given in Fig. 4.1.

F. Gas Holder

As per specification already included in report[1], the gas holder should be got fabricated and installed at suitable place at least 30 meters away from the main gasifier. Further, this should be cordoned off and safety precautions taken as given in reference no. 2.

6.3 Instruments

The list and type of Instruments to be procured are described in section 5. The locations of these instruments necessary to monitor the operation are shown in Fig. 4.1.

6.4 Installation and Pipe Work

The Layout of equipment, their relative heights and the sizes of the interconnecting pipe work with location of valves and fittings have been shown in

Fig. 4.1. To expedite the installation, it is recommended that a contract to an outside party should be given at the earliest.

M/S Dela Cruz Metal Works who are already fabricating the main rotary gasifier and have, in the process, got acquainted with the functions of this plant, may be preferred for this installation contractual assignment provided: (a) They do a good job of the gasifier, and (b) the bid is relatively competitive. During the course of our interaction with them for the fabrication of the gasifier, they have been found accommodating in incorporating modifications and minor changes. This flexible approach for the installation of the plant is an important parameter for consideration.

7.0 PRELIMINARY ECONOMIC EVALUATION - Steam Gasifier

The techno-economic evaluation of an integrated ricehulls steam gasification system shall be more realistic once the proposed pilot plant of envisaged capacity of 25 kg/hr. becomes operational and is thoroughly tested. The technical and economic data thus generated shall form the basis for the study and evaluation. However, to justify the time and quantum of investment involved for its development, a preliminary preinvestment economic evaluation at the present stage is very desirable which constitutes the subject matter of this section.

7.1 Basic Data

The analysis is based on the ricemills having capacities to process one tonne, two tonnes and four tonnes of paddy per hour. These mills in turn shall produce 250, 500 and 1000 kg. of ricehulls per hour respectively. The ricehulls so produced can then be gasified to generate electrical power and also produce pozzuolana cement. Pozzuolana cement is made when resulting ash from ricehulls is mixed with lime.

A typical mechanized ricemill normally generates a spectrum of products as given in Table (7.1) and electrical power required in Table (7.2).

TABLE 7.1

Basis 100 kg. of Paddy (without parboiling)

(A) TYPE: Course Variety Rice such as 'IR-8*' or equivalent.

Rice	68-70 kg.
Rice Bran	5-7 kg.
Small Rice	0.5-1 kg.
Ricehulls	24 kg.

(B) TYPE: Fine 'Long Grain' Variety Rice such as "Basmati"* or equivalent.

Rice	55-60 kg.
Rice Bran	7-8 kg.
Small Rice	up to 1 kg.
Ricehulls	25-30 kg.

(C) TYPE: Medium Variety Rice such as 'Parmal'* or equivalent.

Rice	62-65 kg.
Rice Bran	7-8 kg.
Small Rice	up to 1 kg.
Ricehulls	26-30 kg.

With parboiling additional 2% recovery of rice is obtained and corresponding less rice bran up to 4-5% but superior in quality is obtained.

TABLE 7.2

Electrical Power Input: in Rice mills

CAPACITY (Tonnes per hour)	POWER CONSUMED (HP)	INSTALLED (HP)
1	25-35	40
2	55-65	70
4	105-110	120

Based on above and other data [4], it is reasonable to assume that 25 kg. of ricehulls with 10% moisture on wet basis is obtained from 100 kg. of paddy milled.

* Data obtained from Government Cooperative Federation operating many rice mills in Northern India.

7.2 Gasification Products

According to the preliminary calculations in the earlier report[1], the final output product distribution of steam gasification are:

Basis 1 kg. of rice hulls (Heat Content 3000 KCal)

Pyro-Gases: 0.336 kg. (Heat Content 1207 KCal)

Ash : 0.2 kg.

In case the gases are used to produce electrical power through internal combustion engine generator system, with 30% overall efficiency, 105 kw. energy can be generated by using 250 kg. per hour of rice hulls.

Ash when mixed with lime in the proportion of 80% ash to 20% lime can be used to make pozzuolana cement. According to Mehta and Pitt[5], blocks made of this material can attain a compressive strength of 5130 psi in 28 days. Hence, this proportion or any other suitable proportion can be used to make hollow blocks for building construction.

