Gasification and Pyrolytic Conversion of Agricultural and Forestry Wastes*

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1. INTRODUCTION

Therse are many processes for converting biomass into a more useful form of fuel. Most are classified as wet (biological) or dry (non-biological) conversion processes (Fig. 1).

This paper considers the conversion of agricultural and forestry wastes which are relatively dry, and for which dry conversion processes are more suitable. These processes are of three kinds: conversion under pressure (hydrocarbonization), heating in the absence of air (pyrolysis) and combustion.

Pressure processes (hydrocarbonization) need auxiliary compressors which make the systems impracticable and too expensive for developing rural areas.

Direct combustion in excess air (incineration) is the best understood and most widely used energy conversion process today. At some time almost everyone has used wood for cooking. Many sawmills use their waste to drive boilers that power their equipment. Farmers routinely use corn stalks and groundnut shells as fuel for their home energy needs. Much research is underway to develop suitable combustion systems for biomass and to study optimum particle size, feeding systems, particulate control, biomass mixtures with oil or coal, suspended burning systems, etc. However, direct combustion in excess of air has several problems, especially for general large scale use.

Perhaps only 60% of the available energy in wastes can be realized through this process. Thus the material is consumed with a relatively low heating value. There is also a serious air pollution problem associated with direct burning in excess of air, since large quantities of particulates are produced.

Combustion in a controlled atmosphere (gasification) is the conversion of solid or liquid to a gas. If the oxygen supply is restricted, incomplete combustion occurs releasing combustible gases such as carbon monoxide, hydrogen and methane.

A gasifier used to burn biomass produces gases of low or medium calorific value. A person with a good knowledge of metal working could build and operate a gasifier.

The capabilities of this process were shown during World War II in Europe and Japan where gasifiers were often used to operate tractors, automobiles and buses because petroleum was scarce.

Heating in the absence of air (pyrolysis) is the transformation of materials into another form by heating in the absence of oxygen. If heat is applied slowly, the initial products are water vapor and volatile organic compounds. Increased heat leads to recombination of the organic materials into complex hybrocarbons and water.
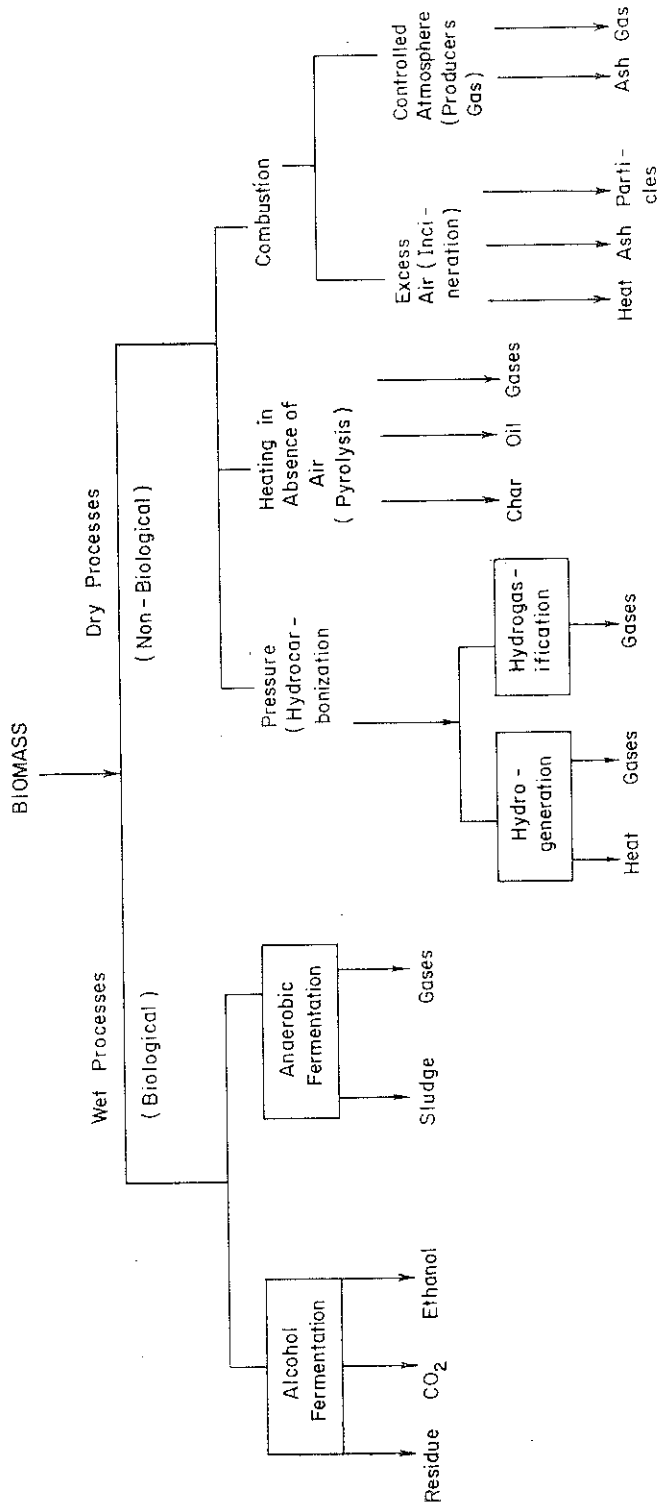

Fig. 1 Process alternatives for converting biomass to gaseous, liquid or solid fuels (1)

This approach appears to offer a number of advantages over incineration and leads one to think of waste materials in terms of utilization rather than disposal. This can significantly affect the economics of a particular case when the cost of pollution control and the value of the fuel are considered. Generally pyrolysis and gasification can be considered as very efficient means of increasing the options available for utilizing waste materials. In this case the wastes are made more readily usable, and environmentally more acceptable.

Pyrolysis and gasification will be discussed in more detail in this paper by considering some experiments conducted at the Institute of Technology, Bandung, Indonesia. It is apparent that much of this work can be applied to small scale gasification and pyrolysis.

2. GASIFICATION

2.1 *Chemistry of the Gasification Process*

The gas produced is formed by the partial combustion of solid biomass in a gasifier through which oxygen or air for combustion is passed towards the bed. The process is called *gasification* as it converts the majority of the bound chemical energy of the solid fuel into the gas phase.

Most gasification processes use air as opposed to pure oxygen. The main advantages of using air are as follows:

(i) It is already available anywhere, and

(ii) The nitrogen content of air hardly reacts with oxygen in the gasifier. Therefore it may be regarded as an inert dilutent which reduces the sensitivity of the reaction to temperature. Under lower temperatures less expensive materials can be used for constructing the gasifier.

(iii) The air flow is easily varied thus facilitating the control of the process.

