CONVOCATION PDWA1657

RICE RESIDUE UTILIZATION TECHNOLOGY
MARKET PROSPECTS: U.S. AND OVERSEAS

January 28-29, 1988

Postharvest Technology Divisi
International Programs
LSU Agricultural Center
Baton Rouge, Louisiana

INTERNATIONAL PROGRAMS
LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER

POSTHARVEST TECHNOLOGY DIVISION

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January 28, 1988

Convocation
Rice Residue Utilization Technology
Market Prospects: U.S. and Overseas

Dear Participant,

Welcome to the Louisiana State University Agricultural Center. We appreciate your taking time off from your busy schedule to attend this convocation. We are confident that your participation and contribution will be very valuable to us all. Enclosed in this packet are an agenda, several charts and copies of papers that will be presented. To those of you who need transportaion, vans will be available at the front of the LSU Agricultural Center or the Ramada Hotel. Messages will be handled at the registration desk. Parking is available at the back of the LSU Agricultural Center. If you need any assistance please contact the registration desk or anyone wearing a purple name tag. We hope you enjoy the convocation and your stay in Baton Rouge.

Sincerely,

Lakshman Velupillai
Project Coordinators

Brett W. Craig

TELEX: TWX 5109933217 INT AGR BTR

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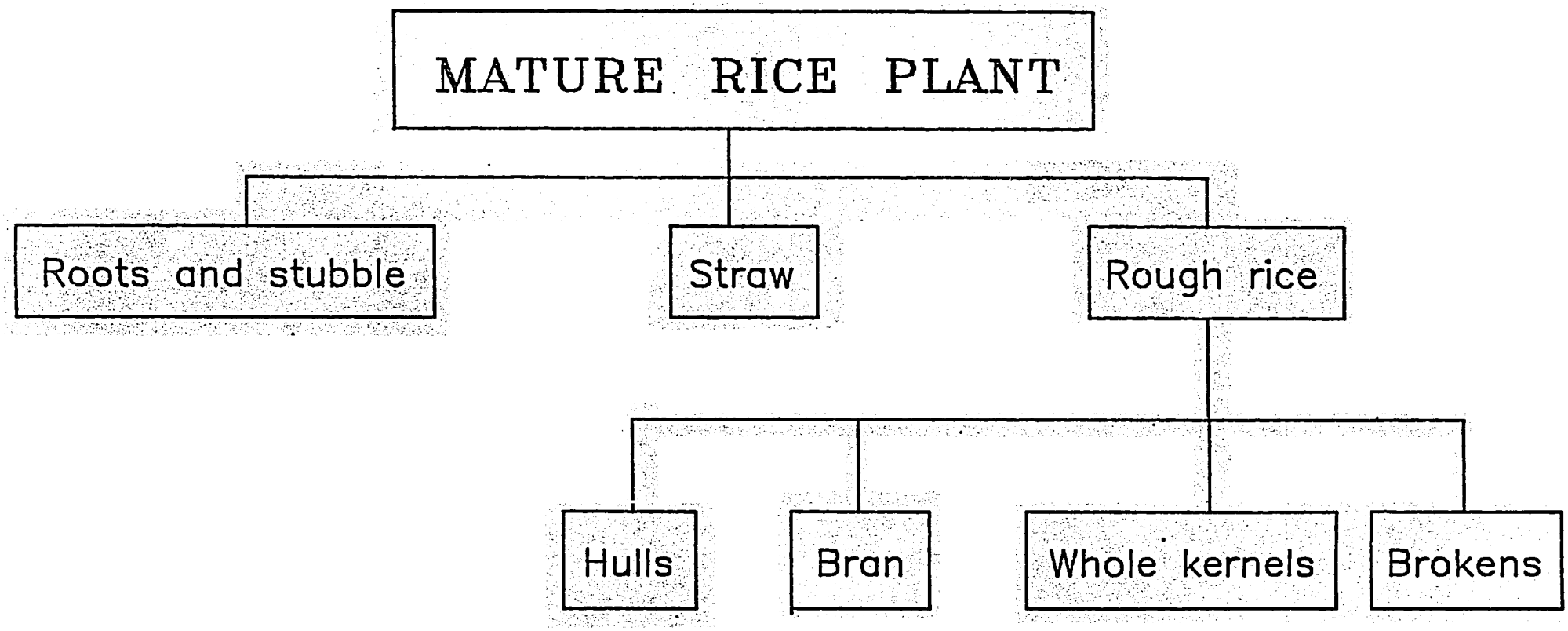
MATURE RICE PLANT
Roots and stubble
Straw
Rough rice
Hulls
Bran
Whole kernels
Brokens

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RESOURCE – ROUGH RICE & STRAW

Environmentally acceptable technologies for conversion

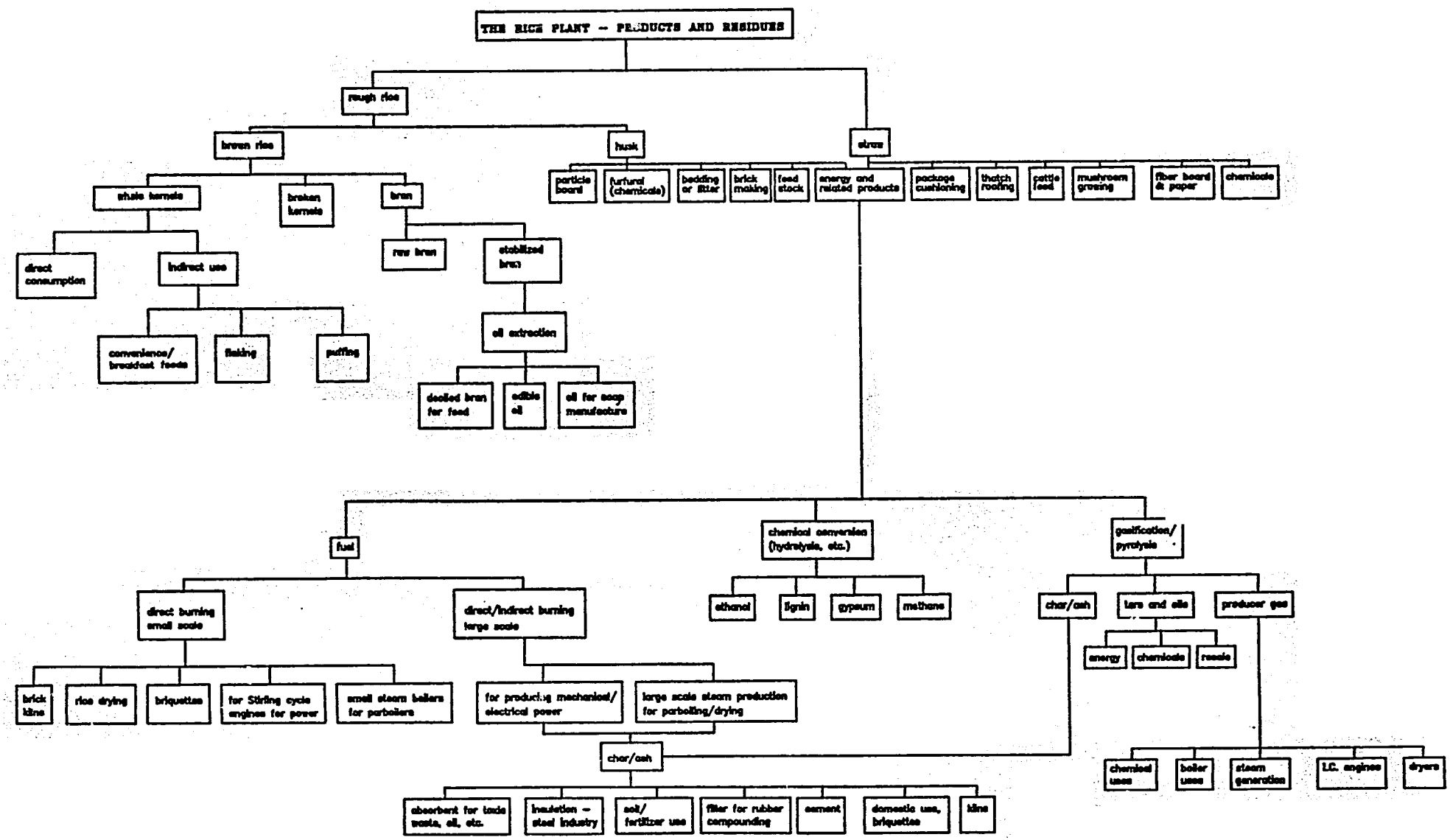
Edible rice

Direct energy

Byproducts

- Food/feed
- Fuels
- Chemicals
- Other products

4


THE RICE PLANT – PRODUCTS AND RESIDUES
rough rice
brown rice
husk
straw
whole kernels
broken kernels
bran
direct consumption
indirect use
convenience/ breakfast foods
flaking
puffing
raw bran
stabilized bran
oil extraction
deoiled bran for feed
edible oil
oil for soap manufacture
particle board
furfural (chemicals)
bedding or litter
brick making
feed stock
energy and related products
package cushioning
thatch roofing
cattle feed
mushroom growing
fiber board & paper
chemicals
fuel
chemical conversion (hydrolysis, etc.)
gasification/ pyrolysis
direct burning small scale
direct/indirect burning large scale
ethanol
lignin
gypsum
methane
char/ash
tars and oils
producer gas
energy
chemicals
resale
brick kilns
rice drying
briquettes
for Stirling cycle engines for power
small steam boilers for parboilers
for producing mechanical/ electrical power
large scale steam production for parboiling/drying
char/ash
chemical uses
boiler uses
steam generation
I.C. engines
dryers
absorbent for toxic wastes, oil, etc.
insulation – steel industry
soil/ fertilizer use
filler for rubber compounding
cement
domestic use, briquettes
kilns

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Rice Bran As A Potential Source Of Higher Value Chemicals

Robert N. Sayre, Research Chemist
Food Quality Research Unit, Western Regional Research Center
ARS, USDA, Albany, California

The annual world rice production is about 466 million metric tons (MMT) of rough rice. Approximately 25% of this production is processed through two stage mills to produce rice bran suitable for further processing. If bran is calculated at 8% of rough rice, then 9 MMT of rice bran is theoretically available for extraction and processing. The corresponding figure for the U.S. would be somewhat less than 490,000 MT of rice bran.

There is increasing interest throughout the rice growing areas of the world to make better use of rice bran. The most obvious potential is to extract the high quality oil contained in the bran for food use and to use the defatted bran as a stable feed ingredient. However, there are other higher value products that can be recovered from both the oil and the defatted bran. Japan is presently about the only place where chemical products are being manufactured from rice bran.

The following are products which either are in production or could be produced under favorable economic conditions.

1. Edible rice bran oil
2. Free fatty acids
3. Glycerol
4. Oryzanol
5. Phospholipids
6. Wax
7. Sterols, tocopherols, triterpenes
8. Defatted rice bran
9. Phytin (calcium magnesium phytate)
10. Phytic Acid
11. Inositol
12. Calcium phosphate di-basic
13. Activated sludge

Product Prices in Japan (September, 1987) ($/Lb.)

Rice Bran Oil	.39
Free Fatty Acids	.28
Oryzanol (normal)	19.44
Oryzanol (high campesterol)	64.80
Defatted Rice Bran	.08
Phytic Acid	3.60-5.80
Inositol	8.10-14.58
Calcium Phosphate	.23

Rice Bran Oil:

Rice bran oil has unusual oxidative stability under frying conditions. This is due not only to the tocopherol content of 0.04%, but to other more powerful antioxidants which are esters of ferulic acid. These esters comprise much of the unsaponifiable materials which amount to 4.2% in crude rice bran oil. Part of these compounds are retained through the refining process. The major use for rice bran oil in Japan is in commercial frying operations.

Free Fatty Acids:

Palmitic, oleic, and linoleic acids comprise 95% of the fatty acids in rice bran oil. These can be fractionated to give various melting point ranges and other characteristics. Fatty acids are used in the manufacture of paints, soaps, cosmetics, and pharmaceuticals.

Oryzanol:

Oryzanol is apparently a mixture of ferulic acid esters of various triterpenes and sterols. Crude rice bran oil contains 1-2.5% of these compounds. Oryzanol has been reported to have various hormonal-like effects on the autonomic nervous system and to have beneficial effects on the skin. Oryzanol is marketed for use in medicine, cosmetics, food additives, veterinary medicines, and feed additives.

Phytic Acid:

Rice bran contains 6.5-7% phytin (calcium-magnesium salt of phytic acid). This can be extracted from the defatted bran as phytic acid with dilute sulfuric acid. Phytic acid is a strong chelating agent and antioxidant. It is used in food processing in Japan, but is not on the GRAS list in the U.S. Phytic acid is used in offset printing and as a corrosion and rust inhibitor on metals. It is also used to improve the adhesion of paints to metals.

Inositol:

Inositol is derived from phytic acid by removing the phosphoric acid groups. Inositol comprises about 27% of the weight of phytic acid. Inositol is used in vitamin mixes, food and feed additives, medicines, and cosmetics. Consumption in the U.S. is currently about 300 MT/yr.

Calcium Phosphate Di-basic:

This is a by-product of inositol production from phytic acid. It is used as a feed additive and fertilizer. Another use is in the manufacture of bone china, since no heavy metals are present.

Defatted Rice Bran:

This product contains 16-18% protein, is over 30% dietary fiber, and since no oil is present, has excellent storage stability. It is mainly used in feed mixes, but could also be used as a food ingredient. Other uses in Japan are for fermentation media, and seasoning vegetables.

Phospholipids are not presently isolated from the gums in Japanese rice bran oil processing and the gums are mixed back into the defatted bran for use as animal feed. Soybean oil processing produces a larger supply of phospholipids which meet present market demand. Likewise, waxes generally are not refined in Japan due to economic considerations. The waxes are mixed with heavy mineral oils and used for fuel.

GASIFICATION OF RICE HULLS

Development of a Five-Horsepower Gasoline Engine Rice Hull Gas Producer System

John R. Goss, Professor
Department of Agricultural Engineering, UC Davis

INTRODUCTION

Beagle estimated in a 1976 publication that one-half of the approximately 60 million tons of rice hulls from the annual world rice production was used for energy or other purposes. He stated that India uses 40 percent of its annual rice hull production to produce steam for parboiling rice. The potential use for rice hulls as gas producer fuel to operate small diesel and gasoline engines is indicated by the number of small rice mills in Indonesia (20,000) and the Philippines (10,000) as reported by Goss and Creamer. Pumping water for flooded rice culture is an additional potential use. India is reported to have 8 million small tube wells pumped with engines or electric motors rated at about 5 horsepower. In the Philippines, the total market potential for small scale stationary gas producers was estimated to be 32,000 units. It was projected that the Gasifier and Equipment Manufacturing Corporation (GEMCOR), a Philippine Government Agency, would produce 28,800 gasifiers for small engines between 1983 and 1989. This projection will not be achieved because of the difficulties encountered with the biomass gasification effort in the Philippines.

OVERVIEW OF RICE HULL GASIFICATION AT U.C. DAVIS

The need for biomass-based energy supply for small engines in Developing Countries and the availability of rice hulls in these countries, as noted above, was the basis for initiating research to meet this need in 1981 with support from the Briggs and Stratton Corporation and the U.S.A.I.D. Office of Science and Technology during 1983-1985. In 1983, Kaupp completed an extensive study of the physical and chemical properties of rice hulls which resulted in his development of a unique, down-draft type gas producer to gasify rice hulls (Albrecht Kaupp: Fig. 10-34). A worldwide survey conducted by Goss and Stephenson in 1983 revealed the complete lack of commercial or successful operating, small-scale research gas producers fueled with rice hulls.

In 1986, Creamer documented the performance of a 5 hp. single cylinder, gasoline engine* operated with producer gas generated from rice hulls in an improved model of the system developed by Kaupp (Kurt S. Creamer, et al.: Figs. 12 and 14). Since the batch-fed, rice hull gasifier required refueling at intervals of 1 1/2 to 2 hours of engine operation there was a need to develop a system for continuous operation. In 1986, Tiangco reported the development and testing of such a design, accumulating 134 hours of engine operation (Valentino M. Tiangco, et al: Fig. 4). The reactor built by Kaupp for his studies was used by Creamer and Tiangco. These three researchers are estimated to have operated the initial reactor for more than 200 hours without any deterioration of the reactor components. Creamer found the optimum spark advance to be 23 degrees before top-dead-center. Both Creamer and Tiangco found the engine to develop 40 to 45 percent of the rated engine power at 3600 rpm when fueled with producer gas generated from rice hulls. The engine brake thermal efficiency ranged from 16 to 20 percent. Because the gas producer-gas clean-up system had a low pressure drop (around 25 mm of water) and cooled the gas to about 5 to 7°C above ambient temperature, equipping the engine with compression ratios greater than the normal value of 6.2 to 1 was the next logical step to improve overall system performance.

INFLUENCE OF COMPRESSION RATIO ON ENGINE PERFORMANCE

The principal reasons for increasing engine compression ratio are to improve brake thermal efficiency and brake mean effective pressure (hence, brake power). Brake mean effective pressure (bmep) is expected to increase with increasing compression ratio, at least within the knock limited region for most spark ignited engines, as shown by considering the influence of compression ratio on indicated mean effective pressure (imep) and friction mean effective pressure (fmep). Both imep and fmep will tend to increase

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* Briggs and Stratton 5 hp Gasoline Engine Specifications

Model	132432
Type	0111-01
Rated HP	3.7 kW (5 hp) @ 3600 rpm
Displacement	206 cc (12.571 in^3)
Bore	61.0875 mm (2.5625 in)
Stroke	61.9125 mm (2.4375 in)
Compression Ratio	6.2 to 1
Connecting Rod	98.4250 mm (3.8750 in)

with increasing compression ratio. At lower compression ratios, improvements in imep will dominate, while at higher compression ratios, the fmep begins to offset gains in imep. Increasing compression ratio also serves to reduce clearance volume, thereby increasing the heat addition to the cycle for any fixed cylinder displacement. Taylor indicates that compression ratio can also have an influence on volumetric efficiency by causing an increase in volumetric efficiency with increased compression ratio when the exhaust pressure is higher than the intake pressure.

ENGINE TEST RESULTS FOR THREE COMPRESSION RATIOS

In 1987 Camacho completed a study of the influence of compression ratio on engine performance.

A new 5 hp. engine with the standard 6.2 compression ratio head was first "run-in" for about 10 hours on gasoline at 1/4, 1/2 and rated power. The producer gas compression ratio tests added another 54 hours of engine operation. The engine was modified for the 7.3 and 8.2 compression ratio tests by machining two production-line cylinder heads that had not been milled for the standard 6.2 compression ratio.

The engine performed best at the 7.3 compression ratio in that for all test loads, very small and infrequent load or combustion air adjustments were needed to maintain a constant speed (Inigo R. Camacho, et al.: Fig. 7). For the 6.2 and 8.2 compression ratio, these adjustments were made frequently to control the engine speed. For most of the tests, the amount of CO in the engine exhaust gas ranged from 0.35 to 0.55% while the hydrocarbons ranged from 0.15 to 0.50 ppm. The combustion chamber and spark plug showed very little carbon deposit at the end of the tests. The spark plug closely resembled that of an engine fueled with LP or natural gas. Rice hull char was the filter material in the packed bed filter (See Tiangco, Fig. 4).

The lower heating value of the producer gas induced by the engine averaged 3801 kJ/m^3 (102 Btu/ft^3) and ranged from 3652 to 3877 kJ/m^3 (98 to 104 Btu/ft^3). Lower quality gas was produced with the 6.2 compression ratio and improved at the higher compression ratios. The best quality gas (3877 kJ/m^3, 104 Btu/ft^3) was for one of the 7.3 compression ratio tests when one reactor of fuel was used for the speed range starting at 3600 rpm and ending at 2400 rpm in 200 rpm steps. The molecular weight of the gas changed very little. However, a small change in the hydrocarbon concentration has a large effect on the lower heating value of the producer gas. The 7.3 compression ratio increased the brake power over the standard 6.2 compression ratio by 13.5% at 2600 rpm and nearly 19% at 3600 rpm. Similarly, the increase for

the 8.2 compression ratio ranged from 8% at 2600 rpm to 11.6 percent at 3200 rpm and then dropped to 9.3% at 3600 rpm. This result is not expected from a theoretical standpoint and likely indicates deficiencies in combustion chamber and valve configuration.

CONCLUSIONS

1. A specialized, downdraft-type gas producer system has been developed and extensively tested with rice hulls for fueling small gasoline engines. The system is made from standard steel stock components, requires no auxiliary power to operate and can provide gas fuel for continuous engine operation.

2. Standard gasoline engines will be derated 55 to 60 percent. The required spark advance for optimum power from rice hull generated producer gas is 23 degrees before top-dead-center.

3. An increase of around 20% in the brake power was achieved with the 7.3 compression ratio in comparison to the standard 6.3 compression ratio for the 5 hp Briggs and Stratton engine. This compression ratio gave the best engine-gas producer performance in terms of speed stability at each of the fixed loads.

4. Combustion chamber deposits from producer gas fueling were similar to those for gasoline fueling, indicating that the gas clean-up system provided clean gas.

REFERENCES

Camacho, I. R., J. R. Goss and B. M. Jenkins. 1987. Compression Ratio Effect for a Gas Fueled Engine, for presentation at the Pacific Region Meeting, American Society of Agricultural Engineers, ASAE Paper #87-0107.

Creamer, K. S. and B. M. Jenkins. 1986. Small Scale Rice Hull Gas Producer-Gasoline Engine Performance, for presentation at the 1986 Summer Meeting, American Society of Agricultural Engineers, ASAE Paper #86-3071.

Kaupp, A. 1984. Gasification of Rice Hulls, Theory and Praxis, a publication of GATE, Vieweg & Sohn, Federal Republic of Germany.

Tiangco, V. M., B. M. Jenkins, J. R. Goss and W. J. Chancellor. 1986. Design and Development of a Continuous Small-Scale Rice Hull Gas Producer, for presentation at the 1986 Summer Meeting, American Society of Agricultural Engineers, ASAE Paper #86-3070.

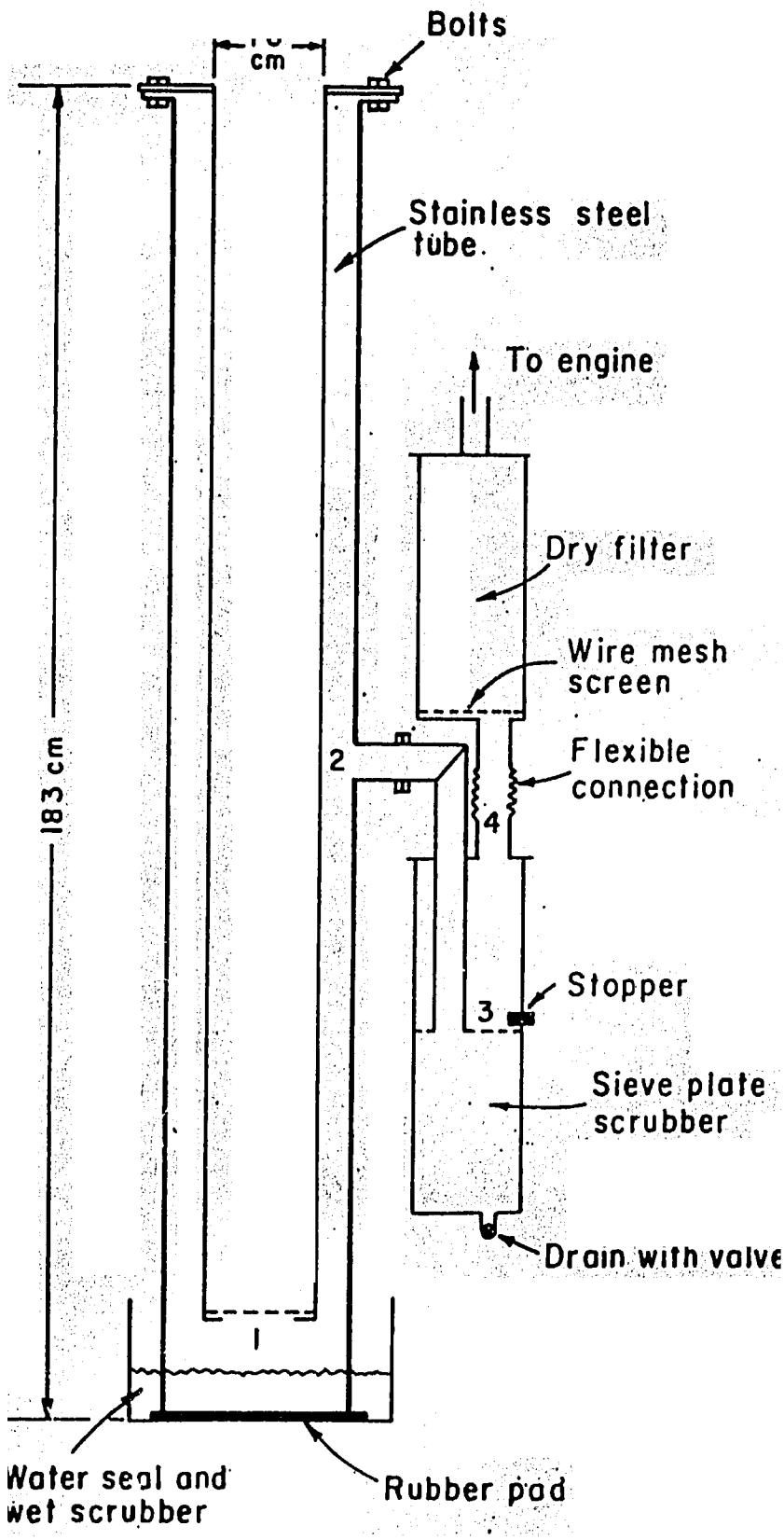

Figure 10-34. Batch fed gas producer without ash removal
1, 2, 3, 4 location of thermocouples.

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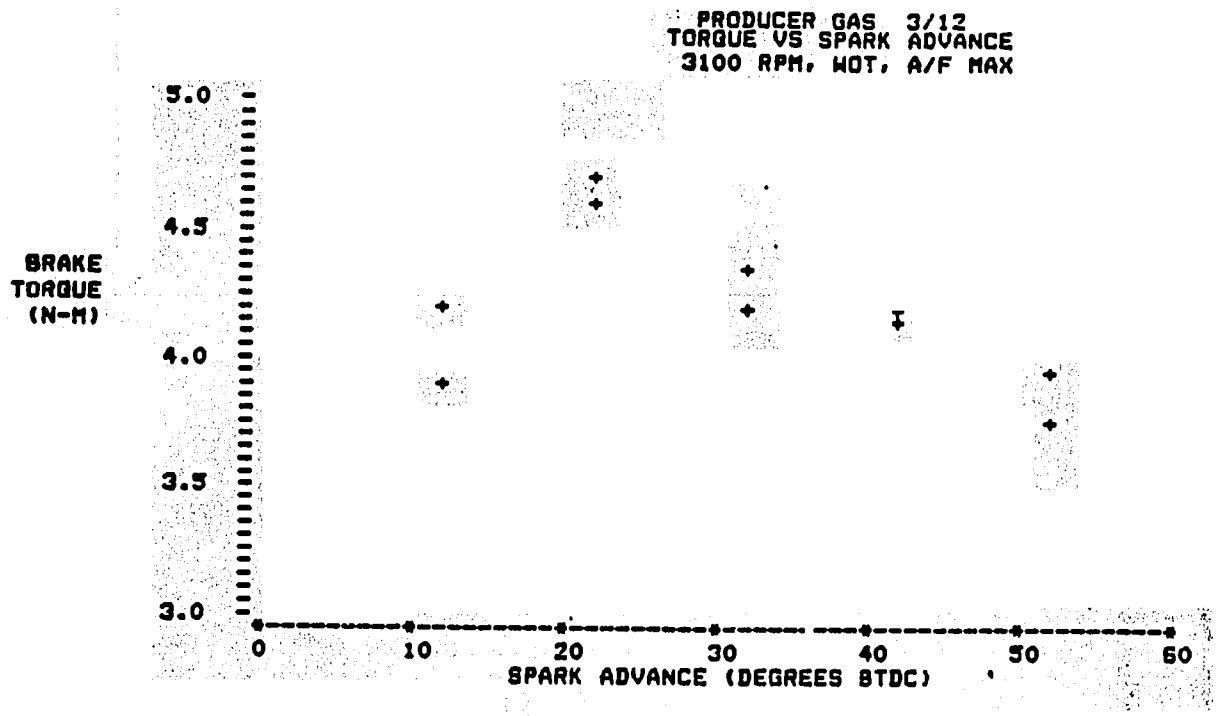


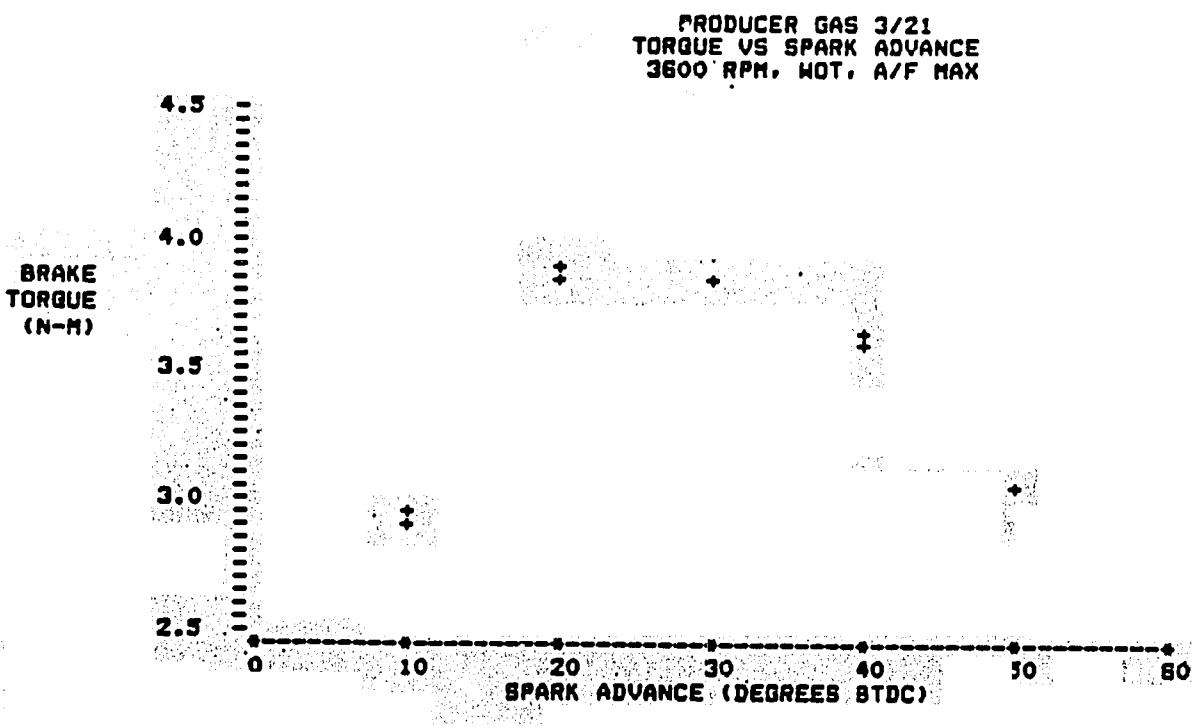


Fig. 12 Torque vs. spark advance at 3100 and 3600 RPM on producer gas.

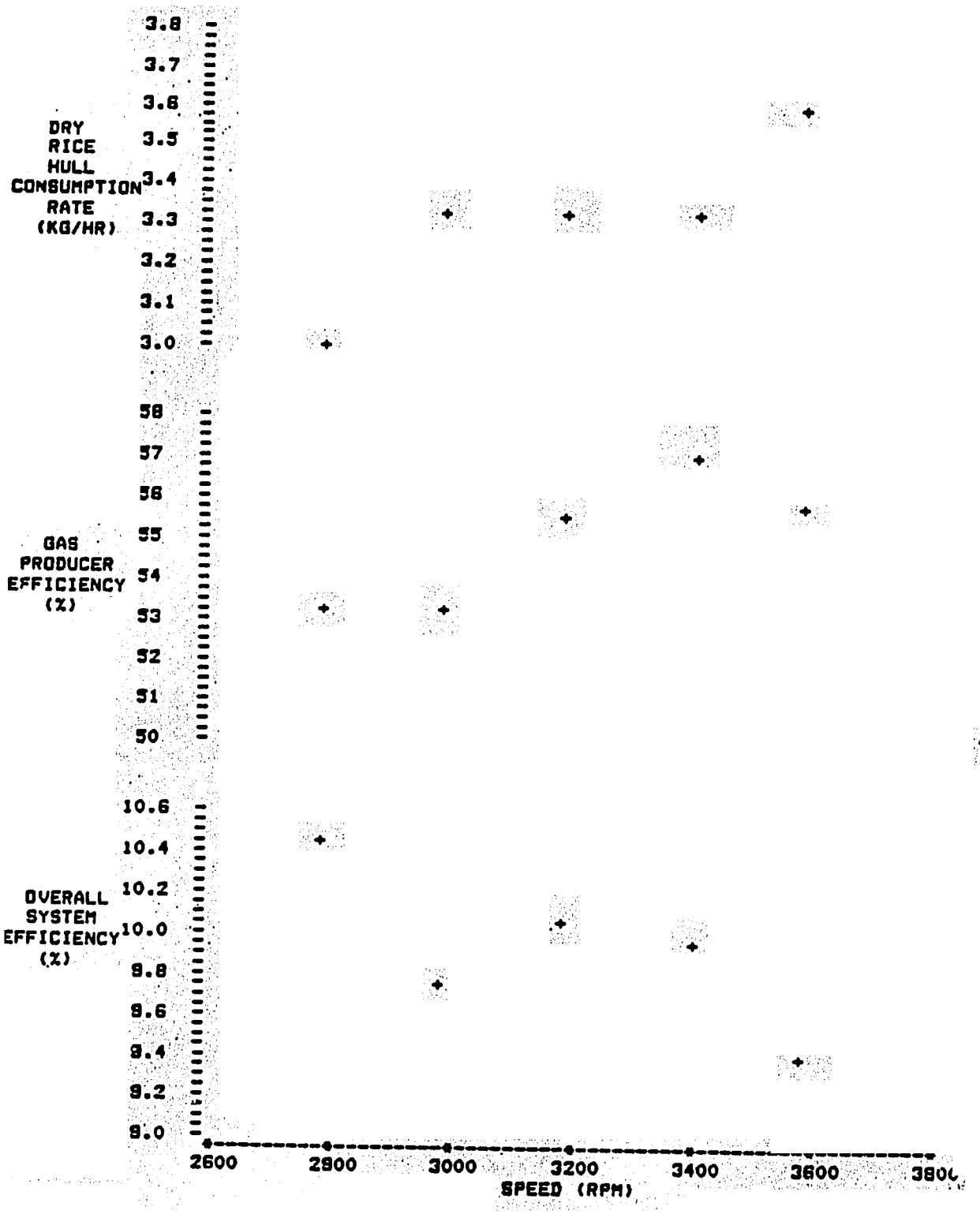
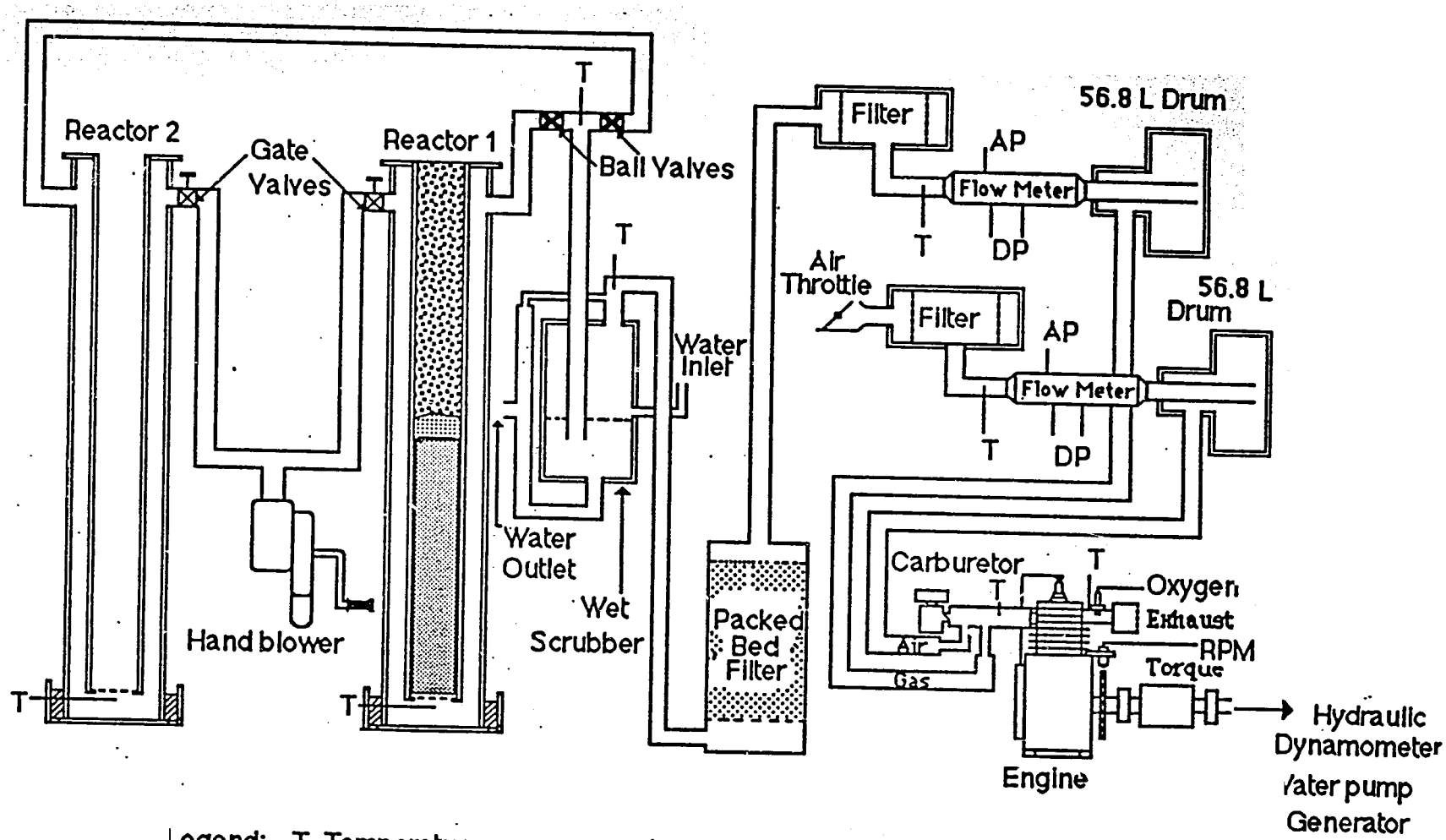


Fig. 14 Gas producer performance and overall system efficiency vs. engine speed.



