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WOOD GASIFICATION FOR HEAT AND POWER THE PHILIPPINE EXPERIENCE

Ibarra E. Cruz, Ph.D.
Professor and Chairman
Department of Mechanical Engineering
University of the Philippines

ABSTRACT

The technology of wood gasification for heat and power in the Philippines is discussed, starting with research and development activities in 1968 in several institutions in the country (notably the University of the Philippines), the commercialization efforts to propagate wood charcoal gasifiers by the Gasifier and Equipment Manufacturing Corporation (GEMCOR) in 1981, the monitoring of performance of several gasifier-engine systems in actual field operation, a study commissioned by the World Bank in 1983, culminating with a survey of 64 gasifier installations and interviews with 29 gasifier owners in 1985 to determine the problems and hindrances to widespread use of gasifiers in the country. A number of gas producer systems are described and operational data presented. Experiences in marketing of the systems are recounted and reasons for the failure to propagate wide use of the technology are evaluated.

INTRODUCTION

Research work on wood and biomass gasification in the University of the Philippines started in 1968.* Theoretical and experimental work were carried out to gasify wood, coconut shells and coir (coconut fiber) dust with air or air-steam blasts in various designs of updraft and down-draft gasifiers. Mathematical models simulating the performance of air/oxygen/steam-blown gas producers, under various operating conditions, were developed and validated. Multiple projects were carried out to demonstrate the feasibility of gas producer technology for various heat and shaft power applications. Dual-fueled diesel engines were demonstrated in the field to irrigate farms and to provide power for post-harvest operations such as threshing of paddy and rice-milling. Oil-fired furnaces for a steam boiler and a ceramic kiln were retro-fitted with wood gasifiers and monitored for several weeks. Commercialization of the technology was initiated in 1980 with the establishment of GEMCOR, the Gasifier and Equipment Manufacturing Corporation, which in 1981 started mass producing wood and charcoal gasifiers for heat and shaft power applications. In the same year, the Energy Research and Development Center (ERDC) of the Philippine National Oil Company was established and its first thrust was to accelerate R&D efforts in biomass gasification.

RESEARCH AND DEVELOPMENT

Mathematical Models for Updraft and Downdraft Fixed Bed Gasifiers

Early R&D work employed a mathematical model to predict the performance of several designs of biomass gasifiers, building the hardware, testing and evaluating the performance of the gasifiers and validating the results of the model.

The mathematical model assumed a certain percentage approach to chemical equilibrium of the reactions taking place in the gasifier fuel bed at an equivalent reaction temperature obtained through a heat balance of the system. This reaction temperature would depend upon a number of factors, namely: the heating value of the solid fuel, its ultimate analysis, its moisture content, the mode of gasifier operation (updraft or downdraft), the 'composition and temperature of the gasification medium (percent O_2, N_2 and steam), the heat losses due to radiation and unburnt carbon in the ash residue. Table 1 shows examples of the calculated performance compared with experimental results.

The degree to which chemical equilibrium was attained by the heterogenous water-gas reaction $C + H_2O = CO + H_2$ is defined by the parameter y in the relation:

$$y * K_{pw} = \frac{[CO] * [H_2]}{[H_2O]}$$

where Kpw is the equilibrium constant for the heterogenous water-gas reaction at the calculated reaction temperature, and the gas components in brackets are the experimental wet gas composition in percent. Since actual H_2O in the gas could not be experimentally measured, it was estimated to be the same as the calculated equilibrium H_2O. The calculation of the equilibrium gas composition takes into account the degree of approach to equilibrium (in percent) defined as y in the above equation. The other reactions ($C + CO_2 = 2\,CO$ and $C + 2H_2 = CH_4$) are assumed to have reached 100% chemical equilibrium.

It is noted in Table 1 that for updraft gasifiers, the approach to equilibrium is low (from 30% in Gasifiers D to 37% in Gasifier B), while in the downdraft gasifiers, the approach to equilibrium is high (from 75% in Gasifier A to 100% in Gasifier C). This is so because in the downdraft gasifier, moisture and combined water in the fuel are forced down through the reaction zones in the bed and therefore have increased chances of undergoing reaction. In the updraft gasifier, unless steam is introduced with air as gasifying media, H_2O has little chance to react since moisture and combined water in the fuel are driven off in the drying zone which is

Table 1: Comparison of experimental results of gasifier performance with results of mathematical model

Gasifier A : Downdraft with 6-inch diameter throat and 20% radiation heat losses
Fuel A : Coconut Shell Charcoal (5% moisture)
Percent carbon with ash in the refuse: 60%
% Steam/Air : 0/100 (No steam in the gasification medium).