However, the presence of nitrogen in the resulting gas lowers its calorific value. Also it has a disadvantage when the feedstock is too wet and there is a need for more heat for drying.
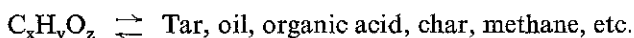
The main reactions of the conversion process are:

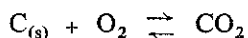(1) *Drying/evaporation process.*
(temperatures 25 to 150°C)

$$H_2O_{(liq)} \; \rightleftharpoons \; H_2O_{(gas)}$$
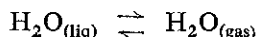
This produces $H_2O_{(gas)}$ which will be used as a reactant in the shift and methanation reactions.

(2) *Pyrolysis (distillation) process.*
(temperatures 150 to 900°C)

$$C_xH_yO_z \; \rightleftharpoons \; \text{Tar, oil, organic acid, char, methane, etc.}$$

(3) *Combustion (oxydation) reactions.*
(temperatures 900 to 1400°C)

$$C_{(s)} \; + \; O_2 \; \rightleftharpoons \; CO_2$$

This is an exothermic reaction with H = 406,042 kJ/kg atom of carbon.

$$\text{Tar, oil.. } + O_2 \rightleftharpoons \text{ mixture of: } CO, CO_2, H_2O, CH_4.$$
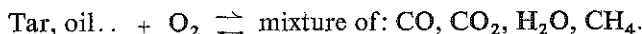
These are exothermic reactions.

The conversion process revolves around the combustion reaction which supplies heat to the neighbouring zones in the reactor. An important function of the combustion zone is to raise the reaction zone temperature to promote the carbon/steam gasification reaction which has a high activation.

(4) *Reduction reaction.*
   (temperatures 600 to 1400°C)

$$C_{(s)} + CO_{2(g)} \rightleftharpoons 2\ CO_{(g)}$$
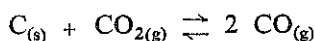
This is an endothermic reaction with H = 159,905 kJ/kg atom of carbon.

This reaction is very important in the gasification process, where it is the main reaction to convert the major noncombustible CO_2 gas to become combustible CO gas. At temperatures above 900°C over 90% of the CO_2 is reduced to CO.

(5) *Shift reaction.*

   (i) temperatures 900°C and above)

$$C_{(s)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + H_2$$
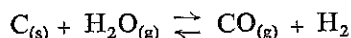
This is an endothermic reaction with H = 118,045 kJ/kg atom of carbon.

Increasing the humidity (water content) of the combustion air can improve the calorific value of the gas produced by this reaction. This reaction is important because it produces CO and H_2 which are both combustible gases.

   (ii) The other reaction at lower temperature (500-600°C) is:

$$C_{(s)} + 2H_2O \rightleftharpoons CO_2 + 2H_2$$
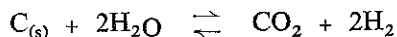
This is an endothermic reaction with H = 88,000 kJ/kg atom of carbon.

   (iii) A further steam reaction which occurs with an excess of steam is:
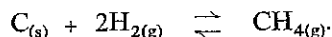
$$CO + H_2O \rightleftharpoons CO_2 + H_2$$
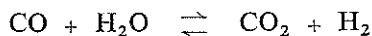
This is an exothermic reaction with H = 42,000 kJ/kg mol of CO.

This reaction should be avoided in gasification as it reduces the CO content in the gas produced.

(6) *Methanation reaction*

Another reaction which occurs in the char at temperatures around 500°C is:

$$C_{(s)} + 2H_{2(g)} \rightleftharpoons CH_{4(g)}.$$

This is an endothermic reaction with H = 88,324 kJ/kg atom of carbon.

As indicated in the above equations the reactions are in chemical equilibrium, where the position of equilibrium and the yield of the reaction depends on the temperature and quantities of reactants. It is clear that the presence of water in the feed or the air is an important factor for promoting the required reactions. As the reactions proceed at different temperatures, it is very important to control the temperatures in the zones where the different reactions occur.

2.2 Gasification converter (Gasifier)

There are three main types of converter: up-draught, down-draught and cross-draught. In all three converters the solid biomass feed is in a vertical flow packed bed through which oxygen or air for combustion is passed downwards, upwards or across the bed. The direction of gas flow defines it as a down-draught, up-draught or cross-draught converter, or producer gas generator.

Down-draught systems will be discussed here since these systems were specifically developed for use with wood and other uncarbonized residues, and they will be more suitable also for agricultural wastes than other types.

Down-draught systems are shown in Fig. 2. In this type of converter air is fed into the vertical converter at the base of the hearth (also called the "throat") and the gas emerges from the lower part of the converter. In both the systems the principles of the process are the same; the difference is in the air distribution. In the system at the Department of Chemical Engineering, Institute of Technology, Bandung, air is distributed by a pipe which can move up and down and rotate. These movements are important tools for controlling the zone of the reaction by changing the air injection position and hence for controlling the temperature of the zones, and also for agitating the feed to keep it flowing downwards.
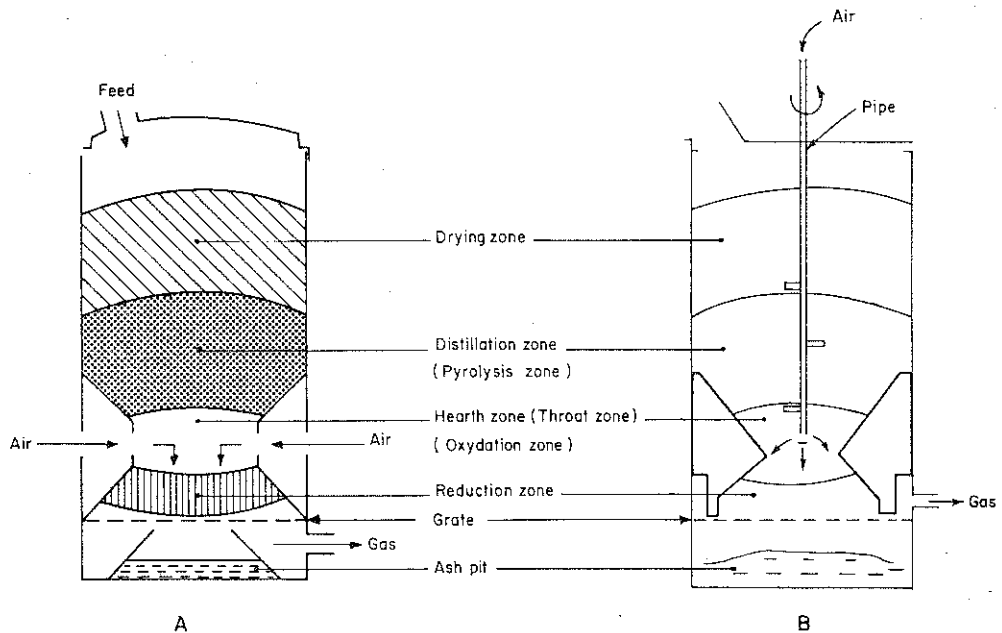

Fig. 2   Down-draught converters (A-(2), B-(9)).

This system was developed with the aim of converting the tars formed mainly in the pyrolysis zone into a gaseous product when they enter the throat, or oxidation zone, of the converter. An increase in the air velocity in this region raises the temperature of operation rapidly and thus facilitates the conversion of the tars into gaseous components. The gas produced thus has a low tar content. The reactions in the converter occur in zones as shown in the figure.