Legend: T- Temperature measurement
DP-Differential pressure measurement
AP- Absolute pressure measurement

Fig. 4 Instrumentation and test set-up of dual reactor rice hull gas producer-engine system

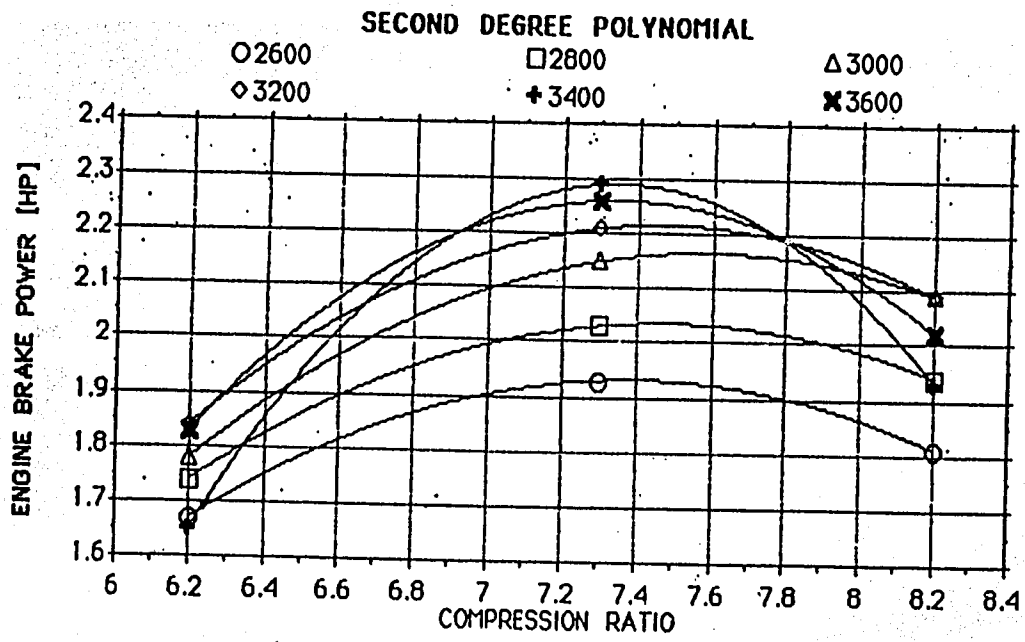


Fig. 7. Corrected engine brake power (hp). Data from Table 5 with compression ratios 7.3a and 7.3b deleted

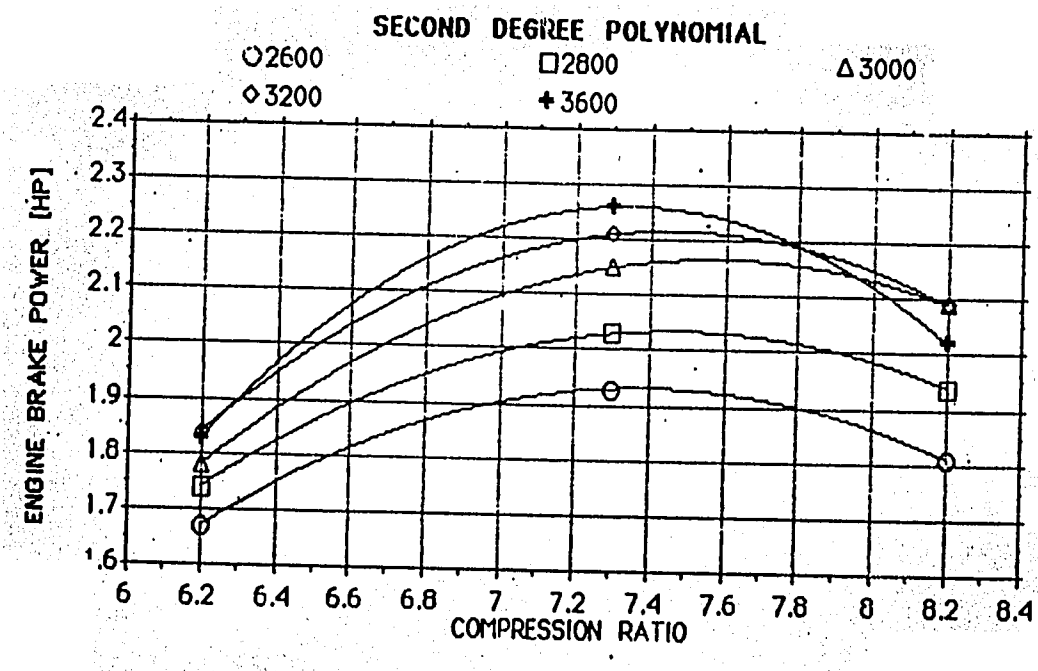


Fig. 8. Corrected engine brake power (hp). Data from Table 5 with compression ratios 7.3a and 7.3b and 3400 rpm deleted.

GAS TURBINE COGENERATION WITH AGRICULTURAL RESIDUES

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Viewgraphs for presentation at the

Convocation on Rice Residue Utilization Technology
Market Prospects: U.S. and Overseas

Louisiana State University Agricultural Center
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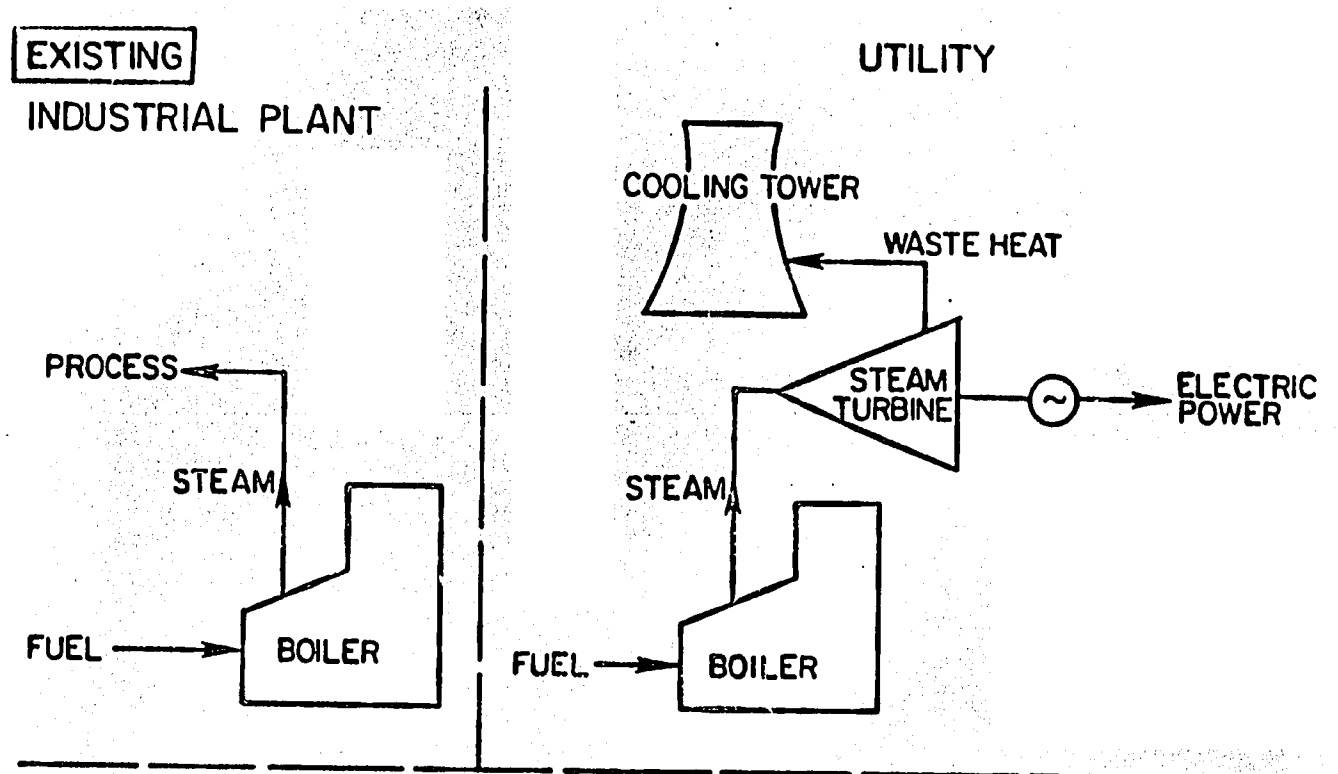
CEES APPROACH TO TECHNOLOGY ASSESSMENT

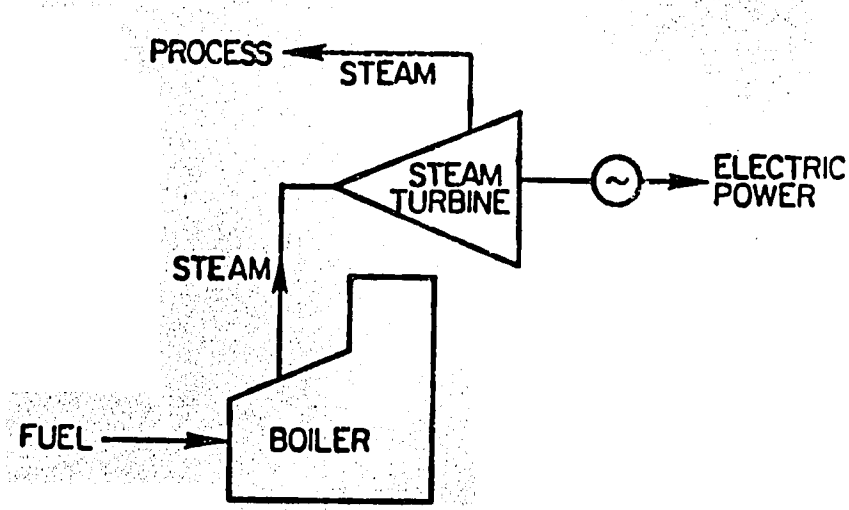
- IDENTIFY PROMISING <u>NEAR TERM</u> TECHNOLOGIES WHICH
  - ARE PRESENTLY UNEXPLOITED OR UNDEREXPLOITED
  - COULD HAVE LARGE IMPACT IF SUCCESSFULLY DEVELOPED
- CARRY OUT IN-DEPTH TECHNICAL, ECONOMIC, AND INSTITUTIONAL ANALYSIS
- OUTREACH TO POTENTIAL PRODUCERS AND POTENTIAL USERS

CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES
TECHNOLOGY ASSESSMENT ACTIVITIES

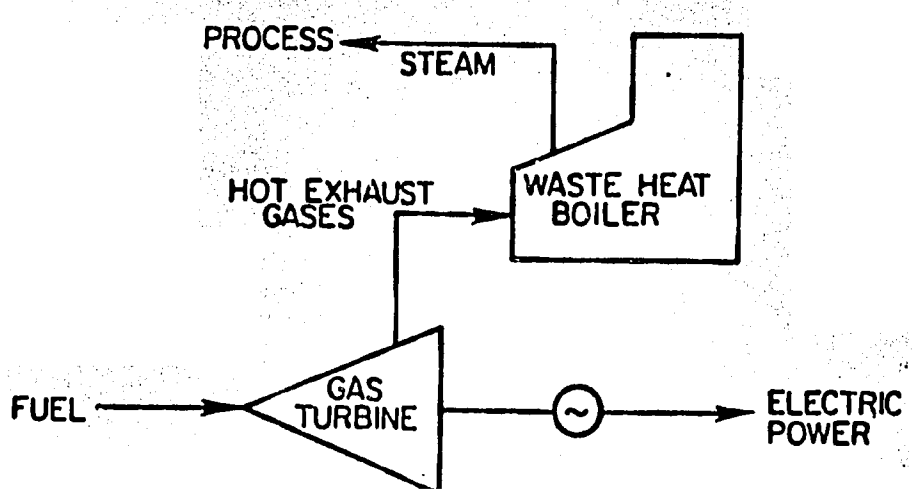
- STEAM-USING TECHNOLOGIES FOR SUGAR FACTORIES
- NEW ELECTRIC MOTOR TECHNOLOGIES
- NEW BUILDING COOLING TECHNOLOGIES
- ENERGY EFFICIENT FUELWOOD COOKING STOVES
- ADVANCED GAS TURBINES FOR
  - CENTRAL-STATION BASELOAD POWER (GAS FIRED)
  - CENTRAL-STATION BASELOAD POWER (COAL-FIRED)
  - INDUSTRIAL COGENERATION (GAS FIRED)
  - ⟶ INDUSTRIAL COGENERATION (BIOMASS-FIRED)
  - COMMERCIAL/RESIDENTIAL COGENERATION (GAS FIRED)



BETTER COGENERATION AT INDUSTRIAL PLANT VIA STEAM TURBINE



EVEN BETTER COGENERATION AT INDUSTRIAL PLANT VIA GAS TURBINE



WHY GAS TURBINE COGENERATION ?

====> LOWER UNIT CAPITAL COSTS THAN STEAM TURBINES

====> WEAKER SCALE ECONOMIES THAN STEAM TURBINES

====> HIGHER THERMODYNAMIC EFFICIENCY THAN STEAM TURBINES

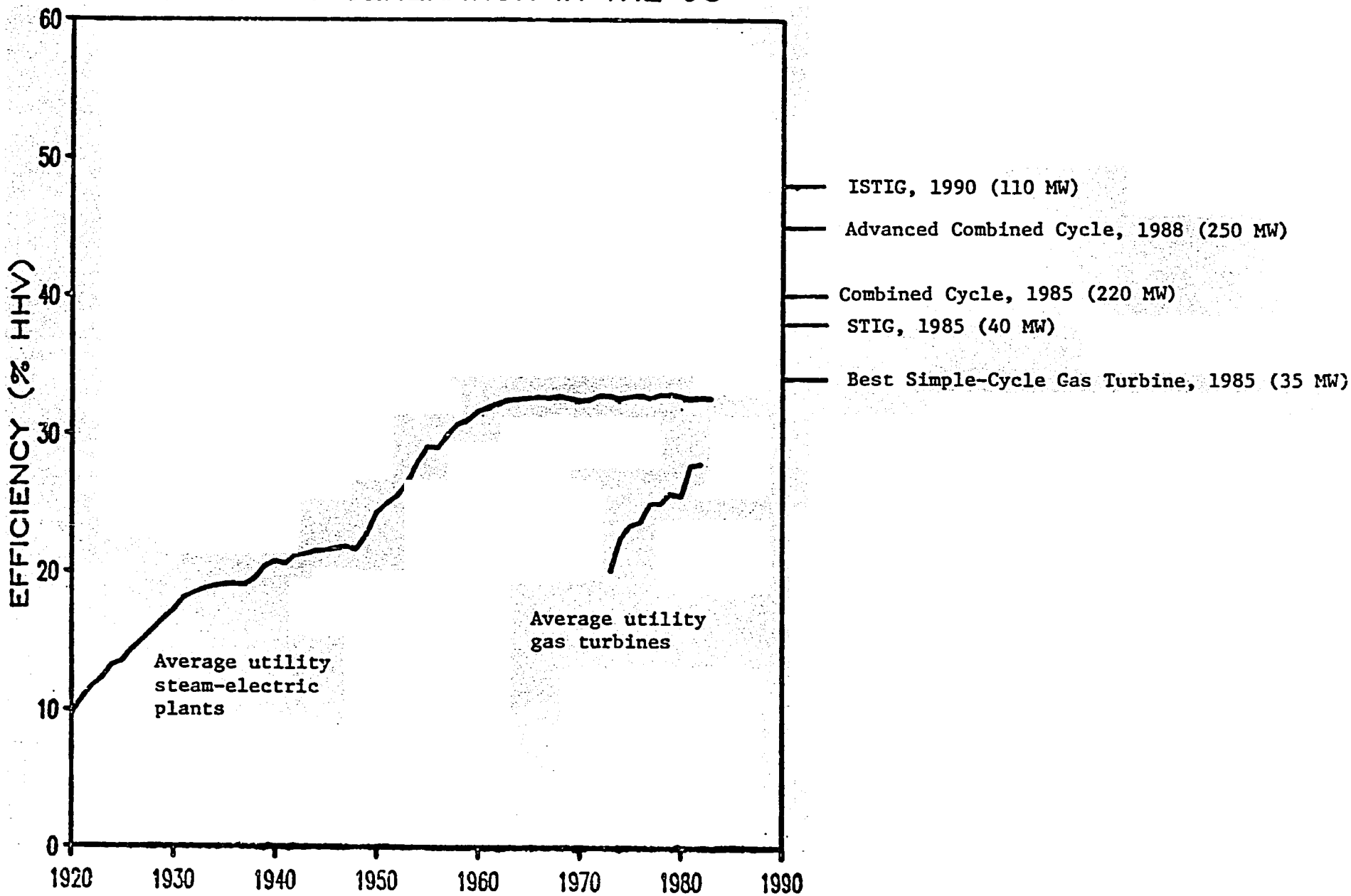
====> UNDER ACTIVE DEVELOPMENT FOR FIRING WITH SOLID FUELS

====> ONGOING TECHNOLOGICAL REVOLUTION DUE TO:

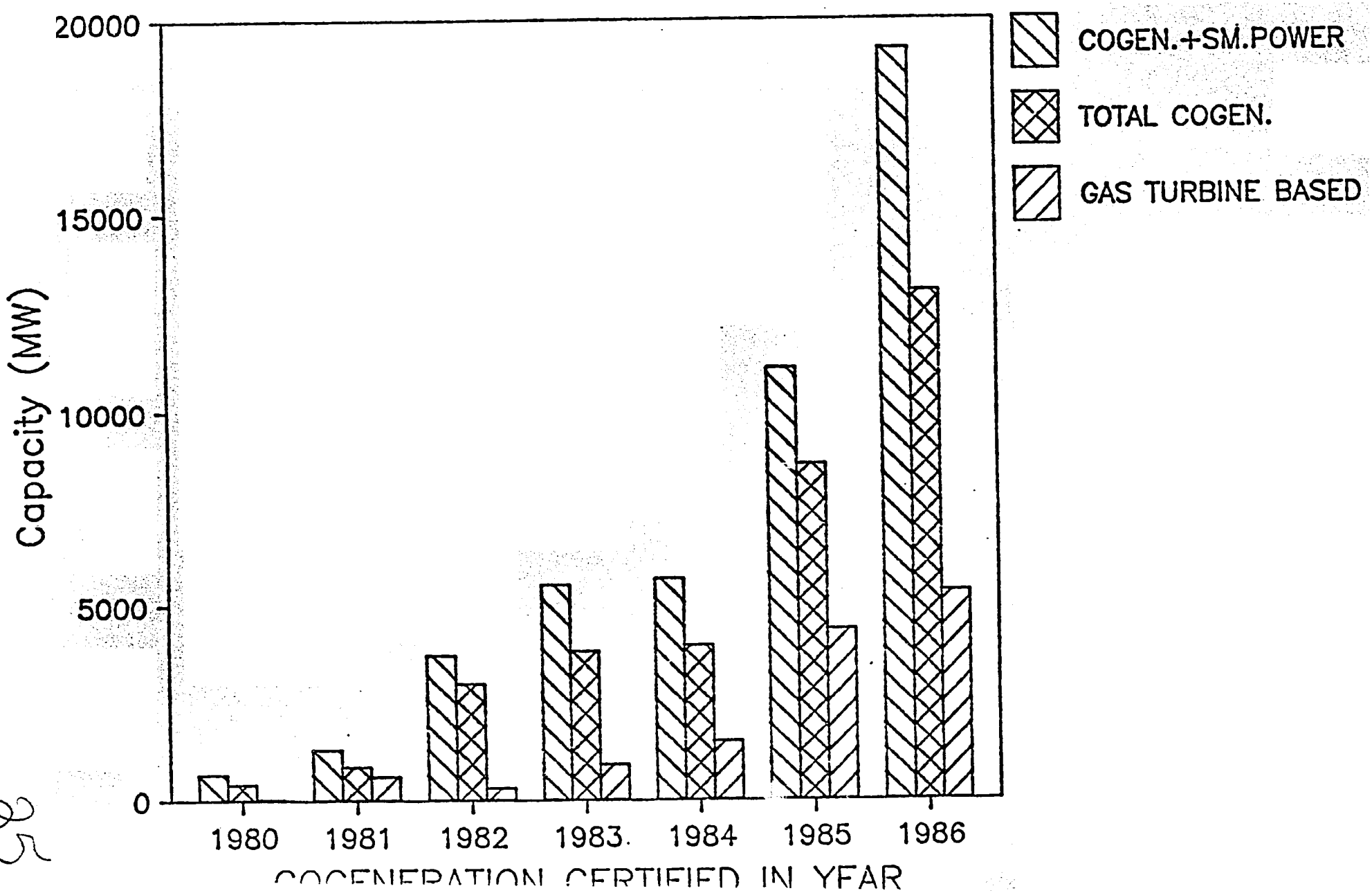
- ===> $400 MILLION/YR DoD R&D INVESTMENTS
- ===> MARKET DEMANDS OF COMMERCIAL AIRLINES
- ===> PURPA AND THE COGENERATION BOOM

CENTRAL-STATION

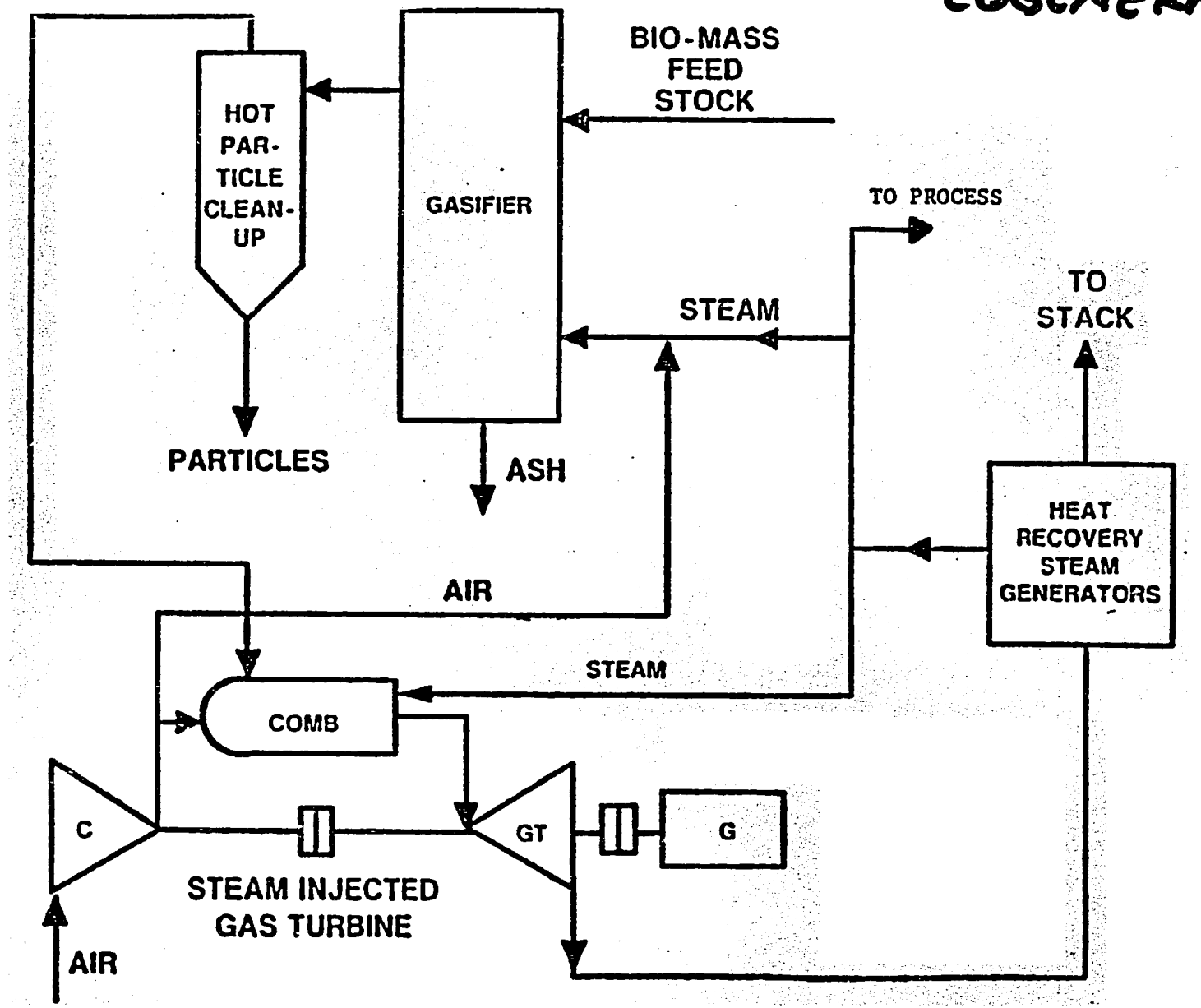
ELECTRICITY GENERATION IN THE US



CERTIFIED COGENERATION IN THE U.S.



BIOMASS-GASIFIER STEAM-INJECTED GAS TURBINE COGENERATION



DRAFT

POTENTIAL FOR PRIVATE INVESTMENT IN RICE RESIDUE POWER GENERATION

INDONESIA 1987

PRELIMINARY ANALYSIS

Betsy Amin-Arsala, Project Leader
Dr. Marcia M. Gowen
Dr. Macon D. Faulkner

prepared for

Bioenergy Systems and Technology
Office of Energy
Science and Technology Bureau
U. S. Agency for International Development

by

Tennessee Valleu Authority Under RSSA: BST-5709-R-TV-2181

November 1987

ROLE OF A.I.D. S&T/EY

IN

PROJECT DEVELOPMENT

<u>Project Stages</u>

Pre-feasibility Analysis*

- Assess Potential/Risks
  - Resource
  - Technical
  - Economic/Financial
  - Institutional/Policy
  - Institutional/Policy
- Outline Options

Project Development/Risk Assumption

- Pre-Investment Analysis*
- Technical Feasibility Analysis
  - System Performance
  - System Scale
  - Feedstock Supply
  - By-product Sales
- Financing Package*
  - Captial Financing
  - Equity Financing
  - Insurance
- Policy Support Initiatives*
  - Contract Sanctity
  - Power Puchase Agreements
  - Power Distribution

Project Implementation

- Construction
- O&M
- Power Sales
- Loan Repayment

*Role for A.I.D.

PRE-FEASIBILITY ANALYSIS OF RICE RESIDUE ENERGY SYSTEMS IN INDONESIA

SUMMARY OF RISKS

29

RESOURCE BASE

SITUATION

Husk

Small average mill capacity (1 T gabah/day) severely restricts on-site husk supply

Cumulative supply of unused husks in many districts is adequate to meet small (600 KW) to larger (1.5 MW) rice residue plant needs

Low competition for alternative uses (10-25 %)

Neglible husk collection network exists

Collection from mills by husk users (brickmakers, etc)

Straw

Adequate straw available in fields, even if 1/2 left on field

Existing cases of field collection extremely limited (pulp mills)

Conclusion:

Collection of husk or straw manditory for stand-alone systems (1.5 MW still likely for integrated systems (600 KW)

Given lower melting point of rice straw, systems should not presume mixed-fuel possibility.

RISKS

Establishment of husk collection and transport system

Collection may lower feedstock quality

Need consortia of mills or to identify large government mill to meet small (600 KW) or larger (1.5 MW) power plant husk demand

TECHNICAL

SITUATION

U.S. commercial rice residue power systems range from 10-24 MW, pilot systems of 600 KW for steam heat producton

Due to average mi[illegible] of 1 T gabah/hr in Indonesia, current scale of U.S. rice residue pow[illegible] systems too large for most mills

Conclusion:

Downsizing of U.S.commercial power systems necessary

RISKS

New smaller systems will require commercial demonstration

U.S. manufacturers will need to explore local manufacturing

Quality of ash may change with dowscaling and husk collection

ECONOMIC

SITUATION

Models developed for 600 KW and 1.5 MW systems

Essential to financial feasibility are:

- Ash sales/market
- Operating days/load factor
- Electricity price
- Husk price
- Fincancing terms (interest rate, discount rate) and capital costs

Conclusion:

- Pre-feasibility models indicate smaller scale system (600 KW) has lower unit costs and greater competitive range than larger system (1.5 MW)
- Economics of the systems revolve around market for ash, size of plant, operating days and electricity price

RISKS

Ash market must be assured

Husk transport network must be feasibile

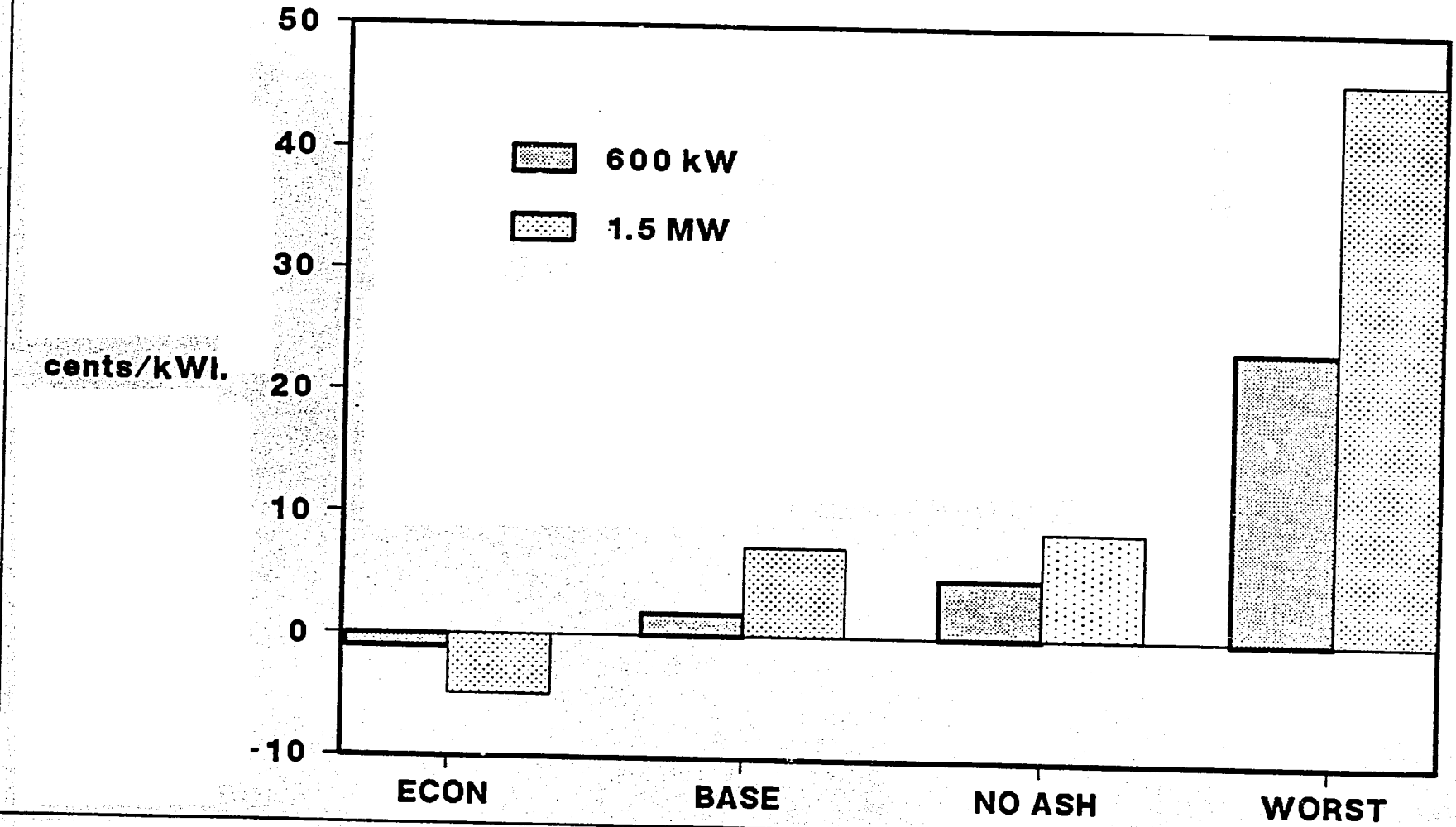
Guaranteed electricity prices- pay or take contract

Financing terms must be reasonable, below average market rates for larger system

Demand must exist for adequate operating days

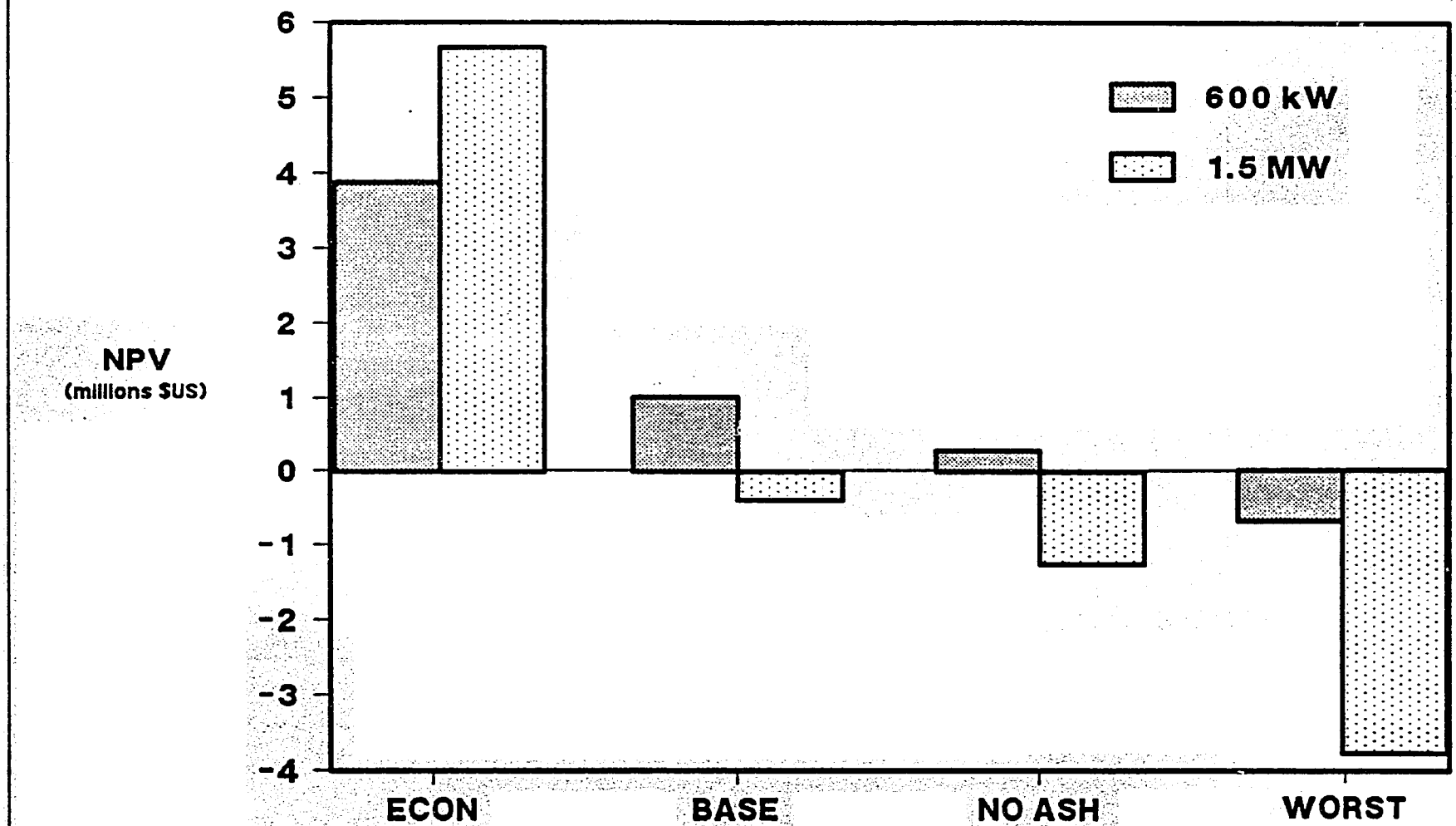
RICE RESIDUE POWER SYSTEMS IN INDONESIA (1987)

ELECTRICITY PRODUCTION COSTS
600 KW AND 1.5 MW SYSTEMS



RICE RESIDUE POWER SYSTEMS IN INDONESIA (1987)

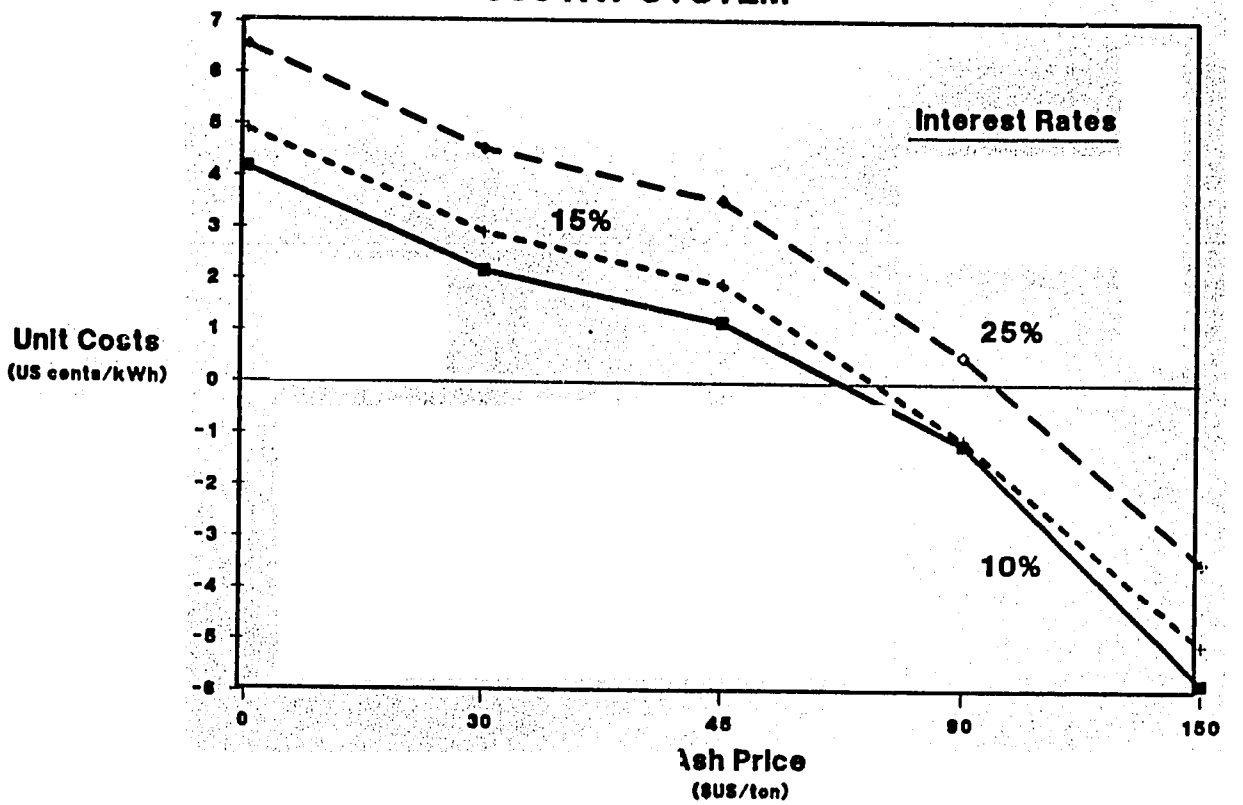
NET PRESENT VALUES
600 KW AND 1.5 MW SYSTEMS