Gas Composition (Experimental Vs. Calculated)

	Experimental	**Calculated at Tr =693 °C**	
Percent by Volume	**Dry Gas**	**Dry Gas**	**Wet Gas**
% CO_2	6.5	6.5	6.4
% CO	24.5	24.9	24.4
% H_2	9.9	10.1	9.9
% H_2O	0.0	0.0	2.2
% CH_4	-----	0.1	01
% N_2	59.3	58.4	57.0
Sum	100.0	100.0	100.0
HHV, Btu/cu. ft.	117.	121.	119.
Cold Gas Therm. Eff..	61 %	62 %	
% Approach to Equil.			75 %

Gasifier B : Updraft with 8.5-inch diameter grate and 9% radiation heat losses
Fuel B : Coke (5% moisture)
Percent carbon with ash in the refuse: 5%
% Steam/Air : 17.4/82.6 (17.4% by vol. steam in the gasification medium.)
Gas Composition (Experimental Vs. Calculated)

Gas Composition (Experimental Vs. Calculated)

	Experimental	**Calculated at Tr =729 °C**	
Percent by Volume	**Dry Gas**	**Dry Gas**	**Wet Gas**
% CO_2	4.9	5.0	4.8
% CO	29.9	29.5	28.5
% H_2	11.2	11.8	11.3
% H_2O	0.0	0.0	3.6
% CH_4	-----	0.1	0.1
% N_2	54.0	53.6	51.7
Sum	100.0	100.0	100.0

Table I (cont'd.)

HHV, Btu/cu. ft.	140.	143.	138.
Cold Gas Therm. Eff..	75 %	78 %	
% Approach to Equil.			37%

Gasifier C : Downdraft with 20-inch grate diameter and 12% radiation heat losses
Fuel C : Wood (Leucaena) with 5% moisture
Percent carbon wifh ash in the refuse: 20%
% Steam/Air : 0/100 (No steam in the gasification medium.)

Gas Composition (Experimental Vs. Calculated)

	Experimental	Calculated at Tr =611 ^{o}C	
Percent by Volume	**Dry Gas**	**Dry Gas**	**Wet Gas**
% CO_2	15.3	15.1	14.1
% CO	14.8	14.4	13.4
% H_2	17.0	16.0	14.9
% H_2O	0.0	0.0	6.6
% CH_4	1.0	0.9	0.9
% N_2	51.9	**53.6**	50.1
Sum	100.0	100.0	100.0
HHV, Btu/cu. ft.	119.	114.	106.
Cold Gas Therm. Eff..	68 %	71 %	
% Approach to Equil.			100%

Gasifier D : Updraft with 20-inch grate diameter and 14% radiation heat losses
Fuel D : Wood (Leucaena) with 4% moisture
Percent carbon with ash in the refuse: 2%
% Steam/Air : 0/100 (No steam in the gasification medium.)

Gas Composition (Experimental Vs. Calculated)

	Experimental	Calculated at Tr =721 ^{o}C	
Percent by Volume	**Dry Gas**	**Dry Gas**	**Wet Gas**
% CO_2	15.3	15.1	14.1
% CO	14.8	14.4	13.4
% H_2	17.0	16.0	14.9
% H_2O	0.0	0.0	6.6
% CH_4	1.0	0.9	0.9
% N_2	51.9	**53.6**	50.1
Sum	100.0	100.0	100.0

Table 1 (cont'd.)

HHV, Btu/cu. ft.	131.	132.	127.
Cold Gas Therm. Eff..		76%	
% Approach to Equil.			30 %

near the top of the fuel bed. Thus, in updraft Gasifier D, with no steam in the gasifying medium but with wood fuel containing 4% moisture and about 50% combined water by weight (ultimate analysis of wood is 48.5% C, 6.0% H, 44.4% 0, 1.0% Ash), the approach to equilibrium was only 30%. On the other hand, in updraft Gasifier B2 with 17.4% steam in the gasifying medium and coke as fuel (89.7% C, 0.5% H, 0.1% N, 0.9% S, 7.0% Ash) the approach to equilibrium improved to 37%, but still on the low side, since coke is relatively less reactive compared to charcoal or wood. In the downdraft air gasification of charcoal (71.6% C, 3.9% H, 21.6% O, 2.9% Ash) in Gasifier A3, there was no steam used but moisture and combined water were respectively 5% and 25% by weight of the dry fuel. Approach to equilibrium of the heterogenous water-gas reaction was relatively high at 75%

Note also that in the downdraft reactor the percentage carbon in the refuse was high 60% and 20% in gasififers A and C respectively) compared to the updraft reactor 5% and 2% in gasifiers B and D respectively).

In the above calculations, equilibrium temperature was determined from a heat balance of the gasifiers system and is regarded as a pseudo-temperature that has no physical significance. In order to get a picture of the variation of temperature and gas composition relative to fuel bed depth, a kinetic model was developed based on both diffusional and chemical rates of reaction of carbon with oxygen and steam. Figure 1-A shows the gas composition profile and Figure-1-B that of the gas and solid temperature profiles. Note that downdraft dry air gasification of charcoal (or wood) containing moisture and combined water would be equivalent to air-steam gasification of Carbon. (Compare predicted exit gas composition in Figure 1-A with that obtained in Table 1., Gasifier A).