2.3 *Process conditions*

There are many factors influencing the process conditons of gasification. The variables for the feed include:

- Heating value and chemical composition
- Ash characteristics and ash content
- Tar formation tendency
- Size homogeneity
- Shape homogeneity
- Density
- Flow tendency
- Moisture content,

while for the air the variables are:
- Moisture content (humidity)
- Temperature
- Flow rate
- Injection position
- Shape of the flame (depending on the air spread)
- Air/feed ratio.

It is difficult to make generalisations on the correlation of each variable with the quality of the gas produced. The effects of changing one variable are influenced by the values of other variables.

However, certain general statements can be made for some variables. Thus, it can be shown that large particle sizes of feed are to be avoided as they form large voids and decrease the conversion efficiencies by encouraging channeling of the gas streams, with subsequent reduction in contact time. On the other hand, particle size should not be so small as to cause excessive resistance to the suction of the blower, which occurs for example with sawdust feed. A small amount of silicon, as little as 2%, makes feed unacceptable for down draught gasification because it can make a blockage in the hearth zone. High ash and tar contents decrease the quality of the gas produced. High ash and silicon contents have given trouble in experiments using rice straw and rice husks as feed.

The following general requirements are listed for a fuel to be satisfactorily gasified in down-draught gas producers (5).

1. High inter particle porosity.
2. Moisture content (wet basis) at or below 20%.
3. Low ash content (5 to 6 percent seems to be the upper limit depending on the amounts of slag producing elements such as silicon, calcium, magnesium, aluminium, etc.).

Table 1. Organisations working on producer gas generation plant (2).

Feed	Carbonised residues (wood charcoal)	Particulate uncarbonised residues	Particulate uncarbonised residues	Particulate uncarbonised residues	Particulate uncarbonised residues	Particulate uncarbonised residues
PRODUCER TYPE	Cross-draught*	Down-draught/Fluid bed	Down-draught	Down-draught	Down-draught	Down-draught
HEAT OUTPUT	Up to 150 000 kJ/h	1.8×10^5 to 3.6×10^6 kJ/h	5.0×10^5 to 3.0×10^6 kJ/h	5.0×10^5 to 2.0×10^6 kJ/h	Similar to Volvo	2.0×10^5 to 6.0×10^6 kJ/h
ENGINE TYPE	Spark ignition	Spark ignition	Dual fuel compression ignition	Spark ignition	"	/
POWER OUTPUT	Up to 8 kW	10-200 kW	30-150 kW	30-100 kW	"	/
STAGE OF DEVELOPMENT	3 kW output unit almost developed	Developed/Fluid bed still to be developed	Developed	Developed	"	Developed
PRODUCER	Designs available	Units available commercially. Work on fluid bed gasifiers to be made commercially available	Units not available commercially. Research organisation for Government	Units not available commercially but are built & kept in store as part of a national strategy. Collaborates with SMP	"	Units available commercially
PRODUCER AND ENGINE	Not available	Available	"	"	"	Not available
STATIONARY OR MOBILE	Stationary	Stationary or transportable	Stationary or mobile	Mobile	"	Stationary
ORGANISATION	Tropical Products Institute 56/62 Gray's Inn Rd London WC1X 8LU UK	Imbert Energietechnik Steinweg, Nr 11 D 5760 Arnsborg 2 WEST GERMANY	Statens Maskin Provningar (SMP) National Swedish Testing Institute for Agricultural Machinery Postadress 7035 75007 Uppsala 7 SWEDEN	Volvo Postadress S 40508 Aktiebolaget Volvo Goteborg SWEDEN	SAAB Scania Goteborg SWEDEN	Thalorat AG Feldstrasse 51 CH 84000 Winterthur SWITZERLAND

4. Absence of tramp metals, glass or soil.
5. Bulk density greater than 160 kg/m³.
6. Spherical or cube-like particle shape with little bridging tendency.
7. Uniform particle size distribution (low percentage of fines).
8. Good mechanical strength in the particles, and resistance to breakdown in handling.

2.4 *Plant & plant description*

The gasification process was used in blast furnaces over 190 years ago to produce combustibles from organic foods, and (as mentioned earlier) was used to operate tractors during World War II. Many kinds of producer gas generators are being developed by the organisations shown in Table 1, which summarises the main centres where producer gas technology is being pursued today.

A schematic diagram of the pilot plant for gasification in Indonesia is given in Fig. 3.
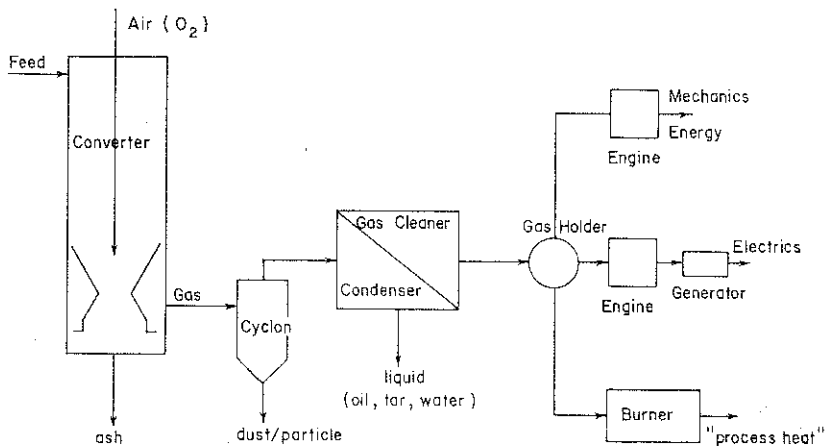
Fig. 3   Gasification process plant in Indonesia (7)

2.5 *Results of tests*

The results given in this section are from the experimental research done in the Chemical Engineering Department, Bandung Institute of Technology, Indonesia, since 1977 in collaboration with T.H. Delft and T.H. Twente of the Netherlands. The results represented here are limited to preliminary tests, which are still continuing to improve process conditions and the geometry of the converter.

The biomass feeds that have been tested are: rubber tree waste, oil palm shell, coconut palm shell, sawdust, and rice husk. The results of using sawdust and rice-husk are not presented since they have not yet been made productive.