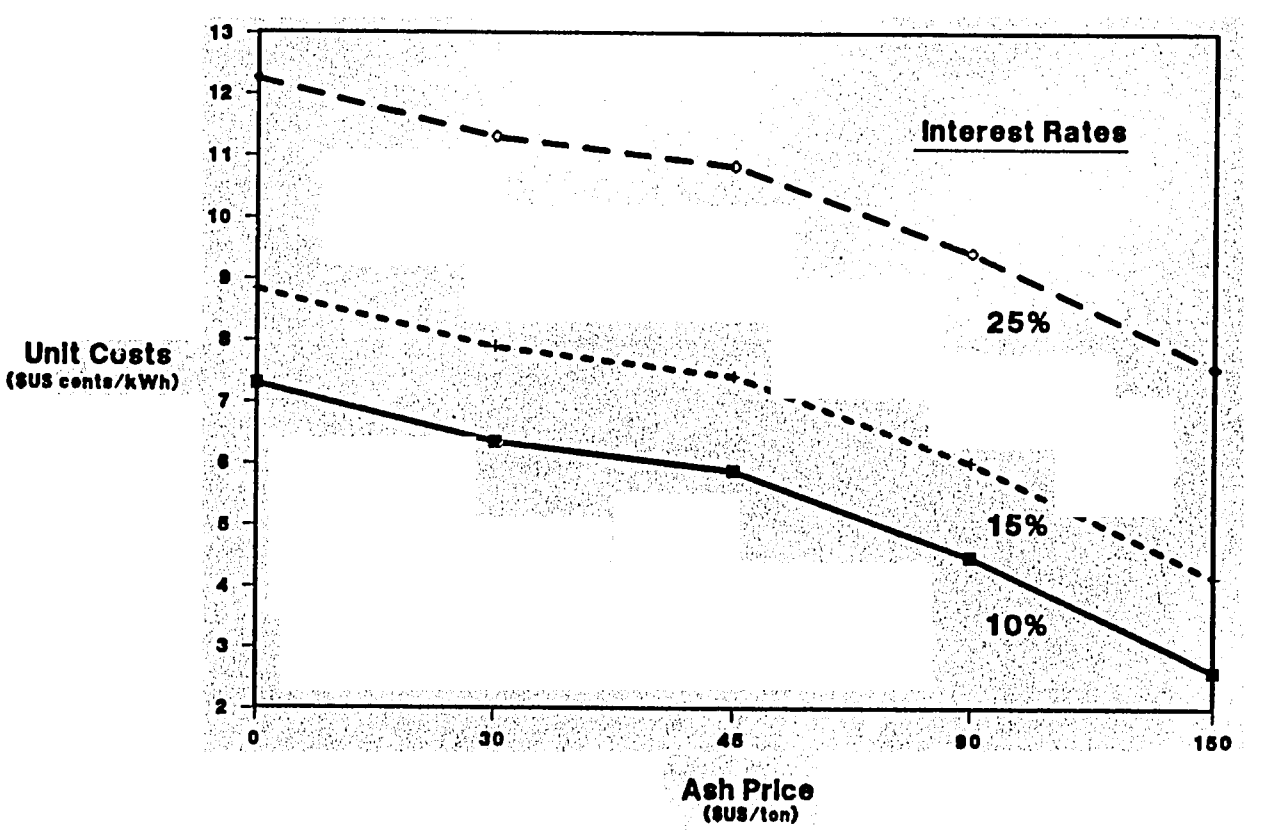
34

ELECTRICITY PRODUCTION COSTS BY ASH PRICE

600 KW SYSTEM

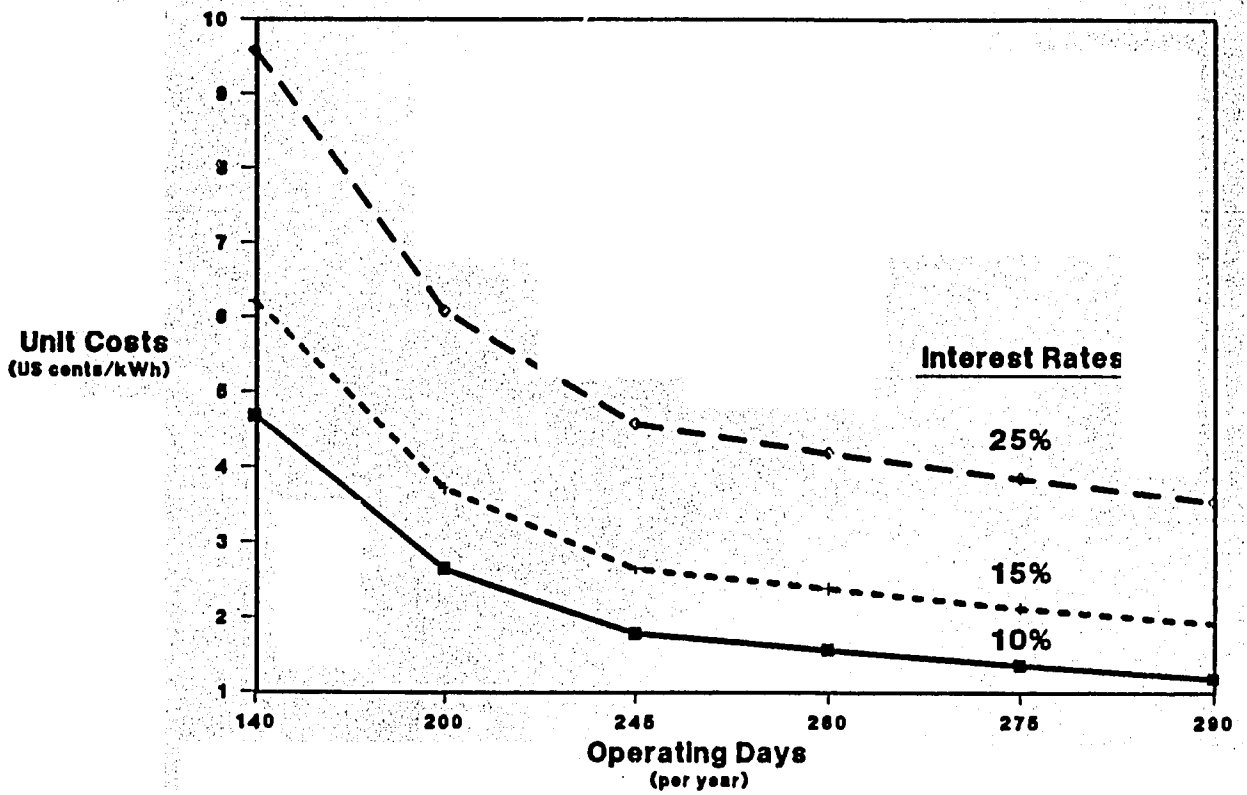


1.5 MW SYSTEM



ELECTRICITY PRODUCTION COSTS BY ANNUAL OPERATING DAYS

600 KW SYSTEM



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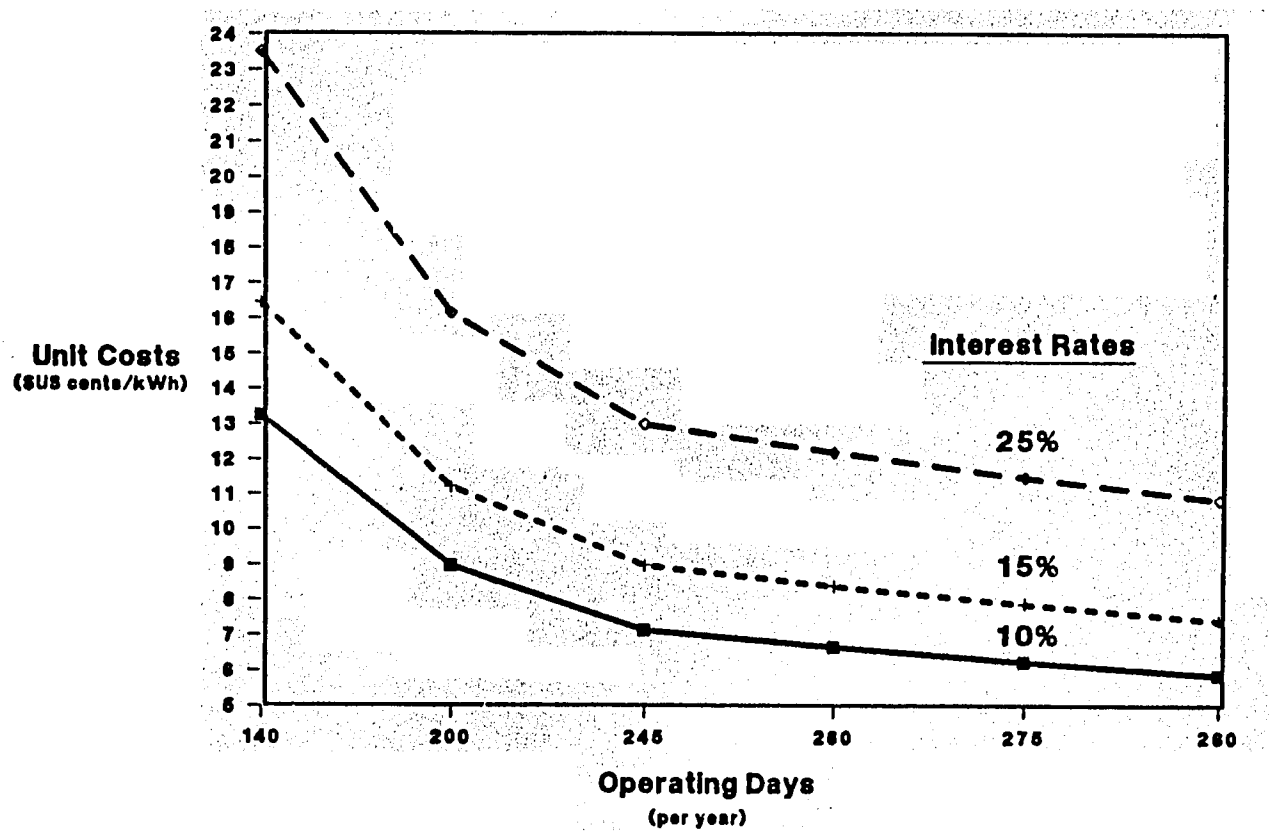
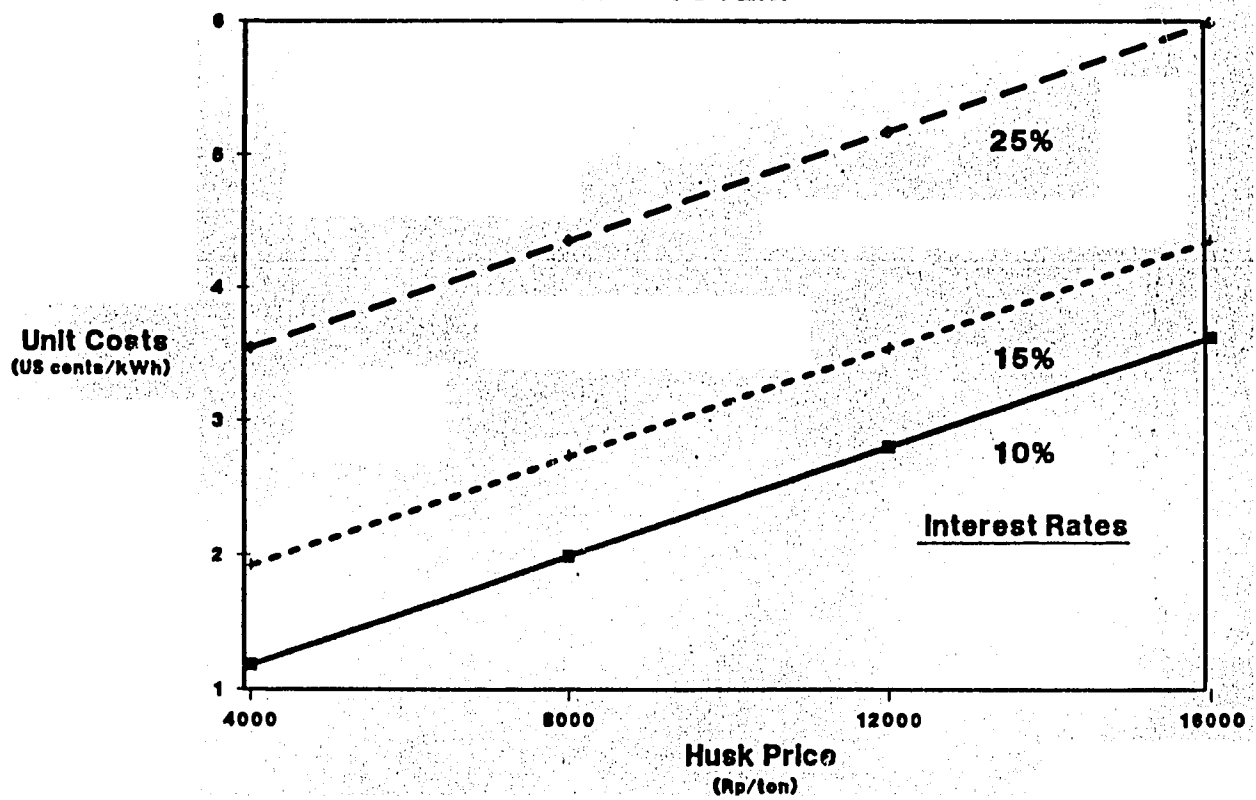
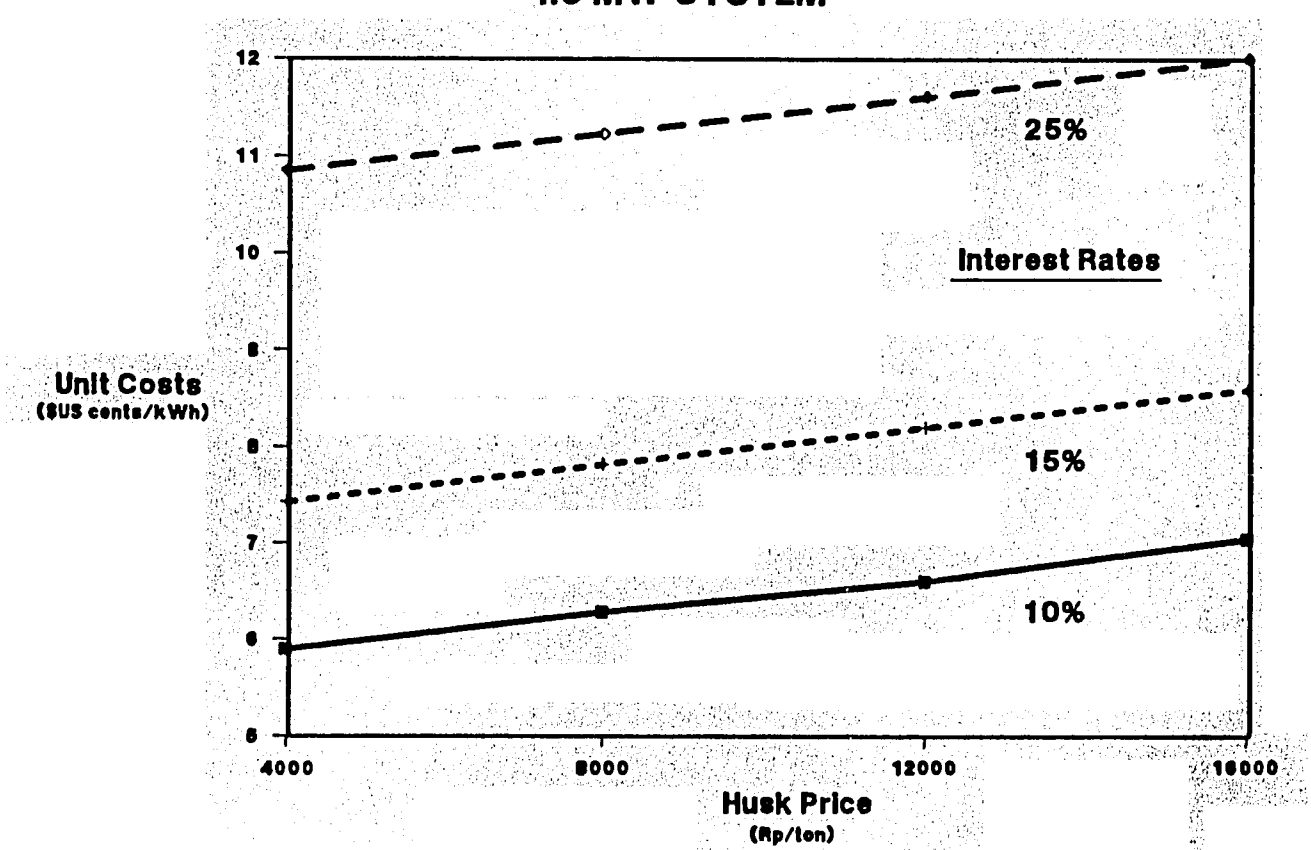


ELECTRICITY PRODUCTION COSTS BY HUSK PRICE

600 KW SYSTEM

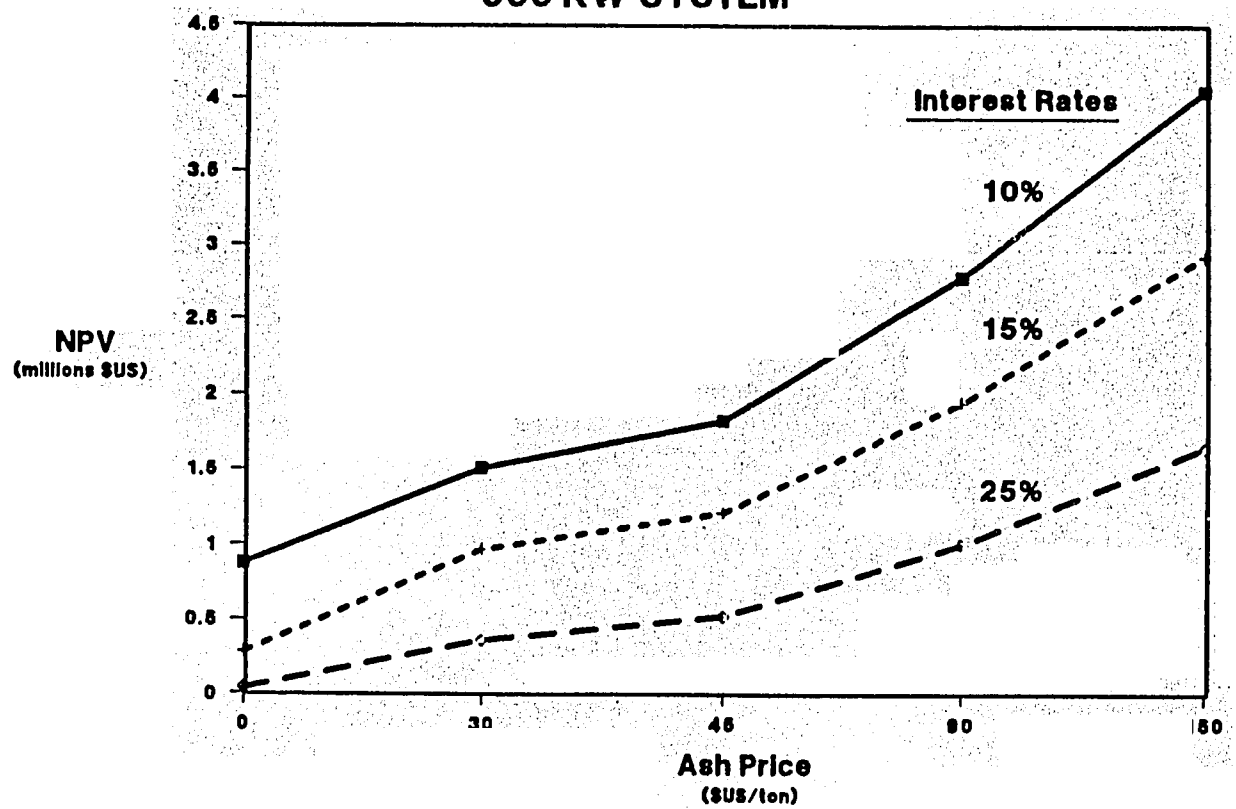


1.5 MW SYSTEM

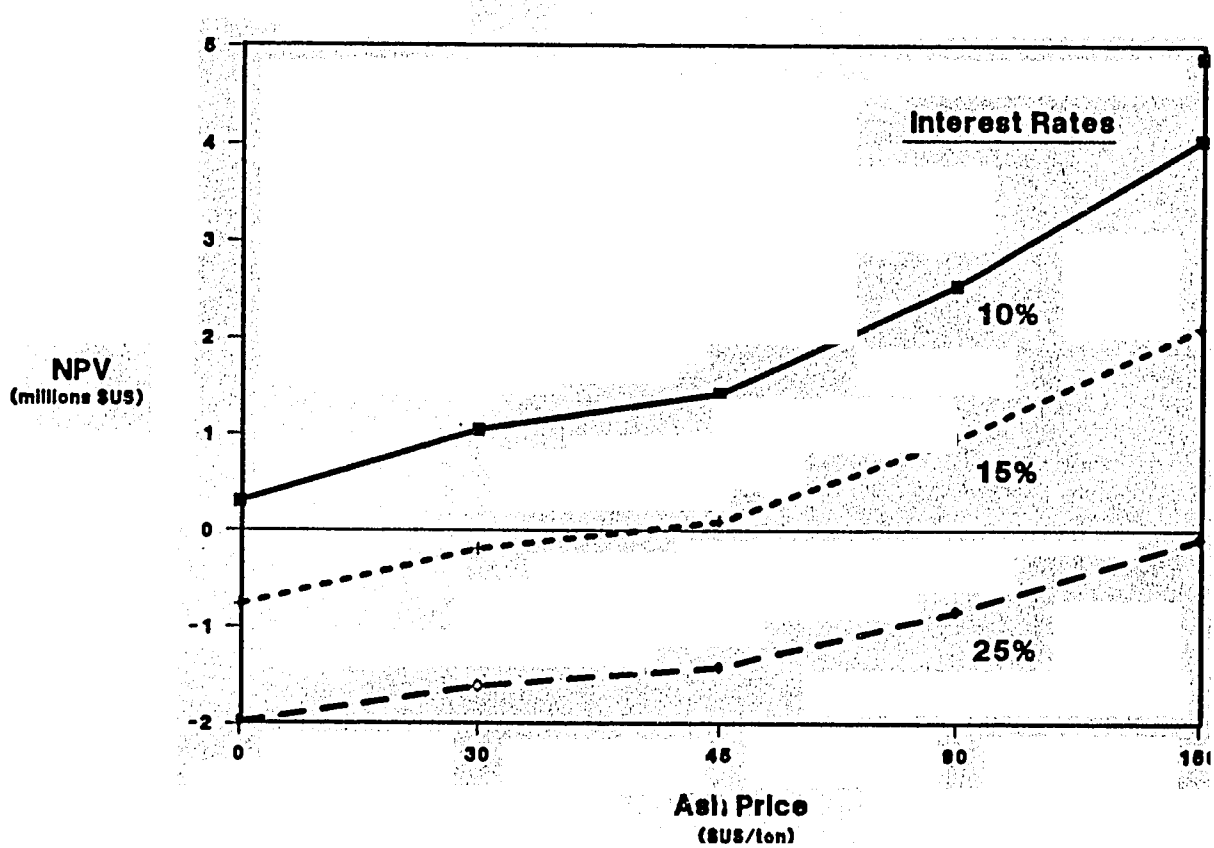


NET PRESENT VALUE BY ASH PRICE

600 KW SYSTEM



1.5 MW SYSTEM



NET PRESENT VALUE BY ANNUAL OPERATING DAYS

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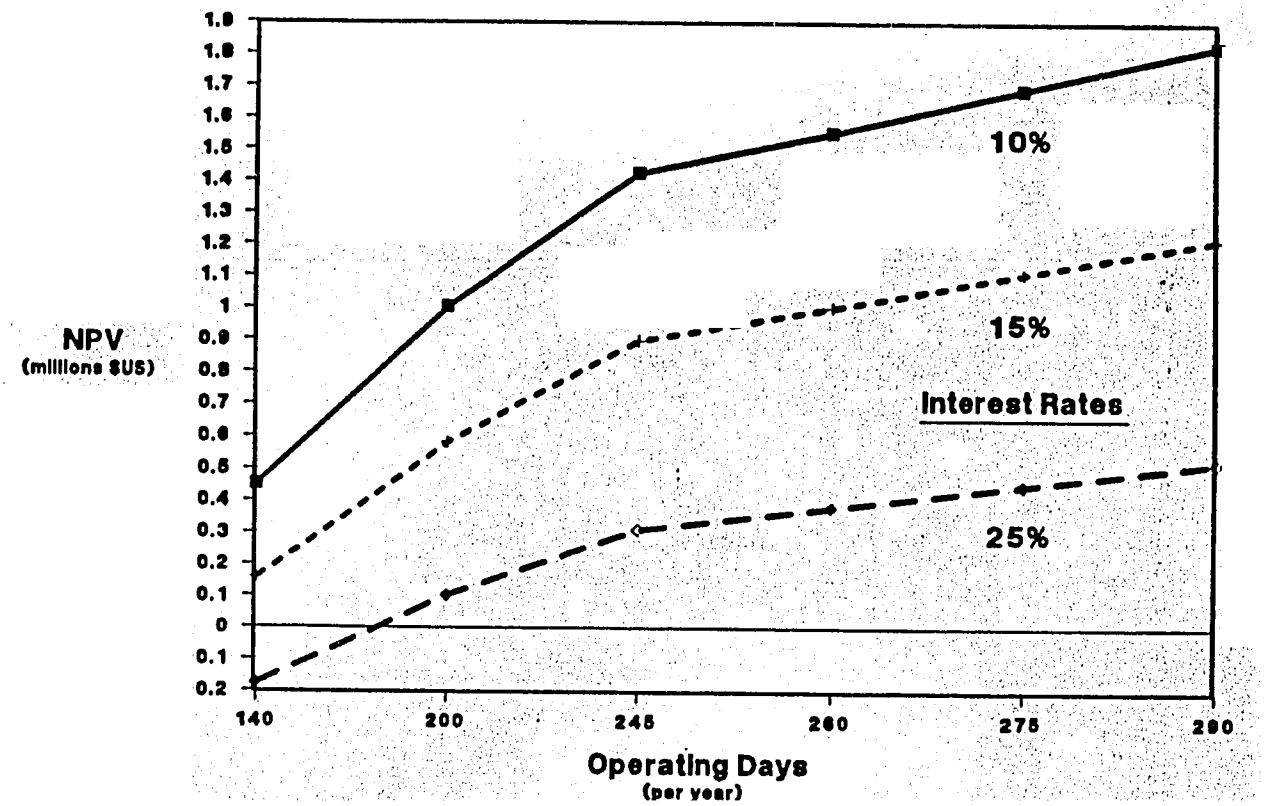

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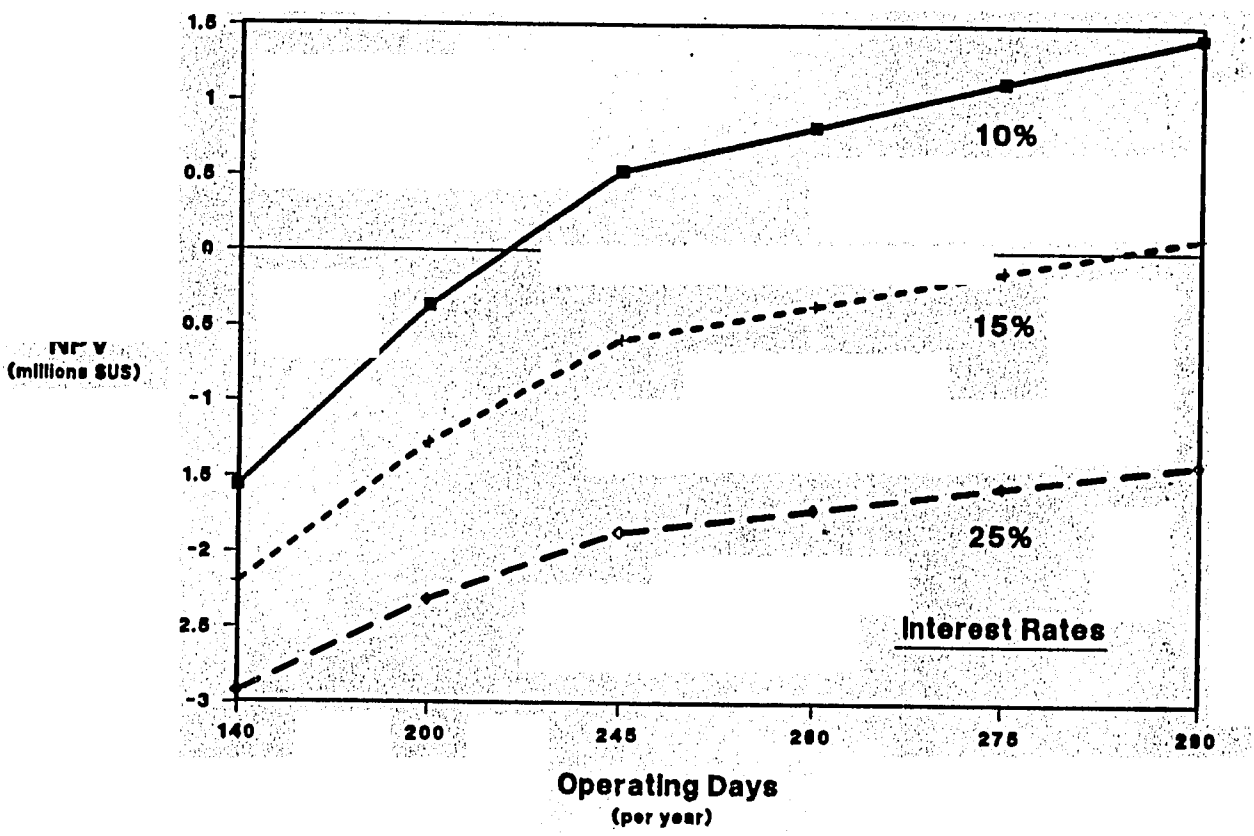
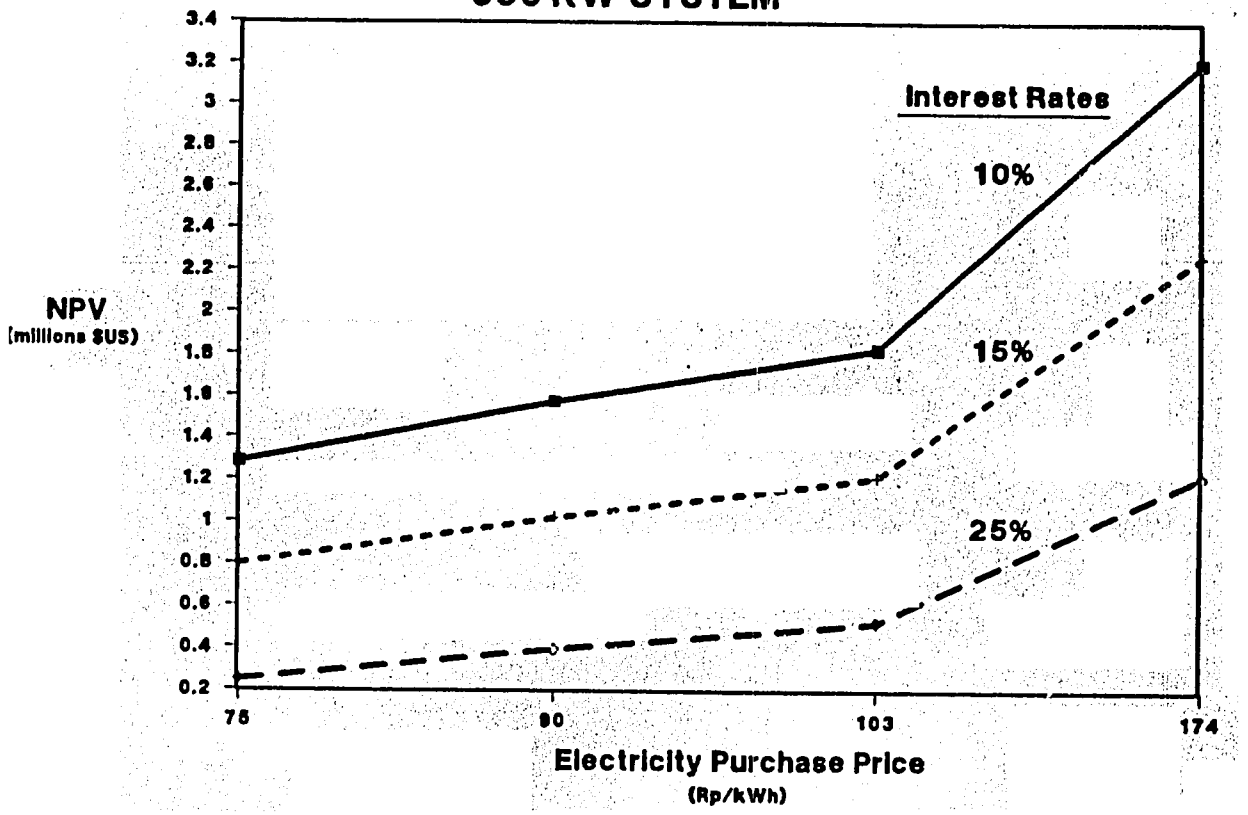


NET PRESENT VALUE BY ELECTRICITY PURCHASE PRICE

600 KW SYSTEM



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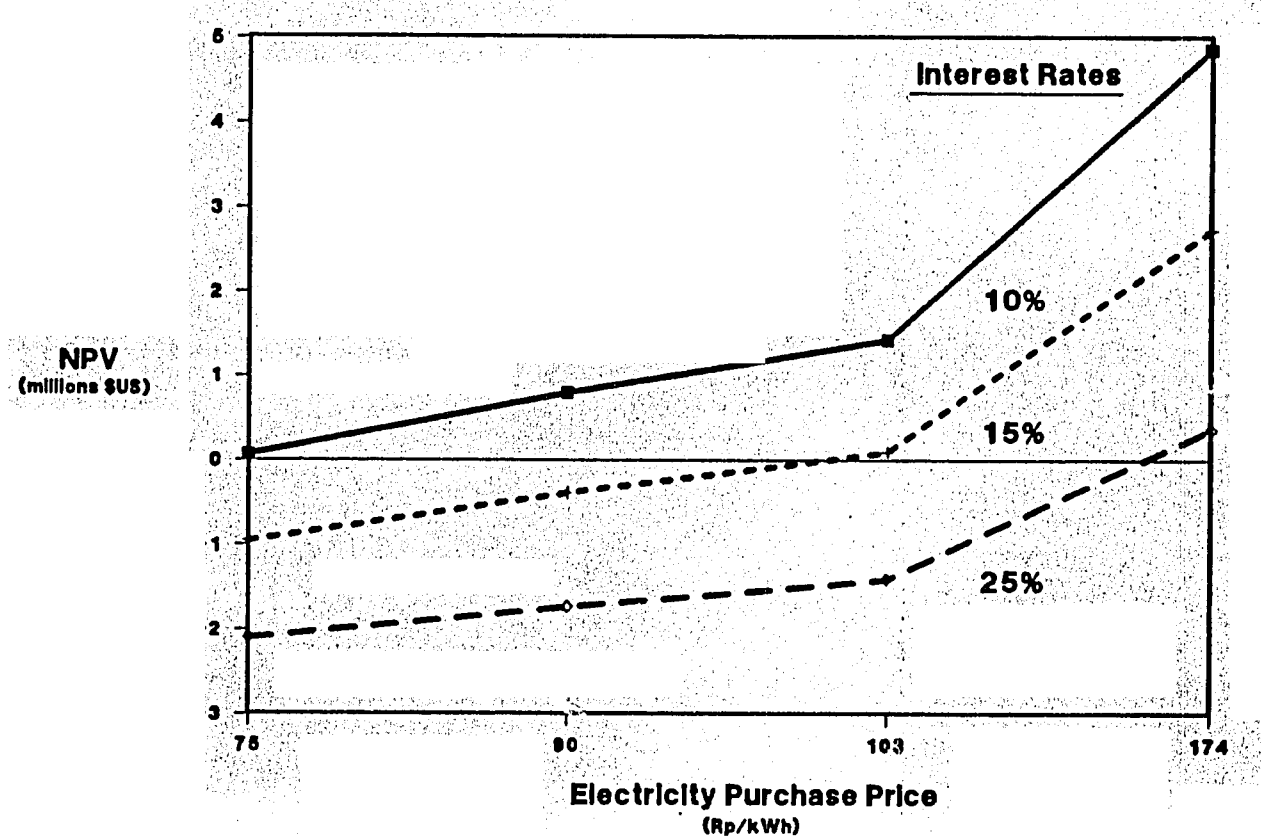

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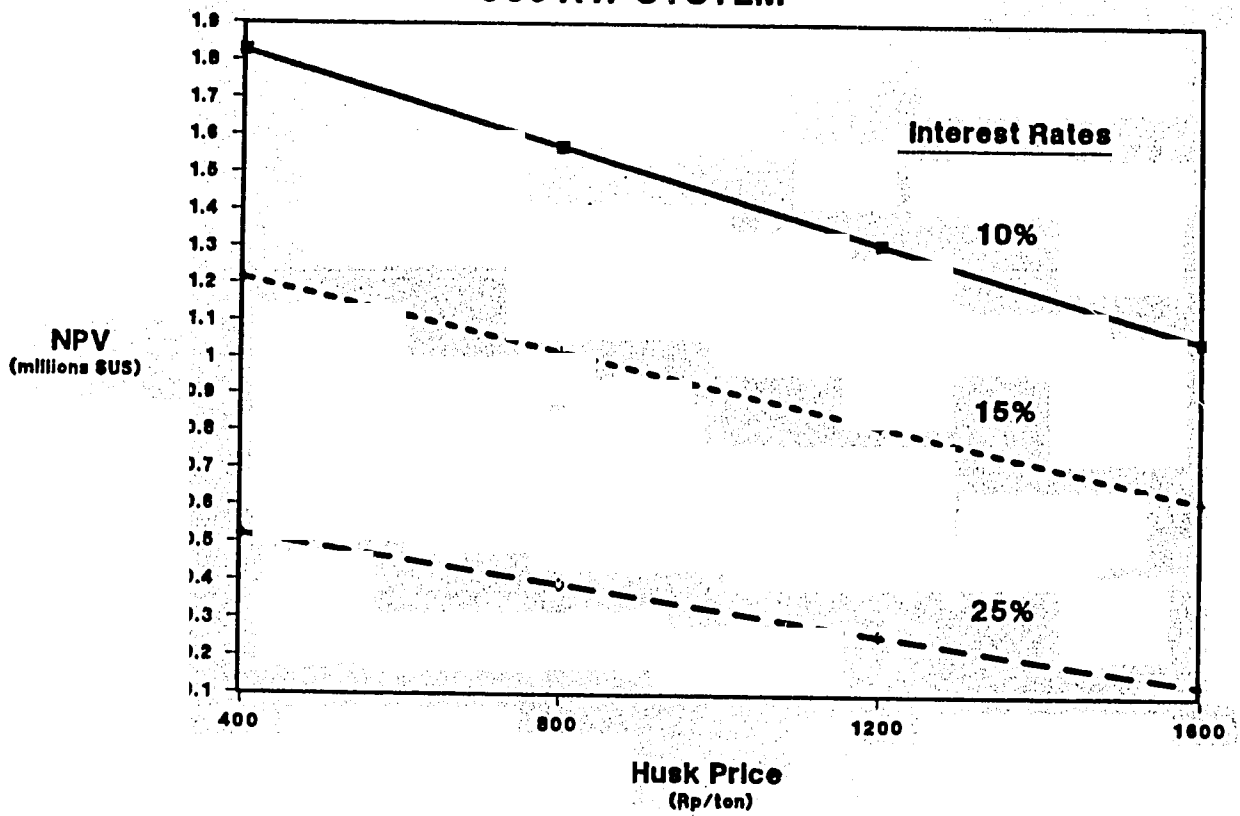

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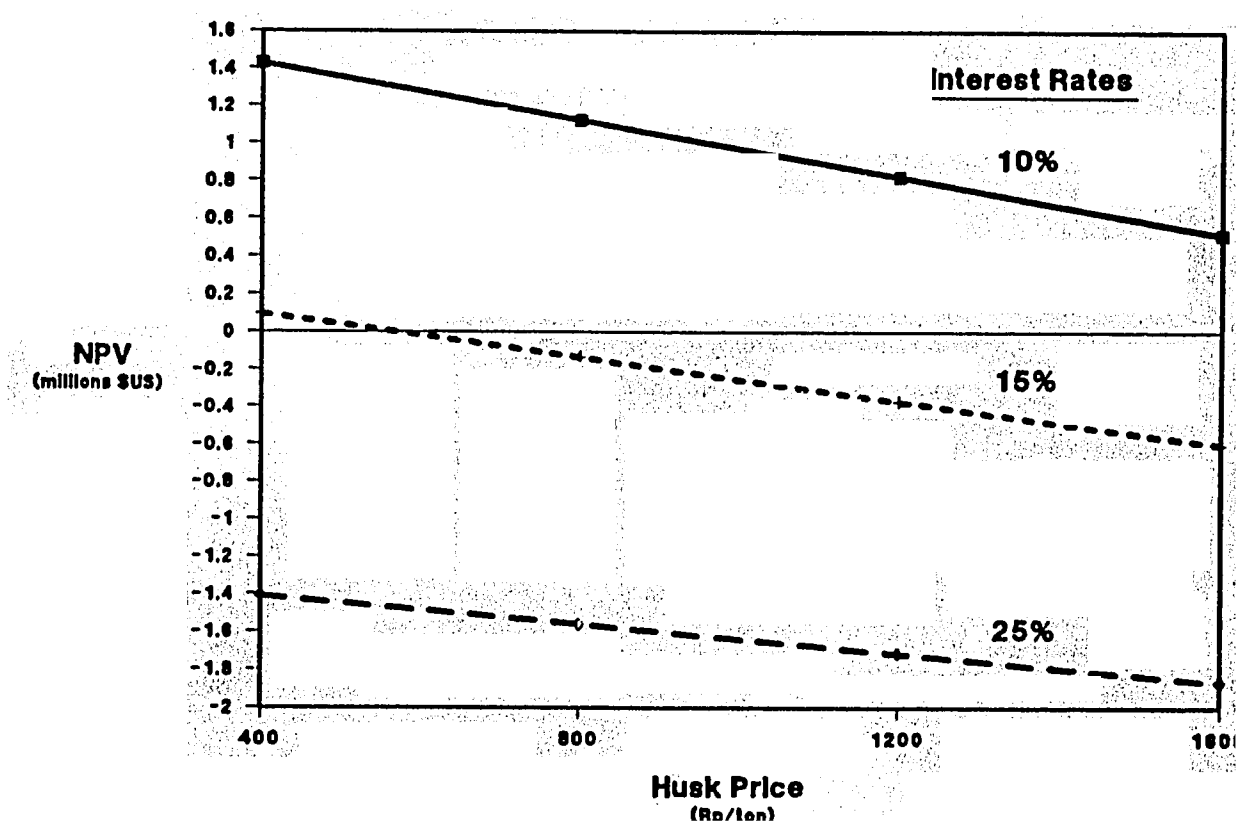


FINANCIAL

SITUATION

Local investors require extremely short payback periods (6 mos to 1 year)

High returns are required, 16-24 % prime rates of return

Tax and legal policies discourage private investment

Limited local equity available

Economy suffered from loss oil revenues, major 1986 devaluation

RISKS

Investors will require short loan periods

Low loan rates are necessary to attract local investors

Private sector investments, joint ventures need greater support from the government

POLICY and INSTITUTIONAL

SITUATION

Rice

Current policies encourage small mills (1 T/hr) for rural job generation, income benefits and national food supply stability

Electricity

Over 50% total electricity production comes from captive power generation

New 1985 Law allows private sale of electricity

Few cases of private power sales exist

RISKS

Either large mills must be identified to produce captive power or small mills must form consortiums for power generation

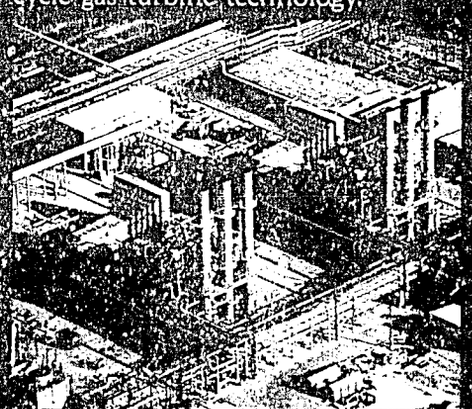
Private power sale laws and guidelines must be better established and promoted

THE DOW SYNGAS PROJECT DOW CHEMICAL U.S.A.