DEMONSTRATION PROJECTS

Direct Heat Applications

Research work on biomass gasification in U.P. started in 1968, even before the onset of the oil crisis in the early seventies. Experiments were carried out in 1969 to gasify wood, coconut shells and coir dust with air and with air/steam mixtures in an updraft gasifier with a one-square-foot grate area.[4] Coconut shells were gasified with air (with or without steam) into producer gas with a net calorific value of 130 Btu/cu ft. The raw producer gas, together with the tar evolved with the gas during the gasification process, was burned efficiently in a furnace to supply heat for a mechanical dryer for copra. The coconut shells recovered from copra-making were more than enough to meet the fuel requirements of the copra dryer. The surplus shells

Figure 1A. GAS PROFILE

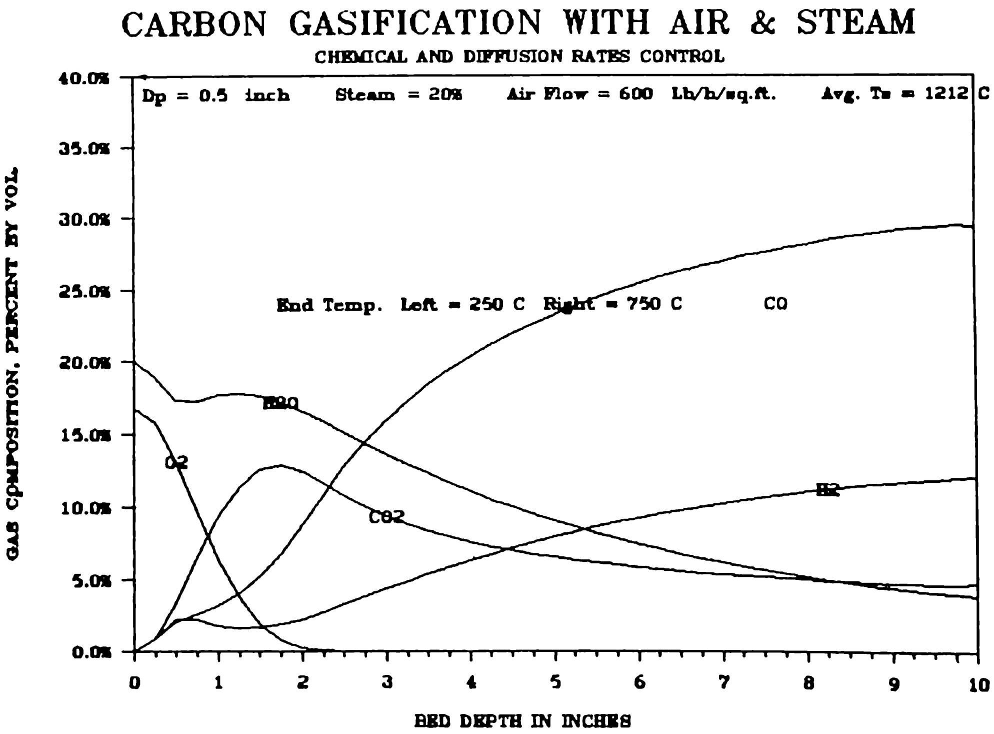
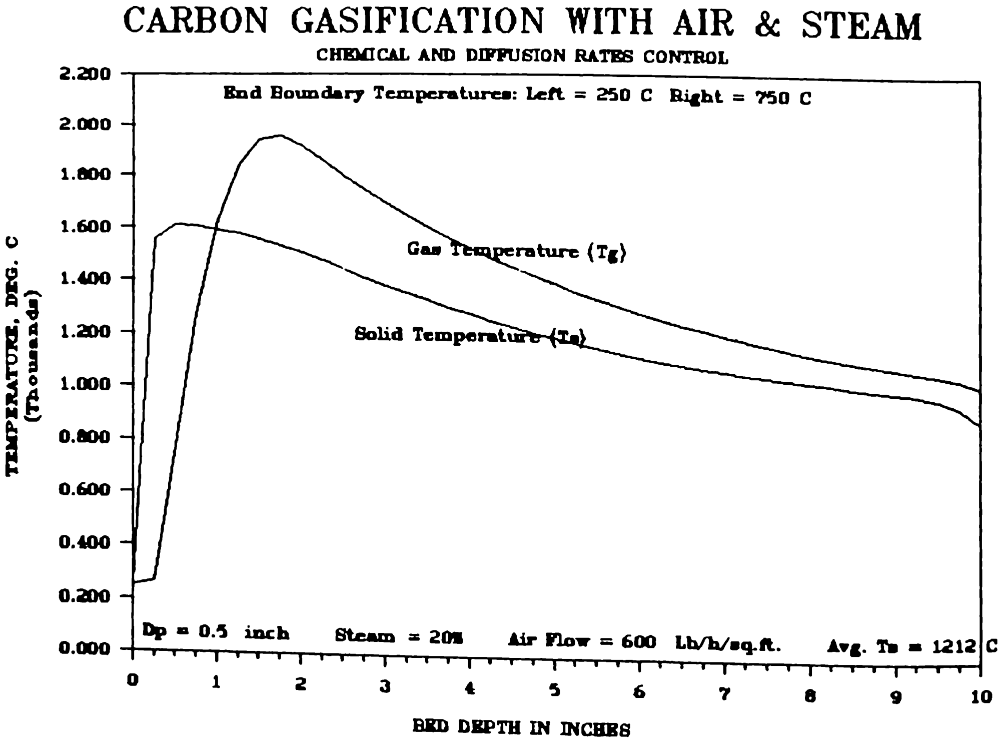


Figure 1B. TEMPERATURE PROFILE



could be carbonized into charcoal. Producer gas from coir dust could be used for coir fibre drying. Its utilization was a solution to the problem of coir dust disposal.