7.3 Data-Hollow Blocks

The data on hollow blocks obtained from one of the building contractors in Manila are given below.

<u>Size 4"</u> ordinary hollow blocks
<u>Dimensions</u> W = 9 cm.
H = 19.5 cm.
L = 40 cm.
<u>Weight</u> 12-13 kg. per piece
<u>Present Price</u> ₱2.50 per piece

<u>Size 6"</u> ordinary hollow blocks
<u>Dimensions</u> W = 14.7 cm.
H = 20.3 cm.
L = 40.0 cm.
<u>Weight</u> 15-16 kg. per piece
<u>Present Price</u> ₱2.70 per piece

<u>Proportion of the Mixture for Hollow blocks</u> - by weight

Cement : 1
Gravel (9 mm size): 2
Sand : 3

One bag of cement costing ₱45.00 per bag of 40 kg. and with the above mix proportion normally gives 70 pieces of hollow blocks of 4" size and 55-60 pieces of 6" size.

The present costs in Manila of sand and gravel are ₱40-45 and ₱60-65 per tonne respectively. The labour cost is estimated at ₱15 per 100 hollow blocks.

7.4 Cost of Plant and Equipment

In the present analysis, the cost of plant and equipment is taken as an economic design variable and the economic analysis carried out to find out the profit-investment relationship to obtain investment design criteria. This approach is necessitated by the fact that the exact sizes of equipment for a commercially viable unit and their costs are not presently known till the tests are completed on the proposed pilot plant and scale-up data obtained.

The cost analysis is carried out for three capacities viz: 250, 500 and 1000 kg. per hour of ricehulls gasified corresponding to rice milling capacities of one tonne, two tonnes and four tonnes per hour of paddy processed respectively.

The cost of plant with 250 kg/hr. capacity is assumed as : x Pesos (₱)

Using the established cost equation (7.1), the costs of other capacities can be obtained

$$I = x \left(\frac{A}{250}\right)^{0.6} \quad \text{----------------} \quad (7.1)$$

where I is the cost of plant having capacity 'A' kg/hr.

Accordingly, from equation (7.1), the cost of plant of capacity 500 kg/hr.

$$= x \left(\frac{500}{250}\right)^{0.6} = ₱1.5\ x$$

and the cost of plant of capacity 1000 kg/hr.

$$= x \left(\frac{1000}{250}\right)^{0.6} = ₱2.3\ x$$

7.5 Cost of Production per month (Basis 25 days, 24 hrs/day)

I. Cost of Raw Materials

Material \ Capacity (kg/hr.)	250	500	1000
A. Ricehusk (tonnes)	₱ 150	₱ 300	₱ 600
B. Cost of Ricehusk (₱10/tonne - handling only)	1,500	3,000	6,000
C. Lime	12.5	25	50
D. Cost of Lime (₱1000/tonne)	12,500	25,000	50,000
TOTAL (B + D)	₱14,000	₱28,000	₱56,000

II. Salaries and Wages

The wages per month including payroll expenses are follows:

Capacity: 250 kg/hr.

Category	No.	Rate	Amount
Foreman	1	₱ 2,000	₱ 2,000
Skilled Workers	3	1,000	3,000
Semi-skilled	3	800	2,400
Unskilled	10	400	4,000
Accountant	1	1,000	1,000
Clerk-cum Typist	1	700	700
Supervisor	1	2,000	2,000
TOTAL			₱ 15,100

Correspondingly, by the use of cost equation, the wage bills for other capacities are envisaged as:

Capacity	Wage Bill
250 kg/hr.	₱ 15,100.00
500 kg/hr.	23,000.00
1000 kg/hr.	35,000.00

III. Utilities (Basis one month: 25 days-24 hrs.)

Item \ Capacity (kg/hr.)		250	500	1000
A.	Water (m^3)	₱ 1,200	₱ 2,400	₱ 4,800
B.	Cost of Water (Rate: ₱60/ 100 m^3)	720	1,440	2,880
C.	Electricity (kw H	9,000	15,000	24,000
D.	Cost of Electricity (Rate: ₱1.07/ unit)	9,630	16,050	25,680
	TOTAL (B + D)	₱10,350 vvvvvvv	₱17,490 vvvvvvv	₱28,560 vvvvvvv