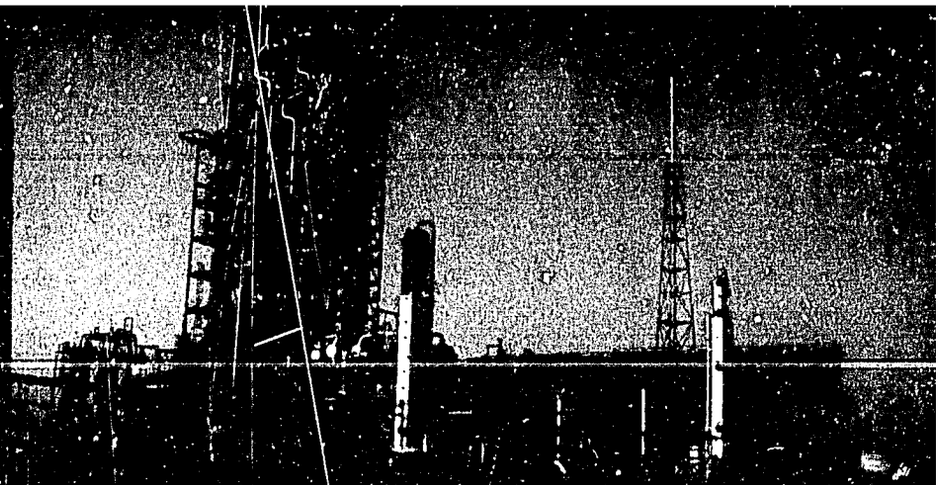
Energy may be society's most valued resource, but it is not always our most accessible one. Often the search for energy seems a futile struggle to make shrinking resources meet ever-growing demand.

The Dow Chemical Company knows the struggle. As a global manufacturer of energy-intensive products such as chlorine, magnesium and a host of petrochemicals, Dow has searched for economical energy sources and efficient conversion processes since the days of the first wood-fired plant built by Herbert Dow himself in the early 1900s.

Today, with an uncertain energy future and unstable costs for foreign oil resources, Dow has turned to a new energy source based on domestic solid fuel reserves and efficient combined cycle gas turbine technology.



Dow's Louisiana Division power houses burn syngas in gas turbines.



The Dow Syngas Project in Plaquemine, Louisiana, began commercial operations in May, 1987.

Developed in the largest research and development project ever undertaken by the company, Dow's efficient coal gasification process produces synthetic gas as a new energy option available to Dow and others in the electrical energy generation industry.

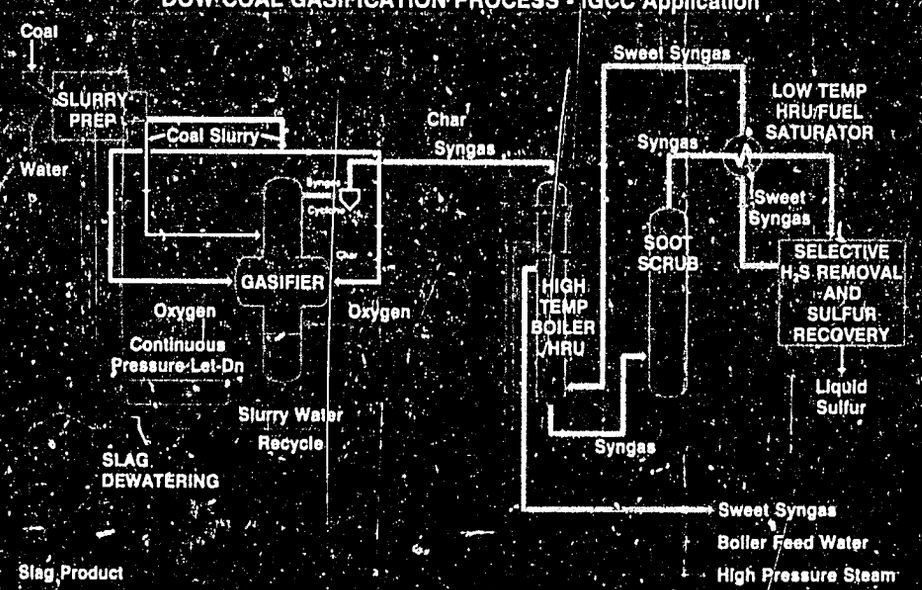
Research on the Dow coal gasification process began more than 10 years ago with the goal of developing a coal-based technology that was environmentally clean, reliable, energy efficient, capable of using a range of coals, competitive in power costs and capable of being introduced with short lead times to meet market needs.

No existing technology met Dow's criteria, so the company began work on its own process. An air-blown pilot plant using 12 tons per day of coal started up in 1978 incorporating Dow's unique two-stage process. It was later converted to a 36-ton-per-day coal oxygen-blown plant.

In 1982 Dow began construction of a 1,600-ton-per-day oxygen-blown proto plant. This plant operated from 1983 to 1985 when data had been collected to establish the design bases for a commercial scale plant.

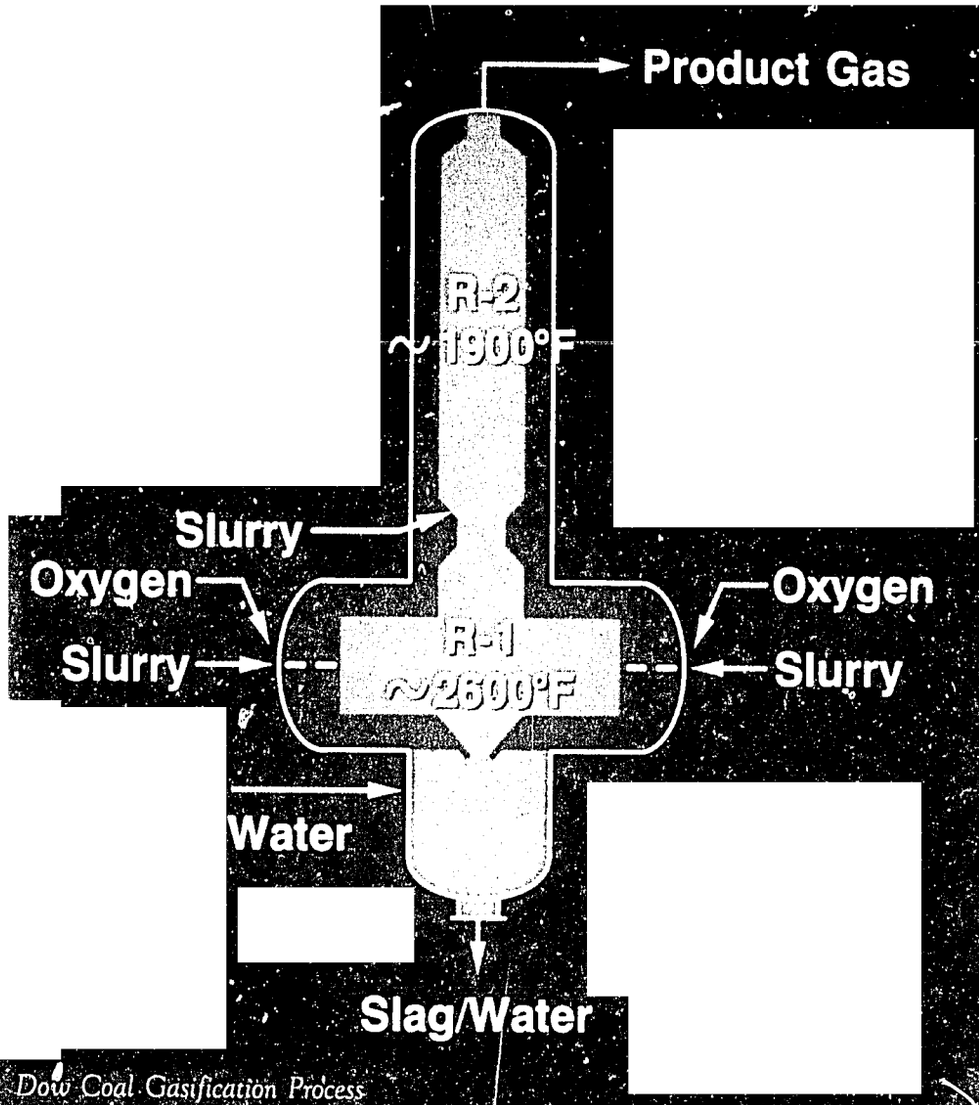
The 2,400-ton-per-day integrated gasification combined cycle plant operating in Plaquemine, Louisiana, is the first commercial-scale demonstration of Dow's technology.

DOW COAL GASIFICATION PROCESS - IGCC Application



The Dow coal gasification process uses a pressurized, entrained flow, slagging, slurry-fed gasifier with a continuous slag removal system. The process includes a unique heat recovery system which provides high efficiency on low rank coals.

The novel slurry feed technology and continuous slag removal technique eliminates high maintenance and problem-prone lockhoppers for introducing the coal to the gasifier or for removal of slag. The design prevents the combustion and raw product gases from escaping into the atmosphere during slurry feeding or slag removal.



Dow Coal Gasification Process

Coal slurry is fed to the reactor and mixed with oxygen in burner nozzles. The feed rate of oxygen is carefully controlled to maintain reactor temperature above the ash fusion point to ensure slag removal. Under these conditions, high carbon conversion is achieved by partial combustion to produce synthetic gas consisting principally of hydrogen, carbon monoxide, carbon dioxide and water. Sulfur is converted almost totally to hydrogen sulfide with small amounts of carbonyl sulfide.

The gasifier system produces essentially no tars, oils or phenols. It includes a unique heat recovery system that provides high efficiency especially on lower rank coals. Ash is fused in the flame, direct quenched in a water bath and removed from the bottom of the reactor as a slurry through a special pressure-reducing system. Slag is dewatered and stored.

Syngas exiting the gasifier system is further cooled by a conventional heat recovery boiler to near its saturation. High-pressure superheated steam produced can be used for power generation via steam turbines or to drive the oxygen plant air compressor.

Particulates are removed by water scrubbing the partially cooled gas. All particulates removed are recycled to the gasifier.

The scrubbed syngas is then cooled through a series of heat exchanges before entering the acid gas removal process. The amount of low level heat recovery is economically balanced with the heat requirements of both the gasifier and the acid gas removal process.

The acid gas removal process from the syngas stream is based on an economic evaluation of the application of several known technologies with the environmental and process constraints of the location. The particulate-free syngas from the Dow gasifier is suitable feed for any of the known commercial desulfurization processes.

The Dow Syngas Project complies with site environmental requirements via a Dow's GAS/SPEC ST-1 Technology acid gas removal system and a commercially licensed sulfur conversion unit.

The Dow Syngas Project began operating during the spring of 1987. After two short preliminary runs on coal slurry feed during April, all parts of the plant, including the use of syngas for power generation were commissioned. Commercial operations began in May.

The plant has performed well at rates up to approximately 90 percent of capacity. Syngas from the process has been used in Dow's Westinghouse gas turbines to make power for use in Dow's Louisiana Division plants.

At full capacity, the plant will provide 30 billion Btu per day of medium Btu gas. The gas and co-produced steam are sufficient to generate approximately 160 megawatts of power.

Initial plant operations surpassed original projections. Gas quality and carbon conversion have also been better than expected.

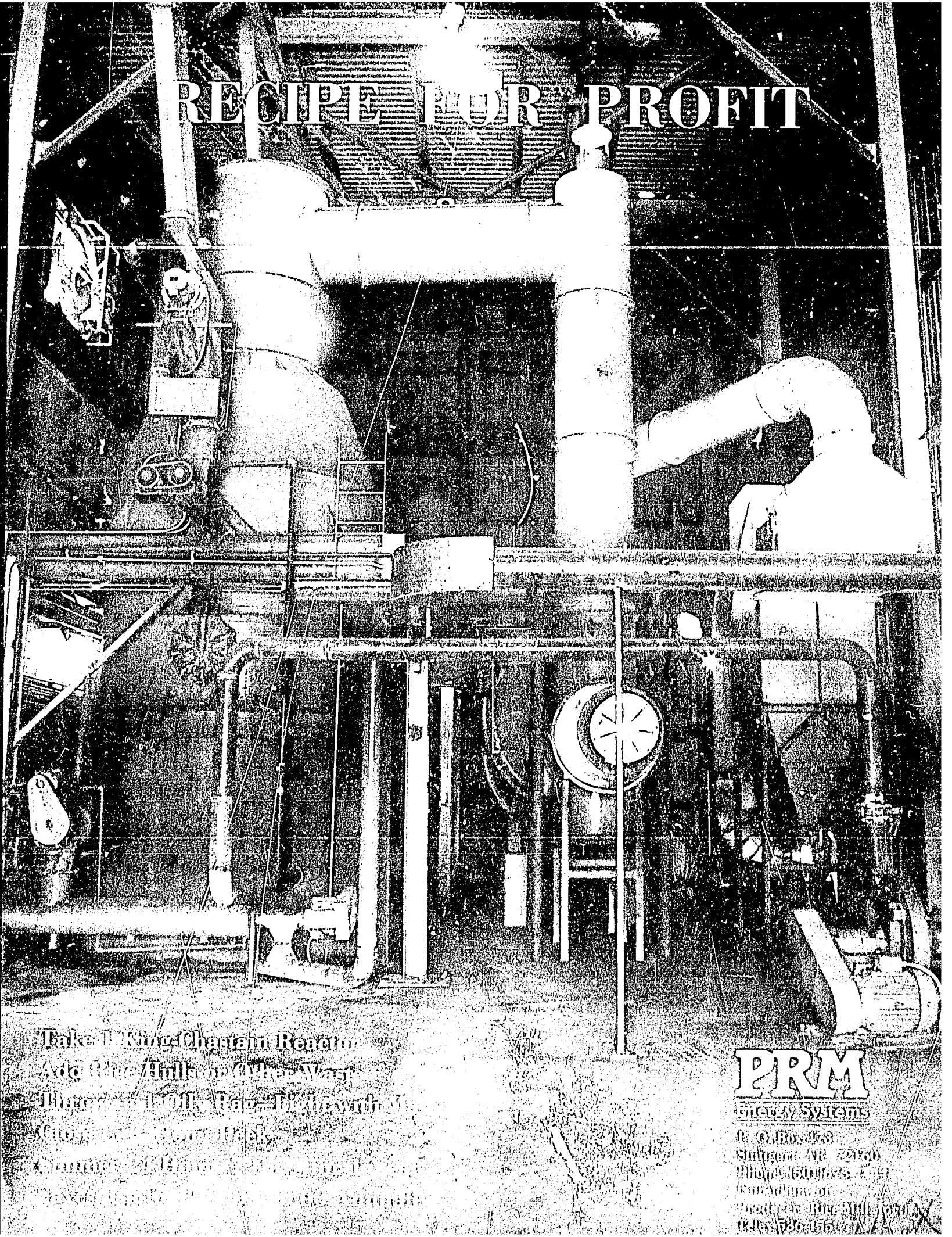
As the world's largest integrated coal gasification combined cycle power plant, the plant's successful start-up demonstrates the technology is reliable and safe on a commercial scale.

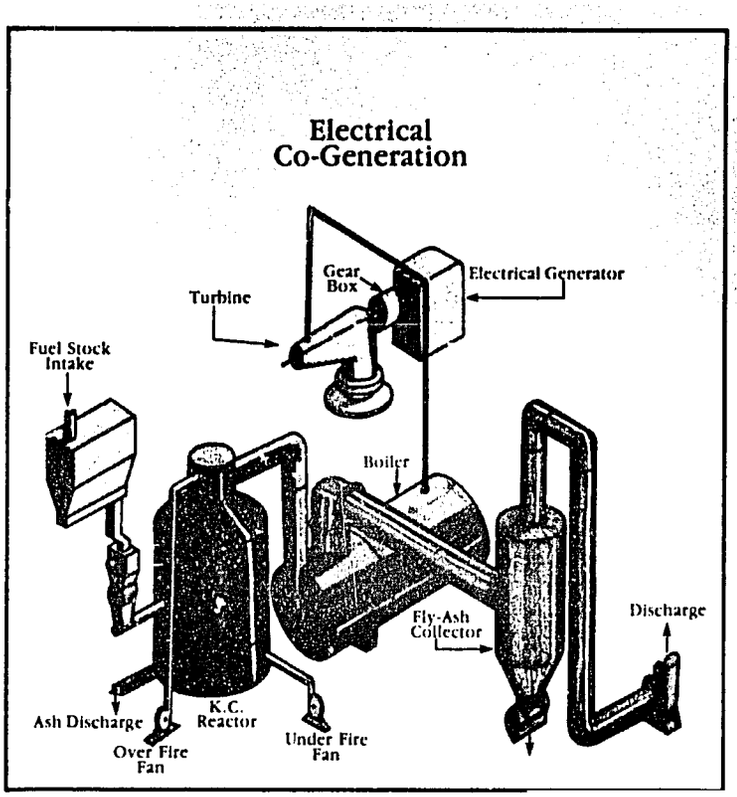
The Dow Coal Gasification Process is being commercially demonstrated in the world's largest integrated coal gasification combined cycle power plant in Plaquemine, Louisiana. The plant is owned and operated by Louisiana Gasification Technology, Inc., a wholly-owned subsidiary of The Dow Chemical Company.

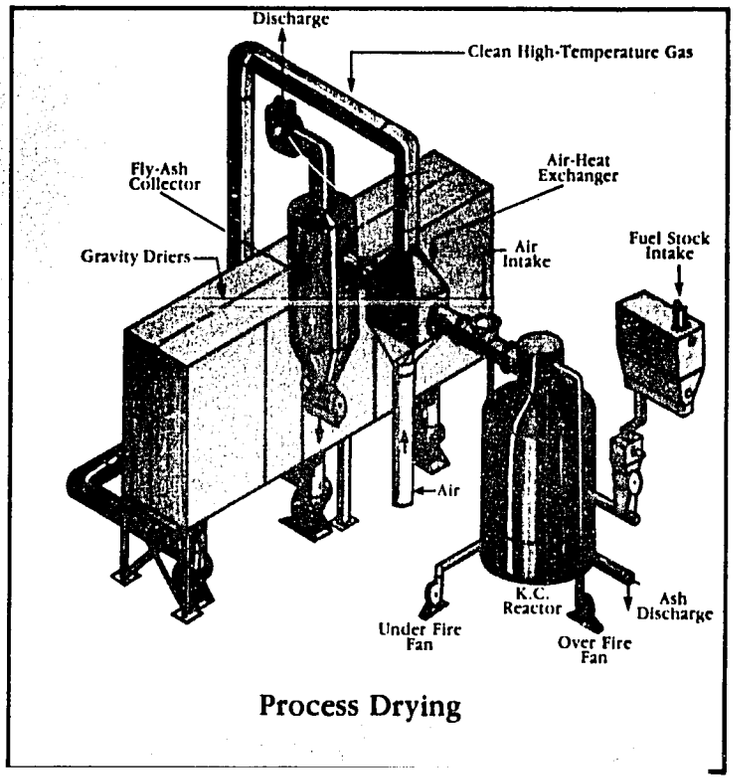
DOW

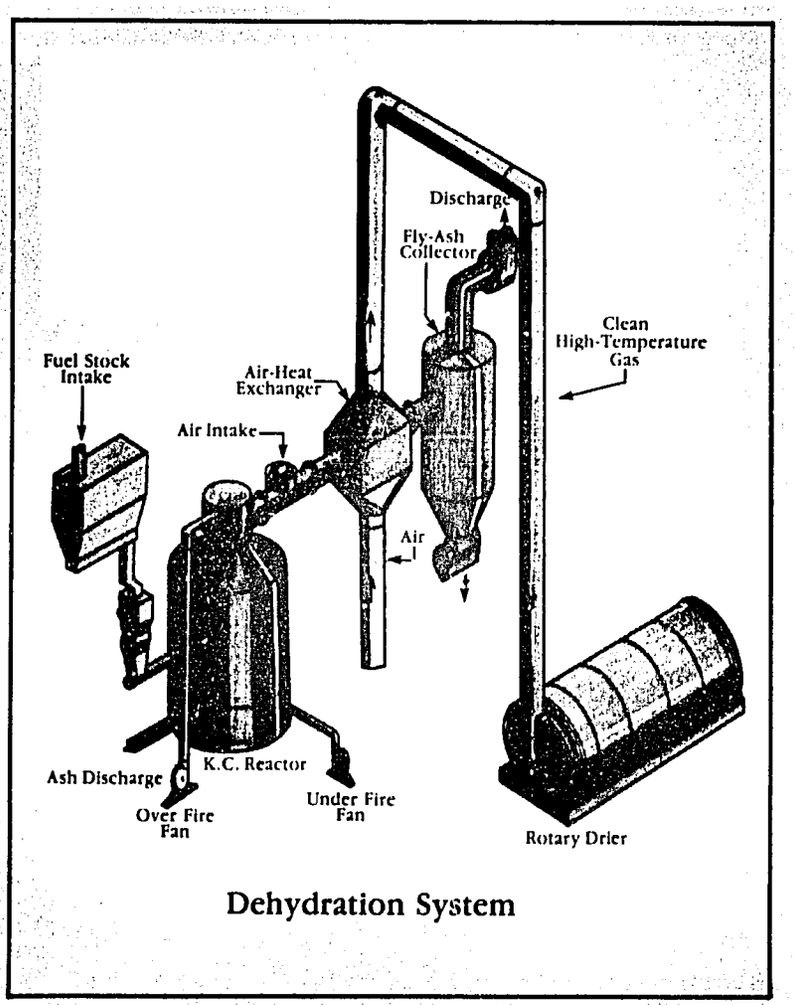
Energy Resources
The Dow Chemical Company
P.O. Box 3387
Houston, Texas 77253-3387
September, 1987

RECIPE FOR PROFIT









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Producers Rice Mill, Inc.)
Telex 536-455

Discussion Draft

OPTIONS TO INCREASE PRIVATE PARTICIPATION IN ELECTRIC POWER DEVELOPMENT IN A.I.D.-ASSISTED COUNTRIES

prepared by:

)ffice of Energy
Bureau for Science and Technology
U.S. Agency for International Development
Washington, D.C.

December 23, 1987

50

EXECUTIVE SUMMARY

This report responds to a Congressional request for an assessment of "appropriate incentives for private sector participation and the feasibility of an Energy Guaranty Program modeled on A.I.D.'s Housing Guaranty Program." Of specific interest to the Congress, and consequently of this report, is the possible role that A.I.D. might play in facilitating developing country private-power projects: projects developed, owned and possibly operated by the private sector.

Interest in private power is proceeding rapidly. Pakistan, the Philippines, Indonesia, Jamaica, the Dominican Republic, Costa Rica, Brazil, Turkey, and other countries are formulating, and in some cases, implementing private-power policies. This introduction of private-market forces into what has traditionally been an exclusive government domain offers two much needed benefits:

- competition and its resultant more efficient management, both within power facilities and more generally within the power sector, and
- the mobilization of private capital to augment scarce public resources for needed power development. (page 1)

Despite the clear advantages of private participation in electrical power development and the expressed interest of private firms and developing countries, to date no private-power generation projects are yet firmly committed. Numerous barriers have discouraged or prohibited private investment in the power sectors of developing countries. These include the following:

- institutional and policy barriers,
- weak domestic economies,
- political risk,
- technical risk,
- financial risk. (page 2)

To overcome these barriers a range of U.S. and host-country government policy initiatives are needed. Currently, neither A.I.D., nor any other U.S. agency, has specific programs devoted solely to private power projects. A.I.D. has, however, devoted considerable resources to the subject through its development assistance and economic support programs to provide technical assistance, policy studies and conferences, as well as prefeasibility and feasibility studies. Some of these have been carried out in

collaboration with other agencies, especially with the Trade and Development Program and with the Department of Energy. Other U.S. programs are provided by the Overseas Private Investment Corporation, the International Trade Administration, the Department of State, and the Export-Import Bank of the United States. (page 5)

Multilateral development institutions, such as the World Bank, the International Finance Corporation, the Asian Development Bank, the Inter American Development Bank also provide limited amount of technical and feasibility study assistance. These multilateral development institutions are currently exploring innovative ways to facilitate private investment in the power sectors of developing countries. (page 6)

Existing U.S. programs share a number of limitations: amidst competing priorities there is a lack of clear policy direction as to the priority of encouraging private investment in developing country power projects, limited staff and financial resources are available for the task, and except in the renewable energy area, limited coordination exists among federal programs and with multilateral programs.

OPTIONS TO INCREASE PRIVATE PARTICIPATION

Since mobilizing market forces to foster economic growth is a major objective of A.I.D. and since U.S. industry is a world leader in electric power, the Agency has a clear opportunity to accelerate this private-sector movement. Based on the status of private participation in the power sectors of developing countries, the Agency challenge is to improve the policy climate for private investment, facilitate actual project development, provide necessary training, and coordinate a well targeted U.S. government effort to accelerate private-power development. The goal of this effort should be to establish a limited number of successful pilot investment projects in A.I.D.-assisted countries that can serve as models for future investments on a broader scale.

Options available to A.I.D to accomplish this goal are the following:

Improve the Policy and Institutional Climate for Private Investment

Option 1: Country-Specific Private-Power Strategies

To help create more favorable investment environments for private power in developing countries, A.I.D. could develop a detailed "private-sector power development strategy" on a county-by-country basis to identify needed policy changes, to examine private-power opportunities and to identify potential private-sector parties interested in power projects. (page 11)

Facilitate Project Development

Option 2: Private-Power Data Base

The Agency could develop a Private-Power Data Base to track specific project opportunities and to provide information to developers, other private parties and to other U.S. agencies involved in private-power development. (page 16)

Option 3: Definitional Missions and Trade Conferences

In collaboration with TDP and Commerce, A.I.D. could increase the number of definitional missions to countries that have favorable policies for private participation. (page 17)

Option 4: Private-Power Investment Promotion Program

Modeled in part on the Investment Promotion Office in Egypt, A.I.D. could establish this program to assist companies on targeted projects to obtain information and technical assistance on potential market opportunities, government policies, and regulations, business assistance programs and contacts in developing countries. (page 19)

Option 5: Private-Power Feasibility Study Program

In collaboration with TDP and other U.S. agencies, the Agency could establish an expanded Private-Power Feasibility Study Program using formal and informal solicitation mechanisms and targeted toward technologies where the U.S. private sector has a competitive edge. (page 23)

Option 6: Innovative Technology and Environmental Assessment Program

This option would provide resources for assessments of innovative energy technologies that are applicable to private-power projects and for assessments of the environmental effects of projects to minimize adverse impacts. (page 24)

Option 7: Energy Loan Guarantee Program

Under this option the Agency would provide a full guarantee against default on loans made by private U.S. financial institutions to finance private-power projects either through the host country government or utility (Housing

Guaranty Model) or directly to private developers (Eximbank Loan Guarantee Model). (page 33)

Option 8: Direct Energy Loan Program

Under this option the Agency would provide direct loans to private sector firms for private-power projects in developing countries, either directly or through financial intermediaries. (page 36)

Option 9: Energy Grant and Export Credit Program

This option would build upon existing legislative and regulatory authority to combine A.I.D. grant and export credit funds with Eximbank "war chest" funds for more affirmative government action for international procurements where U.S. companies are competing with firms from other countries. (page 37)

Option 10: Energy Equity Program

This option would use U.S. funds as equity or to guarantee equity funds for private-power projects in developing countries through any of four mechanisms: venture capital loans, direct equity purchase programs, equity guarantee programs or direct equity grants. (page 39)

Option 11: Negotiation Advisory Team

The Agency, under this option, would create a pool of technical consultants that could provide assistance to the parties in private-power contract negotiations. (page 42)

Provide Training on Private-Power Development

Option 12: Private-Power Training Program

A.I.D. would create a Private-Power Training Program targeted toward government officials, state utility officials and businessmen from developing countries and toward businessmen in the U.S. power industry. (page 45)

Coordinate and Target U.S. Government Efforts

Option 13: Private-Power Task Force

A special Private-Power Task Force under the leadership of A.I.D. would be established to develop a coordinated approach to the private-power potential in developing countries. It would develop a coordinated, targeted interagency initiative for the promotion and implementation of private-power projects in developing countries. (page 49)

Option 14: Integration of U.S. Trade and Aid Policy

Through the Private-Power Task Force, A.I.D. would initiate a clarification of trade and aid policies of the U.S. government as they relate to private-power generation in developing countries. (page 52)

Option 15: Private-Power Pilot Program

Under the auspices of the Private-Power Task Force, a Private-Power Pilot Program would be set up to concentrate U.S. government resources on a few targeted projects where there is a favorable policy and institutional environment and where specific projects are being proposed or negotiated. (page 54)

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Under this option the Agency would provide direct loans to private sector firms for private-power projects in developing countries, either directly or through financial intermediaries. (page 36)

Option 9: Energy Grant and Export Credit Program

This option would build upon existing legislative and regulatory authority to combine A.I.D. grant and export credit funds with Eximbank "war chest" funds for more affirmative government action for international procurements where U.S. companies are competing with firms from other countries. (page 37)

Option 10: Energy Equity Program

This option would use U.S. funds as equity or to guarantee equity funds for private-power projects in developing countries through any of four mechanisms: venture capital loans, direct equity purchase programs, equity guarantee programs or direct equity grants. (page 39)

Option 11: Negotiation Advisory Team

The Agency, under this option, would create a pool of technical consultants that could provide assistance to the parties in private-power contract negotiations. (page 42)

Provide Training on Private-Power Development

Option 12: Private-Power Training Program

A.I.D. would create a Private-Power Training Program targeted toward government officials, state utility officials and businessmen from developing countries and toward businessmen in the U.S. power industry. (page 45)

Coordinate and Target U.S. Government Efforts

Option 13: Private-Power Task Force

A special Private-Power Task Force under the leadership of A.I.D. would be established to develop a coordinated approach to the private-power potential in developing countries. It would develop a coordinated, targeted interagency initiative for the promotion and implementation of private-power projects in developing countries. (page 49)

Option 14: Integration of U.S. Trade and Aid Policy

Through the Private-Power Task Force, A.I.D. would initiate a clarification of trade and aid policies of the U.S. government as they relate to private-power generation in developing countries. (page 52)

Option 15: Private-Power Pilot Program

Under the auspices of the Private-Power Task Force, a Private-Power Pilot Program would be set up to concentrate U.S. government resources on a few targeted projects where there is a favorable policy and institutional environment and where specific projects are being proposed or negotiated. (page 54)

Discussion Draft

OPTIONS TO INCREASE PRIVATE PARTICIPATION IN ELECTRIC POWER DEVELOPMENT IN A.I.D.-ASSISTED COUNTRIES

prepared by:

Office of Energy
Bureau for Science and Technology
U.S. Agency for International Development
Washington, D.C.

December 23, 1987

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EXECUTIVE SUMMARY

This report responds to a Congressional request for an assessment of "appropriate incentives for private sector participation and the feasibility of an Energy Guaranty Program modeled on A.I.D.'s Housing Guaranty Program." Of specific interest to the Congress, and consequently of this report, is the possible role that A.I.D. might play in facilitating developing country private-power projects: projects developed, owned and possibly operated by the private sector.

Interest in private power is proceeding rapidly. Pakistan, the Philippines, Indonesia, Jamaica, the Dominican Republic, Costa Rica, Brazil, Turkey, and other countries are formulating, and in some cases, implementing private-power policies. This introduction of private-market forces into what has traditionally been an exclusive government domain offers two much needed benefits:

- competition and its resultant more efficient management, both within power facilities and more generally within the power sector, and
- the mobilization of private capital to augment scarce public resources for needed power development. (page 1)

Despite the clear advantages of private participation in electrical power development and the expressed interest of private firms and developing countries, to date no private-power generation projects are yet firmly committed. Numerous barriers have discouraged or prohibited private investment in the power sectors of developing countries. These include the following:

- institutional and policy barriers,
- weak domestic economies,
- political risk,
- technical risk,
- financial risk. (page 2)

To overcome these barriers a range of U.S. and host-country government policy initiatives are needed. Currently, neither A.I.D., nor any other U.S. agency, has specific programs devoted solely to private power projects. A.I.D. has, however, devoted considerable resources to the subject through its development assistance and economic support programs to provide technical assistance, policy studies and conferences, as well as prefeasibility and feasibility studies. Some of these have been carried out in

collaboration with other agencies, especially with the Trade and Development Program and with the Department of Energy. Other U.S. programs are provided by the Overseas Private Investment Corporation, the International Trade Administration, the Department of State, and the Export-Import Bank of the United States. (page 5)

Multilateral development institutions, such as the World Bank, the International Finance Corporation, the Asian Development Bank, the Inter American Development Bank also provide limited amount of technical and feasibility study assistance. These multilateral development institutions are currently exploring innovative ways to facilitate private investment in the power sectors of developing countries. (page 6)

Existing U.S. programs share a number of limitations: amidst competing priorities there is a lack of clear policy direction as to the priority of encouraging private investment in developing country power projects, limited staff and financial resources are available for the task, and except in the renewable energy area, limited coordination exists among federal programs and with multilateral programs.

OPTIONS TO INCREASE PRIVATE PARTICIPATION

Since mobilizing market forces to foster economic growth is a major objective of A.I.D. and since U.S. industry is a world leader in electric power, the Agency has a clear opportunity to accelerate this private-sector movement. Based on the status of private participation in the power sectors of developing countries, the Agency challenge is to improve the policy climate for private investment, facilitate actual project development, provide necessary training, and coordinate a well targeted U.S. government effort to accelerate private-power development. The goal of this effort should be to establish a limited number of successful pilot investment projects in A.I.D.-assisted countries that can serve as models for future investments on a broader scale.

Options available to A.I.D to accomplish this goal are the following:

Improve the Policy and Institutional Climate for Private Investment

Option 1: Country-Specific Private-Power Strategies

To help create more favorable investment environments for private power in developing countries, A.I.D. could develop a detailed "private-sector power development strategy" on a county-by-country basis to identify needed policy changes, to examine private-power opportunities and to identify potential private-sector parties interested in power projects. (page 11)

Facilitate Project Development

Option 2: Private-Power Data Base

The Agency could develop a Private-Power Data Base to track specific project opportunities and to provide information to developers, other private parties and to other U.S. agencies involved in private-power development. (page 16)

Option 3: Definitional Missions and Trade Conferences

In collaboration with TDP and Commerce, A.I.D. could increase the number of definitional missions to countries that have favorable policies for private participation. (page 17)

Option 4: Private-Power Investment Promotion Program

Modeled in part on the Investment Promotion Office in Egypt, A.I.D. could establish this program to assist companies on targeted projects to obtain information and technical assistance on potential market opportunities, government policies, and regulations, business assistance programs and contacts in developing countries. (page 19)

Option 5: Private-Power Feasibility Study Program

In collaboration with TDP and other U.S. agencies, the Agency could establish an expanded Private-Power Feasibility Study Program using formal and informal solicitation mechanisms and targeted toward technologies where the U.S. private sector has a competitive edge. (page 23)

Option 6: Innovative Technology and Environmental Assessment Program

This option would provide resources for assessments of innovative energy technologies that are applicable to private-power projects and for assessments of the environmental effects of projects to minimize adverse impacts. (page 24)

Option 7: Energy Loan Guarantee Program

Under this option the Agency would provide a full guarantee against default on loans made by private U.S. financial institutions to finance private-power projects either through the host country government or utility (Housing

Guaranty Model) or directly to private developers (Eximbank Loan Guarantee model). (page 33)

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Discussion Draft

POWER SHORTAGES IN DEVELOPING COUNTRIES: MAGNITUDE, CAUSES, AND FUTURE PROSPECTS

Prepared by:

Office of Energy
Bureau for Science and Technology
U.S. Agency for International Development
Washington, D.C.

January 11, 1988

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EXECUTIVE SUMMARY

BACKGROUND

Recognizing that "energy shortfalls are causing a serious constraint to development in over half of all A.I.D.-assisted countries," the Committee on Appropriations of the U.S. House of Representatives requested a report from the U.S. Agency for International Development on the "magnitude of the crisis, its implications for future economic and social development and the potential for U.S. technologies and services to address this problem", including an assessment of "appropriate incentives for private sector participation...."

The rapidly accelerating problem of electric power in developing countries is of critical importance to the United States. As a key prerequisite for economic development, electric power is vital to efforts to improve living standards in the Third World and to satisfy the demands of their citizens within a stable political context. Also, the electric power market in developing countries provides significant trade opportunities for U.S. businesses.