The results of these early experiments were helpful in the design of a larger gas producer with a grate area of one square meter (10 sq ft). This was retro-fitted to a 100-BHP boiler to burn producer gas from coconut shells.[1] This project was funded by the National Institute of Science and Technology (NIST) in 1974. The gas producer could be operated in either updraft or downdraft modes. Steam from the boiler was used in a steam engine and electric generator set to generate 35 kW of electricity for some 5 hours of operation. A serious problem encountered was the fusion and clinkering of the ash on the grate at a gasification rate of about 80 lb/h/ft^2 of grate area. A solution to this problem was to saturate the air-blast with moisture thus cooling down the ash layer as the moisture-laden air passed through it during it during updraft operation. Another solution tried was to operate the gas producer in the downdraft mode.

In 1985, the tunnel kiln of a local ceramic factory was retro-fitted with a 76-centimeter grate diameter, downdraft wood gasifier. The tunnel kiln burned 54 liters of bunker oil per hour through 6 oil burners (3 burners on each side of the kiln). Complete substitution of bunker oil with producer gas was not possible without increasing the exhaust gas fan capacity. Therefore, only 3 of the oil burners on one side of the kiln were replaced with producer gas burners. The 24-hour per day operation was monitored for 10 days with a recorded average wood consumption of 101 kilograms per hour and bunker oil consumption was reduced by 57% to 23 liters per hour. The required furnace temperature of 1130 ^{o}C was maintained.

Shaft Power Applications

The first project on shaft power application was on the use of charcoal as fuel for a small downdraft gas producer supplying gas to a 5-BHP diesel engine.[3,5] Initially, liquified petroleum gas (LPG) was used in the engine to gage its performance as a dual fuel engine. Figure 2-A compares the performance of the engine on straight diesel with that on dual fuel at varying percentages of energy from LPG. Figure 2-B shows the performance of the engine at 4 brake-horsepower (BHP) as a function of the net calorific value of producer gas. The engine could run at its rated capacity of 5 BHP on 90 percent of the input fuel energy supplied from producer gas if the net calorific value was 130 Btu/cu ft or above.

One practical application of producer gas for shaft power is in farmland irrigation. The National Irrigation Administration (NIA) saw the potential of increased farm productivity if the farmers could avail of cheap fuel for irrigation. Thus in 1978, NIA together with the Ministry of Energy funded a project to demonstrate the feasibility of operating a 65-BHP diesel engine on dual fuel (diesel and producer gas from charcoal) to irrigate 40 hectares of riceland in Siniloan, Laguna.[6] During the dry months of February to May, 1979, the engine was run continuously for 8 hours a day, two days a week on dual-fuel mode. Diesel fuel saved or displaced by charcoal was 59 percent. As a demonstration project, this was considered successful and it led to the implementation of a bigger irrigation project applying producer gas technology. This was undertaken by the Farm Systems Development Corporation (FSDC) in the early 1980's with the establishment of an affiliated company, the Gasifier and Equipment Manufacturing Corporation (GEMCOR) which mass-produced charcoal gasifier units for stationary engines and for vehicles.