IV. Fixed Expenses - overheads per month

Item \ Capacity (kg/hr.)		250	500	1000
A.	Office Expenses	₱ 1,000	₱ 2,500	₱ 5,000
B.	Insurance and Security-Safety, etc.	4,000	6,000	8,000
C.	Rent	1,000	1,500	2,500
D.	Contingency	1,500	3,000	6,000
	TOTAL	₱ 7,500 vvvvvvv	₱13,000 vvvvvvv	₱21,500 vvvvvvv

The total costs of production excluding the cost of capital, maintenance and depreciation are the summation of amount in Sections 7.5.I, 7.5.II, 7.5.III and 7.5.IV.

Capacity (kg/hr.)	7.5.I.		7.5.II.		7.5.III.		7.5.IV.		
250	14,000	+	15,100	+	10,350	+	7,500	=	₱46,950
500	28,000	+	23,000	+	17,490	+	13,000	=	81,490
1000	56,000	+	35,000	+	28,560	+	21,500	=	141,060

7.6 Working Capital

Based on 2 months requirements of raw materials, salaries, utilities and overhead expenses. These are: 2x (total amount in Section 7.5).

Capacity (kg/hr.)	Working Capital
250	₱ 93,900.00
500	162,980.00
1000	282,120.00

7.7 Total Capital Required

Item \ Capacity (kg/hr.)	250	500	1000
Working Capital	₱93,900	₱162,980	₱282,120
Plant Cost	x	1.5 x	2.3 x

7.8 Sales (per month)

Product \ Capacity (kg/hr.)	250	500	1000
Cement (tonnes) (Ash + Lime)	37.5	75.0	150
Sales (₱1,000/tonne) of Cement	37,500	75,000	150,000
Electricity (units)	63,000	126,000	252,000
Sales (₱1.07/unit) of Electricity	67,410	134,820	269,640
TOTAL	₱104,910	₱209,820	₱419,640
	vvvvvvvv	vvvvvvvv	vvvvvvvv

7.9 Profitability Studies (Basis one month)

Item \ Capacity (kg/hr.)	250	500	1000
A. Total Sales Less 10% handling charges and losses	₱ 104,910	₱ 209,820	₱ 4.9,640
B. Net Sales	94,419	188,838	377,676
Less cost of production	46,950	81,490	141,060
C. Gross Profit	47,467	107,348	236,616
D. Less Maintenance (5% per year on Capital Cost)	0.004 x	0.006 x	0.0095 x
Depreciation* (10% per year for 10 years)	0.008 x	0.012 x	0.019 x
Interest on Capital (18% per year)	0.015 x	0.0225 x	0.0345 x
Interest on Working Capital (18% per year)	1,408	2,445	4,232
SUBTOTAL OF (D)	(0.027 x + 1,408)	(0.04x + 2,445)	(0.063 + 4,232)
E. Net Profit before Taxation (C-D)	(46,059-0.027 x)	(104,903-0.04 x)	(232,384-0.063 x)