Typical yields of gaseous fuel from gasification of rubber tree, coconut palm shell and oil palm shell at various air/feed flow ratios are given in Fig. 4a. These curves show that the gas product increases as the air/feed flow ratio increases.
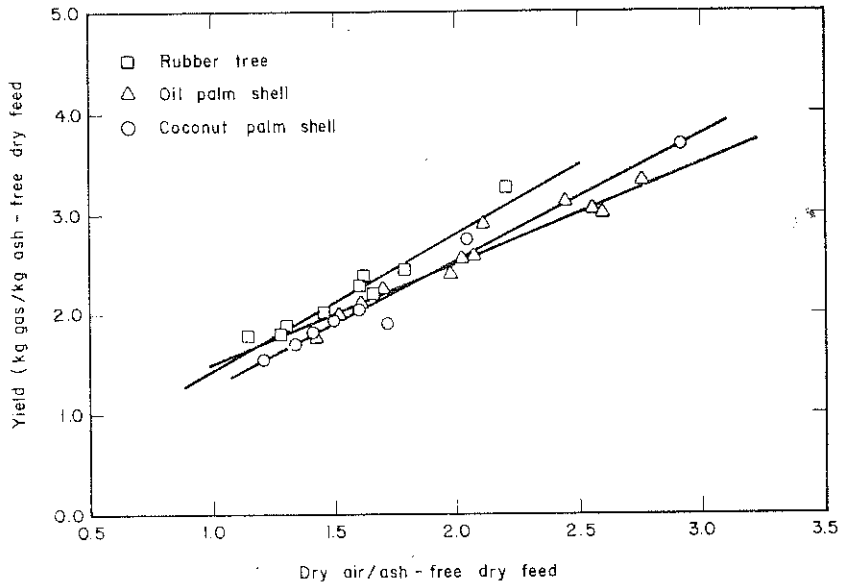
Fig. 4a   Yields at various air/feed flow ratios (Gasifier laboratory scale: capacity 1 to 5 kg/hr) (7)

Typical net heating values of the gaseous fuel from the gasification of rubber tree, coconut shell and oil palm shell at various air/feed flow ratios are given in Fig. 4b. These curves show that the heating value of the gas decreases as the air/feed flow ratio increases.
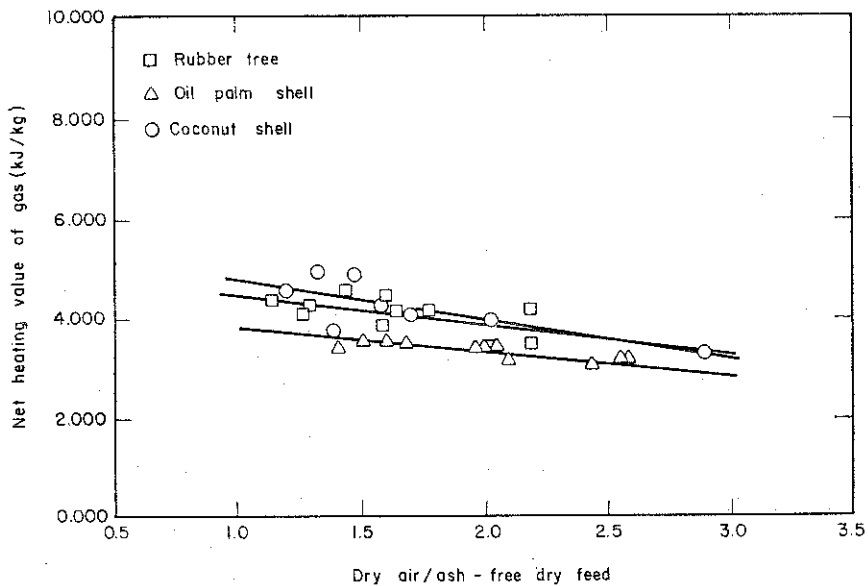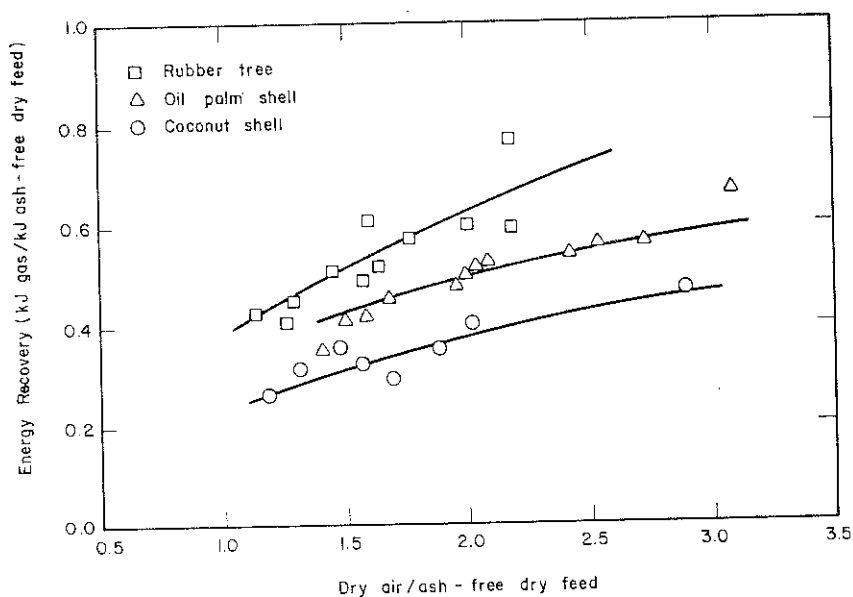

Fig. 4b   Net heating value of gas at various air/feed flow ratios (Gasifier laboratory scale: capacity 1 to 5 kg feed) (7)

Fig. 4c   Energy recovery at various air/feed flow ratios (Gasifier laboratory scale: capacity 1 to 5 kg feed (7)

Typical energy recoveries of the gaseous fuel from the gasification of rubber tree, coconut, shell and oil palm shell at various air/feed flow ratios is given in Fig. 4c.   These curves show that the gas energy recovery increases as the air/feed flow ratio increases.

Typical data for feed and product in the gasification of rubber tree, coconut palm shell and oil palm shell are given in Table 2.

3. PYROLYTIC CONVERSION

3.1 *Chemistry*

By definition, pyrolysis is the transformation of an organic material into another form by heating in absence of air. The principle pyrolysis reaction is the thermal decomposition of ligno-cellulosic material to produce char and oil, for which auxiliary heat is applied to facilitate the drying and pyrolytic conversion. The details of the reactions in pyrolysis have been discussed in many publications. They are quite complicated, and are beyond the scope of this paper.

In almost every case these processes are self-sustaining, with the heat required to dry and carbonize the wet wastes being supplied through combustion of either a small part of the feed itself or products of the pyrolytic conversion. Therefore the main reaction which occurs in gasification is also involved in pyrolytic conversion, namely the pyrolysis (distillation) process (see reaction no. 2). In other words pyrolytic conversion in this meaning includes also the gasification process.

Table 2. Typical data for quality and properties of feed and product for gasification of rubber tree, oil palm shell and coconut palm shell (7)

Feed:	coconut palm shell	oil palm shell	rubber tree
Ash content, (weight %, dry basis)		1.3	18.3
Element content, (weight %, dry basis)			
C	54.64	47.64	39.5
H	7.53	6.16	6.8
O	20.84	44.21	35.1
N	0.38	0.27	0.24
S	0.13	0.06	0.06
Net heating value (kJ/kg dry basis)	22000	17447	14300
Composition of gas (vol. % for air/feed flow ratios 1.4 to 3.1)			
CO	25.0	20.4	20.1
H_2	12.0	11.1	14.5
CH_4	1.5	0.8	2.0
CO_2	10.0	9.8	13.7
N_2	51.0	57.9	49.8
Net heating value (kJ/m^3)	3900-4800	3120-4070	3600-4950

The products of the pyrolysis process depend on the reaction temperature. Typically, high temperature processes lead mainly to gas production, while low temperature processes lead mainly to char and oil production.