PURPOSE AND REPORT ORGANIZATION

In response to the Congressional request, this report highlights the dilemma faced by developing countries and seeks to initiate a discussion about potential solutions and the appropriate role of the United States foreign assistance program. The specific purpose of the report is to assess the magnitude and causes of the present and future power problems in developing countries (Chapter 1), to identify the impacts of inadequate power supply (Chapter 2), to consider the importance of power development to the United States and to U.S. suppliers of goods and services (Chapter 3), and finally to provide strategies for power supply improvement and identify the role of the U.S. Agency for International Development (Chapter 4).

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1. ELECTRIC POWER DEMAND AND SUPPLY OUTLOOK

Unlike recent trends in the United States and some other developed countries, consumption of electricity by developing countries is still growing faster than their overall economies. Between 1970 and 1982, electricity consumption in developing countries increased at an annual growth rate of over 8.6 percent, while the Gross Domestic Product (GDP) grew at 4.6 percent to 5.7 percent per year over the same period. Over the past twenty years, the ratio of electricity consumption to income growth was 1.4 to 1.6.

Although developing countries contain over 75 percent of the world's population, they consume only 18 percent of all electricity produced in the world and have only 19 percent of all power generation capacity. By comparison, in 1984 the United States had an electric power generation capacity of over 630 GW (trillion or "giga" watts), compared with 445 GW for all developing countries.

Per capita consumption of electricity in developing countries is far below that of industrialized countries. The average of all developing countries is 500 kWh (kilowatt hours) per capita per year, and for the lower income, A.I.D.-assisted countries the average is only 300 kWH per capita per year. In contrast, per capita electricity consumption is over 5,000 kWh per year in Western Europe and over 10,000 kWh in the United States. In general, over 80 percent of the rural population in developing countries does not have access to electricity.

Causes of the Power Problem

The fundamental causes of the power problems of developing countries relate to both the supply of and the demand for power. Briefly, these are the key issues:

- Power deficit. In most developing countries, current demand exceeds supply frequently resulting in unplanned power outages and the necessity for industries to devote their resources to installing redundant, onsite generating plants.

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- High transmission and distribution losses. In many countries, transmission and distribution losses from technical inefficiencies and theft are 20 to 30 percent, compared to 8 percent in developed countries.

- Inefficient operation of power plants. Due to improper maintenance and operation, power plants in developing countries are available for operation only 50-60 percent of the time compared with over 80 percent in the United States and other industrialized countries.

- Financial difficulties of electricity authorities. Although on average developing countries devote 25 percent of their public development budgets to electric power, electricity authorities in many countries are unable to raise, through electricity sales, cross subsidies or borrowing, sufficient capital to cover their investment needs. Uneconomic pricing requires substantial subsidies from the central governments for their operations.

- Shortage of skilled manpower. Most utilities in developing countries have been unable to attract and retain a sufficient number of good managers, engineers and technical personnel.

- End-use inefficiencies and lack of conservation. Both the equipment using electricity in developing countries and the manner in which is used are highly inefficient. Also, techniques and methods of conserving power have not been widely adopted.

Future Demand for Electric Power: Current Trend Scenario

If current trends in electric power consumption continue at the recent 8.6 percent annual growth rate, electricity consumption over the next twenty years in developing countries would increase five-fold by the year 2008. **This would require the investment of $4.79 trillion, or an average over $235 billion per year, compared with the $50-60 billion being spent currently.** Developing countries cannot sustain the financial and environmental impacts of such an expansion.

Future Demand for Electric Power: Alternative Scenarios

Recognizing the unsustainability of simply projecting current trends in electric power demand, the report analyzes three alternative scenarios of future demand growth. These alternative scenarios are intended to illustrate the potential range of future outcomes, giving the reader a general order of magnitude rather than a definitive estimate of future conditions. The alternative scenarios are based on the high and low projections for economic growth in developing countries by the World Bank and on rather dramatic reductions in the ratio of electricity consumption to income growth.

These alternative scenarios assume (1) significant efficiency improvements in existing and future power facilities, (2) sharp reductions in transmission and distribution losses, and (3) considerable improvement in the end-use efficiency of electricity consuming equipment and devices. Under this approach, the ratio of electricity to income growth is reduced in stages from its current level of 1.4 down to as low as 0.9 by the year 2000 and beyond (0.9 is slightly less than the ratio being experienced in the United States today).

These projections suggest that from an existing level of 445 GW of capacity in developing countries by the year 2008 generation capacity could increase to between 1150 GW (an annual growth rate of 3.71 percent) and 2008 GW (an annual growth rate of 5.8 percent). These projected growth rates are considerably lower than the 7 percent per year rate projected by the World Bank for 1985 to 1995 or the 8.6 percent per year used in he current trend scenario..

Based on these scenarios, **the projected financial cost of the new generating capacity and its related transmission and distribution facilities would be between $800 billion for the low growth scenario and $1.7 trillion for the high growth scenario.** If, however, no improvements in end-use efficiency, transmission and distribution losses and generation plant utilization occurred (i.e. the ratio of electricity consumption to income growth was 1.4 from 1988 to 2008, instead of declining to 0.9) the investments required would be $1.6 trillion for the low income growth scenario and $3.9 trillion for the high income growth scenario!

2. THE IMPACT OF ELECTRIC POWER SHORTAGES

While not sufficient unto itself, the availability of reliable electric power is a key component of the infrastructure necessary for economic development in the Third World. Expansion of the agricultural and industrial sectors, in particular, depends heavily on electricity to perform productive functions. Currently in most developing countries, the industrial sector dominates electricity consumption, accounting for over 60 percent of total electricity use.

As these nations modernize, electricity use in the commercial and residential sectors is rising sharply, and in some countries has outstripped industrial sector consumption. Electrical services in the form of lighting, heating, cooling, and labor saving devices add to the quality of life and the productivity of individuals and their families and, consequently, are in high demand in developing countries.

Also, most developing countries have adopted aggressive plans for rural electrification in an effort to decentralize their populations and to distribute the benefits of economic growth and electric services. Electricity has direct benefits in rural areas on health through its us in refrigeration of vaccines and food. Electricity also permits the introduction of lighting and small-scale, labor saving devices for rural production and consumer convenience. These programs are endangered if developing countries cannot obtain the financial resources for decentralized, rural electrification.

Electricity and Economic Development

Even though power supply capacity in developing countries has increased significantly over the past two decades, the demand for electrical services has risen more rapidly. Consequently, **many developing countries now face critical power shortages of over 10 percent of their generation capability.** In Pakistan, for example, over the past five years, power shortages have been over 25 percent of the peak demand. In India, power shortages of over 10 percent are common throughout the country with some states experiencing shortages of power of up to 40 percent.

These power shortages and unmet demands for power result in significant economic problems. In Pakistan, for example, load shedding in the industrial sector alone has led to a 1.8 percent decrease in Gross Domestic Product and a 4.2 percent decrease in the

country's foreign exchange earnings. In India, the current 10 percent average supply cut to the industrial sector is estimated to cause an annual production loss of over $6 billion -- equivalent to 12 percent of the country's industrial output. Also, the unreliability of power supplies has caused serious losses of agricultural production, especially in those areas dependent upon electrical pumps for irrigation.

Environmental Impacts of Electric Power Systems

A massive expansion of electric power production in developing countries based on current trends threatens environmental damage to developed, as well as developing countries. Projections of power supply expansion show enormous increases in hydropower and steam thermal (mainly coal) facilities. Large-scale hydropower plants often require the relocation of sizeable populations and permanent alteration of river basin ecosystems. Coal-fired power generation has historically been associated with the emissions of particulate materials, sulfur dioxide, oxides of nitrogen and other pollutants from related mining, cleaning, generating and storage operations. The specter of global climatic change looms over any substantial expansion of coal burning plants. Shifts in climatic zones, a rise in atmospheric temperature, a rise in sea level and other disruptive impacts may result from growing concentrations of carbon dioxide and other by products of fossil fuel use.

Systematic planning, conservation and utilization of new technologies offer opportunities to significantly mitigate the massive environmental impacts anticipated by following the current trends that concentrate primarily on the expansion of generating capacity.

Financial Dilemma

Developing countries, due to inadequate economic growth rates and substantial debt burdens, clearly lack the financial resources needed to satisfy the $4.79 trillion demand projected under the current trend scenario.

To achieve the significant growth in their power sectors experienced to date, the developing countries have had to devote an average of 25 percent of their capital improvement budgets to the electrical power sector. Further proportional increases in

the power-sector budget are unlikely since they are likely to cause negative impacts on other important sectors, such as health care services, education, and transportation. Already the poorer developing countries spend $8 per capita annually on power for every dollar spent on education or health.

Under the alternative scenarios, even with significant conservation measures, developing countries will require roughly $800 billion to $1.7 trillion in additional capital for power sector investment in new generating capacity and related transmission and distribution equipment over the next 20 years -- an average of $40-85 billion per year. This does not include any expenditures on rehabilitating or replacing existing power plants or on conservation measures.

The report projects that multilateral and bilateral development agencies can be expected to provide, by the year 2008, from 20 to 40 percent of the needed capital for the alternative scenarios. The report assumes that through pricing and operational reforms the electric utilities and central governments could raise an additional 20 percent of the required capital from domestic revenues. Given the withdrawal of private financial institutions from the international lending market and given that their participation in power sector lending usually requires significant guarantees by the borrowing country or other third party, no projection was made for their future participation, although some level of participation can be expected on a case by case basis.

Combining external and internal capital flows still leaves a substantial shortfall of funds -- $350 billion for the low growth scenario and $1,065 billion for the high growth scenario -- needed for new generating capacity.

3. IMPORTANCE OF THIRD WORLD POWER DEVELOPMENT TO THE UNITED STATES

The power situation in developing countries directly concerns the United States in several ways:

- Foremost is a humanitarian concern for the living conditions of people in these countries, their employment opportunities, and prospects for achieving sustainable economic development.

- As an essential ingredient for economic growth, sufficient supply and efficient use of electric power is critical in the efforts of the U.S. to encourage developing countries to shift from aid recipients to trading partners.

- Power shortages that have induced public demonstrations and riots have sociopolitical implications affecting the stability of governments and their ability to respond to citizen needs.

- The power market in developing countries provides a major opportunity for U.S.suppliers of equipment and services to increase their export sales.

Importance for U.S. Trade

The Committee on Appropriations specifically asked for an analysis of the potential for U.S. technologies and services to address the power problems of developing countries. The report projects the total export market for power generation, transmission and distribution equipment and related services to range from $367 to $908 billion over the next twenty years, depending on the growth scenario. The largest equipment submarkets will be for boilers, steam turbines, and hydroturbines; the largest service submarkets will be in construction and project management.

The competitiveness of U.S. suppliers in the power industry, however, has dramatically declined in recent years. **U.S. exports now represent less than 10 percent of the total power generation exports to developing countries, down from 17 percent just 5 year ago and down from over 20 percent in the late 1970's.** With the inclusion of transmission and distribution equipment, total U.S. power industry exports to developing countries are currently below the $2 billion mark, compared with Japanese exports to developing countries of $3.7 billion.

If current trends persist, the U.S. share of developing country power market sales will be limited to about 5 percent of the estimated export potential through the end of the century. Reversing the trend is possible if incentives can be developed to assist U.S. suppliers. Also, because of a weakened dollar, U.S. products are becoming more competitive with equipment sold by European and Japanese manufacturers. The

restricted availability of export financing for U.S. companies, however, remains a problem.

The U.S. position could also be improved by targeting incentives toward those technologies and services where U.S. suppliers have a competitive edge, such as high-temperature gas turbines, coal emission control, atmospheric fluidized-bed boiler systems, transmission and distribution equipment, conservation equipment and services and end-use efficient electrical equipment and devices. Furthermore, US. has an edge in project management services and in independent power production through renewable and cogeneration technologies due to our recent domestic experience with these under the Public Utility Reform and Pricing Act (PURPA).

If the declining trend in market share is reversed, the report projects that U.S. suppliers could secure 8 percent of the export market through the year 2008, or from $46.4 to $62 billion.

4. STRATEGIES FOR POWER SUPPLY IMPROVEMENT

Given that the traditional approach to electric power shortages, i.e. expansion of generating capacity, is not sustainable, what strategies can developing countries pursue?

Policy Approaches

Policy reforms can play a major role in improving the quality of electricity supply, increasing the efficiency of electricity use, and alleviating adverse environmental impacts.

- Pricing Policy. Electricity prices in many developing countries are administered prices fixed by the government to achieve sociopolitical and equity, as well as,economic objectives. Consequently, artificially low electricity prices result in excessive and wasteful consumption patterns. Developing countries need to find politically acceptable approaches to raising prices to reflect the true capital and operational costs of supply.

- Energy Conservation Policy. Few developing countries have adequately considered the substantial impact that enacting energy conservation policies

and strategies can have on providing additional power while reducing the need for expensive new generating capacity. Conservation policies on the generation, transmission, distribution and end-use of electricity should be developed and enacted.

- Private-Sector Participation Policy. In almost all developing countries the private sector plays little or no role in the power sector. Policies to increase private-sector participation can inject much needed competition, appropriate pricing , efficient management, and private financial investment.

- Environmental Policy. Developing countries will have to confront the critical issue of environmental degradation resulting from activities in the power sector. Explicit policies for environmental protection should be adopted that set forth goals for environmental protection and enhancement, and procedures for evaluating impact and weighing trade offs.

Institutional Approaches

Existing institutional structures in most developing countries are not well matched to the present and future power situation, which will require innovative approaches, an emphasis on conservation, involvement of the private sector and more efficient operation. Approaches to institutional development in developing countries will be needed in the following areas:

- Utility management improvements. System planning should recognize the importance of adequate training and staff development, and of rational management objectives based on efficiency and productivity.

- Privatization of parastatal utility functions. Privatization of existing and future generating, transmission and distribution activities offer opportunities for significant improvements.

- Research and development. The use of innovative, environmentally acceptable technologies will require an indigenous capacity for research and development.

- Strengthening power-sector financing institutions. Given the shortage of capital, attention should be paid to developing specialized, domestic and foreign sources of financing for the power sector.

- Strengthening institutions related to conservation and end-use efficiency. Within the context of a national energy conservation policy, developing countries need to establish an integrated approach combining engineering, management and financial aspects of electricity conservation and end-use efficiency.

Technological Approaches

Increasing efficiency and power output can be achieved by technological improvements in the power sector, as discussed below:

- Power plant performance improvement. Significant improvements in the order of magnitude of 10 percent in power plant performance can be accomplished through cost effective plant rehabilitation and improved operation.

- Transmission and distribution loss reduction. Technical fixes, which do not require advanced technologies, and attention to the theft problem can significantly reduce transmission and distribution losses at relatively insignificant expense.

- End-use efficiency improvement. The introduction of recent improvements in motors, lighting, air conditioning and refrigeration can, it is estimated, reduce end use consumption of electricity by up to 30 percent.

- Load management. In developing countries where peak demand grows at considerably faster rates than average load, load management -- reduction of peak loads, development of off-peak loads and the transfer of loads from on-peak to off-peak periods -- presents an attractive opportunity for reducing the need for additional generating capacity.

- Cogeneration. Combining the generation of thermal energy and electricity allows industrial and large commercial users to use the waste heat from

power generation for process or other thermal needs and reduce their total energy costs.

- New generation technologies. There are a wide variety of conventional and nonconventional generation technologies that can be used in developing countries to reduce environmental impacts, to utilize indigenous fuel resources and to use renewable resources.

Private-Sector Approaches

Directly involving the private sector in the power development of Third World countries offers promising solutions to solving the power problems. The private sector has greater incentive and ability than the public sector to manage and operate efficiently and productively. Also, the private sector has potential access to private sources of financing that are unavailable to the state-owned utilities. In the limited instances where private companies are generating and selling power in developing countries, there is clear evidence of their greater efficiency and reliability.

Impact on Power Sector Expansion Requirements

To assess the impact of nongeneration approaches to the power-sector problem, the report analyzes specific, achievable performance goals for electric utilities and electricity consumers in developing countries. It appears quite feasible to achieve the following:

- 10-20 percent improvement in plant capacity;
- Reducing transmission and distribution losses from 25 percent to 15-20 percent; and
- Improving the end-use efficiency of electrical equipment and devices by 20-30 percent.

In contrast to the current trend projection discussed in earlier, the alternative scenarios that emphasize conservation can reduce the need for additional generation capacity to 1,000 to 1,760 GW.

Role of A.I.D. In Alleviating Power Shortages

The U.S. Agency for International Development should play a pivotal role in assisting developing countries to alleviate their electric power problems. Building upon its extensive experience, the Agency can make substantial contributions in the following areas:

Policy Dialogue

- Pricing policy. A.I.D. should focus its activities to induce pricing reform policies that reduce or eliminate uneconomic pricing and alleviate current and future demands for power.

- Conservation policy. A.I.D. should assist developing countries to develop and implement national energy conservation plans that address generation, transmission and distribution, and end-use consumption of power.

- Private-sector policy. A.I.D. should expand its current efforts to encourage the implementation of policies and practices that assist private-sector participation in the power sector.

- Environmental policy. A.I.D. should assist developing countries to develop, adopt and implement systematic policies, standards and practices for environmental management for power-sector activities.

Institutional Improvements

A.I.D., through the technical expertise it has available and the its proven ability to provide effective training, should focus particular attention to improving the electric utility institutions in developing countries. The Agency should concentrate its resources on the following:

- Improving utility management

- Assisting in privatization of parastatal utility functions

- Supporting research and development

Strengthening power-sector financing institutions

Assisting institutions involved with conservation and end-use efficiency improvements

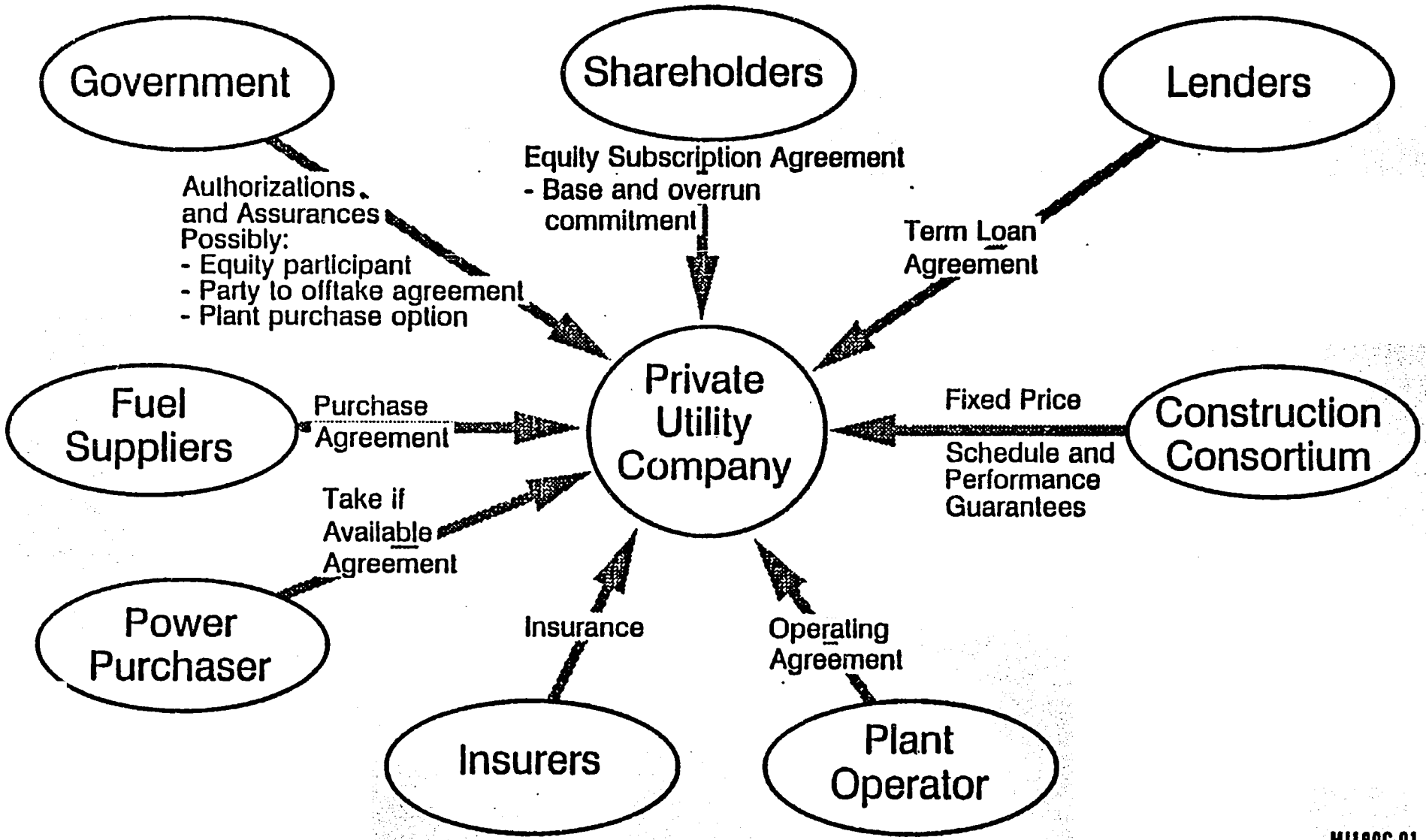
Technology Transfer

A.I.D. should take the lead in coordinating federal activities to promote technology options in which U.S. businesses have special capabilities, such as power plant rehabilitation, transmission and distribution loss reduction, load management, cogeneration, conservation and end-use efficiency improvement, and environmental controls.

Private-Sector Development

A.I.D. should pursue various strategies to induce private-sector participation in the power sectors of developing countries. These are briefly outlined in this report and more fully discussed in the companion report on "Options to Increase Private Participation in Electric Power Development in A.I.D.-Assisted Countries." Initially, A.I.D. should focus on removing the policy and institutional barriers to private-sector participation in the power sector and on assisting the implementation of a limited number of potential projects to provide some actual experience with this innovative approach.

Privatization Structure - Electric Generating Station



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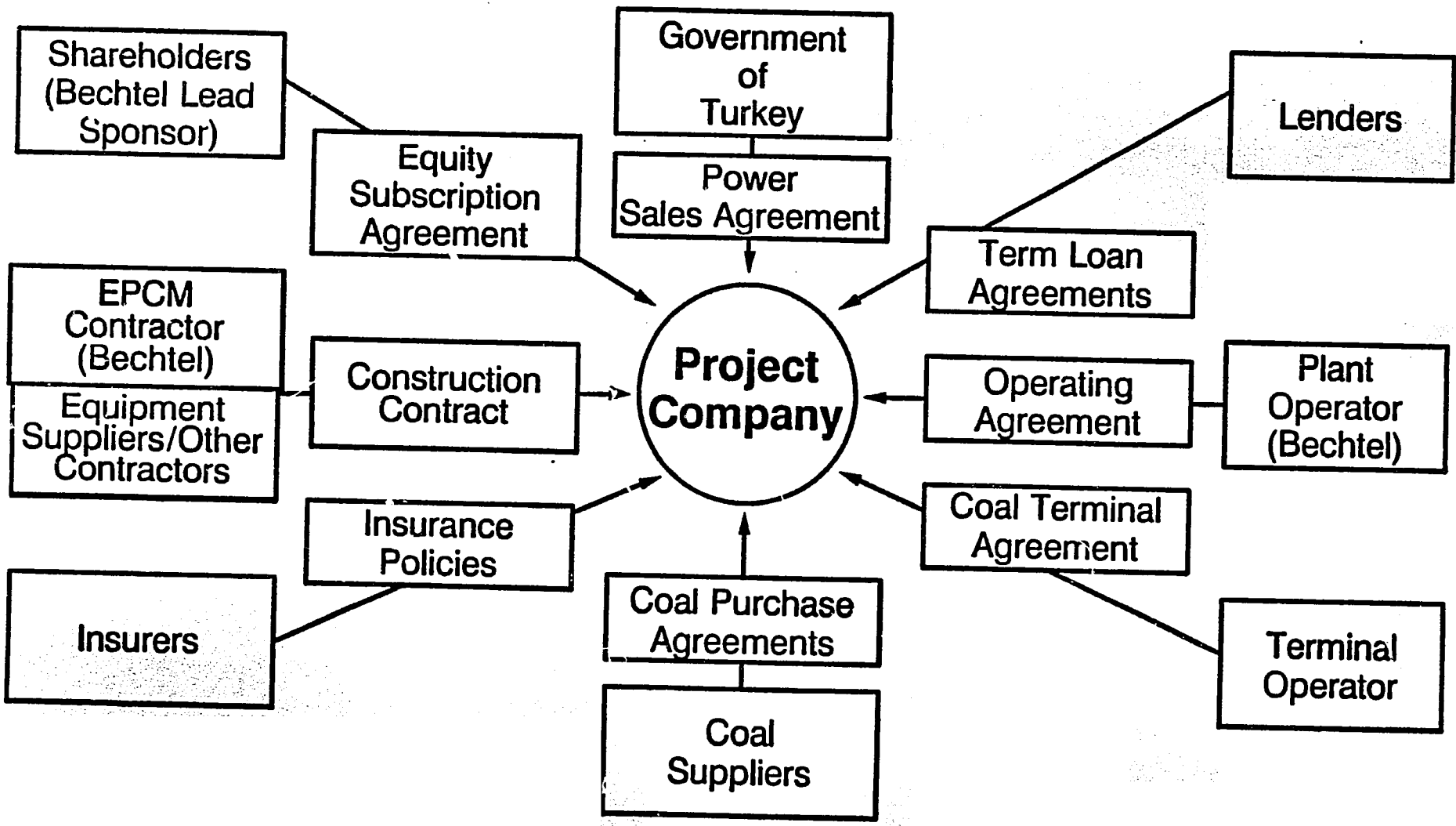
MAJOR CONSIDERATIONS FOR JORDAN OIL SHALE POWER PROJECT

THE PROJECT BASE	OIL SHALE RESOURCE APPRAISAL			
BASIC PROJECT COMPONENTS	MINING AND MATERIALS HANDLING	SHALE COMBUSTION	POWER GENERATION	GAS PROCESSING AND WASTE DISPOSAL
AUXILIARY REQUIREMENTS	PROJECT UTILITIES AND OFFSITE FACILITIES POWER TRANSMISSION SYSTEM			
SUPPORTING FACILITIES	INFRASTRUCTURE			
PROJECT CONSTRAINTS	ENVIRONMENTAL AND SOCIO – ECONOMIC			
PROJECT FUNDING	FINANCING – SOURCES, TERMS			
PROJECT REALIZATION	PROJECT IMPLEMENTATION ENGINEERING – PROCUREMENT – CONSTRUCTION – OPERATION			

Tekirdag Power Project, Turkey

Coal-Fired Power Plant



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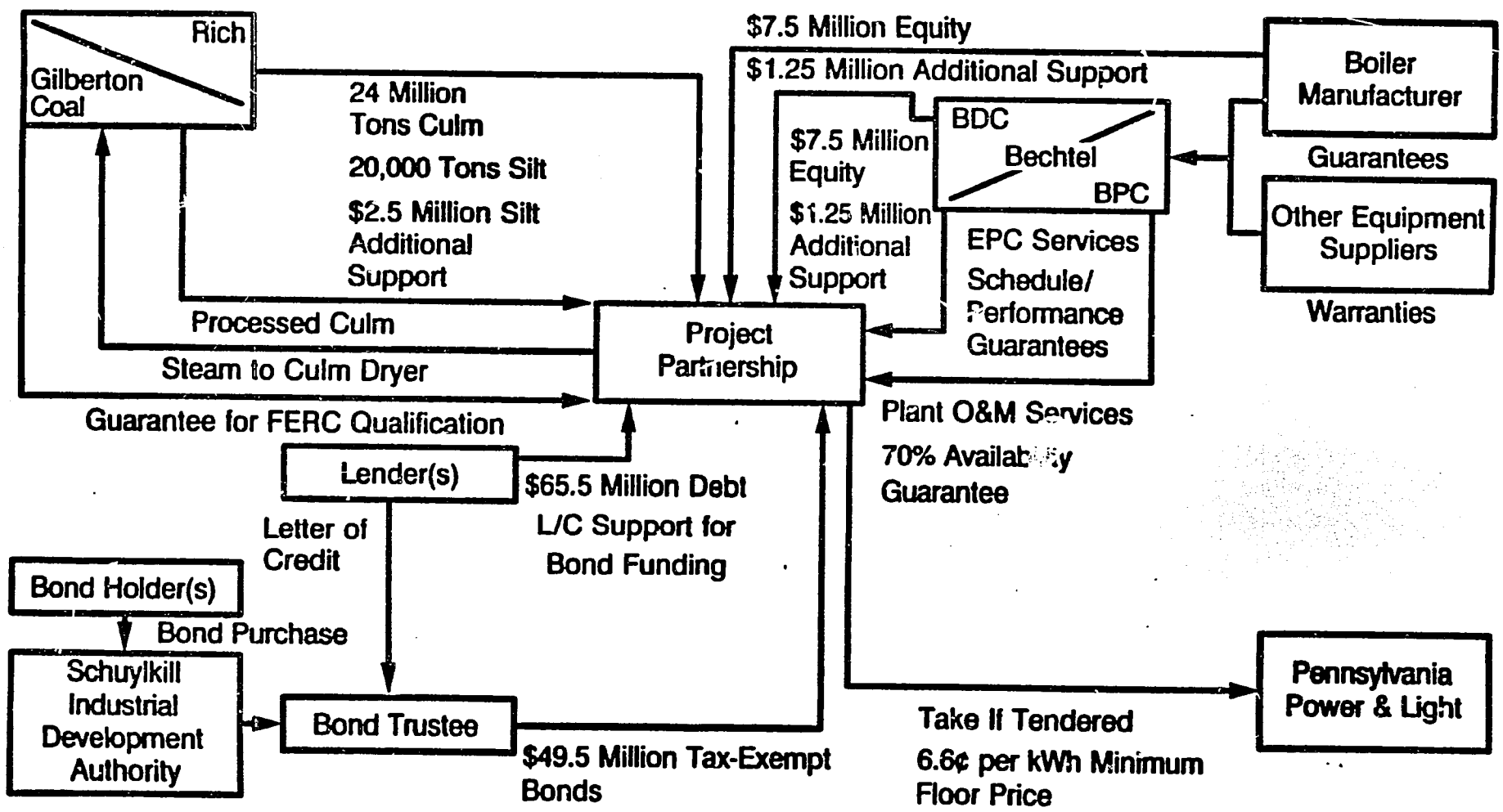
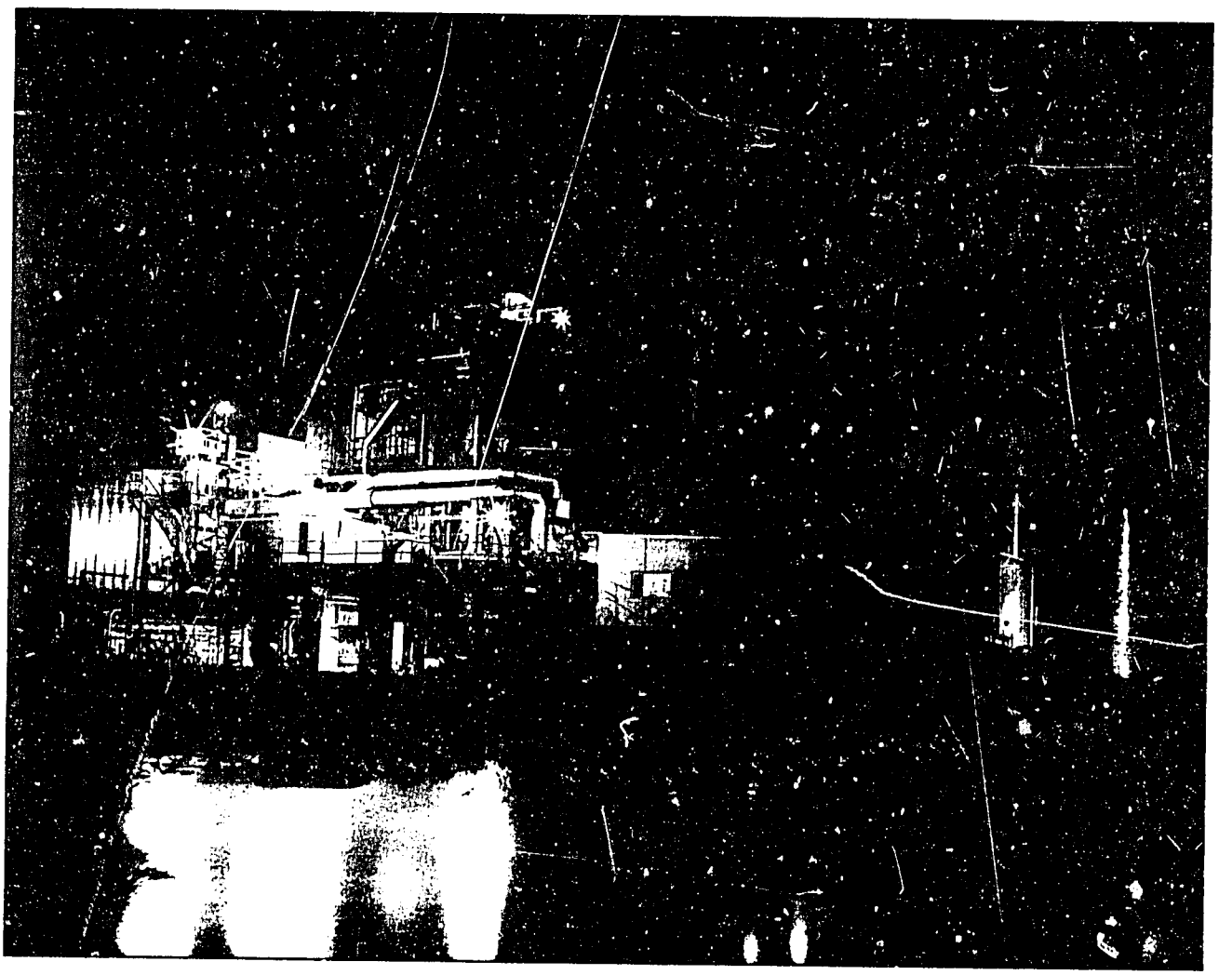
Gilberton Cogeneration Project
$130 Million, 80 MW Facility

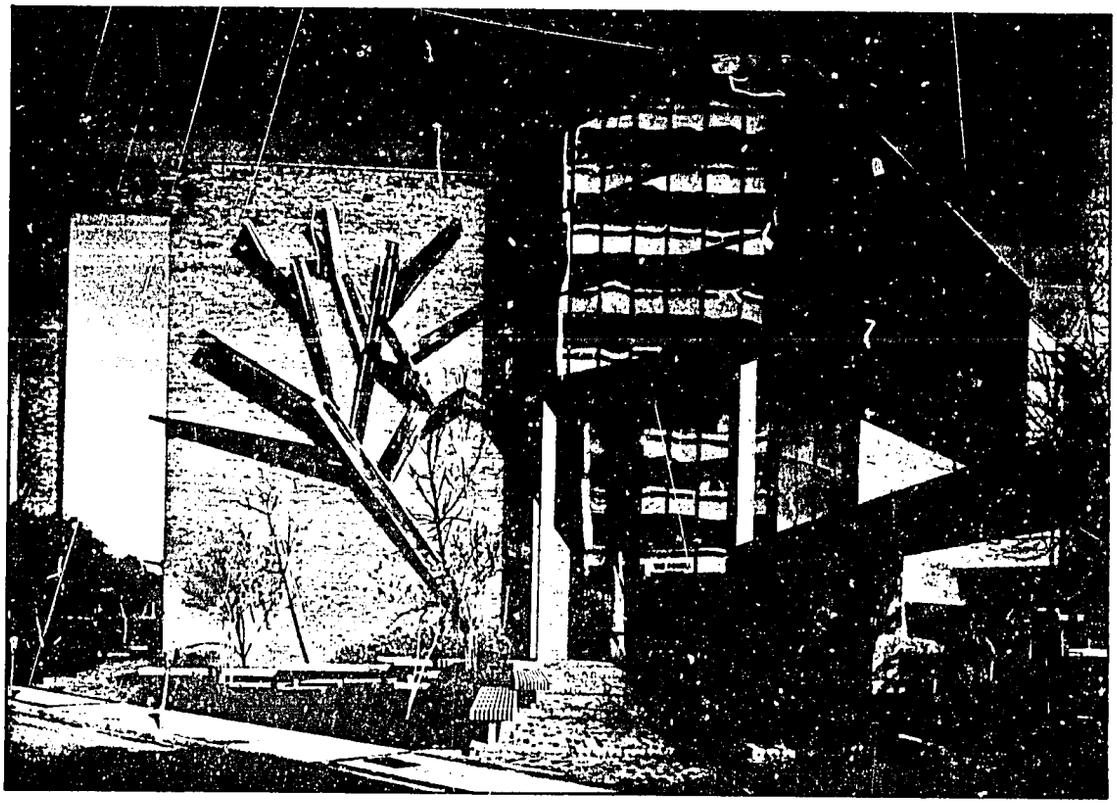


AGRILECTRIC POWER



"CONVERTING RICE HUSKS TO ENERGY"

87



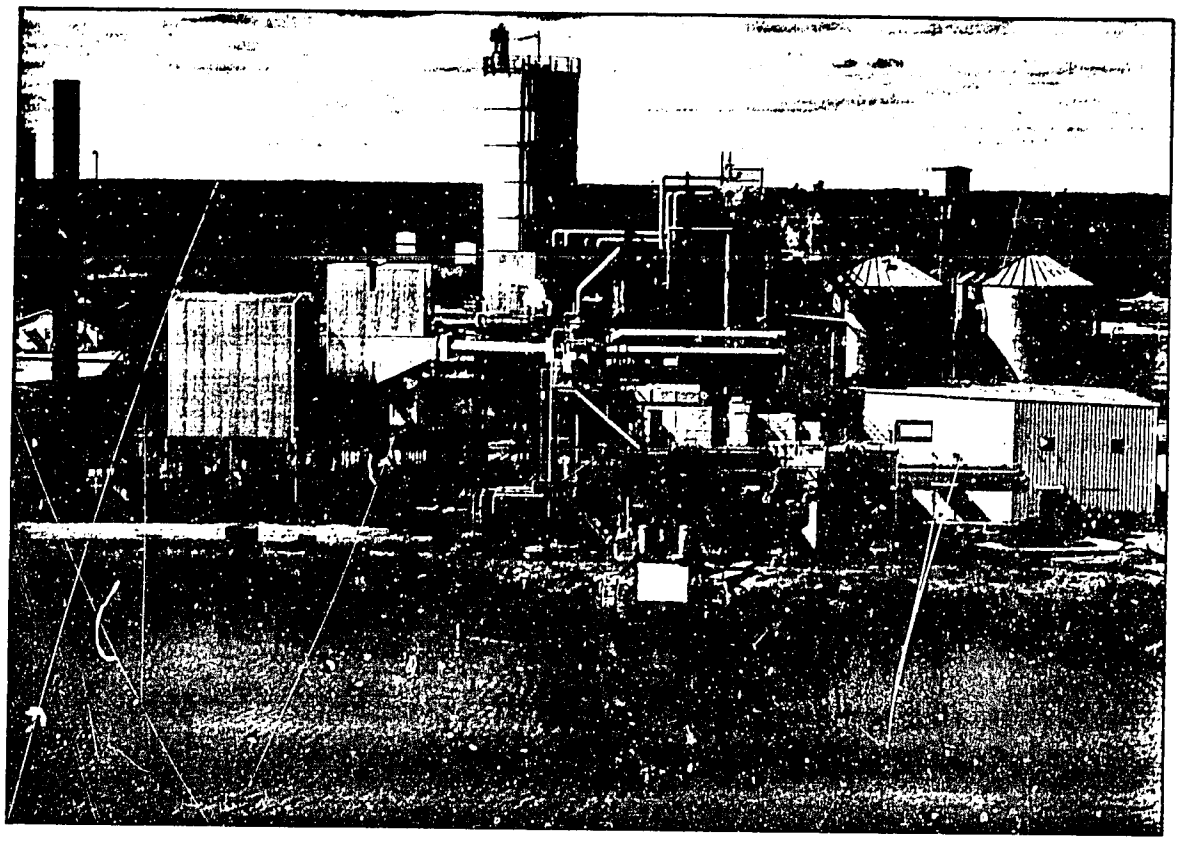
The Powell Group Headquarters, Lake Charles, Louisiana

Some fatherly advice offered to his son in an 1890 letter marked the beginnings of great opportunities for some men of vision. The result of these visions, The Powell Group, through its family management and leadership, continues to thrive as it approaches its second century in business. From humble beginnings as a grocery and dry goods firm, The Powell Group has continued its growth and diversification to become the multifaceted operation it is today.