F. Expected rate of returns. Let this be = Y% per year

* straight line method used

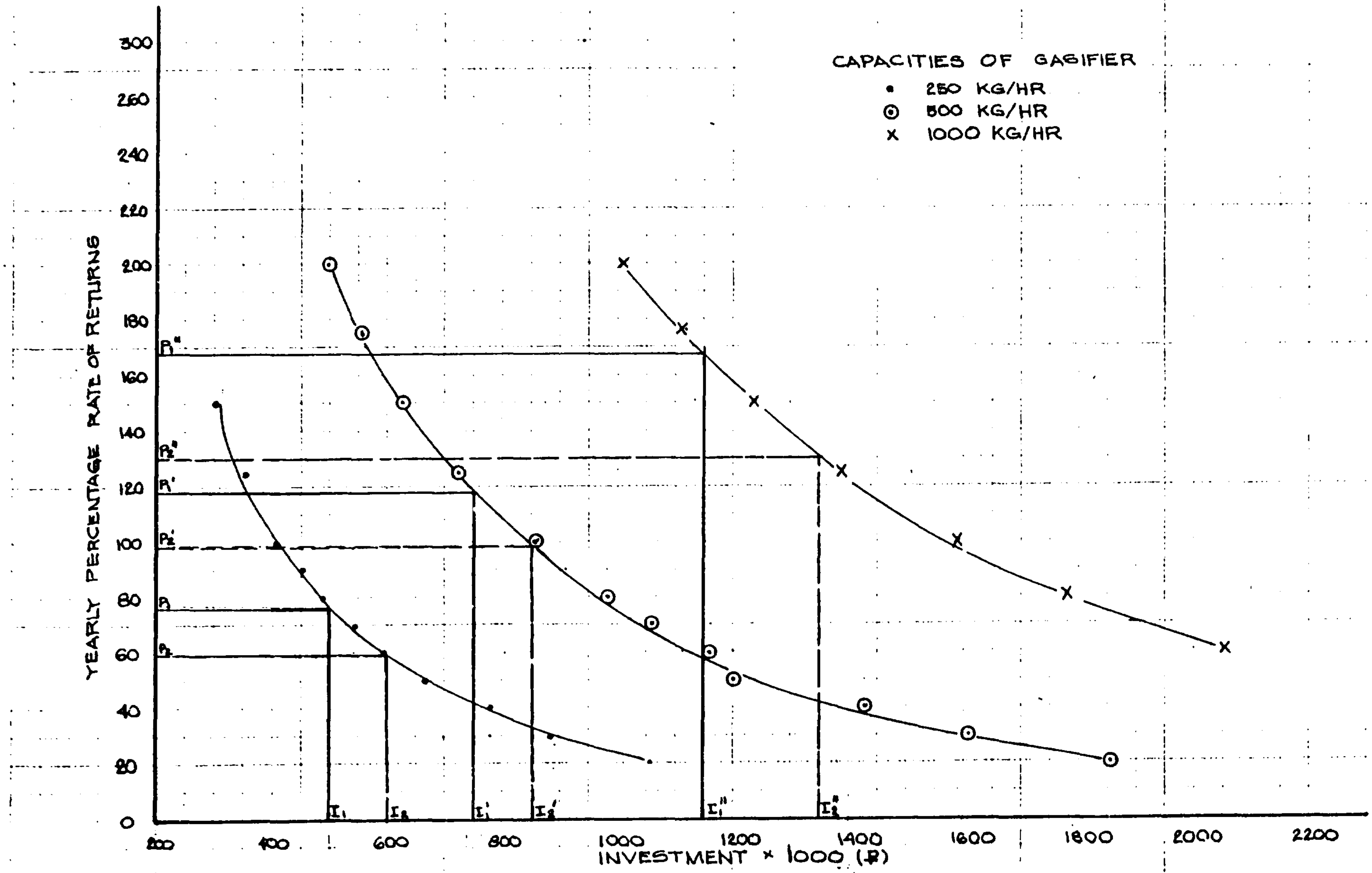

FIG. 7.1 RELATIONSHIP-INVESTMENT-RETURNS-CAPACITY

G. The respective cost equations for different capacities are:

G1 For 250 kg/hr. of rice hulls.

$$12\ (46{,}059 - 0.027\ x)/x = y/100 \qquad (7.9.1)$$

or

$$46{,}059 - 0.027\ x = xy/1200 \qquad (7.9.2)$$

G2 For 500 kg/hr. of rice hulls

$$104{,}903 - 0.04\ x = xy/1200 \qquad (7.9.3)$$

G3 For 1000 kg/hr. of rice hulls

$$232{,}384 - 0.063\ x = xy/1200 \qquad (7.9.4)$$

H Profit - Investment Data

Using equations (7.9.2), 7.9.3) and (7.9.4) and assuming the values of y, the percentage rate of returns, the costs of plant and equipment for gasification capacities of 250, 500 and 1000 kg/hr. are presented in Tables 7.3. These data have also been presented in Fig. 7.1.

TABLE 7.3

Profitability potentials of Rice hull steam gasifier at different capacities.