Figure 2A

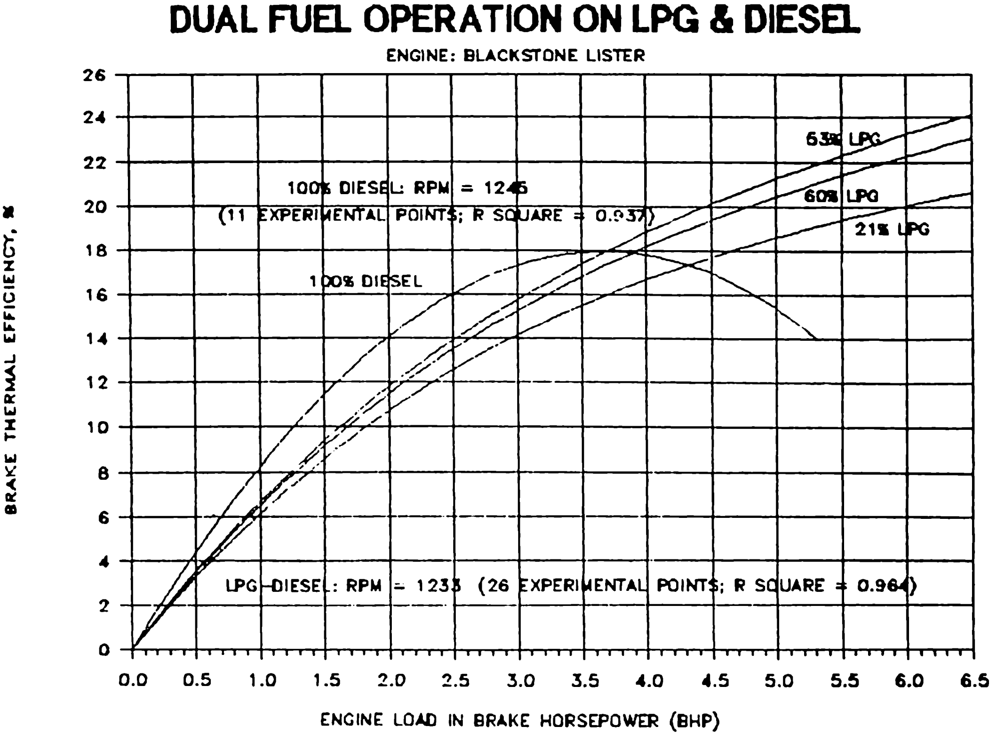
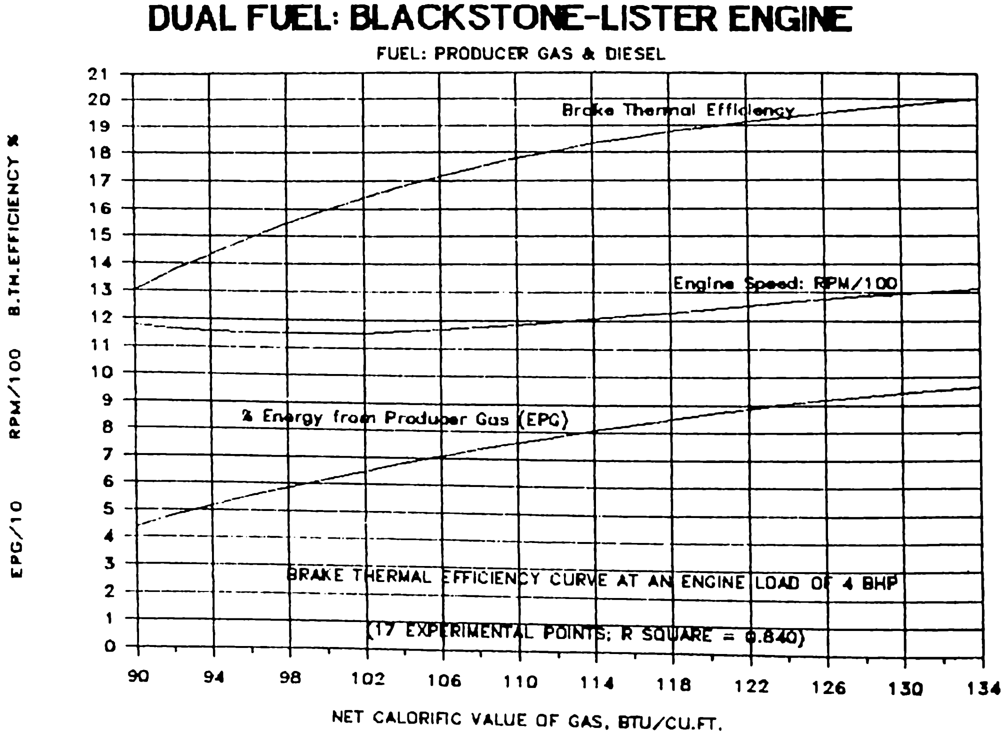


Figure 2B



Meanwhile, studies on the use of other fuels aside from charcoal were undertaken. Specifically, wood and agricultural residues such as corn cobs, coconut husks and rice hulls were studied. The reports indicate that these fuels could be successfully gasified and used to run internal combustion engines for a limited number of hours and save significantly on gasoline or diesel. Figure 3-A and 3-B compare the performances of a 4-cylinder gasoline engine (Toyota 12R) on gasoline, LPG and producer gas from various solid fuels.

But a common problem identified at an early stage was how to clean sufficiently the raw producer gas to remove, in particular, tar which fouled up the intake valves of the engines. A study to address this problem was undertaken by the U.P. College of Engineering from 1983 to 1984 in which was developed a rice husk-gas producer design with two combustion zones and a rather complex gas cleaning train. This design was adapted by the Philippine National Oil Company-Energy Research and Development Center (ERDC) in a demonstration project implemented in a rice mill in San Carlos City, Negros Occidental in the southern part of the Philippines, to test the use of a rice husk-fueled producer gas and diesel engine system to power the mill. The gas cleaning train was made up of several components. The cyclone filter eliminated most of the char and ash entrained by the gas, while a rice-hull-ash filter removed most of the fine dust. The condenser lowered the temperature of the gas and condensed tar and other liquids in the gas. Another dry filter containing either rice hull or char trapped additional tar. A water scrubber and an oil bath filter removed almost all of the remaining tar from the gas.