3.2 *Pyrolytic converter*

The simple type of pyrolytic converter is shown in Fig. 5. A major consideration in the design is the incorporation of technology appropriate to the place where the plant will be built with respect to the availability of materials, fabrication capabilities, etc. The considerations for the operation of the overall system in either the batch or continuous mode are basically similar except for the method of kiln charging or unloading. Hence in the case of batch

type operation a small fire is built in the bottom of a kiln and the larger pieces of wood introduced manually. The kiln is sealed, the nozzles are opened, and the draft fan induces a limited flow of air for combustion of a small fraction of the charge.
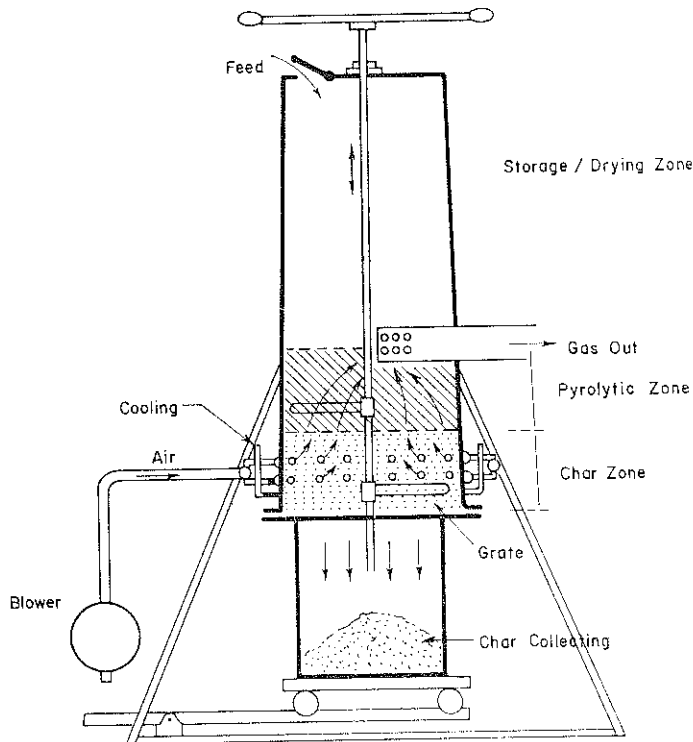

Fig. 5   Pyrolytic converter (8)

3.3 *Process conditions*

Feed

The physical feed requirements for pyrolytic processes are similar to those for the gasification process, but are less stringent.   For example: the size of the feed is not critical but a maximum particle size of one inch is desirable.   Also, the quantity of silicon and ash content found in rice hulls is acceptable for pyrolytic processes.

Air flow rate

Generally high air flow rates favour gas production, while low air flow rates effect low temperature processes and favour char and oil procuction.

The yield and the properties of the products of the pyrolysis process are related to the make-up of the input feed, the degree of shreading, and the moisture content of the feed. Therefore all of these factors determine the pyrolysis conditions that must be maintained. In the case of dry feedstock, if it is desirable to produce oil and gas only,   it has been demonstrated that the process can handle the feed and gasify the char by the simple expendient of raising the air

to feed ratio and recirculating char. This technique has demonstrated that 90 % of the energy in the dry feed can be recovered in the form of gas and oil.

3.4 *Plant description*

The first pyrolysis unit built in a program for utilizing waste material was a retort approximately five feet high with a single air tube, an electric starter, and a movable grate for periodic
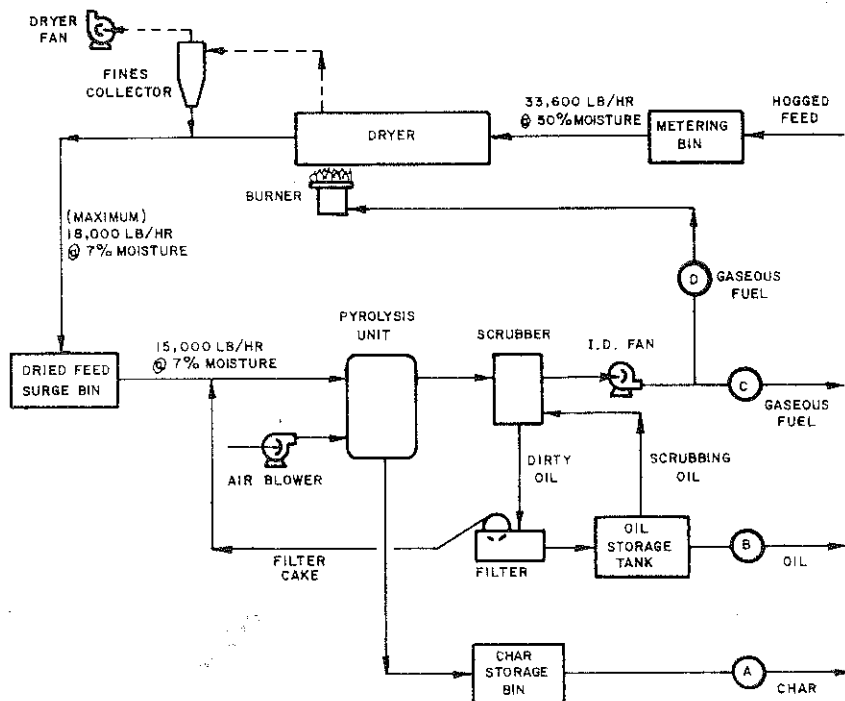

Fig. 6   Wood waste pyrolysis system-7 dry ton/day (3)

char removal. The retort was built and operated with dry agricultural wastes in the late 1960's. In 1970 the Georgia Institute of Technology, using information on the process and the products obtained from the first retort, designed and built the first continuous pilot plant. The system incorporated a vertical bed, with a gravity fed, counter flow pyrolysis chamber having a continuously operating char output system. This unit was designated Blue I. By futher study and development processes Blue II, Blue III and Blue IV were built successively. The commercial plant (prototype plant) was installed in a small lumber mill in Cordele, Georgia in 1973.

The largest problem encountered involved servicing or cleaning the off the gas system which resulted in considerable down time for the plant.   "This down time was drastically changed by the installation of a scrubbing system using a portion of the pyrolysis oil condensed from the off gases." (2)

The process flow diagram for a 7 dry ton per hour wood waste system is shown in Fig. 6. The small pilot plant in Indonesia, which at present uses rice hull as a feed, is shown in Fig. 7.

Remarks .