CAPITAL INVESTMENT* (₱)			Percentage rate of Returns. ₱/₱ year
CAPACITIES - kg/hr. rice hulls			
250	500	1000	
1,055,000	1,853,000	2,905,000	20
886,000	1,614,000	-	30
786,000	1,431,000	2,421,000	40
668,000	1,200,000	-	50
598,000	1,166,000	2,056,000	60
542,000	1,067,000	-	70
490,000	984,000	1,788,000	80
452,000	912,000	-	90
419,000	851,000	1,592,000	100
354,000	727,000	1,392,000	125
303,000	636,000	1,236,000	150
-	564,000	1,112,000	175
-	500,000	1,010,000	200
-	-	742,000	300
-	-	587,000	400

*INVESTMENT ONLY in Plant and Equipment
1 US$ = ₱14.00

7.10 RESULTS AND CONCLUSIONS

The results from Table 7.3 and represented in Fig. 7.1 indicate the yearly percentage returns on investment capital for three capacities of the plant. These returns increase for corresponding capital investment with the increase in the plant capacity.

For example, as shown in Fig. 7.1, for I1 = ₱500,000, the investment for capacity 250 kg/hr., the corresponding investments for 500 and 1000 kg/hr. plants are:

I1' = ₱ 750,000 and

I1" = ₱1,150,000 respectively.

Accordingly, the rate of returns in ascending order of plant capacities are:

P1 = 78%

P1' = 120% and

P1" = 166%

Further, if the cost of plant for 250 kg/hr. capacity is increased from I1 = ₱500,000 to

I2 = ₱ 600,000 correspondingly

I2' = ₱ 900,000 and

I2" = ₱1,380,000

then, the respective rate of returns are:

P2 = 60%

P2' = 92% and

P2" = 128%

According to these results, although an increase in capital costs by 20% in each case have resulted in decreased profitability by 23% but still these are very favourable.

As a preliminary estimate, the present cost of a comme cial unit with capacity to process 250 kg/hr. of rice hulls is likely to be between ₱600,000 to ₱800,000, giving a favourable returns between 60 to 40%.

These conclusions, as mentioned earlier, cannot be confirmed as realistic till tests are completed on the pilot plant. Nevertheless, the economic analysis gives the methodology and the following conclusions can be drawn.

(1) Rice hulls being a waste material, these pose disposal and environmental pollution problems if burnt inefficiently. Their efficient utilization as an alternate to conventional fuels is of national importance to every rice producing country.

(2) The process of steam gasification is not only for the protection of environment but the project is a lucrative one and is commercially feasible.

(3) There exists a wide range of economic flexibility to select relevant capacity and also adjust the cost of plant and equipment.

(4) Cost of plant and equipment has the major influence on its profitability, hence efforts should be direct to keep it as low as technically feasible.

8.0 RECOMMENDATIONS

1. Except for the development of technologies for rice hull steam gasifier and 200 kg/hr. pyrolytic converter, the other outputs incorporated in the project DP/PHI/78/022 can be accomplished within its tenure that is, by June, 1984. To get the benefits of these two main and important technologies (steam gasification and large scale pyrolytic converter), the extension of the present project period for one year beyond June, 1984 is essential.

2. Except for minor modifications, technologies such as rice hull gas stoves, mobile charcoal kilns and rice hull gasifier (Dr. Cruz's design) have reached the developmental stage for field trials. Therefore, immediate and timebound steps should be taken for the transfer of these technologies.

3. 200 kg/hr. pyrolytic converter needs testing in the field having abundant supply of raw materials. Steps need to be taken to get it installed at an appropriate site and operated under the direct supervision of engineers from ERDC or similar technical organization. Iligan Institute of Technology field test facility is one of the potential sites for its installation.

4. Most of the charcoal in the Philippines is made by individual farmers by pit methods. Substitution of pits by reverse flow type drum charring system should be actively considered and technology disseminated.

5. To efficiently utilize coir wastes, coconut husk and similar biomass, the technology of "PARU" fuel developed by Indian Institute of Technology, New Delhi, should be considered and thorough techno-economic appraisal carried out for its possible adoptation in the Philippines. One visit of two weeks duration by a senior technical manager to study the working plants in India seems appropriate and arranged accordingly.

6. Immediate steps are required to be taken to procure remaining auxiliary equipment and instruments and steam gasifier installed at ERDC. This unit needs systematic investigational studies. As per suggestions incorporated in this report, timebound work plans should be prepared and executed.