Performance data when the gasifier was hooked up to a 45-kW diesel engine-generator set at the ERDC gasifier test facility showed an average diesel fuel displacement of 62%, with a maximum displacement of 70% at about one-half of rated generator capacity. Rice hull consumption was an average 2.75 kilograms per kilowatt-hour (kg/kW-h). Tar in the gas, measured qualitatively by means of a cloth filter installed after the second oil bath filter, was observed to be minimal.

The gas producer-engine system (excluding the generator) was connected to the 15-cavan-per-hour cono ricemill in Negros Occidental. The pilot system started providing power to the ricemill on November 15, 1986 and had been in operation for a total of 300 hours during which time performance data was closely monitored. Average diesel fuel oil displacement was 77% with a minimum of 70% and a maximum of 82%. Rice hull consumption was approximately 32 kilograms per hour, while specific gasification rate was 82 kilograms per square meter of grate area per hour. The system operated for an average of 7.5 hours a day, with a maximum of 9.5 hours.

Although the system apparently worked well in so far as tar removal and diesel fuel saving was concerned, latest reports indicated that the mill stopped using the gasifier-engine system because of high maintenance cost. The gas cleaning train was so elaborate that reliability and simplicity in operation was not achieved. Subsequent researches undertaken by ERDC addressed further these problems.[8]

Figure 3A

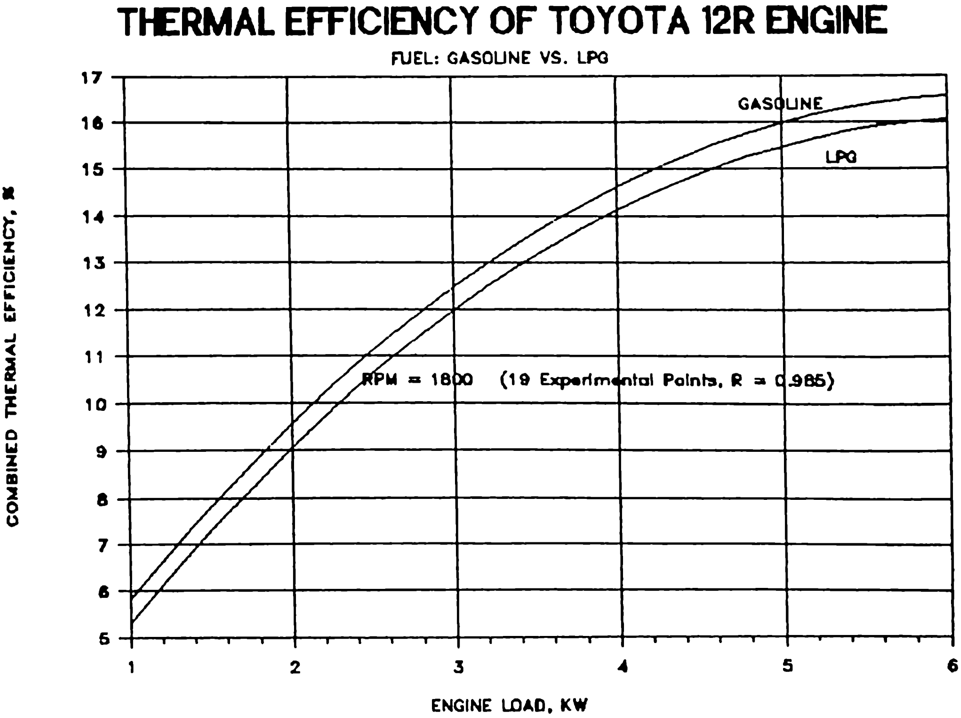
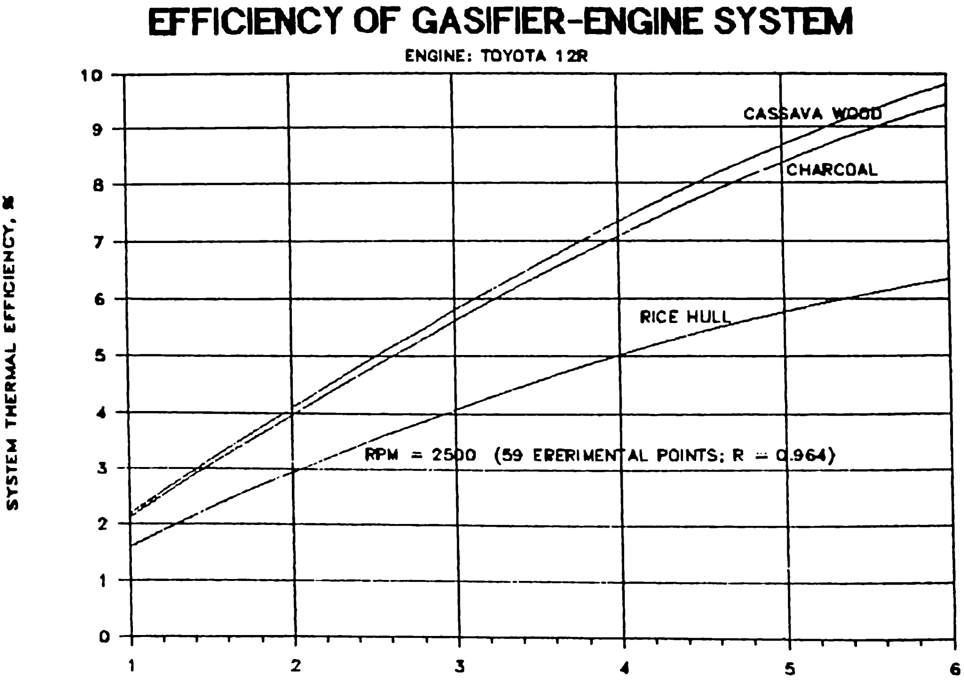