CP : Pyrolytic Converter
OC : Oil Condenser
WC : Water Condenser
EM : Electro motor
DR : Dryer
BR : Burner
DS : Diesel Engine
GN : Generator
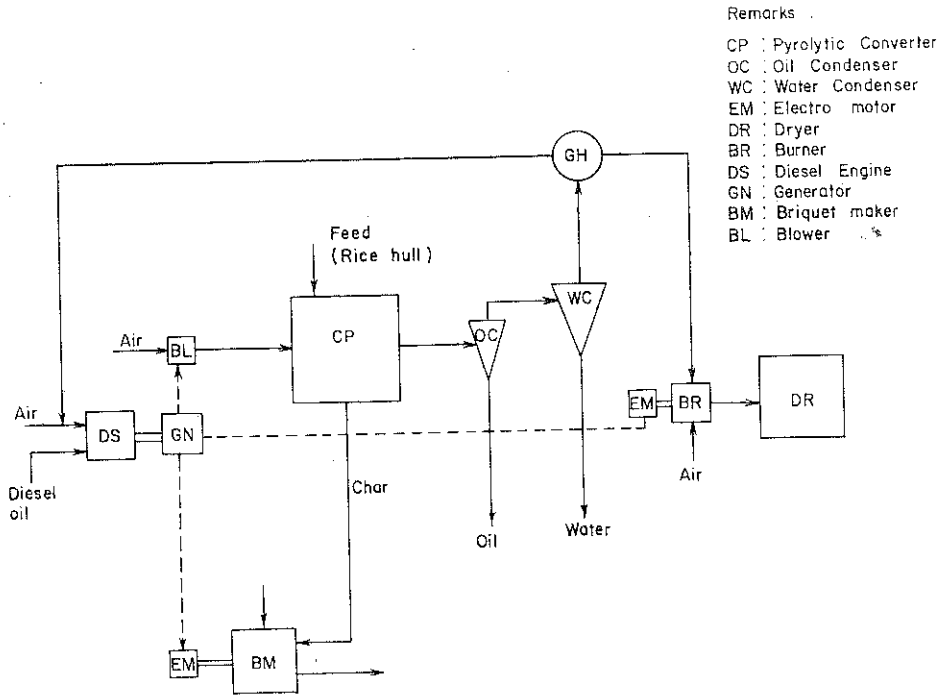BM : Briquet maker
BL : Blower

Fig. 7   Pyrolysis process flow chart

A system to process municipal refuse is somewhat more complex than systems for wood or agricultural waste. The additional complexity results from the added difficulty of the handling and preparing the municipal refuse for pyrolysis feed.   A flow diagram of a municipal refuse system is shown in Fig. 8.
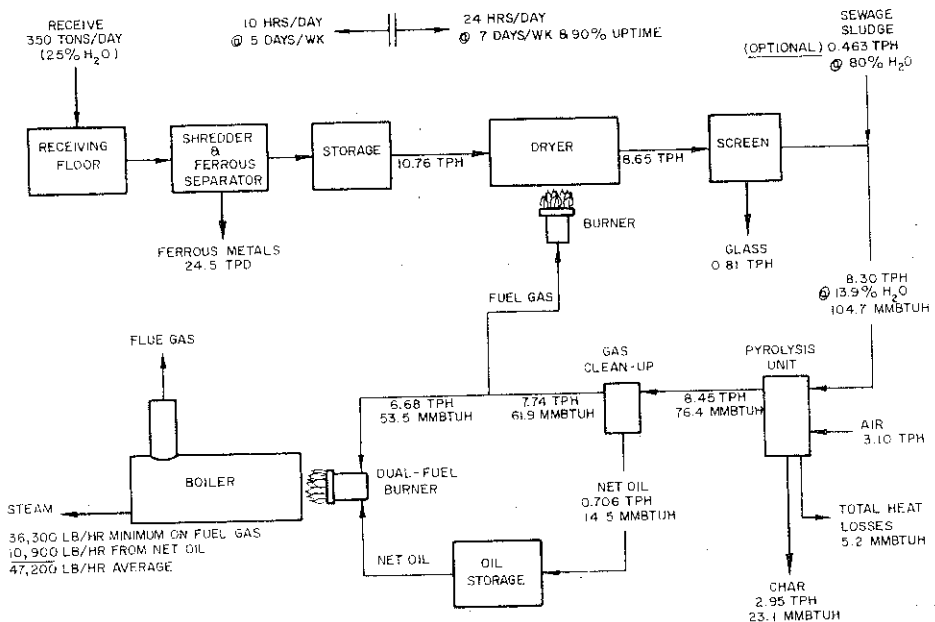
Fig. 8   Small community municipal refuse pyrolysis system-350 tons/day (3)

3.5 *Results*

Typical results of biomass pyrolysis conversion obtained from a small plant in an experiment in Indonesia and from a large plant in the U.S.A. are presented here. It is interesting to mention that the behaviours of the process in the small plant and in the large plant are similar.
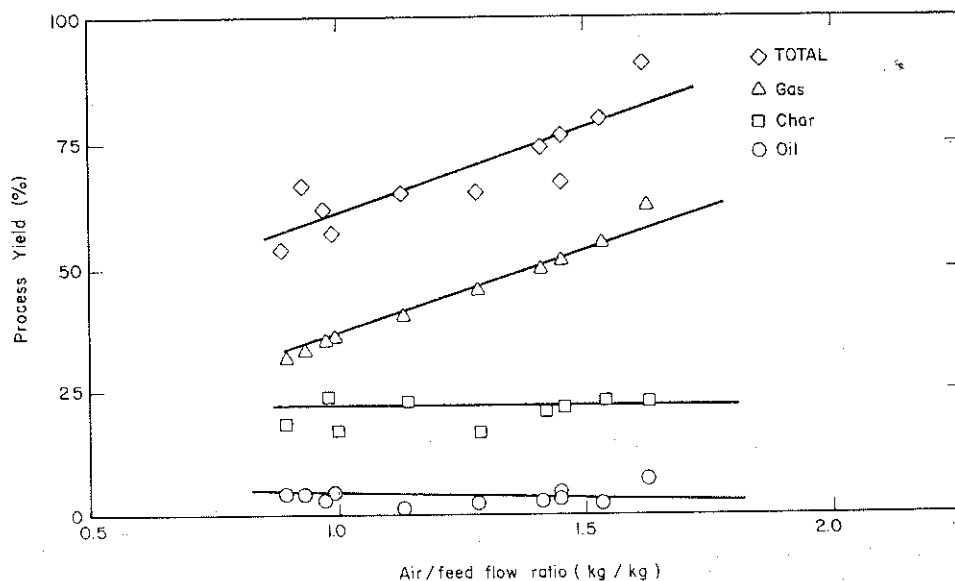

Fig. 9a   Yield at various air/feed flow ratios (8)

Information on the process with different feedstocks is also very interesting as the feedstocks affect product quality directly. The geometrical design of the converter is also very important as shown by the different qualities obtained from different plants.

The results of the Indonesian experiment are given first. Typical yields of char, oil and gaseous fuel from the pyrolysis of rice hulls at various air/feed flow ratios are given in Fig. 9a. This figure shows that increasing of air/feed flow ratio increases the gas produced but decreases the yield of oil.