7. Some of the recommendations proposed in the previous report DP/ID/SER A/63 are still valid and yet to be fully implemented. In particular, recommendations at Serial No. 4, 5, 6, 7, 9, 13 and 14 deserve special consideration.

9. ACKNOWLEDGEMENT

The author wishes to record his appreciation to all members of the Energy Research and Development Center of the Philippine National Oil Company, in particular to the members of the Conventional Fuels Department for their very kind hospitality and excellent cooperation. But for their active technical discussions, secretarial help and overall cooperation, this report could not have been completed before the end of the present mission.

Thanks are also due to the staff at UNIDO/UNDP Office in Manila for their cooperation and prompt follow-up of many administrative and personal matters.

10.0 REFERENCES

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(5) P. K. Mehta and N. Pitt "Energy and Industrial Materials from Crop Residues", Resource Recovery and Conservation 2, 23-38, 1976

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ANNEXURE-I

DUTIES OF DR. P. D. GROVER FROM DECEMBER 5, 1983 -

1) Prepare a scientific procedure in testing the ricehull stove.

2) Conduct tests on the ricehull stove.

3) Give comments and suggestions on the 200 kg/hr. pyrolytic converter design.

4) Suggest modifications on the mobile charcoal retorts.

5) Make a day-to-day inspection of the fabrication works on the remaining components of the steam pyrolysis-gasifier system.

6) Locate at various points in the system where instrumentation is needed.

7) Prepare an experimental procedure in testing the steam pyrolysis-gasifier system.

8) Prepare trouble shooting techniques in case of anticipated breakdowns.

ANNEXURE-II

MODIFICATIONS FOR AUXILIARY EQUIPMENT

Modifications required on the auxillary equipment already procured for steam gasifier.

The following equipment have been already procured, which are required for the steam gasification of rice hulls:

a) Cyclone - Fig. 5.7a[1]
b) Evaporator Condenser - Fig. 5.7a[1]
c) Spray Tower - Fig. 5.7b[1]
d) Demister - Fig. 5.7b[1]

These have already been inspected and need some minor modifications to facilitate their proper operation.

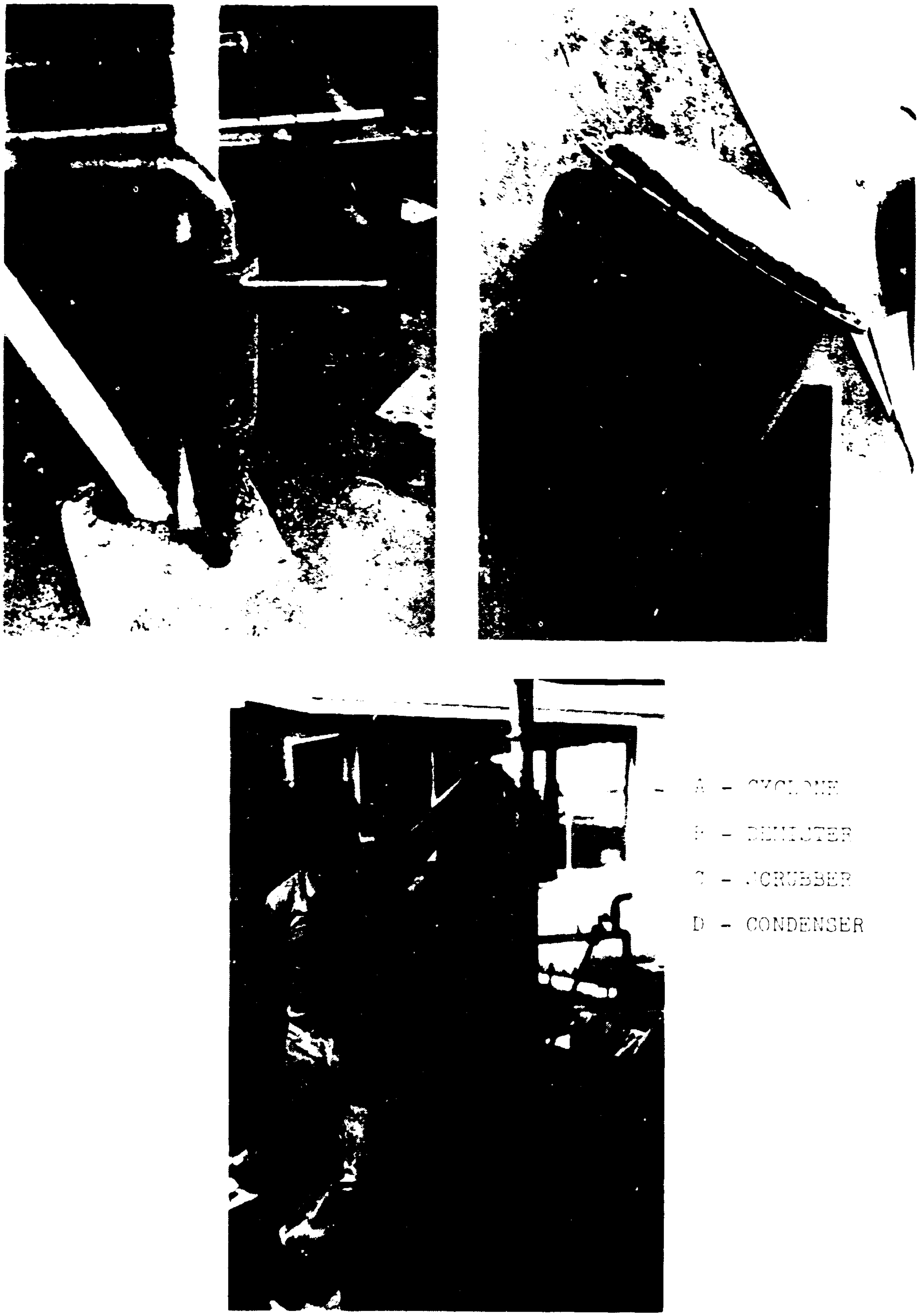
1. Cyclone. This has been fabricated as per the specifications except that the gas inlet pipe which should have been 63 cm. (2 ½") diameter instead of 1 ½" presently provided. This should be replaced.