Headquartered in Lake Charles, Louisiana, U.S.A., The Powell Group is composed of a number of related corporations and partnerships. Agrilectric Power is just one of several affiliated companies that make up The Powell Group. All of these entities work in a coordinated effort to maximize their achievements.

- **Farmers Rice Milling Company, Inc.** is one of the five (5) largest white rice mills in the world on a throughput basis, and is capable of producing over 800,000,000 pounds of rice a year.
- **Powell Lumber Company** and its affiliated land-holding companies (W.G. Ragley Lumber Company, American Sulphur and Oil Company of Louisiana, Hayes Lumber Company, and Kelly, Weber & Company, Inc.) have continued to manage their timberlands, and have developed considerable rice and soybean farming activities on those lands where suitable. The Powell Group annually markets five (5) to ten (10) million board feet of pine sawtimber and several million feet of hardwood sawtimber, along with poles, piling, and pulpwood.
- **Farmers Land and Canal Company** operates a rice, irrigation, soybean, and cattle farming operation on 14,000 acres of land.
- **W-K-N Real Estate** actively subdivides and develops urbanized land belonging to The Powell Group.

As operations have expanded, The Powell Group has added to its management strength with a combination of advancement from within, attracting talented people from other organizations, and aggressive college recruiting.



Agrilectric, Lake Charles Facility

Agrilectric Power, of Lake Charles, Louisiana, U.S.A., an affiliate of The Powell Group, has designed and built an 11.5 megawatt power plant that generates electricity from rice husks. The plant has successfully operated in conjunction with Farmers Rice Milling Company since 1984. Using only rice husks for fuel, this Southwest Louisiana facility is the first commercially operated rice husk fueled power plant of its kind.

Agrilectric Power's experience and no-nonsense approach in turning husks-to-energy are bringing new life to the rice growing regions of the world. Through determination and innovative engineering, Agrilectric has taken a waste product and converted it to a usable energy source to supply low cost electricity to agricultural nations.

In addition to supplying its own internal power needs, Agrilectric sells the excess production (approximately 84%) to the public utility grid. This cost effective means of producing electricity can supply the needs of the most rural of the third world countries, or enhance the energy climate existing in the most advanced nations.

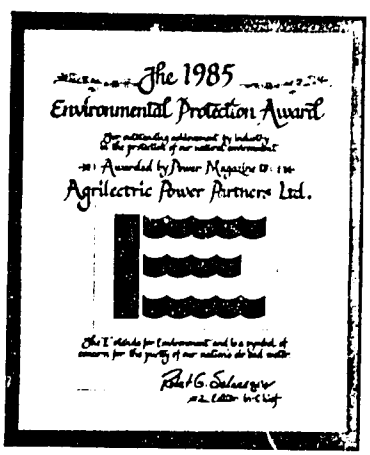
The engineers at Agrilectric knew the potential of taking a waste product from the rice milling industry and converting it into saleable energy. The potential is now unlimited. With proven technology and operating experience, Agrilectric Power is seeking opportunities for joint ventures or turn key projects with progressive, aggressive partners, to build and operate rice husk fueled power plants in your area or country.

Energy from Rice Husks

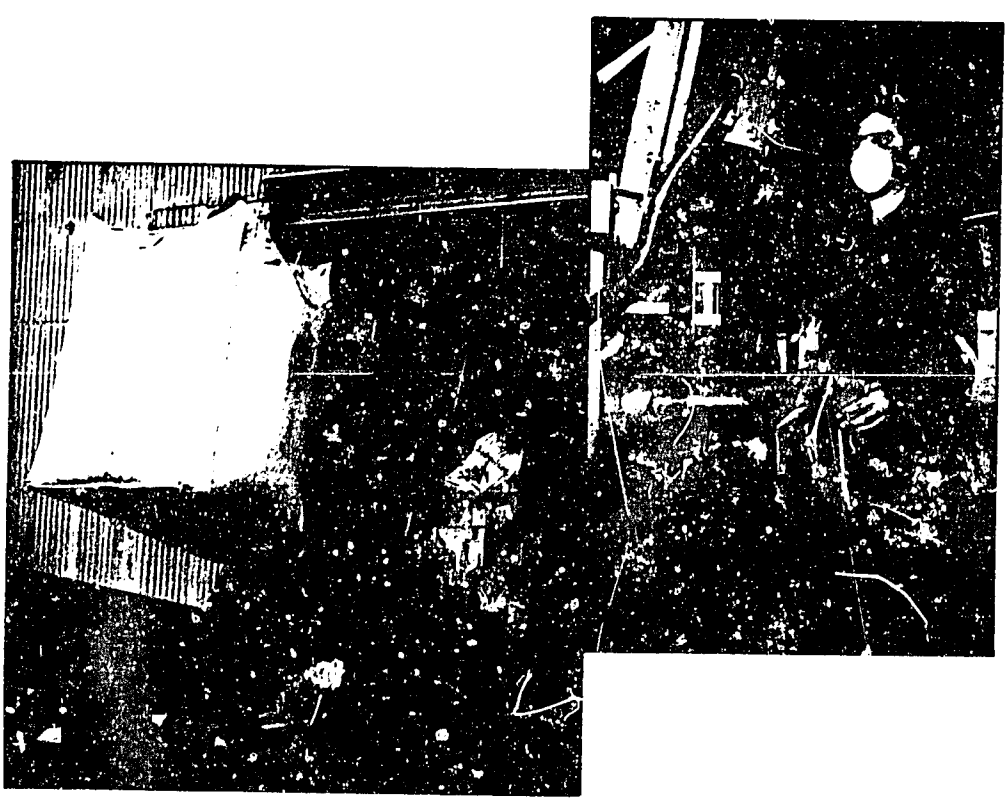
Historically, rice husks have been a liability to the rice industry. Transportation, disposal, and handling of rice husks have plagued the industry for years. Added to these ever increasing costs and logistical problems are the environmental regulations regarding dumping and dust control. As these laws change, the problem of handling rice husks will only become more complex.

The experts at Agrilectric Power were cognizant of what a rice husk-fueled power plant would mean to the rice growing regions of the world. By converting rice husks to energy, steam, or electricity, Agrilectric has now transformed a liability into an asset by taking a fuel source that is both available and renewable in almost every country in the world and transforming it into saleable energy . . . energy that will be the engine for growth and economic development.

By burning the waste husks, Agrilectric has overcome an environmental nuisance often associated with rice processing. For its innovation in burning process wastes, Agrilectric earned Power Magazine's 1985 Environmental Protection Award.



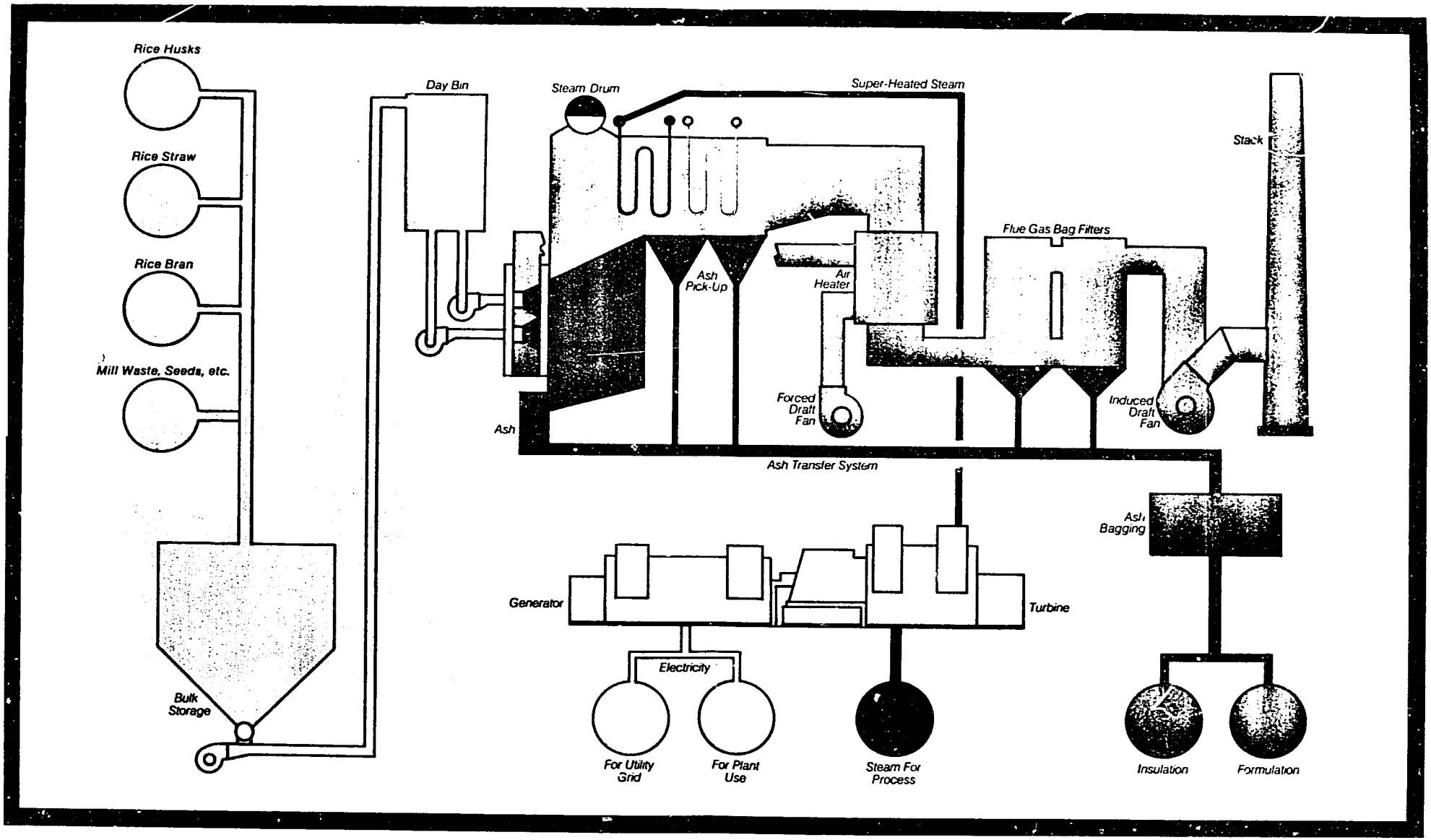
Environmentally Sound



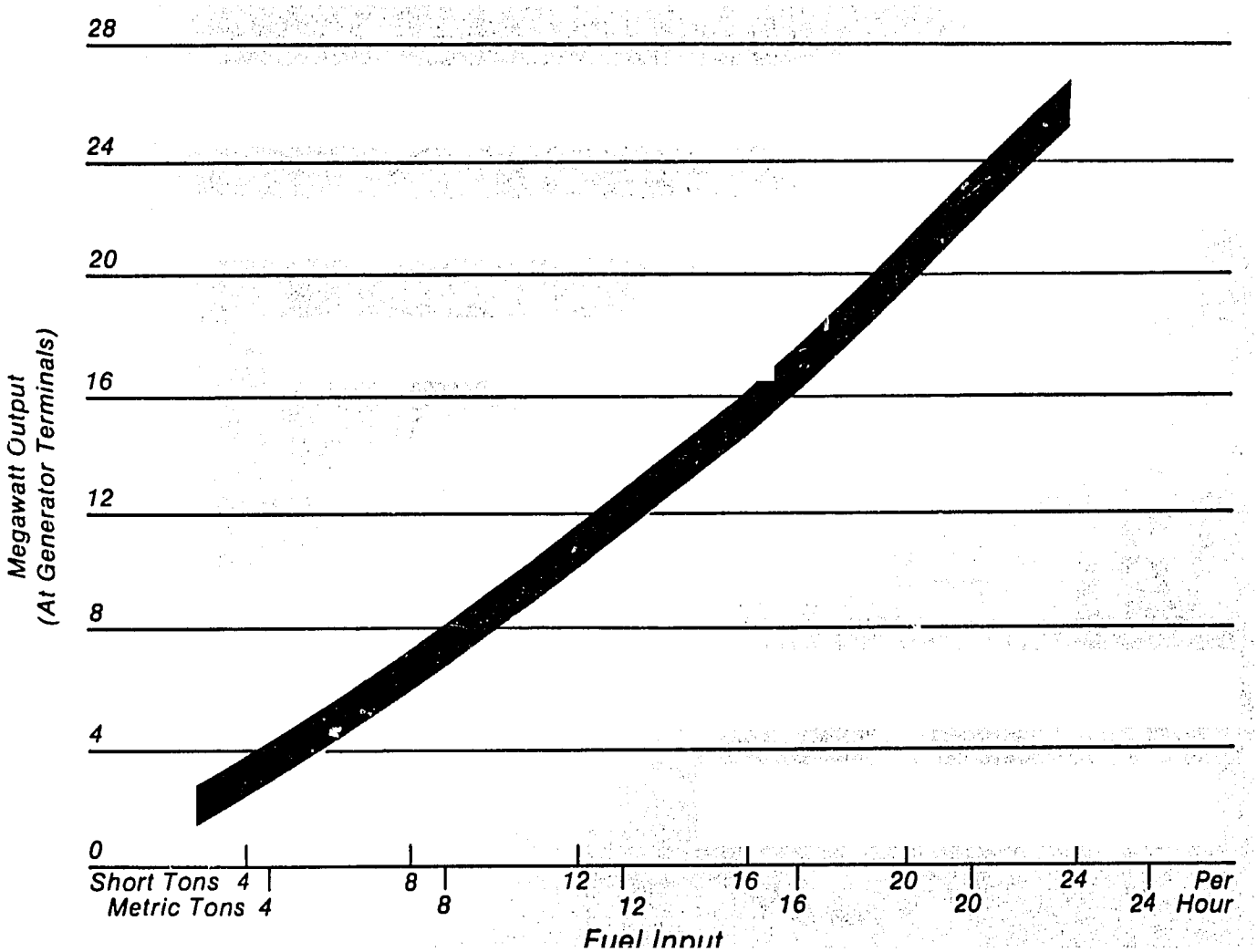
Waste to Energy to Saleable By-Product

After the husks are burned, the resultant ash can be sold, thereby generating even more revenue. The export potential for the ash is unlimited. The ash, which is 94% silica, has value to the steel industry and refractory manufacturers for its insulating properties.

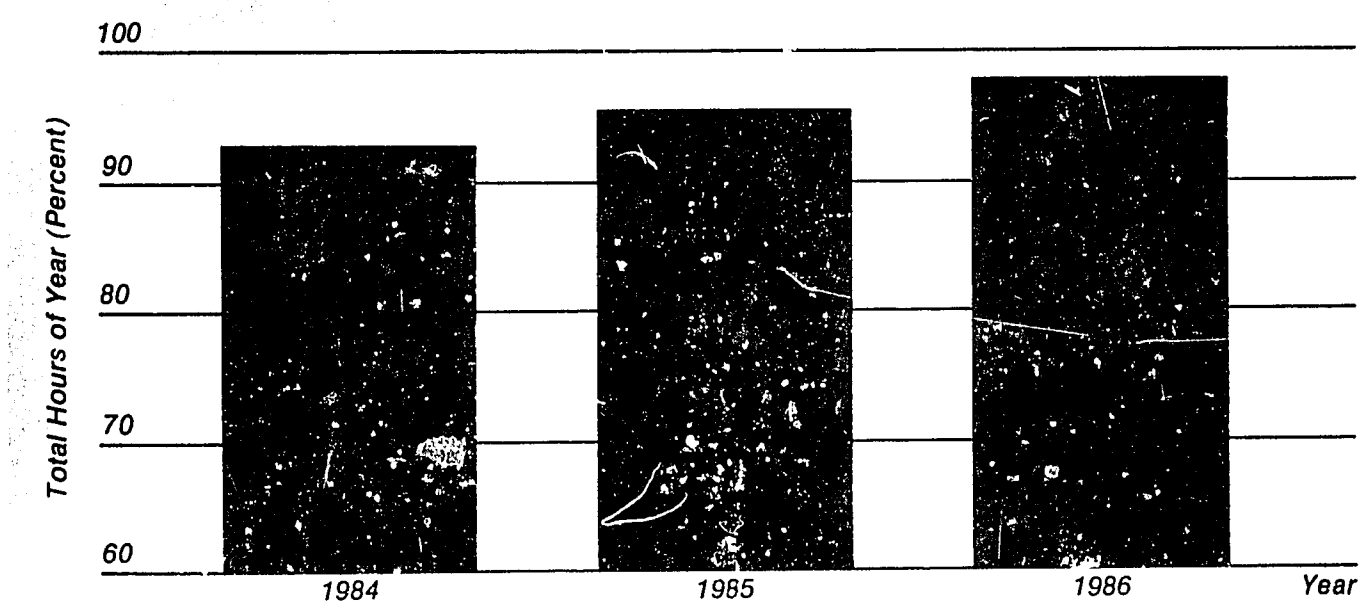
Energy Utilization

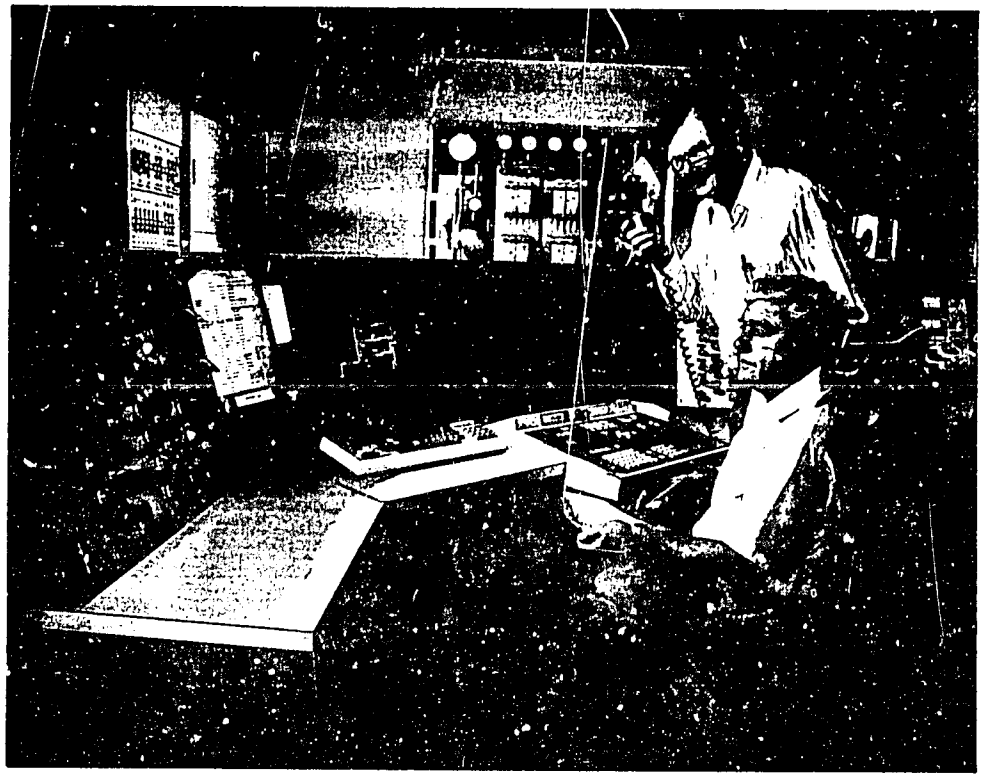


Fuel Consumption



Plant Reliability





State of the Art Computerized Control Center

RELIABILITY

Many people are amazed to learn that Agrilectric has proven plant reliability that exceeds most generating stations . . . 97% synchronization with the power company in 1986 (See chart). This reliability translates into hard cash profits:

- Efficient disposal of agricultural waste
- Low cost power for in-plant consumption
- Potentially lucrative steam contracts
- Revenue from the electric utility
- Domestic and/or export sales of ash

FLEXIBILITY

The flexibility of alternative fuels, such as rice straw, bagasse, sawdust, and various other biomass materials, assures not only a good return on investment, but also provides an investment in a country's future growth.

You may prefer to have a small power plant at your mill. Several mills, cooperatives, or farms may prefer to pool husks and straw to fuel a large plant that will electrify whole regions of an area or nation.

State-of-the-art automation permits a small plant staff. Conversely, should manpower be inexpensive, employment for many can be designed into operational programs.

In addition to electricity and ash products, your plant can be designed to extract steam for process purposes. Food processing and parboil plants then become additional options for profit centers.

Plants can range in size from 1 megawatt up to 29 megawatts . . . enough power to electrify a small city.

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1221 Avenue of the Americas, New York, N.Y. 10020

Cogen plant burns rice hulls, avoids waste-disposal problem

Agrilectric Power Partners eliminates the environmental nuisance of smoldering rice hulls in landfills. It operates year-round on its own supply and outside surplus

Food producers have a unique environmental problem when dealing with the disposal of agricultural wastes and process byproducts: Profitable, yet environmentally sound methods are scarce. The advent of the Public Utility Regulatory Policies Act (Purpa) has dramatically changed disposal practices for many food processors by providing incentives to use the waste products as fuel for electricity production—kilowatts that Purpa requires the local utility to purchase.

The first small-power-production facility designed to operate on rice hulls reportedly is the 10.6-MW plant owned by Agrilectric Power Partners Ltd, Lake Charles, La (Fig 1). The limited partnership (not a third-party tax shelter) was formed by the management of the Powell Group, a consortium with lumber, rice, soybean, and other business interests in the Louisiana/Texas area. The Powell Group owns the Farmers Rice Milling Co, one of the 10 largest rice mills in the world on a throughput basis, and Agrilectric's source of hulls.

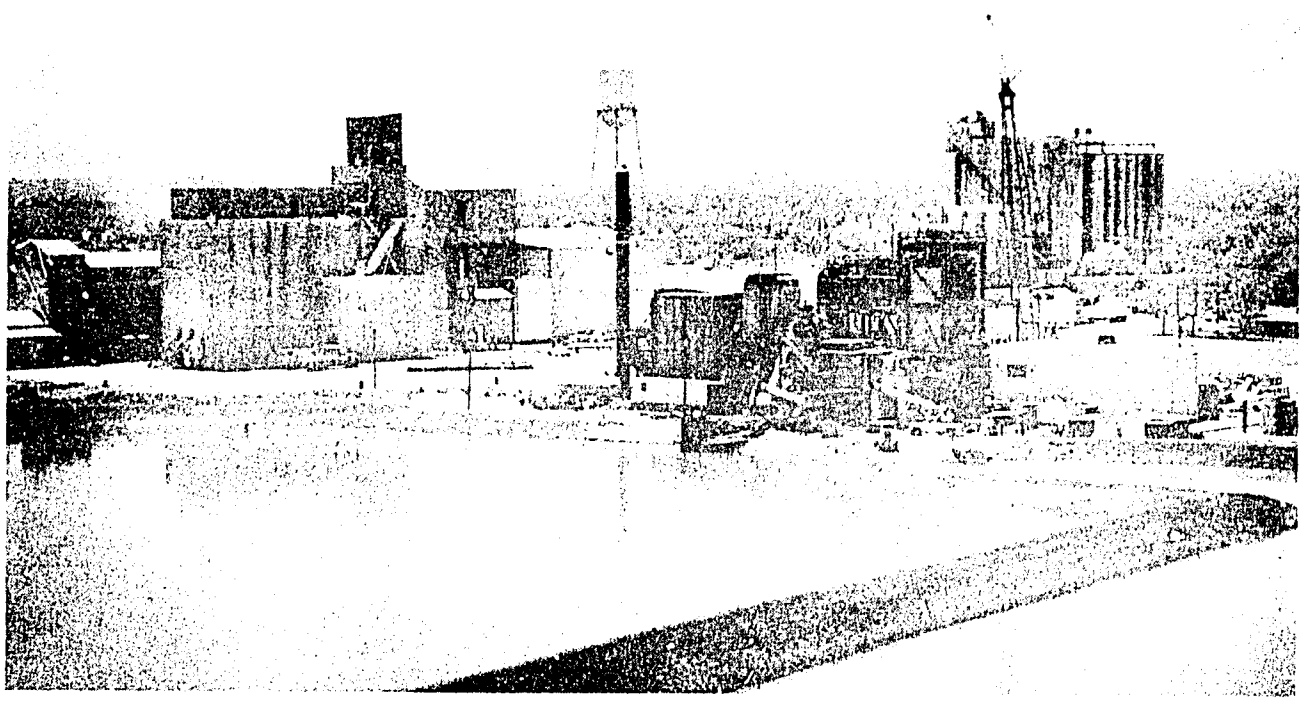
By burning the waste hulls, Agrilectric is confronting an environmental nuisance often associated with rice processing. The rice hulls that are not burned, which represent 20% of the harvested rice by weight, normally are run through a hammermill to increase their bulk density from 10 to 12 lb/ft^3 to 20 lb/ft^3. Disposal involves spreading or piling them on land adjacent to the mill. The hulls often smolder in the fields, like mine tailings from coal production, creating continuous, uncontrolled burning. Installation of its rice-hull-burning, electric-generating plant has helped Agrilectric avoid the costs associated with landfilling and disposal, as well as the environmental problems. For its innovation in burning process wastes Agrilectric earns POWER's 1985 Environmental Protection Award.

Fuel quality, availability

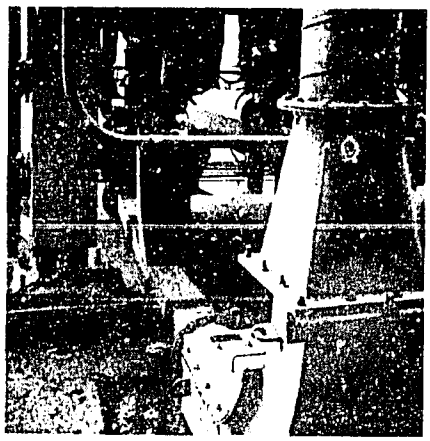
While the use of rice hulls for fuel is not a new idea, producing electricity from them is. Most prior experience with burning hulls has been limited to producing steam for parboiling rice (a process in which the unhulled rice is heated to mend grains broken during harvesting, thereby making a more saleable product).

Hulls essentially are a mixture of cellulose and silica; as they come from the mill, hulls contain about 8-10% moisture and have a heating value of about 6200 Btu/lb (Table 1).

A major consideration in planning any



1. Agrilectric's powerplant burns rice hulls from its own process and buys other producers' surplus for continuous operation



2. Blower/venturi arrangement (left) is being considered for moving hulls from bin to boiler because of fan wear problems

3. Four burners on two elevations fire rice hulls. Work is ongoing to improve flame stability and carbon burnout

4. Boiler plant controls represent the latest in industrial-grade technology

Table 1: Proximate analysis of rice hulls

Constituent	As-received	Dry basis
Moisture, %	8.18	—
Ash, %	18.44	20.09
Volatile matter, %	59.93	65.27
Fixed carbon, %	13.45	14.64
Heating value, Btu/lb	6202	6755*

* 8452 Btu/lb on a moisture- and ash-free basis

Table 2: Typical analysis of rice-hull ash

Constituent	Concentration, %
Silicon dioxide	92.0
Magnesium oxide	2.0
Manganese oxide	0.2
Iron oxide	0.1
Calcium oxide	0.1
Barium oxide	0.04
Potassium oxide	0.02
Aluminum oxide	0.01
Sodium oxide	0.01
Copper oxide	<0.01
Nickel oxide	<0.01
Carbon (average)	2.5
Moisture (maximum)	3.0
Bulk density, lb/ft³	17-22

power project, and particularly one firing rice hulls, is fuel availability. Farmers Rice, Agrilectric's fuel source, supplies the powerplant 250 tons/day of hulls, but what's more important is the mill operates year-round and it is only 1/4 mile away. Many mills work only until a particular harvest is processed and then shut down. Farmers Rice is able to run continuously because it buys rice stored by producers waiting for the market to improve and from government surplus. Bear in mind that rough rice dried after harvesting can retain its food value in bins for up to several years.

Building a powerplant close to the source of the hulls is extremely important, too, because the low density of the fuel does not permit economical transportation over long distances. US rice production is concentrated in Arkansas, Louisiana, Texas, and California. The last is the possible location of another rice-hull-fired plant being planned by Agrilectric, producing upwards of 25 MW.

Farmers Rice grinds its hulls so that the particle size of the fuel going to Agrilectric essentially falls between 20 and 100 mesh. This is a slightly finer grind than would be specified for field disposal. The ground hulls are transported from the mill to the day silo by a medium-density pneumatic conveying system supplied by Fuller Co, Bethlehem, Pa. Suction fans move the lightweight fuel from the bin to the boiler's four burners (one fan per burner). However, erosion problems caused by the very abrasive hulls have engineers investigating the merits of a clean-air-blower/venturi system as a replacement (Fig 2).

Plant performance

The boiler island—one of three fixed-price construction packages—was erected by McBurney Corp, Atlanta, Ga. The burners, which create a cyclone effect, have been the source of a few minor problems (Fig 3), but modifications have improved flame stability and increased carbon burnout. The latter must be controlled to produce an ash product high in silica for sale to steel producers (Table 2). They use it for ladle and tundish insulation. The ash also has value as an absorbent in cleaning up liquid-waste spills.

Tube wear in the 112,000-lb/hr (at 650 psig/750F) Deltak Corp (Minneapolis, Minn) boiler, a primary concern of engineers designing for rice-hull firing, has not been noticeable in the first year of operation. One reason is the straight-through design of the heat-transfer sections—screen tubes, superheater, evaporator, and economizer. A feature of the boiler is its modular tube bundles which make for easy removal and replacement of any bundle. The last heat trap in the system before the fabric-filter dust collection is a tubular air heater.

Plant controls represent the latest thinking for industrial facilities of this size. Boiler (Fig 4) and turbine/generator control modules are microprocessor-based, with the latter package equipped with a sequence-of-events recorder.

The synchronous generator, manufactured by General Electric Co, Lynn, Mass, is rated at 12.5 MVA. When the turbine operates at 5% overpressure with valves wide open (which is normal at Agrilectric), output ranges from 11.2 to 11.8 MW. Power is produced at 13.8 kV and stepped up to 69 kV in Agrilectric's switchyard. The firm upgraded Gulf States Power Co's recommendations for relay protection when designing this substation. Note that Gulf States buys all the electricity Agrilectric does not use internally, at an average price of 3¢/kWh. Negotiations aimed at securing a capacity credit and a more favorable avoided-cost rate are ongoing with the utility. The turbine/generator and the substation were erected under separate fixed-price contracts by two different GE divisions.

A 22,000-gal/min condenser with a divided waterbox serves the turbine/generator. It gets its cooling water from an artificial lake supplied by deep wells, more economical than cooling towers. ■

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Food

Rice-hull-fired powerplant burns a nuisance waste, sells electricity, ash

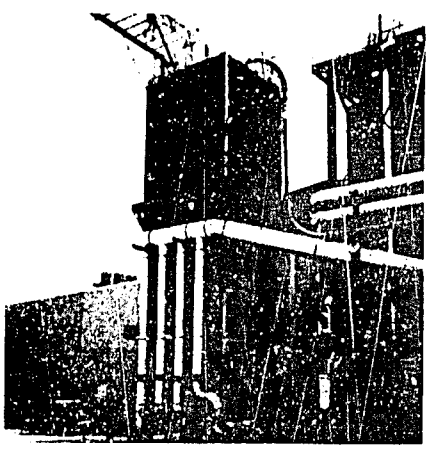
Incentives offered by the Public Utility Regulatory Policies Act, better known as Purpa, give many food producers the opportunity to dispose of agricultural wastes and process byproducts in an environmentally sound manner—profitably.

Consider, for example, the wastes resulting from rice production. After harvesting, rice is transported to a mill where a so-called sheller removes the hulls and a purler prepares it for market by removing the thin layer of brown bran coating the grains. Hulls, which represent 20% of the harvested rice by weight, normally are run through a hammermill to increase their bulk density from 10 to 12 lb/ft³ to 20 lb/ft³ and then are disposed of by spreading or piling them on land adjacent to the mill. A problem with this method of disposal is that the hulls often smoulder in the fields, like mine tailings from coal production, making them an environmental nuisance.

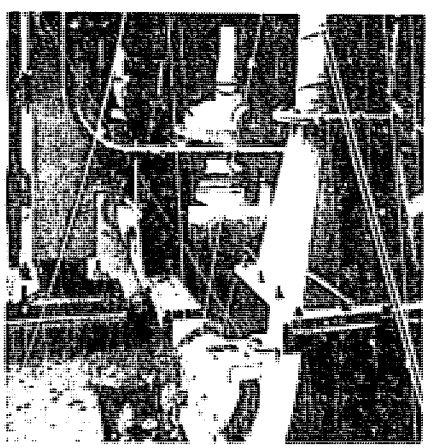
In certain areas, millers are able to sell some of their hulls to chicken farmers for bedding and to cattle ranchers who make a winter feed by mixing ground hulls with the protein-rich bran in about a 2:1 ratio. However, neither of these markets demands much of the byproduct hulls and profits from their sale are slim.

Perhaps the best way to dispose of rice hulls is to use them as a fuel. Hulls essentially are a mixture of cellulose and silica; as they come from the mill, hulls contain about 8-10% moisture and have a heating value of about 6200 Btu/lb (Table 1). Using rice hulls for fuel is not a new idea. In the Far East, they have been used for cooking and heating homes for centuries; here they have been burned in at least two mills to produce steam for parboiling of rice (a process in which the unshelled rice is heated to mend grains broken during harvesting and handling, thereby making a more saleable product).

But the idea of producing electricity from the combustion of rice hulls is new and offers large mills that do not parboil



1. Rice hulls are delivered pneumatically to day bin at Agrilectric plant (line at right corner of bin) from mill



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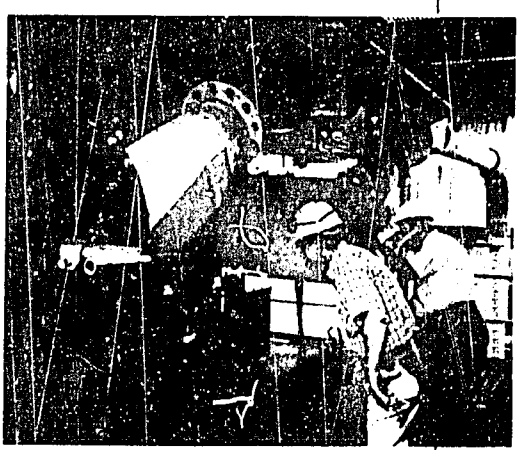

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their product a way to improve their balance sheets. Purpa makes such generation viable by requiring the local utility to buy excess power from the producer.

The first small power-production facility designed to operate on rice hulls reportedly is a 10.6-MW plant owned by Agrilectric Power Partners Ltd, Lake Charles, La. The limited partnership (not a third-party tax shelter) was formed by the management of the Powell Group, a consortium with lumber, rice, soybean, and other business interests in the Louisiana/Texas area. The Powell Group owns the Farmers Rice Milling Co, one of the 10 largest rice mills in the world on a throughput basis, and Agrilectric's source of hulls.

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The boiler island—one of three fixed-price construction packages—was erected by McBurney Corp, Atlanta, Ga. The company was selected for its experience in the combustion of rice hulls; it previously supplied rice-hull-fired boilers to Uncle Ben's Inc, Houston, Tex, for two mills. Burners designed by McBurney for those units essentially were the same ones installed at Agrilectric.

The burners, which create a cyclone effect, have been the source of a few minor problems (Fig 3), but modifications have improved flame stability and increased carbon burnout. The latter must be controlled to produce an ash product high in silica for sale to steel producers (Table 2). They use it for ladle and tundish insulation. The ash also has value as an absorbent in cleaning up liquid-waste spills. What Uncle Ben's experience has been with its burners is unknown because the company will not discuss its business with outside parties.

Tube wear in the 112,000-lb/hr (at 650 psig/750F) Deltak Corp (Minneapolis, Minn) boiler, a primary concern of engineers designing for rice-hull firing, has not been noticeable in the first nine months of operation. One reason is the straight-through design of the heat-transfer sections—screen tubes, superheater, evaporator and economizer. A feature of the boiler is its modular tube bundles which make for easy removal and replacement of any bundle. The design is based on one for an Olin Corp Unit (POWER, July, 1982, p 82). The last heat trap in the system before the fabric-filter dust collector is a tubular air heater.

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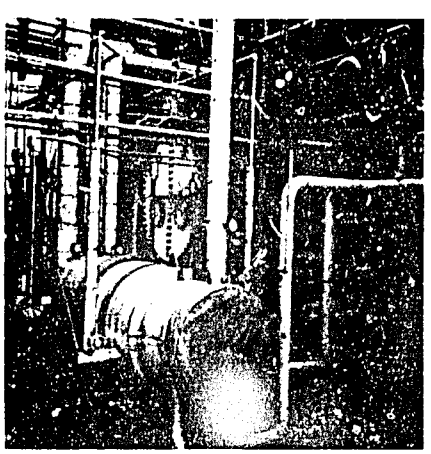
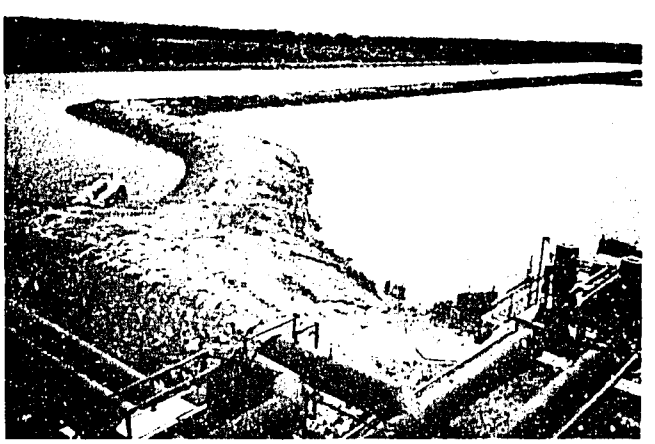
A 22,000-gal/min condenser with a divided waterbox serves the turbine/generator (Fig 5). It gets its cooling water from the artificial lake shown in Fig 6. Supplied by deep wells, the cooling lake was a more economical alternative than cooling towers.

BOB SCHWIEGER





5-6. Two-stage closed heat exchanger alongside condenser discharges feedwater to deaerator (left). Pond dissipates heat in cooling water (right). Discharge is at left in photo, inlet at right

GULF STATES UTILITIES COMPANY
POST OFFICE BOX 2892 • LAKE CHARLES, LOUISIANA 70602
AREA CODE 318 436-4351

J. TED MEINSCHER
Vice President — Lake Charles Division

April 27, 1987

Agrilectric Power Partners, Ltd.
Post Office Drawer P
Lake Charles
Louisiana 70602

Gentlemen:

On behalf of Gulf States Utilities Company, I would like to express our congratulations to you as you approach the anniversary of your third year of operations.

Our records indicate that you were synchronized with and supplied electric power to the GSU Grid beginning in 1984. The first full year's operation the plant reliability was 94%. During 1986 you achieved the exceptional level of performance in excess of 97%.

This enviable, demonstrated record of reliability is particularly noteworthy considering that your fuel is a reproducible, biomass product and the plant is based on a unique technology that you developed.

You have without question achieved an outstanding record as a supplie of reliable electric power, while at the same time enhancing the economic stability of our agriculture industry. You have continued to play an important role in the economic development of Southwest Louisiana and we are pleased to be team members of that effort.