Figure 3B



COMMERCIALIZATION OF GASIFIERS IN THE PHILIPPINES

Initial Success of GEMCOR

In 1981, the Gasifier and Equipment Manufacturing Corporation (GEMCOR), a government entity, was established for the purpose of commercializing the gas producer technology. The decision to commercialize was based upon the following considerations:[9]

1. Applied research data were already available prior to 1980 from research institutions like the University of the Philippines.

2. There was a felt need to assist farmers using diesel engine pump irrigation systems in looking for viable alternative energy technologies which can be introduced to existing projects as a means of enhancing rural development.

3. The market potential of the gasifier existed not only for irrigation engine-pump systems but also for other shaft power and direct heat applications.

4. There was strong support from the national leadership coupled with a strong determination from cooperating agencies and concerned individuals to fully develop and disseminate the technology.

From 1981 to 1983, GEMCOR sold a total of 1083 gasifier units, 25 of these were for direct heat applications (furnaces and the rest (1058) for internal combustion engine systems of capacities ranging from 16 horsepower to 250 horsepower. The gasifiers were retro-fitted not only to stationary engines, but later on to vehicle engines.

GEMCOR registered profits in 1981 up to the year-end of 1982. It would seem that the commercialization efforts were successful. This was not to be the case. By 1983, technical troubles of installed gasifiers reached such a proportion that placed GEMCOR engineers under tremendous pressure. In that year, GEMCOR landed in the top ten losing government corporations. In December 1985, the GEMCOR plant closed down.

Reasons for the Failure of Commercialization

An analysis of the GEMCOR gasifier program cited several reasons for its failure.[10] Causes of a firm's failure may be due to any or a combination of the following factors: (1) **Market**, (2) **Product**, and (3) **Management**.

As far as market was concerned, there was indeed a marketing opportunity for oil-saving technologies at the time. The primary target was the various Irrigator's Service Associations (ISA) in the country, organizations among farmers formed with the support of the government and which had installed some 334 diesel engine-driven pumps since 1975, ranging in capacities from 10 to 200 kilowatts. The government-set price for the gasifier and gas-cleaning equipment (average of US$75 per kilowatt of engine capacity) was reasonable to the associations and many farmers were willing to buy and indeed bought gasifier equipment.

As far as the product was concerned, the gasifier for stationary engine systems was the primary product line of the corporation, and although these had several technical problems still, they were not major ones that could not have been resolved with further research. However, GEMCOR later on embarked on the manufacture of gasifiers for vehicle installations. It was discovered too late that these were not at the commercial stage of development and in fact were troublesome judging from the numerous complaints from customers who bought them for their vehicles. GEMCOR could have fared better had they concentrated on its original objective of commercial development and propagation of stationary gasifier installations where at least a number of successful applications have been cited in a subsequent gasifier survey (see section below).

The third factor, management or the lack of it, was though to have been the real cause of failure. There was speculation that the corporation did not escape from the scourge of graft and corruption that plagued the country at the time. It was alleged that the corporate goals were not clearly defined and were rather focussed on the self-interest-seeking behaviour of corporate managers.

Other reasons for failure of the commercialization efforts were implied in one of two major gasifier surveys conducted in the Philippines.

GASIFIER SURVEYS

World Bank/UNDP Survey

A World Bank/UNDP Gasifier Monitoring Project in the Philippines was implemented from 1983 to 1984, aimed at monitoring and compiling uniform global data on the performance, safety and public acceptability of biomass gasifiers.[11] The project selected four sites from a list of about 300 existing small stationary gasifier installations throughout the country, following selection guidelines provided by World Bank/UNDP. The four sites selected consisted of three irrigation pumping systems with capacities ranging from 272 to 681 cubic meters of water per hours, and one 75-kilowatt diesel engine-generator electric plant supplying power to a rice mill. All installations used wood charcoal gasifiers to supply producer gas to diesel engines in dual-fuel operation. Except for the electric generating plant which stopped operation due to technical problems, data collection for the three other plants were completed and reported. The diesel engine load varied from 5 to 15 kilowatts and the diesel fuel displacement from 47% to 90%. The corresponding fuel cost savings for each installation ranged from P0.70 to P8.75 per hour or 5% to 26% (averaging 18%) of normal fuel cost when using straight diesel based on the then current price of diesel and charcoal of P6.48 per liter and P23 per sack of 18.5 kilograms respectively. Twenty-two Philippine pesos (P22.00) is equivalent to US$1.00.