2. Evaporator Condenser. Although fabricated as per specifications, it needs rounding off the tube edges welded to the tube plates on both sides of equipment. By hand grinder these should be smoothened and sharp edges removed. The sharp edges will give obstruction to the flow of tar and other liquids.

   Further as per Fig. 5.4 reference (1), two such units are required while only one has been procured. Order for another similar unit should be placed incorporating an additional level gauge.

3. Spray Tower. A flanged joint should be provided at a distance of 115 mm (4.5") from the center of the bottom gas inlet pipe. The flange outside diameter should be 330 mm (13"), 6 mm thick having 12 bolts of 9 mm (3/8") diameter. A perforated plate of 3 mm thickness with 12 mm holes having 10-15 percent hole area should be fixed between these flanges. The whole area should only cover the inside cross sectional area of the spray tower. This will act as a support plate for the packing as given in the enclosed sketch.

4. Demister. A 3 mm thick baffle plate equivalent to the diameter of demister should be welded in the center of the top cover to act as an inpingment plate. The plate should be extended downward to the height of 56 cm. (22") from the center of the top flange.


C - SCRUBBER
D - CONDENSER

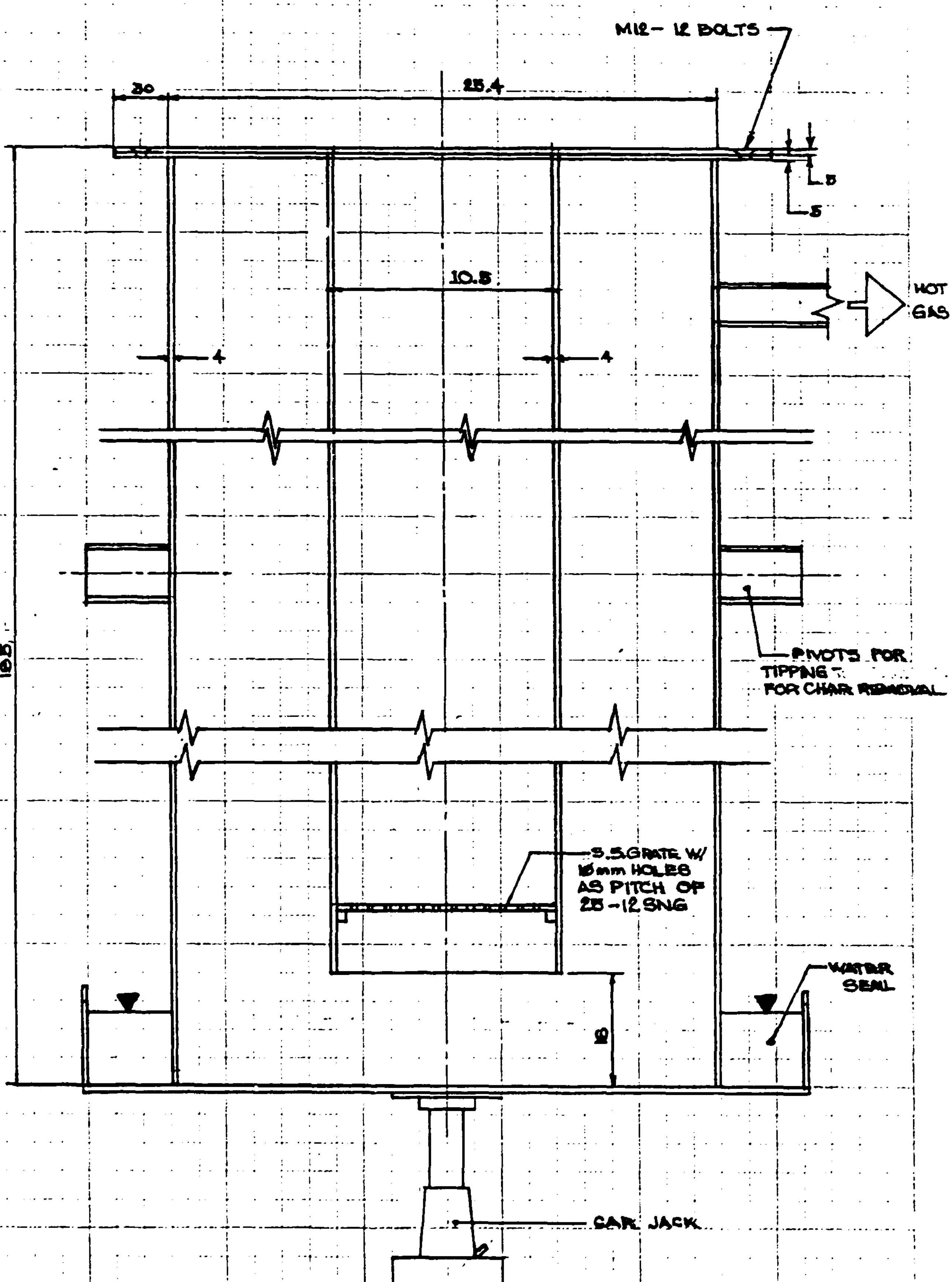


FIG. III-1 RICE HULL GASIFIER – UNIVERSITY OF CALIFORNIA DAVIS – DESIGN

(a) Modified Reverse Flow Drum

TAR COATED
(protected)

ALUMINIUM
COATED
(corroded)

(b) Perforated Drum showing protection with tar

FIG. [illegible]-1 DRUM CHARCOALING SYSTEMS AT I.I.T. NEW DELHI

COCONUT SHELL CHARCOAL KILN
AT
ILIGAN INSTITUTE OF TECHNOLOGY (M.U.)
ILIGAN, MINDANAO

DATA—SHEET STEAM ROTARY GASIFIER

DATE________ TEST RUN NO. __________ TEST TYPE : PRETESTING/PYROLYSIS/STEAM GASIFICATION

PURPOSE OF TEST TIME STARTED ________ TIME FINISHED ____________________

REASONS FOR UNANTICIPATED SHUTDOWN ____

____

____

TIME	RPM	LOAD	RATE (kg/hr)		TEMPERATES °C											PRESSURE - PRESSURE DROPS								FLOW RATES		
EVERY 30 min	FI SGI	FI SGI	FEED	ASH/CHAR	TIC	TII	TI	T2	T3	T4	T5	T6	T7	T8	T9	PI	PI-P2	P2-P3	P3-P4	P4-P5	P5-P6	P6-P7	P8	GAS ΔP	STEAM ΔP	REMARKS