Sincerely,

JTMeinscher

98

DATA

1. Rice husks heat value is based upon 6,200 BTU's per pound at approximately 8% moisture content.

2. Power plants in the 1-5 MW range require about 1.55 ST (1.41 MT) of husks per MWH.

3. A test of the Lake Charles Plant revealed that it takes about 288 ST per day to produce 11.12 MW. Therefore, a figure of roughly 1.1 ST per MWH is required for our mid-sized plants. Larger plants, up to about 28 MW, require something less than one ton of fuel per MWH.

4. Our popular Power Pak 1500 model generates about 2.0 MW at the generator terminals and yields roughly a 1.7 net MW output on approximately 25,668 ST of rice husks per year. (2.0 MW X 1.55 ST X 24 Hrs X 345 Days = 25,668 ST)

5. The rice husk ash (not flyash), which contains a high percentage of nonhazardous silica, has several ready markets which yield additional income.

6. The mid-sized Lake Charles Plant was constructed within one year. The Power Pak 1500 is shipped from the Port of New Orleans as 13 completed modules which can be fitted together on site in a relatively short period of time.

7. Smaller plants, down to 250 KW, can be built. They tend to be less cost efficient on a comparison of cost per unit of electrical energy production basis than the 2.0 MW and larger systems.

8. Currently, plant costs for the Power Pak 1500 are in the vicinity of $3,500,000 FAS U.S. Erection, depending upon the local situation, may cost up to $750,000 USD.

9. Manpower requirements depend upon the plant size and local situation. Modern control systems can reduce requirements greatly, or if the preference is to employ many people, then either method can be included in plant design.

10. Agrilectric Plants are environmentally sound. The soon to be constructed California Plant has met or exceeded all of that state's stringent requirements. Likewise, the Lake Charles Plant passes all of Louisiana's requirements.

*All information concerning fuel is based on utilizing rice husks. If a proposal is made for other biomass fuels, specific calculations will be made for that material(s).

Agrilectric Power

A Member of The Powell Group

P. O. Drawer P
Lake Charles,
Louisiana
USA
70602
(318) 433-6355
Telex: 502433
FARMERICO LKC

FOR FURTHER INFORMATION PLEASE RETURN THIS DATA SHEET TO:

AGRILECTRIC POWER
PROJECT DEVELOPMENT MANAGER
P.O. DRAWER P
LAKE CHARLES, LA 70602
U.S.A.

1. NAME OF COMPANY/AGENCY: _____

2. PRODUCT OR SERVICE: _____

_____

3. LOCATION: _____

4. NUMBER OF EMPLOYEES: _____

5. MAILING ADDRESS: _____

_____

_____

6. INFORMATION REQUESTED: _____

_____

_____

_____

_____

_____

_____

GAS TURBINE COGENERATION WITH AGRICULTURAL RESIDUES

Eric D. Larson

Center for Energy and Environmental Studies
Princeton University
Princeton, New Jersey 08544

Viewgraphs for presentation at the

Convocation on Rice Residue Utilization Technology
Market Prospects: U.S. and Overseas

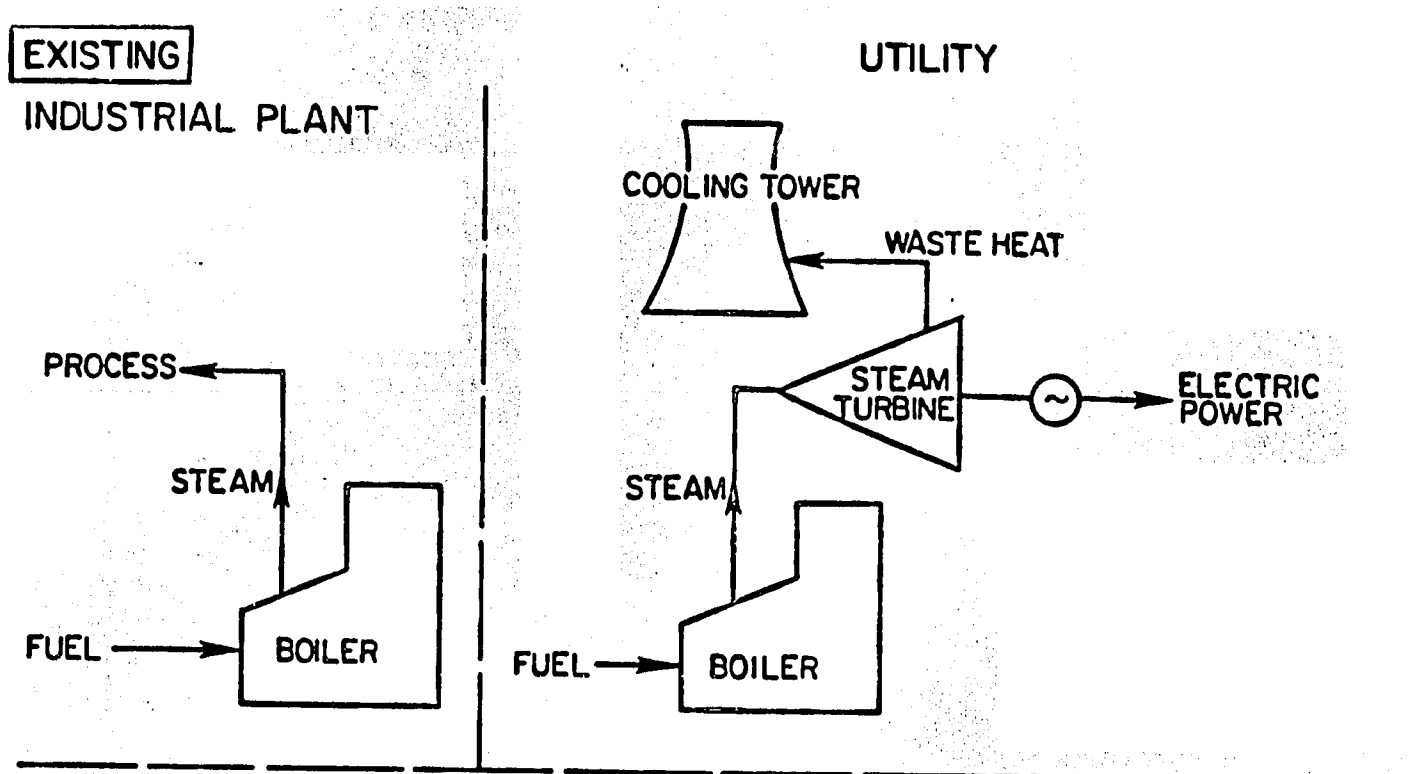
Louisiana State University Agricultural Center
Baton Rouge, Louisiana
January 28-29, 1988

CEES APPROACH TO TECHNOLOGY ASSESSMENT

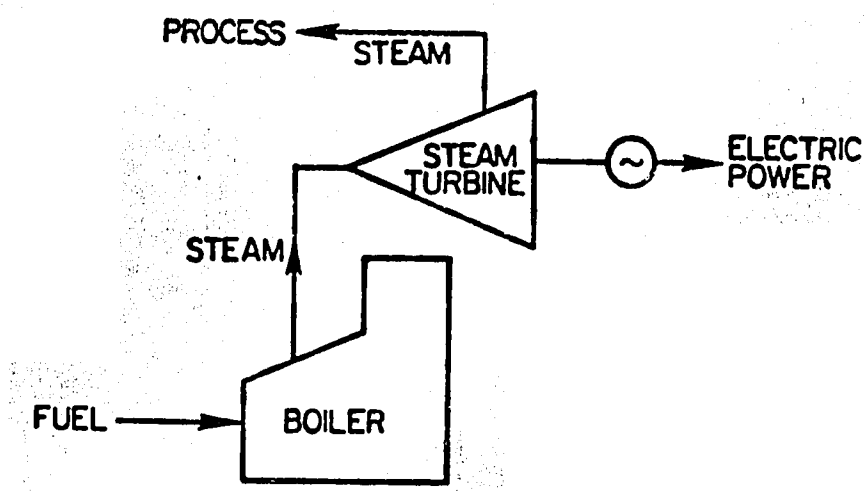
- IDENTIFY PROMISING <u>NEAR TERM</u> TECHNOLOGIES WHICH
  - ARE PRESENTLY UNEXPLOITED OR UNDEREXPLOITED
  - COULD HAVE LARGE IMPACT IF SUCCESSFULLY DEVELOPED
- CARRY OUT IN-DEPTH TECHNICAL, ECONOMIC, AND INSTITUTIONAL ANALYSIS
- OUTREACH TO POTENTIAL PRODUCERS AND POTENTIAL USERS

CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES
TECHNOLOGY ASSESSMENT ACTIVITIES

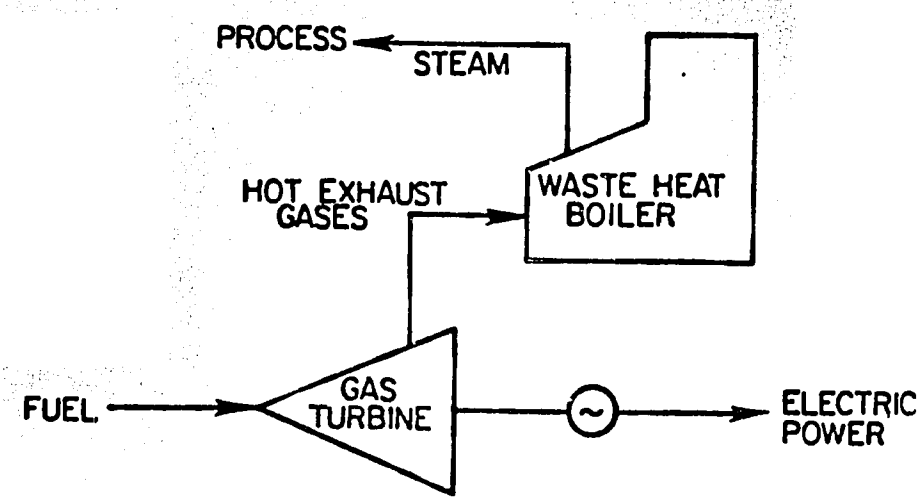
- STEAM-USING TECHNOLOGIES FOR SUGAR FACTORIES
- NEW ELECTRIC MOTOR TECHNOLOGIES
- NEW BUILDING COOLING TECHNOLOGIES
- ENERGY EFFICIENT FUELWOOD COOKING STOVES
- ADVANCED GAS TURBINES FOR
  - CENTRAL-STATION BASELOAD POWER (GAS FIRED)
  - CENTRAL-STATION BASELOAD POWER (COAL-FIRED)
  - INDUSTRIAL COGENERATION (GAS FIRED)
  - ——> INDUSTRIAL COGENERATION (BIOMASS-FIRED)
  - COMMERCIAL/RESIDENTIAL COGENERATION (GAS FIRED)



BETTER COGENERATION AT INDUSTRIAL PLANT VIA STEAM TURBINE



EVEN BETTER COGENERATION AT INDUSTRIAL PLANT VIA GAS TURBINE



WHY GAS TURBINE COGENERATION ?

=====> LOWER UNIT CAPITAL COSTS THAN STEAM TURBINES

=====> WEAKER SCALE ECONOMIES THAN STEAM TURBINES

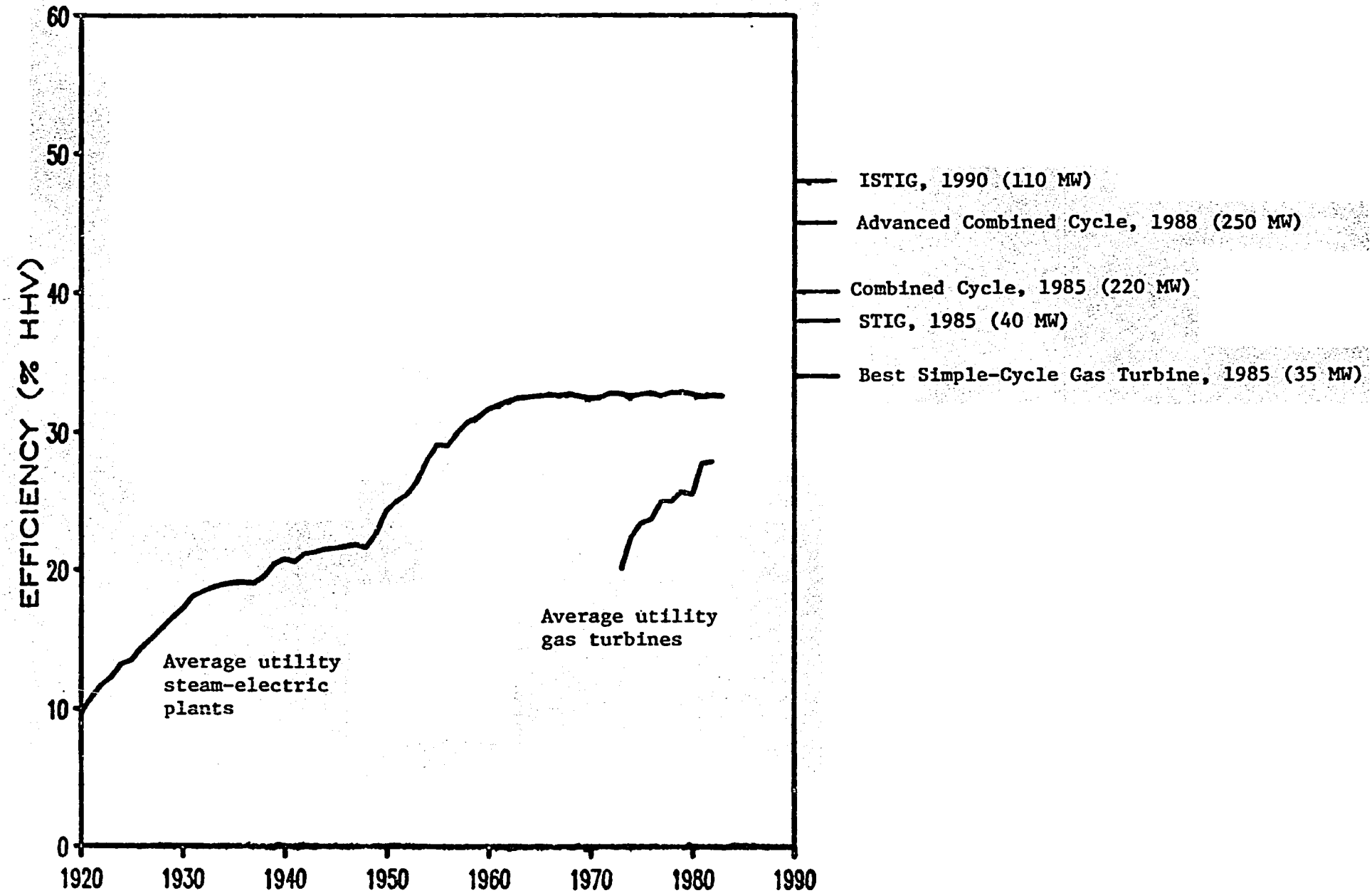
=====> HIGHER THERMODYNAMIC EFFICIENCY THAN STEAM TURBINES

=====> UNDER ACTIVE DEVELOPMENT FOR FIRING WITH SOLID FUELS

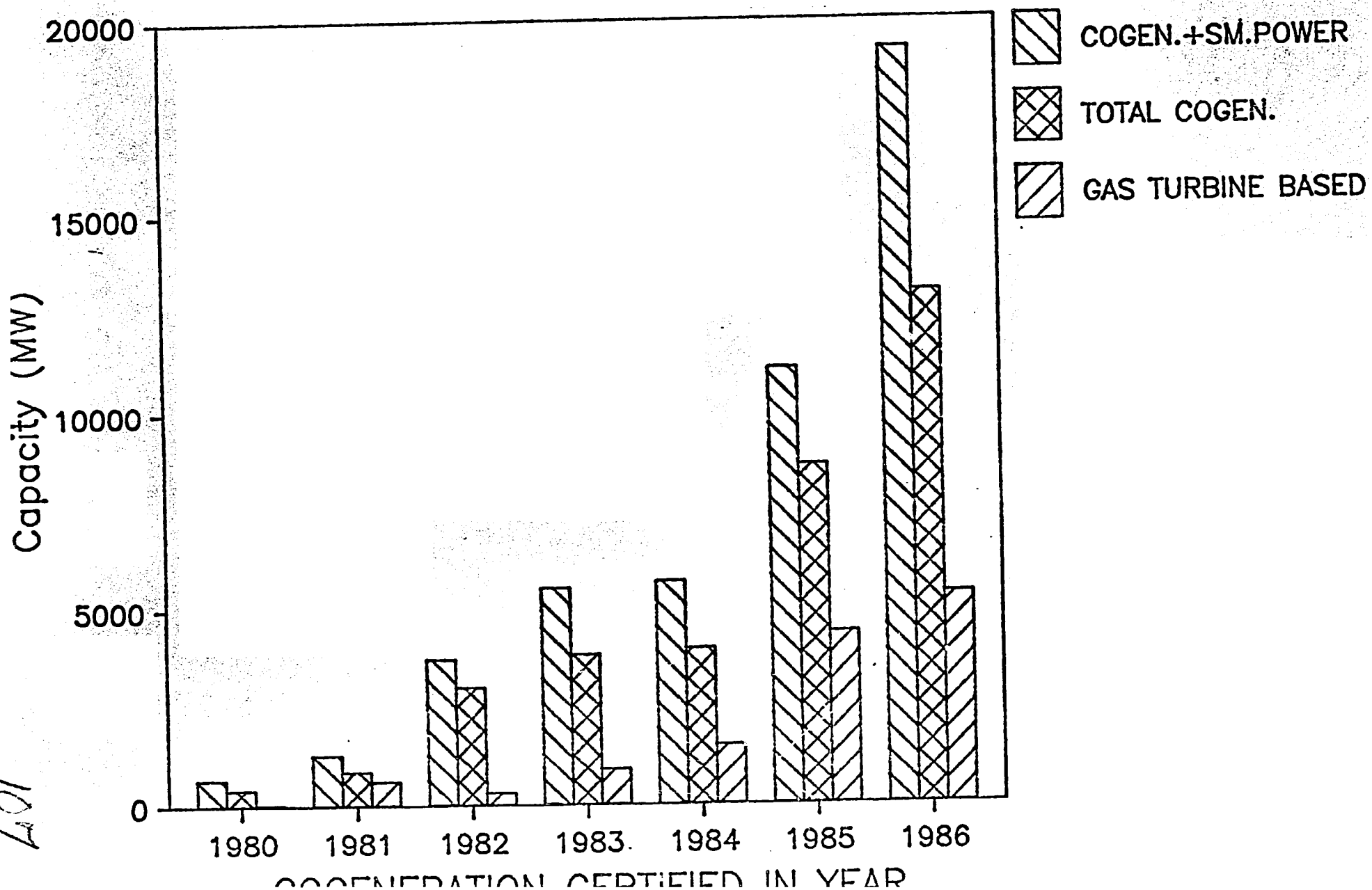
=====> ONGOING TECHNOLOGICAL REVOLUTION DUE TO:

- ===> $400 MILLION/YR DoD R&D INVESTMENTS
- ===> MARKET DEMANDS OF COMMERCIAL AIRLINES
- ===> PURPA AND THE COGENERATION BOOM

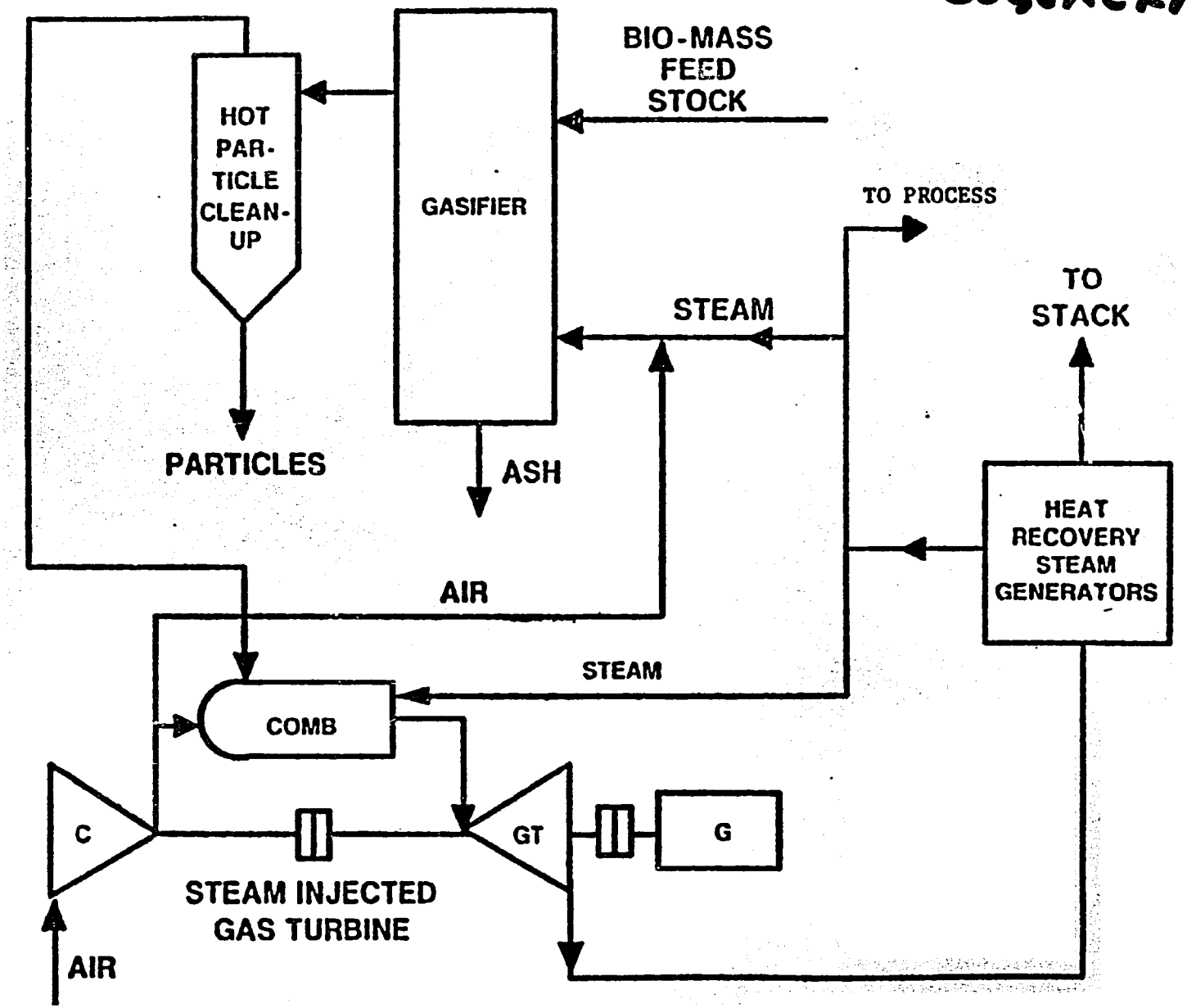
CENTRAL-STATION ELECTRICITY GENERATION IN THE US



CERTIFIED COGENERATION IN THE U.S.



BIOMASS-GASIFIER STEAM-INJECTED GAS TURBINE COGENERATION



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WORKSHOP ON BIOMASS-GASIFIER STEAM-INJECTED GAS TURBINES FOR THE CANE SUGAR INDUSTRY

(JUNE 19, 1987, WASHINGTON, DC)

Sugar Industry Representatives

SUGAR INDUSTRY RESEARCH INSTITUTE, JAMAICA
HAWAIIAN SUGAR PLANTERS' ASSOCIATION
HAMAKUA SUGAR COMPANY, HAWAII
COPERSUCAR, BRAZIL

Electric Utility Industry Representatives

NAT'L DEPT OF WATER AND ELECTRIC ENERGY, BRAZII
HAWAIIAN ELECTRIC LIGHT COMPANY

Lending/Funding Agencies

WORLD BANK
INTERAMERICAN DEVELOPMENT BANK
US AGENCY FOR INTERNATIONAL DEVELOPMENT
US TRADE AND DEVELOPMENT PROGRAM
US DEPARTMENT OF ENERGY
ROCKEFELLER BROTHERS' FUND

Vendors and A&Es

GENERAL ELECTRIC COMPANY
BECHTEL NATIONAL, INC.

Others

UNIVERSITY OF SÃO PAULO, BRAZIL
INT'L. INST. FOR ENERGY CONSERVATION, WASHINGTON
IT POWER, INC., WASHINGTON
ORT INTERNATIONAL COOPERATION, WASHINGTON
RONCO CONSULTING CORP., WASHINGTON
SYLVATEX, INC., WASHINGTON

BIOMASS-GASIFIER STEAM-INJECTED GAS TURBINE

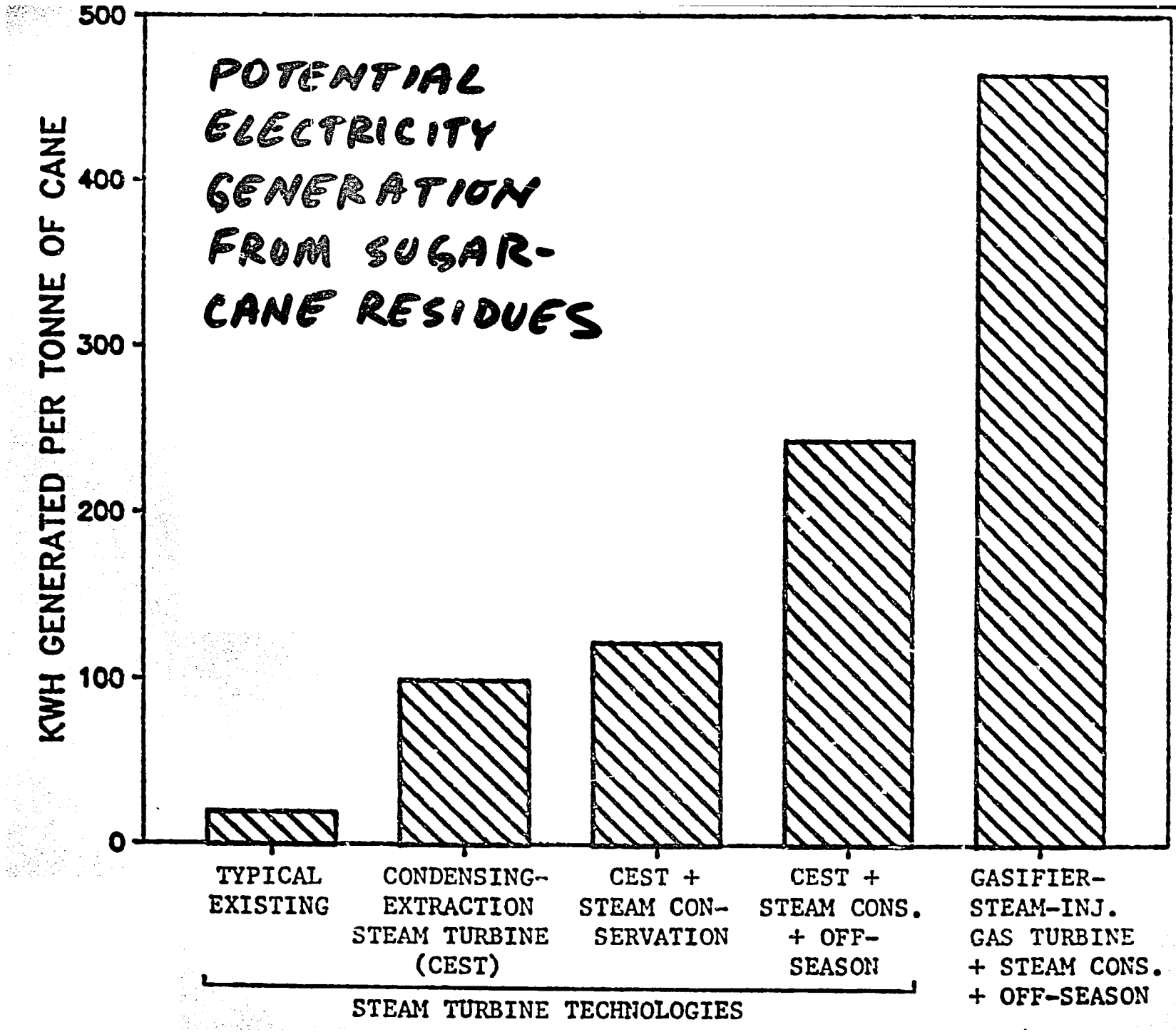
- SPIN-OFF FROM WORK ON COAL-GASIFIER GAS TURBINE SYSTEMS -- NO SULFUR REMOVAL.

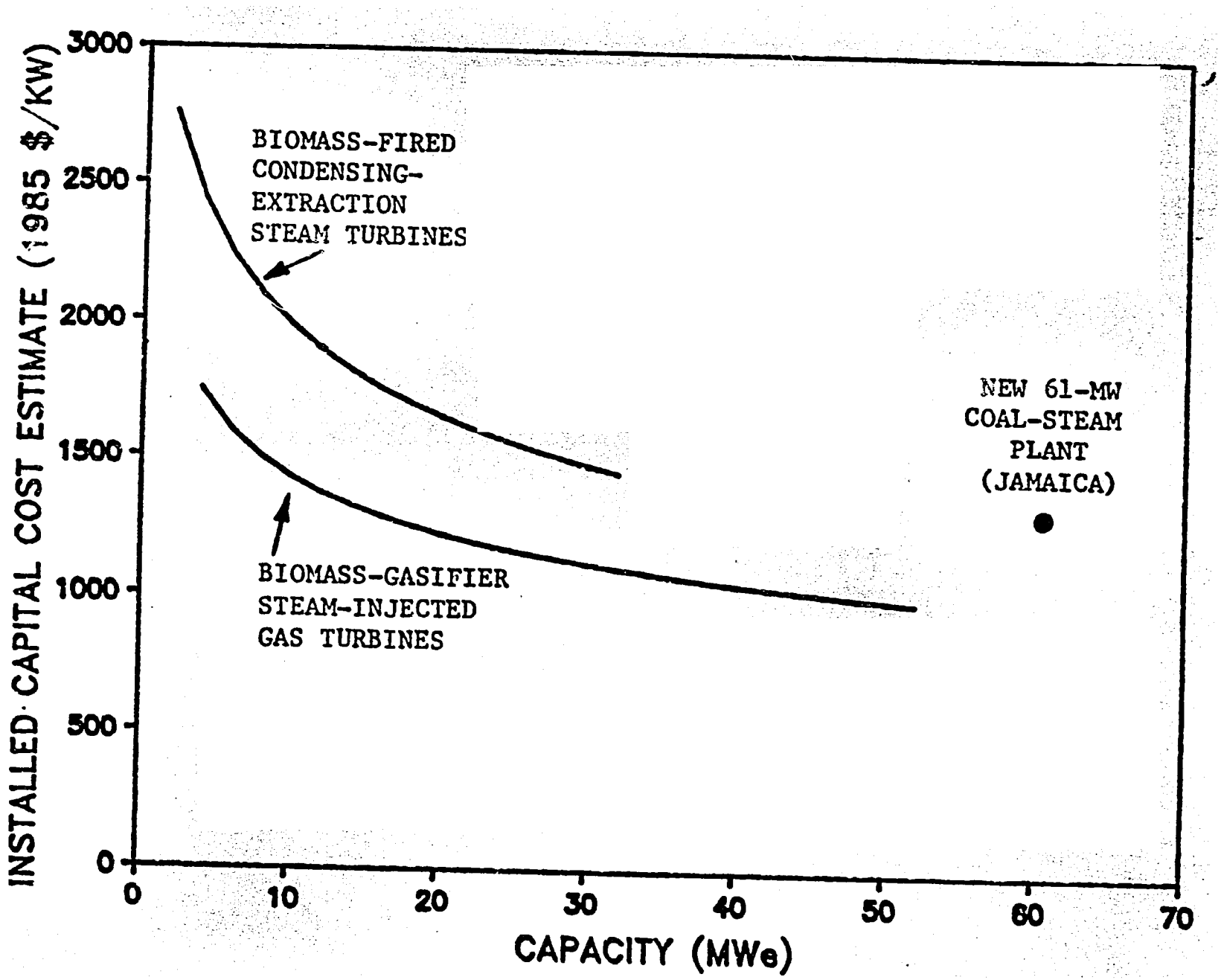
- HIGH EFFICIENCY DUE TO HIGH TURBINE INLET TEMPERATURES

- FUTURE IMPROVEMENTS IN PERFORMANCE LIKELY DUE TO STRONG R&D SUPPORT

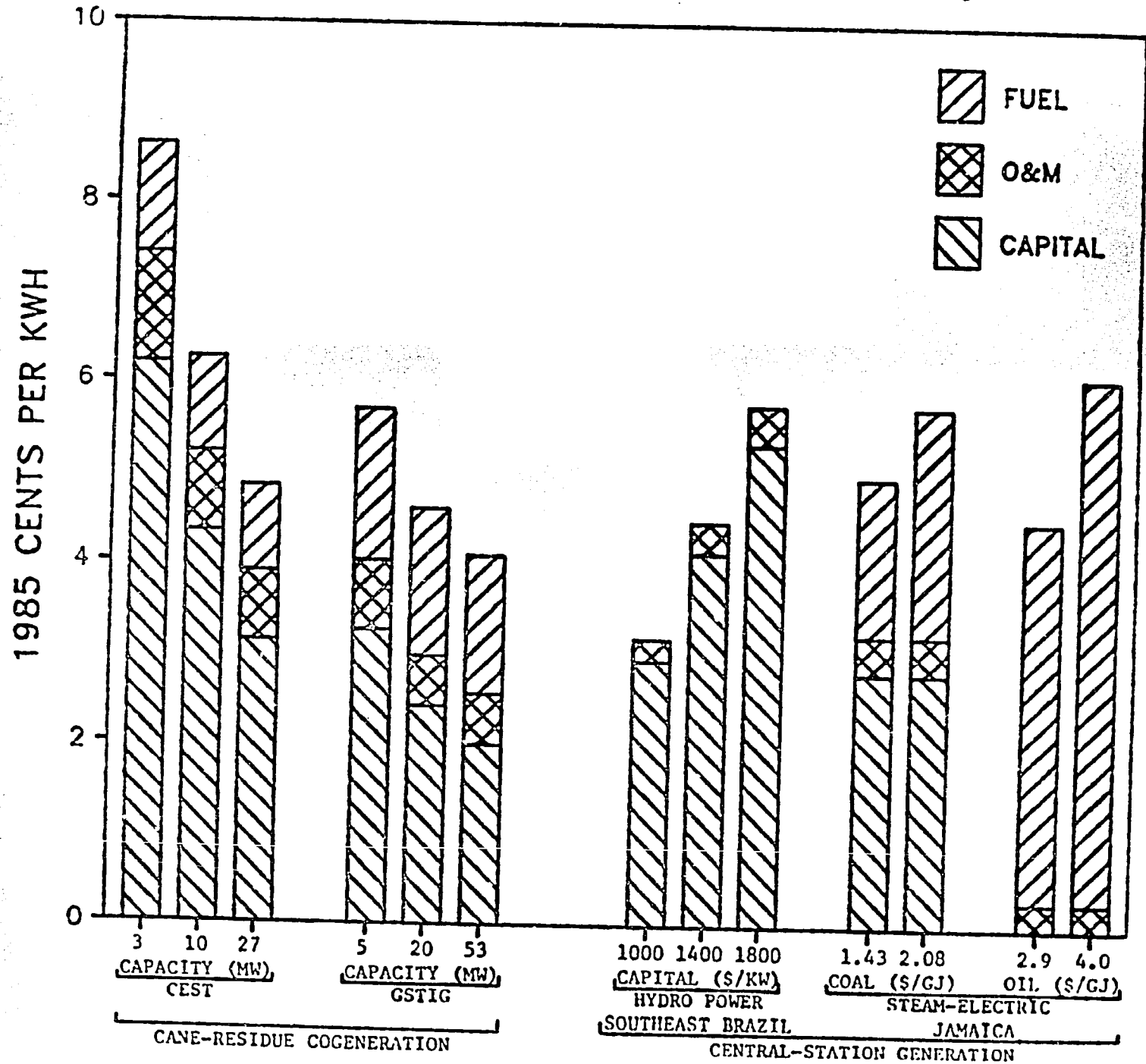
- ENGINEERING DEVELOPMENT WITHIN 1 YEAR
  - BIOMASS FEED TO PRESSURIZED VESSEL
  - PARTICLE CAPTURE IN CYCLONES
  - LOW-BTU GAS COMBUSTOR

- PILOT DEMONSTRATION PROJECT WITHIN 3 YEARS


POTENTIAL ELECTRICITY GENERATION FROM SUGAR-CANE RESIDUES
KWH GENERATED PER TONNE OF CANE
500
400
300
200
100
0
TYPICAL EXISTING
CONDENSING-EXTRACTION STEAM TURBINE (CEST)
CEST + STEAM CON-SERVATION
CEST + STEAM CONS. + OFF-SEASON
GASIFIER-STEAM-INJ. GAS TURBINE + STEAM CONS. + OFF-SEASON
STEAM TURBINE TECHNOLOGIES


INSTALLED CAPITAL COST ESTIMATE (1985 $/KW)
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
CAPACITY (MWe)
BIOMASS-FIRED
CONDENSING-
EXTRACTION
STEAM TURBINES
BIOMASS-GASIFIER
STEAM-INJECTED
GAS TURBINES
NEW 61-MW
COAL-STEAM
PLANT
(JAMAICA)

LEVELIZED ELECTRICITY GENERATING COSTS



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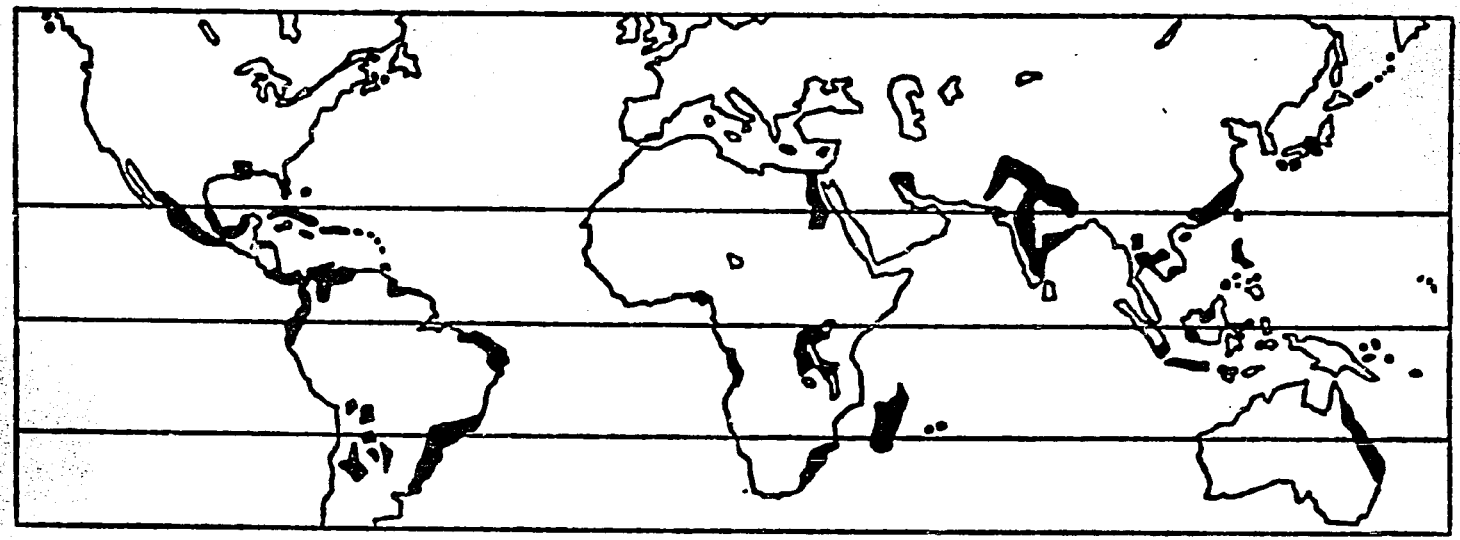


Figure I. The major sugar cane growing regions of the world are indicated by the darkened areas on this map. From (I. Sangster, Sugar and Jamaica, Thomas Nelson & Sons, London, 1973).