Gasifier Survey by the Office of Energy Affairs

In 1985, the Office of Energy Affairs commissioned a survey-engineering study of gasifiers in the Philippines to get an idea of problems encountered by users of gasifiers in the country.[12] The survey included 64 gasifiers for shaft power and direct heat applications owned by 29 companies/individuals in 7 widely distributed regions in the Philippines. The gasifiers surveyed used mainly charcoal, woodchips, coconut shells/husks. The highlights of the survey results are enumerated as follows:

- Out of 64 gasifiers, field researches were able to interview respondents for 45 gasifiers (22 of which were found to be operating and 23 were found not operating). Of the 45 gasifiers, 14 were used for irrigation, 10 for power generation, 19 for drying or direct heating, and 2 for ricemilling.

- Average monthly usage of gasifiers ranged from 40 hours per month to 480 hours per month. The majority of gasifiers were used for 180 hours per month.

- Ten of the 45 gasifiers reportedly operated for 240 to 260 hours per month. Of these 10, eight were used for irrigation.

- The single major problem cited in 15 of the 22 gasifiers which claimed to have unresolved problems was the clogging of feedstock in the reactor. Other problems cited were inefficient/ incomplete gasification (three of the 22 gasifiers) and spot reddening on reactor sides (two of the 22 gasifier).

- Respondents for 42 of the 45 gasifiers claimed that they did not have any significant safety problems.

- Average monthly expenses for gasifier maintenance and spare parts ranged from 250 to 900 Pesos (U.S.$ 11 to U.S.$ 41). The most mentioned amount ranged from 250 to 300 pesos (U.S.$11 to U.S.$14). Average monthly expenses for equipment maintenance and spare parts ranged from 100 to 500 pesos (U.S.$5 to U.S.$23) with the most mentioned amount ranging from 150 to 300 pesos (U.S.$7 to U.S.$14).

- None of the engines coupled with gasifiers had any major overhaul. Only 3 of the 26 engines coupled to gasifiers had top overhauls and these were done every 6 months.

- The most commonly preferred feedstock was charcoal primarily due to its abundant supply and higher Btu content. Thirty-nine of the 45 gasifiers used charcoal for feedstock. Other feedstock used included coconut shell/husk (two gasifiers), chopped wood (one gasifier) and wood chips (one gasifier).

- Of the seventeen owners/operators of gasifiers interviewed representing 45 gasifiers, 4 owners/operators were generally satisfied with their gasifiers (13 gasifiers), five were unsatisfied (21 gasifiers), and eight were either neutral or did not express their satisfaction with their gasifiers.

In summary, on the basis of the results of field surveys, the major findings are:

1. Gasifiers field tested did not actually generate cost savings when compared to alternative systems that could deliver the same required power output.

2. There seemed to be a general lack of technical field support on the current gasifier program. Technical support would be particularly needed in the operations of the gasifier relating to the reactor, gas cooling system and filtration.

3. There were various improvements that could still be made on the current features of the available gasifiers in the market as indicated by the various innovations that had been made by some of the owners. The more significant modifications included enlargement of the reactor, addition of another reactor in the system to ensure continuous operation during fuel loading, change in the filter media and size, installation of a water or oil bath scrubber, and installation of a spray cooling tower.

CONCLUSION

Over 20 years have passed since research work on biomass gasification was resumed in the Philippines in 1968 (some work was done during World War II) and much work still needs to be done to come up with a truly reliable system for shaft power applications.

When charcoal was used as fuel, problems were minimized which was a basis for GEMCOR's decision to mass produce charcoal gasifiers in 1981. The units worked well initially, for instance those retro-fitted to diesel engine irrigation pumps, but when problems arose later on, GEMCOR lacked the back-up services needed by the farmers to keep the gasifiers operational. As a result, engines were run on straigth diesel more often than on dual fuel. The economics became unfavorable and disillusionment with the technology became widespread.

In the GEMCOR operations, research and development was somewhat neglected after initial installations were apparently successful. Continuous efforts should have been made to improve the reliability of a few designs, in particular those applied for stationary engine use. The resources of GEMCOR had been dissipated and spread too thinly when it embarked on developing numerous models that included units for mobile or vehicle applications.

Future research and development points towards concentrating more intensively on stationary gas producer systems, both for shaft power and direct heat applications. There is a need to improve the design of specific reactors to gasify non-charcoal fuels, such as wood, corn cobs, coconut husks, rice hulls and other agricultural residues that are plentiful in various regions. It is also important to improve the performance of the gas cleaning system, to bring down the cost of its fabrication and to make the system truly reliable. In commercializing the technology, the target should not only be the Philippine market but the whole Southeast Asian and Pacific region.

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