Typical energy recoveries from the char, oil and gaseous fuel from the pyrolysis of rice hulls at various air/feed flow ratios are given in Fig. 9b. The figure shows that the total gas energy recovery increases but the energy recovery from the char is almost constant and that from the oil decreases as the air/feed flow ratio increases.

Typical average heating values of the char, oil and gaseous fuel from the pyrolysis of a mixture of pine bark and sawdust are given in Fig. 9c and Fig. 9d. The curves show that the heating value decreases as the char yield increases.

Mass and energy data are given for the pyrolysis of several wood feedstocks in Table 3, and for several kinds of dried municipal refuse in Fig. 9e.

Typical data for the oil from pine bark sawdust are presented in Table 4. At 26% moisture content, as shown in the table, the heating value is 21.1 MJ/kg, or approximately 21,000 MJ/m³, which is 60% of the heating value of No. 6 fuel oil.
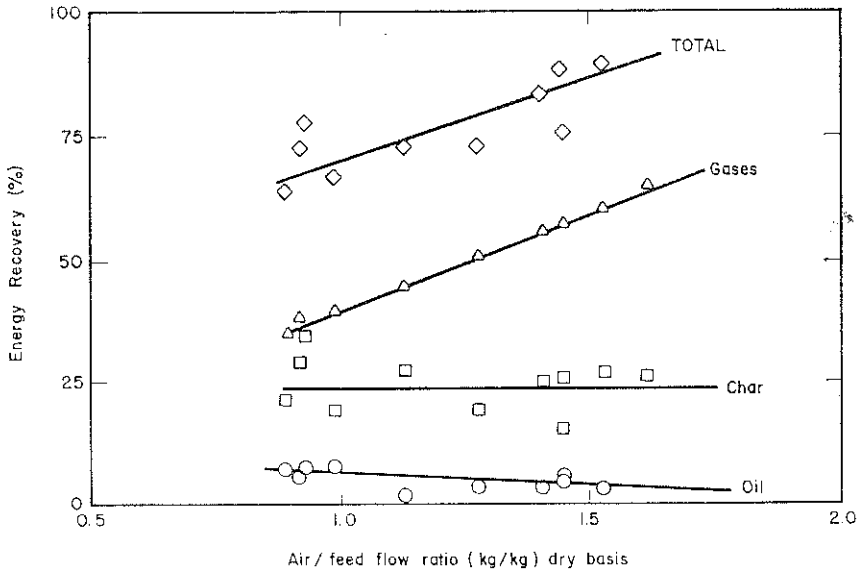
Fig. 9b   Energy recovery at various air/feed flow ratios (8)

Typical data for products from pyrolysis of single shredded, dried municipal refuse with metal removed are given in Table 5.   The fuel gas produced from garbage will vary as the physical characteristics and the composition of the refuse vary (3).
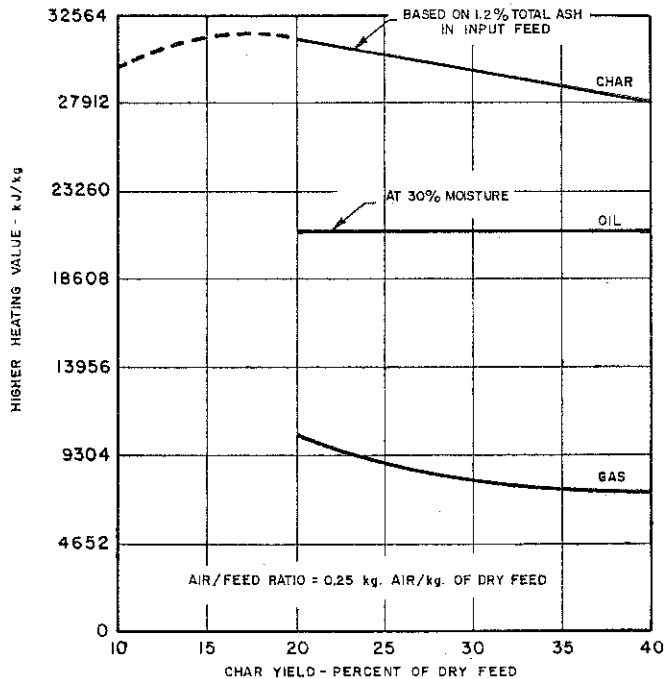

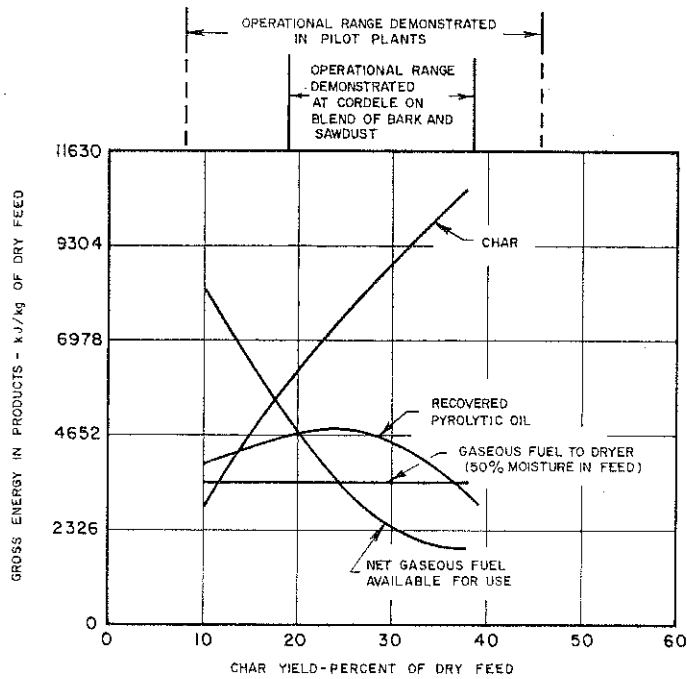Fig. 9c   Higher heating value of pyrolysis products from pine bark-sawdust mixture (3)

Fig. 9d   Energy distribution vs. char yield for product of pyrolysis from blend of pine sawdust and bark (3)
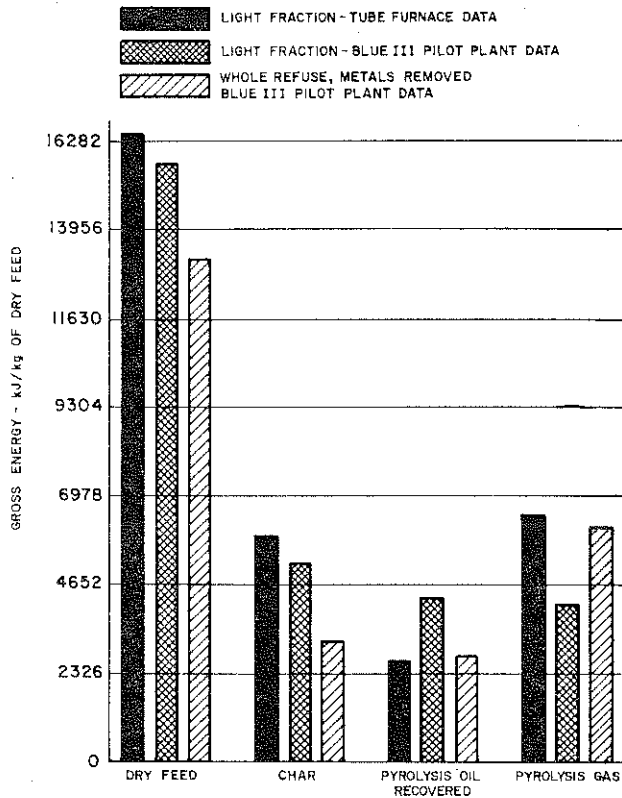
Fig. 9e   Energy balance for dried municipal refuse (3)

Table 3. Summary of mass and energy data for pyrolysis of several wood feedstocks

MATERIAL	HIGHER HEATING VALUE (DRY) (kJ/kg)	PERCENT MOISTURE	MASS YIELD (PERCENT OF DRY FEED)			ENERGY YIELD (kJ/kg OF DRY FEED)		
			Char	Oil	Fuel Gas	Char	Oil	Fuel Gas
Pine Tree Top Chips	22876	5.7	20.5	34.6	76	6120	8136	5745
Pine Tree Top Chips	22876	5.8	25.6	31.9	71	7936	7383	4622
Pine Bark-Sawdust	20555	1.4	20.5	19.2	103	6438	5068	7134
Pine Bark-Sawdust	20025	7.5	24.4	23.7	103	7701	5231	6869
Pine Bark-Sawdust	20150	13.5	38.2	17.5	111	10848	2503	5168
Pine Bark	20729	12.2	18.9	7.8	116	5634	1940	12212
Pine Bark	20471	7.4	45.7	12.8	88	13347	2873	3061

Table 4. Typical data for pyrolysis oil from pine bark-sawdust

ITEM	UNITS	VALUE
CHEMICAL COMPOSITION		
carbon	% by weight	49.4
hydrogen	,,	4.7
oxygen	,,	19.7
nitrogen	,,	0.16
water	,,	26.0
ash	,,	0.04
VISCOSITY		
@ 20°C	mm²/s	62
@ 38°C	,,	24
@ 55°C	,,	18
HIGHER HEATING VALUE	kJ/kg	21122
DENSITY	kg/m³	986 to 1025
FLASH POINT (Open Cup)	°C	128 to 152
POUR POINT	°C	-17

Table 5. Typical data for products from pyrolysis of single shredded, dried municipal refuse with metals removed (3)

OIL		
HIGHER HEATING VALUE	(kJ/kg)	24190
WATER CONTENT	(Wt. Percent)	30
DENSITY	(kg/m³)	948
FUEL GAS		
COMPOSITION (Wt. Percent)		
Water Vapor		26
Pyrolysis Oil		13
"Dry" Gas		61
HIGHER HEATING VALUE (kJ/kg)		7166
DENSITY at 93° C (kg/m)		0.8
HIGHER VOLUMETRIC HEATING VALUE		
at 93° C (kJ/m³)		5738
CHAR		
HIGHER HEATING VALUE	(kJ/kg)	9239
TOTAL ASH	(Wt. Percent)	69
ACID INSOLUBLE ASH	(Wt. Percent)	60
DENSITY	(kg/m³)	320

4. DISCUSSION

Use of Producer Gas

Heating

There is considerable scope and potential for the use of gas produced by gasification in heat exchangers and boilers in the process industries. Some of its uses are to fire open hearth furnaces, cement kilns, tunnel kilns for heavy clay industries, ceramic processes, glass melting, agricultural and industrial driers. It is also used in heating processes where clean gas and small diameter burners are essential.

A further advantage is that producer gas can directly replace natural gas, town gas or oil with simple modification of the boiler heat transfer areas and burner equipment (for cooking, etc.). The use of gas produced by gasification as a heat source can be applied in both small and large scale systems provided power is available to draw gases through them.

Power

The power generation from producer gas can use spark or compression ignition engines. The systems for generating motive power with producer gas using spark ignition engines can be fuelled with gas produced by gasification alone, whereas compression ignition engines should be fuelled with gas produced by gasification mixed with a fossil fuel.

Power generation using gas produced by gasification can be used for small scale (10 kW) or medium to large scale (10 kW-200 kW) systems. The choice of engines will depend almost entirely upon the size of the operaiton. For example, on the scale 200 kW and above, the use of dual fuel engines is attractive.

Application of the Products of Pyrolysis

Gas

Gas generated by a pyrolytic converter can be used for heating and power generation by using the same engines as mentioned above. However, since most agricultural and forestry wastes have a high degree of moisture content, the gas generated would be largely consumed for drying these materials at the plant site. The gas is burned as a fuel to supply heat to the dryer.

Oil

The use of pyrolysis oil as a fuel has been demonstrated. It also has a potential as a chemical raw material. Although the oil cannot at present be used directly as a fuel for cooking, drying, steam and electrical power generation and lighting, it has been sold commercially for use as a fuel in a cement kiln, a power boiler and a lime kiln.

Char

The char from the pyrolysis of wood and agricultural waste is widely used in the manufacture of charcoal briquettes.

Charcoal is commonly used for cooking and heating purposes in homes and shops.

Charcoal can be used for various industrial applications such as fuel for boilers and brick kilns, drying of agricultural products such as tobacco and grain, and as a fuel in lime and cement manufacture. It can also be used for the metal extraction of copper and iron.

Some charcoal can be made into activated carbon, which commands a much higher price in the world market than ordinary charcoal.

In addition, in the Georgia Institute of Technology, laboratory studies have demonstrated the effectiveness of the activated char from pyrolysis in removing colour from kraft mill effluents.

Comparison of Methods

The converters for gasification and pyrolysis are basically the same, but the gasification converter requires a more carefully designed geometrical configuration, and more strictly controlled operating conditions to ensure that the temperature profile in the converter produces drying, pyrolysis, oxidation, reduction, shift reaction, and methanation in the correct order. Moreover, the quality of the feed as regards homogeneity, water content, ash content, metal content, shape and size of particles, etc., must lie between closer tolerance limits for gasification than for pyrolysis. Consequently, more knowledge and skill is needed for operating gasification plants than for operating pyrolysis plants.

The product of the gasification process is a better quality fuel than the product of pyrolysis, being a gas of high net heating value and low tar content. The low tar content is important if the gas is to be used in engines.

The products of pyrolysis are mainly oil and char. It may happen that net heating value of the fuel from pyrolysis is higher than that of the gas from gasification. However, the productivity of the gasification process is much higher than the productivity of pyrolysis.

If some air is admitted to the converter during pyrolysis one can obtain gas, oil, and char. By this means fuels useful for a larger variety of different applications can be obtained.

To compare the two methods economic analysis is an important indicator. This may be different from one place to another. It depends on the materials of construction, labour, feed preparation and the general economy of the place. For example, at the moment, pyrolysis converters are more economical in Indonesia, because the oils produced have a high price for use to protect equipment made of wood as materials of construction, such as in boats.

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