Table I. Estimated potential worldwide gas turbine generating capacity at sugar factories with the 1985 level of sugar cane production.[a]

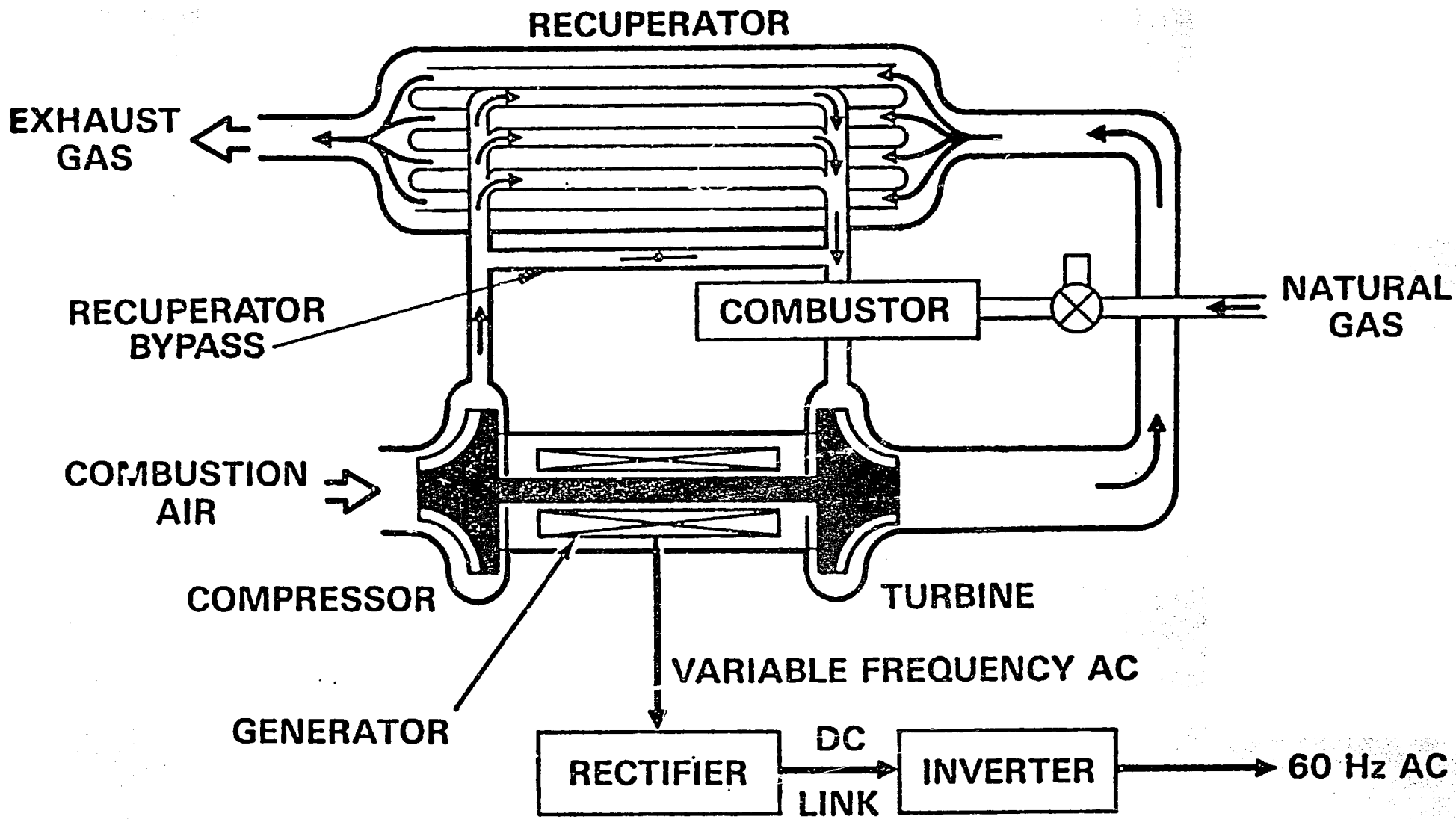
Region	Potential Electrical Capacity (MW)
SOUTH AMERICA	17,800
ASIA	14,000
CENTRAL AMERICA	10,100
AFRICA	4,900
OCEANIA	2,700
UNITED STATES	1,900
EUROPE	200
TOTAL	51,600

[a] See Table 17 in text for sources and explanatory notes.

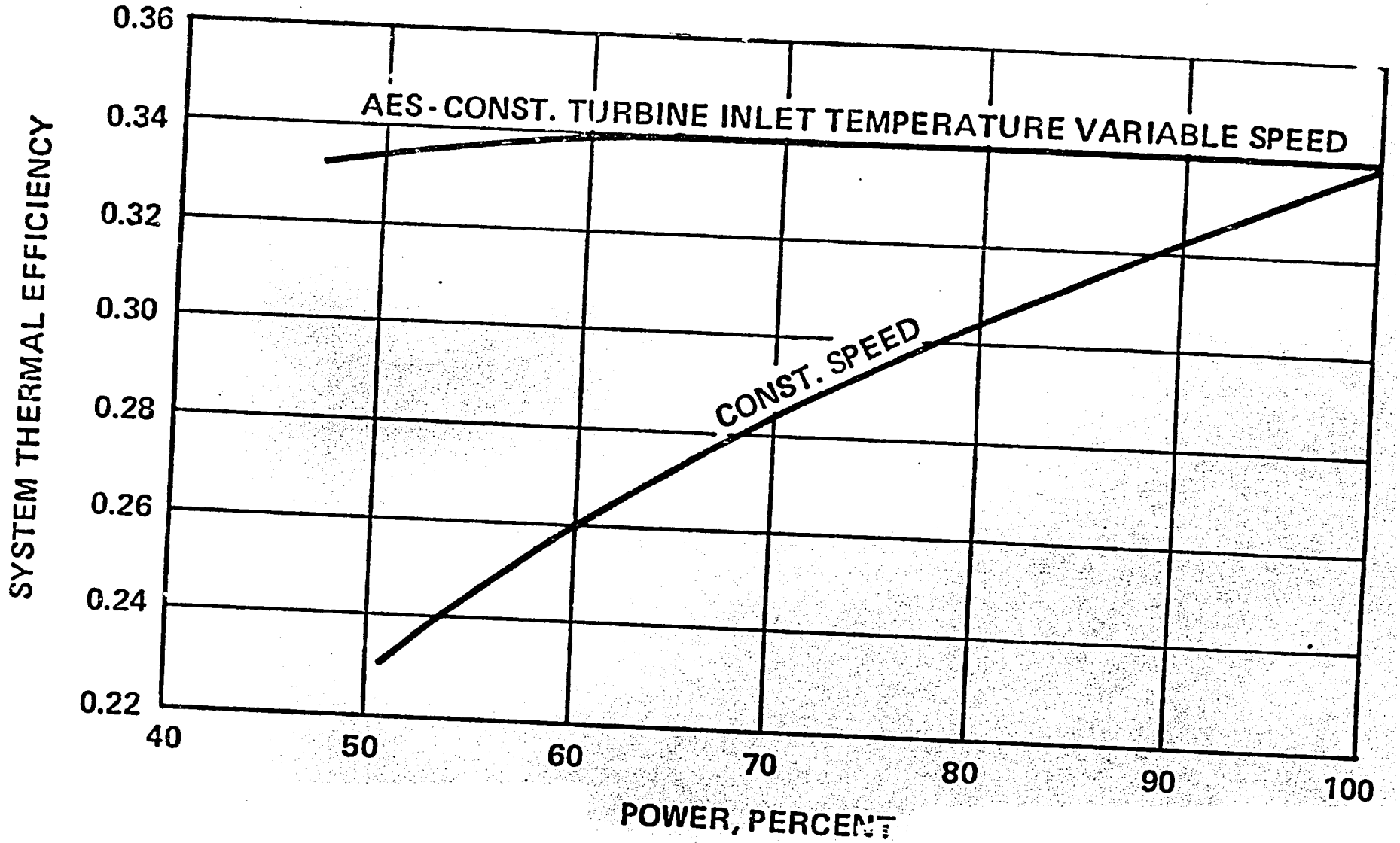
NUMBER OF RICE MILLS IN THAILAND BY REGION AND SIZE OF POWERHOUSE.[a]

POWERPLANT SIZE RANGE (KW) ⟶	0 - 22.5	22.5 - 45	> 60
REGION			
NORTH	7,256	388	319
NORTHEAST	15,684	360	181
CENTRAL	3,499	627	409
SOUTH	4,329	75	39
TOTAL	30,768	1,450	948
(PERCENT)	(93)	(4)	(3)

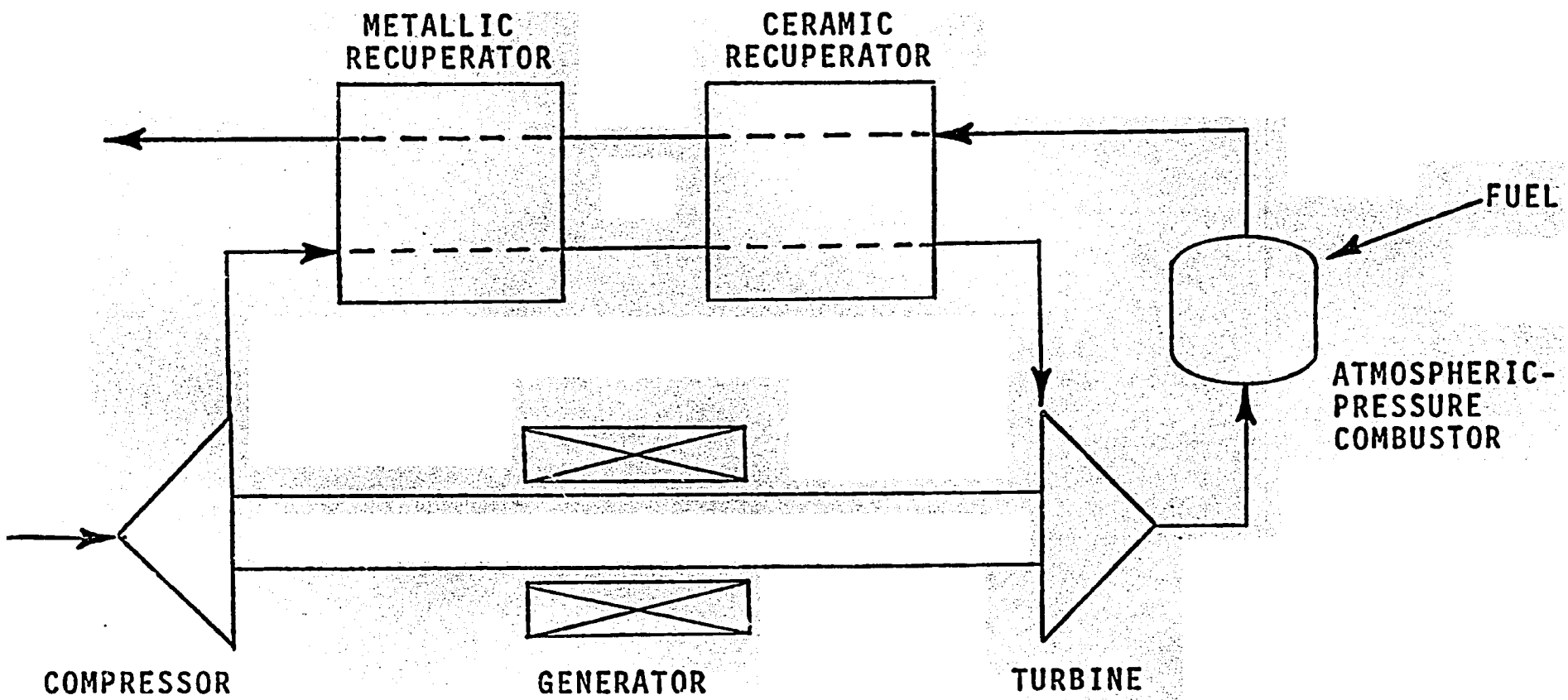
(a) For 1978, from N. Pitakarnnop and C. Boonrowd, "Conversion of Rice Husks to Pyrolytic Gas for Rice Mill Application in Thailand," in Second Expert Consultation on Producer Gas Development in Asia and the Pacific Region, FAO, Bangkok, November 1983.



PROPOSED 50-kW "ADVANCED ENERGY SYSTEM"



AES PART-LOAD CHARACTERISTICS



CERAMIC AES CONCEPT

ESTIMATED POTENTIAL WORLDWIDE GAS TURBINE GENERATIG CAPACITY THAT COULD BE SUPPORTED BY THE 1983 PRODUCTION OF RICE HUSKS.[a]

REGION	POTENTIAL ELECTRICAL CAPACITY (MW)
ASIA	16,800
SOUTH AMERICA	500
AFRICA	190
UNITED STATES	180
EUROPE	180
CENTRAL AMERICA	50
OCEANIA	20
TOTAL	18,000

(a) Assuming 0.25 tonnes of husks from each tonne of rice, an energy content of 14.8 GJ/tonne of husk, and a husk-electricity conversion efficiency of 33%.

WASTE CONVERSION SYSTEMS INC.

Energy Savings Through Ecology

WHY THE THERMAL BURNER?

Waste Conversion Systems, Inc. as its name indicates, converts most types of combustible waste products into economically and ecologically safe energy.

Waste Conversion Systems, Inc. is able to create energy from waste because of it's unique Thermal Burner. The patented Thermal Burner is a High-Tech burner which is capable of burning common waste products and can be retrofitted to most existing industrial boilers to create the energy requirements of industry. This means the Thermal Burner can create steam, heat, air conditioning and electricity.

An important feature of the burner is that it burns waste products at very high temperatures in excess of 2,500 degrees Farenheit. This allows the fuel to be burned completely producing very little ash while conforming well within the limits of air quality standards imposed by regulatory agencies of all States.

The Thermal Burner is a major breakthrough in the energy industry because it reduces dependency on fossil fuels and decreases the impact of the huge tonnage of waste products that is rapidly filling up our unpopular and fast disappearing landfills.

The Thermal Burner's efficiency allows its entrance into the field of hazardous waste incineration.

There are several types of hazardous wastes which can be burned safely and economically in the Thermal Burner. This allows generators of hazardous waste to destroy their combustible waste on site or at an approved collection point.

The Thermal Burner can solve many of today's industrial energy problems easily and safely. Waste Conversion Systems, Inc. has its own extensive mobile testing laboratory known as AMOLAB to provide the necessary documentation of its capabilities. This unique van is equipped with state-of-the-art testing equipment. A National Bureau of Standards library of mass spectra for 42,000 chemical compounds is contained in a computer for identification of the components

of flue gases. Burner ash is monitored by an Atomic Absorption Spectrophotometer. This demonstrates to regulatory authorities and other organizations, the Thermal Burner's ability to burn a wide variety of waste products in a completely safe and clean manner.

Waste Conversion Systems, Inc. has developed an exciting program for substantial fuel consumers. The B.T.U. program allows the user to save a major percentage of his current fuel bill with no capital investment. Thus, the user can reduce his operating costs and significantly increase his bottom line profits.

Any industry which generates substantial amounts of waste products can install a Thermal Burner and create energy from its own waste, while significantly reducing its waste disposal expenses.

Because the Thermal Burner's design allows complete retrofitting to most existing boilers it leaves a complete back-up system of the users' original equipment.

Its multi-fuel capability combined with a wide range of burner sizes creates an exciting and inexpensive source of energy, which is the heart of industry. Thus, it severs our dependence on fossil fuels and the constantly rising cost of fossil fuel derived energy.

Sincerely,

Stan Abrams, President

WASTE CONVERSION SYSTEMS INC.

TM

MAIN FEATURES AND ADVANTAGES OF THE THERMAL BURNER

* MULTI-FUEL CAPABILITIES
* FULLY COMPUTERIZED (WITH OPTIONAL COMPUTER)
* STANDARD MANUAL CONTROLLER WITH MOTOR STARTERS
* REMOTE MONITORING (WITH ENHANCED COMPUTER)
* ULTRA HEAVY CONSTRUCTION
* UNIQUE PATENTED AIR COOLED GRATE SYSTEM
* AUTOMATIC FEED SYSTEM
* AUTOMATIC ASH REMOVAL SYSTEM
* HIGH EFFICIENCY
* NON-POLLUTING (BURNING TEMPERATURES IN THE 2000 F. TO 3000 F. DEGREE RANGE)
* RETROFITTABLE TO MOST GAS AND OIL FIRED BOILERS (BOTH FIRE BOX AND SCOTCH MARINE BOILERS)
* FUEL SAVINGS CAN YIELD 40% TO 100% ANNUAL RETURN ON INVESTMENT

WASTE CONVERSION SYSTEMS INC.

Price Sheet

BURNER

Thermal 100 HP BTU 3,348,000 per hr. steam 3,450 Lbs. / hr.	**$ 61,000.00**
Thermal 150 HP BTU 5,022,000 per hr. steam 5,175 Lbs. / hr.	**$ 76,000.00**
Thermal 200 HP BTU 6,696,000 per hr. steam 6,900 Lbs. / hr.	**$ 90,000.00**
Thermal 250 HP BTU 8,370,000 per hr. steam 8,625 Lbs. / hr.	**$110,000.00**
Thermal 300 HP BTU 10,044,000 per hr. steam 10,350 Lbs. / hr.	**$128,000.00**
Thermal 400 HP BTU 13,392,000 per hr. steam 13,800 Lbs. / hr.	**$158,000.00**
Thermal 500 HP BTU 16,740,000 per hr. steam 17,250 Lbs. / hr.	**$196,000.00**
Thermal 550 HP BTU 18,414,000 per hr. steam 18,975 Lbs. / hr.	**$215,000.00**
Thermal 600 HP BTU 20,088,000 per hr. steam 20,700 Lbs. / hr.	**$234,000.00**
Thermal 700 HP BTU 23,436,000 per hr. steam 24,150 Lbs. / hr.	**$270,000.00**
Thermal 800 HP BTU 26,784,000 per hr. steam 27,600 Lbs. / hr.	**$307,000.00**
Thermal 1000 HP BTU 33,480,000 per hr. steam 34,500 Lbs. / hr.	**$360,000.00**

Prices are subject to change without notice.
Prices listed above include the THERMAL burner and manual controller. Feed systems are optional.
Price are FOB Sterling, Colorado.

OPTIONAL EQUIPMENT

Item #

1. Automatic Draft Control
2. Stack Draft Control Shutters
3. Cyclone-Collector
4. 4" Dia. × 15' Long Cyclone Ash Auger w / motor and drive unassembled
5. 6" Dia. × 15' Long Main Dish Ash w / motor and drive unassembled
6. Induced Draft Stack Fan w / motor
7. One lot of misc. material—Stack Fan Elbow, Stack Fan Piping, Auger Transitions, Flanges, etc.
8. Custom Designed Storage Bins and Fuel Handling Systems
9. Computerized Controller
10. Enhanced Computer (for remote monitoring)
11. Printer on controller
12. Automatic Fire Extinguisher System

For prices on Optional Equipment please contact Waste Conversion Systems, Inc. or Authorized Representative.

6848 S. Revere Pkwy. # 220
Englewood, CO 80112
(303) 790-8300

WASTE CONVERSION SYSTEMS INC.

TM

THE BURNER IN BRIEF

The Waste Conversion Thermal Burner (the "Burner") has been developed to produce heating, cooling and power by using alternate fuels other than oil and gas. The ability to burn inexpensive alternate fuels efficiently and cleanly reduces cost and pollutants. The Burner is designed to be retrofittable to most boilers now burning gas or oil.

The Burner is unique in several ways. First, a patented burning process allows the entrained fuel supply to be brought up to ignition temperature in a reduced atmosphere. After the proper temperature is achieved, the burning chamber is injected with air to cause a secondary burn, which creates a blow torch effect and projects a flame into the Morrison tube of the boiler to heat the water.

Second, there are very few moving parts. The ash grate, which removes the by-products of the burning process, is the only component of the Burner which uses moving parts. Thus, the Burner is simple to operate in either a manual or automatic mode, and can even be monitored from a remote location.

Third, most components of the Burner can be easily repaired. The durable and "over-built" quality of the Burner means low maintenance costs. For example, the inner lining is a cast refractory material which is ingrained with stainless steel needles to prevent cracking, and will withstand about twice the normal heat produced in the burning chamber. All liners can be replaced quickly and easily.

Fourth, the operation of the Burner is very simple. A small oil gun is used to start the Burner, which usually takes from 20-120 seconds. Because of the special insulation process used in the Burner, the external jacket is normally only about 15 degrees Farenheit above the ambient air temperature. To achieve maximum reliability, all fans, motors and gear boxes are of the highest quality and are oversized so that they will not be used beyond their capacity.

The heart of the Burner is the secondary burning chamber. A specially designed grate is used to supply air to the gases produced in the primary burning chamber, which then ignites the gases to project a flame into the Morrison tube of the boiler. The spacing of the tubes and the angle of the grate controls the burning process. By varying the size of the grate and the volume of air introduced into the chamber, the Burner can produce the required levels of horsepower to meet the design requirements of most package boilers.

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The basic controller used to operate the Burner is a state-of-the-art product with simultaneous remote controlling and monitoring. A more elaborate controller will allow the operator to easily recognized any improper function, and will automatically shut down the systems if a failure or malfunction should occur. The fuel handling and feeder systems are also operated by a controller, which automatically feeds fuel to the Burner.

The Burner can be operated with a wide variety of fuels, including refuse derived fuel (R.D.F.), sawdust, wood chips, rice hulls and practically any carbonaceous material. These fuels can have a moisture content of as much as 25%; however, the most efficient burn occurs at a moisture content of about 15% or less.

The Thermal Burner has proven to be an environmentally safe system. Since the 1000 HP Unit produces 33 million B.T.U. per hour, it is exempt under current Federal EPA regulations, which cover solid fuel burners producing over 300 million B.T.U. per hour. However, the ability to satisfy all local and state safety standards can easily be demonstrated on-site by AMOLAB - the 24-foot Analytical MObile LABoratory designed and built by Waste Conversion Systems, Inc. - with its state-of-the-art capability of analyzing and testing over 42,000 compounds.

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WASTE CONVERSION SYSTEMS INC.

TM

GENERAL SPECIFICATIONS

The Waste Conversion THERMAL BURNER (the "Burner") is a close-coupled, two-stage combustor which is rugged and simple in design, and capable of being operated by low or moderately skilled labor. The Burner operates by using a unique and patented controlled air principle of combustion. It has a continual feed loading system to allow uninterrupted, twenty-four hour operation with continuous ash removal. Fuel is loaded into a holding or storage bin and is automatically conveyed into a metering bin which then automatically feeds the fuel into the Burner at a continuous and regulated rate.

The pyrolysis process of the Burner has two basic stages: initial combustion and secondary combustion. The initial combustion takes place in a reduced, oxygen-starved atmosphere and occurs within a highly insulated refractory-lined pyrolytic chamber. This process gasifies the carbonaceous wastes in the presence of a reducing flame. The heat generated by this initial burn serves to superheat the secondary air, which is flowing through a patented stainless steel heat exchanger located in the primary burning chamber.

In the second stage of combustion, the superheated secondary air is mixed with the produced gases by use of a set of venturies to produce a projected flame in a controlled manner. This burning of gases, as well as any unburned particles from the primary chamber, takes place in a four foot long fire tube which, in the case of waste burning, flanges to a highly insulated refractory-lined secondary chamber. This secondary chamber is lined with two inches of first class castable refractory material and two inches of hardboard thermal insulation. The flame temperatures produced in the secondary fire tube can reach 1,800 to 2,800 degrees Farenheit, depending upon the type of fuel being used.

The close-couple capability of the Burner gives it a distinct advantage over other systems. When the user desires to use the heat generated by the Burner, the secondary fire tube can be flange connected to any type of package or firebox boiler. The Burner then becomes an extremely efficient power source for the generation of steam or hot water, for absorption chillers in air conditioning and refrigerators and for the cogeneration of electricity. Another advantage of the Burner is that it is not merely an incinerator. It has been designed as a multi-fuel burner, which can accept a wide variety of waste products such as refuse derived fuel processed from municipal solid waste (R.D.F.), low level toxic waste, wood chips, sawdust, rubber, plastic, rice hulls and peanut hulls as well as practically any carbonaceous materials.

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CONSTRUCTION

Three things are of foremost importance in the design and construction of the Burner: quality, ruggedness and simplicity of operation. There is an inherent "over-built" concept of construction which results in very low maintenance and very high safety.

The main shell of the Burner is one-quarter inch steel plate which, in turn, is inner lined with two inch hardboard insulation capable of withstanding temperatures of 2,000 degrees Farenheit. The hardboard insulation is lined with a two to four inch monolithic refractory capable of withstanding temperatures of 3,000 degrees Farenheit, which results in an approximate fifty percent higher temperature range than is required.

The castable refractory used in the Burner is not constructed from a single form as in most systems, but, rather, is cast from molds into easily replaceable and interlocking parts. Thus, any portion of the refractory liner can be quickly replaced by low or moderately skilled labor with a minimum of downtime. These cast replacement parts are inventoried at warehouse facilities for quick delivery. No special equipment is necessary to effect replacements.

Unlike other systems, the Burner does not use firebrick. Liners made of firebrick require hundreds of mortar joints, each of which is subject to failure. In addition, firebrick is much more difficult to replace, especially in the field.

It must be noted, however, that any type of refractory liner material is subject to wear and tear with time and use. For this reason, Waste Conversion engineers chose to use easily replaceable, pre-cured refractory cast plates. And, in a final effort to ensure the longest life possible, type 310 stainless steel needles have been added to the refractory liner for added strength against cracking and thermal shock.

The primary burning chamber is enclosed in a heavy gauge metal, air cooled cabinet, which has two advantages: First, the air space between the primary combustion chamber and the cabinet will become slightly heated from the convection heat generated by the reducing flame in the chamber. The Burner is designed to draw off this preheated air and inject it into the secondary burning chamber to create greater efficiency. Second, it keeps the outer skin at a relatively low temperature so that any portion of the Burner can be safely touched or handled. As an additional precaution, a thermocouple probe is positioned in the cavity of the cabinet to automatically shut down the system if the temperature in the air space reaches a predetermined level.

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The Burner has very few moving parts so that little can go wrong with the system. All bearings are self-sealed and designed to withstand temperatures of 900 degrees Farenheit, even though normal operation would not exceed 300 degrees. All fans and blowers are presently made by Cincinnati Blower from high quality cast aluminum. All electric motors are presently made by Baldor Motor and are three-phase, totally enclosed and fan-cooled.

Gear reducers, instead of a hydraulic system, are used throughout the Burner system. Experience has demonstrated that any contamination in a hydraulic system can easily cause system failure and expensive repairs and maintenance costs. However, the replacement of a gear reducer system has proven to be much faster, less expensive and the maintenance simpler than for a hydraulic system. All gear reducers are presently made by Browning Corporation.

Most components of the Burner are bolted together with one-half inch #6 hardness bolts on six inch or less spacing. Other systems use welded construction, which is less expensive but can result in high maintenance and repair costs. For the few parts on the Burner which are welded, mig welding techniques of the highest quality are used. All joints and seams are thermal sealed with a high temperature fibre gasket. No asbestos material is used in the Burner.

AUTOMATIC ASH REMOVAL

The ash removal system is a simple, rugged and safe design. As fuel is fed from the metering bin into the Burner, it drops onto a specially designed stainless steel belt located at the base of the primary combustion chamber. This belt travels at a low speed and carries the burning waste from the back to the front of the primary burning chamber. The rate of travel of the belt depends upon the type of fuel being burned and the residence time required to complete the burn. As the burned material moves to the end of the belt, it drops off onto a thick, refractory liner U-shaped trough through which travels a heavy duty auger. This auger is constructed with one-quarter inch flighting on a two inch shaft designed to withstand high temperatures. The ash material is carried out of the primary chamber, through a cooling water bath and then emptied into a container designed for easy handling and removal. Should a jam occur, the entire system will automatically shut down. An access door permits easy and safe entry to the ash auger at the front base of the Burner. If a jam occurs beyond the primary combustion chamber, access is easily made by the removal of the cover plates.

SAFETY FEATURES

The operator of the Burner system can rely on several

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built-in safety features which result in reliable and safe operation. A standard control panel is equipped with interlocks and visual and audio alarms which will alert the operator in the event of any failure or malfunction in the entire system. The following is an explanation of the individual systems, including safety features:

1. **Ignition Bu** The ignition burners are used in the start sequence a partially in any restarts, and can be operated with #2 fuel , kerosene, natural gas or propane. A fire eye, located in the ignition system, monitors the flame and conveys a signal to the control panel which will alert the operator if there is any failure or malfunction in the ignition burner sequence and will automatically shut down the system.

2. **Induced Draft Fan.** The induced draft fan, or stack fan, provides a purging system for the Burner. The initial sequence in the start-up of the Burner requires that the draft fan run for a period of time. This control feature is automatic and allows the draft fan to run for about 60 seconds, which purges the entire system and evacuates any gases which may have accumulated in the system during non-operating periods. The operation of the draft fan is monitored by a high temperature sail switch which will inform the operator when the draft fan is operational. An interlock is installed in the control system to prevent a manual or automatic start-up until the draft fan is operational.

3. **Control Interlocks.** The control panel of the Burner has a complete system of interlock switches to ensure a proper and safe start-up sequence in either the manual or automatic mode.

4. **Primary Air Fan.** An air switch is located on the pressure side of the primary air fan which monitors the operational status of the primary air fan and signals the controller to automatically shut down the system in the event of a failure or malfunction. The fan also has an interlock switch so that it comes on line in the proper sequence during start-up.

5. **Secondary Air Fan.** An air switch is located on the pressure side of the secondary air fan which monitors the operational status of the secondary air fan and signals the controller to automatically shut down the system in the event of a failure or malfunction. The fan also has an interlock switch so that it comes on line in the proper sequence during start-up.

6. **Ash Removal System.** The automatic ash removal system is equipped with an alarm in the controller to alert the operator in the event of a jam. The ash auger has an auto-reverse feature which will clear most obstructions

without any action by the operator. If a jam persists, easy access to the auger is achieved by either opening a hinged door at the front base of the primary combustion chamber or removing the cover plates outside of the primary combustion chamber. The ash removal system also uses a water misting bath to cool the hot ash as it passes out of the system.

7. Access/Observation Doors. The Burner has three access doors which provide the operator with an easy and safe method to inspect the entire interior of the Burner during operation. Each door has an air purged peep sight. The front access door allows entry to the ash auger and observation of the front area of the fire belt, is covered with a five inch refractory cast plate and is held shut by two quick locks with a heat dissipating handle. The rear access door allows entry to, and observation of the fire belt, is covered with a five inch refractory cast plate and is held shut by three quick locks with a heat dissipating handle. The top access door allows observation of the incoming fuel, the fire belt and a portion of the stainless steel secondary air heat exchanger, is covered with a two inch refractory cast plate and is held shut by two quick locks with a heat dissipating handle.

8. Control Panel. The control panel uses an NEMA 4 standard enclosure for outdoor application and an NEMA-12 standard enclosure for indoor application. The system is started by a keyed "start" switch and can be stopped by a single push button. All functions are color coded -- green indicates functional or on-line and red indicates malfunctional or off-line. All automatic functions have manual override and interlock switches where applicable. An access door of the control panel also incorporates two temperature controllers which monitor the primary and secondary combustion chambers. Each controller reads to 2,500 degrees Farenheit and automatically controls he firing rate of each chamber to prevent excessive operating temperatures. When the Burner is flange connected to either a package or firebox boiler, the controls of such boiler interface with the controls of the Burner. The boiler controls normally consist of a pressure-trol or aquastat and a water level indicator. In the event of low water in the boiler, the Burner will automatically shut down, and both an audio and visual alarm will activate.

9. Air Jacket. The air jacket surrounds the primary combustion chamber. Due to the high temperatures generated in the primary combustion chamber, some heat will radiate through the refractory liner and the insulating hardboard to the steel shell. The air space between the air jacket and the steel shell is connected by duct to the secondary fan, which cools the steel shell and provides preheated air to the secondary fan. This results in an increased efficiency and generally keeps the surface of the

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air jacket at about fifteen degrees Farenheit above the ambient air temperature.

RETROFITING THE BURNER TO EXISTING BOILERS

The Burner is basically designed to replace the oil or gas guns on existing boilers in order to burn a wide variety of waste and carbonaceous fuels. The Burner will interface with existing or standard boiler operating controls, which normally include a pressure-trol or aquastat and a water level indicator.

The pressure-trol has two adjustable functions which control the steam pressure in the boiler. The first function controls the high limit pressure setting and turns the boiler off. The second function controls the low limit pressure and turns the boiler on. For example, consider a steam boiler with a modulating valve set at 100 pounds pressure to match the requirements of a steam powered turbine designed to operate at the same pressure. The low limit function would be set at 125 pounds and the high limit function at 150 pounds. There would thus always be sufficient steam pressure to supply the turbine. An aquastat serves the same function as a pressure-trol except that it is used to control water temperature instead of steam pressure.

The water level indicator is also a two function control. It maintains the water level in the boiler between two preset functions, high and low, by turning the boiler feed pump on and off. It will also shut down the boiler if the water level falls below the predetermined level.

WASTE CONVERSION SYSTEMS INC.

Energy Savings Through Ecology

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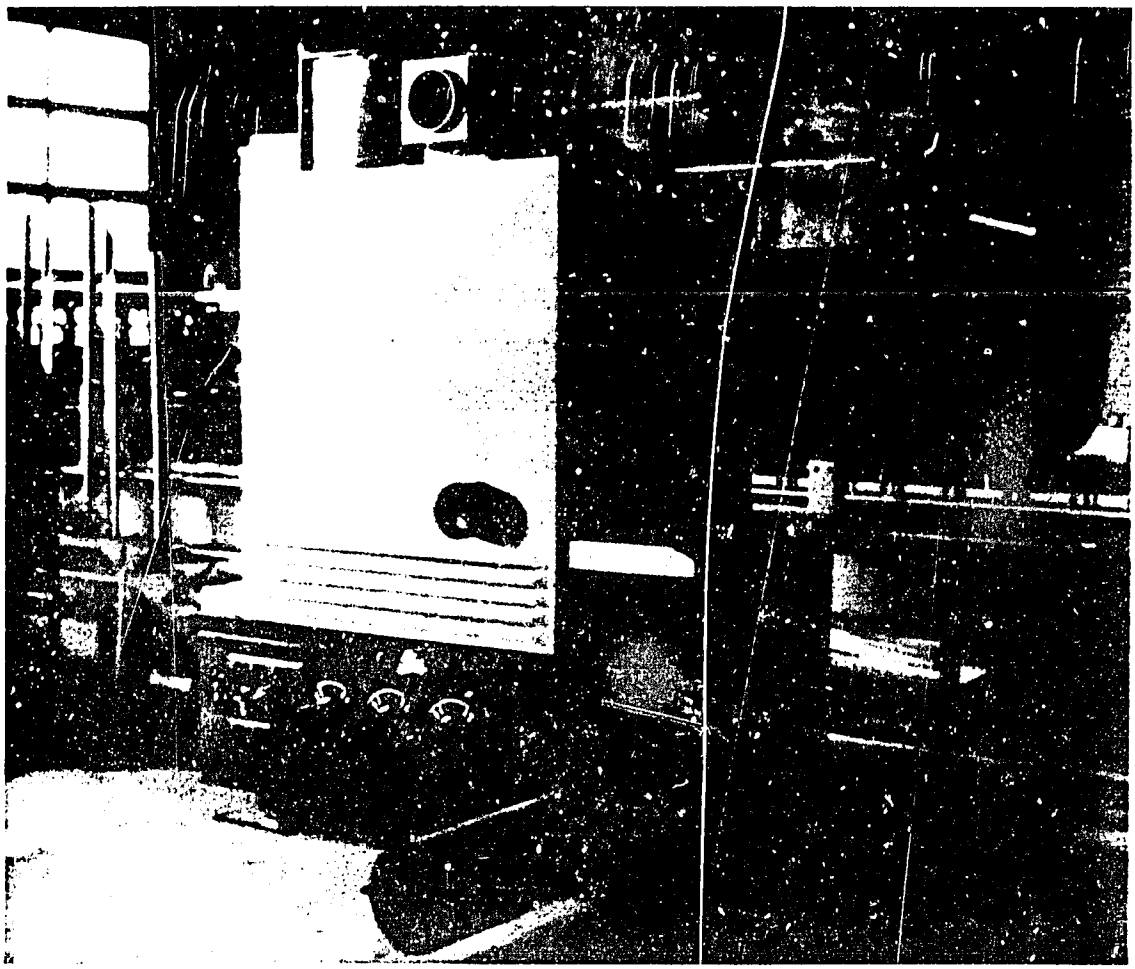
WASTE CONVERSION SYSTEMS INC.

Model 150



THERMAL Burner

U.S. Patent
I. 4,341,199
II. 4,395,956
III. 4,475,471

(See reverse side)

THE BURNER: AN OVERVIEW

The Waste Conversion Systems Inc. THERMAL BURNER (the "Burner") is a state-of-the-art staged combustion burner capable of using a wide variety of solid fuels in a highly efficient mode of operation. The design basis for the Burner is the age-old gasification process; however, this process has been uniquely modified, and is immediately followed by a very turbulent mixing and combusting process. The result is a controllable, radiant projected flame for application in boilers, kilns, heat exchangers and other devices which typically use an oil or gas gun. A flame temperature of up to 2,800 degrees Fahrenheit is typical with the use of most solid fuels.

The uniqueness of the Burner is achieved by using a hybrid gasification process which incorporates a falling fuel, entrained-bed zone in the burner chamber above a moving grate which holds a more conventional fixed-bed. The Burner is designed to handle fuels of varying reactivity characteristics; however, the less reactive the fuel, such as some grades of coal, the smaller the particle size that must be fed into the Burner to take full advantage of the entrained-bed reactions. The entrained-bed zone leads to a shallow bed moving grate zone that provides the temperature and flame stability necessary to ensure operational safety and provide for ash removal. The shallow bed moving grate zone can be maintained at a temperature of up to 1,800 degrees Fahrenheit, depending on the reactivity of the fuel being consumed. The temperature control is achieved by use of initial start-up oil burners and by variation of the grate speed and primary air damper position during normal operation.

The shallow bed characteristic of the grate, combined with the falling fuel entrained-bed, results in a relatively small fuel inventory in the Burner at any given time. Thus, the Burner quickly responds to load swings in either direction without loss of operational safety.

The key to achieving clean, efficient flame generation and combustion is the unique pre-heating of the secondary combustion air in the entrained-bed zone, and the resulting mixture of the pre-heated air at temperatures that can exceed 800 degrees Fahrenheit, with combustible gases being generated. The mixing zone is very turbulent, and a flame is projected that can easily fill the longest of combustion chambers or furnaces to take full advantage of the highly efficient radiant heat transfer process.

The Burner is equipped with light oil burners which are used for cold start-ups and to process trim heat, if necessary. These oil burners are used to bring the moving grate zone up to a temperature where stable combustion of the primary fuel can be achieved in the grate zone without the need for a secondary heat source, after which the gasification process can commence safely. Thermal sensors provide signals which can automatically restart the oil burners if needed to guarantee operational safety; however, it has been demonstrated that only a fractional percent of the monthly fuel requirements will come from the oil burners in a typical installation.

The Burner is operated by simple computerized controls that provide state-of-the-art ease and reliable safety protection. The control system is equipped with manual/automatic selection controls so that special requirements can always be met. The Burner can operate in either the on/off mode or the true full load following mode, as the application requires.

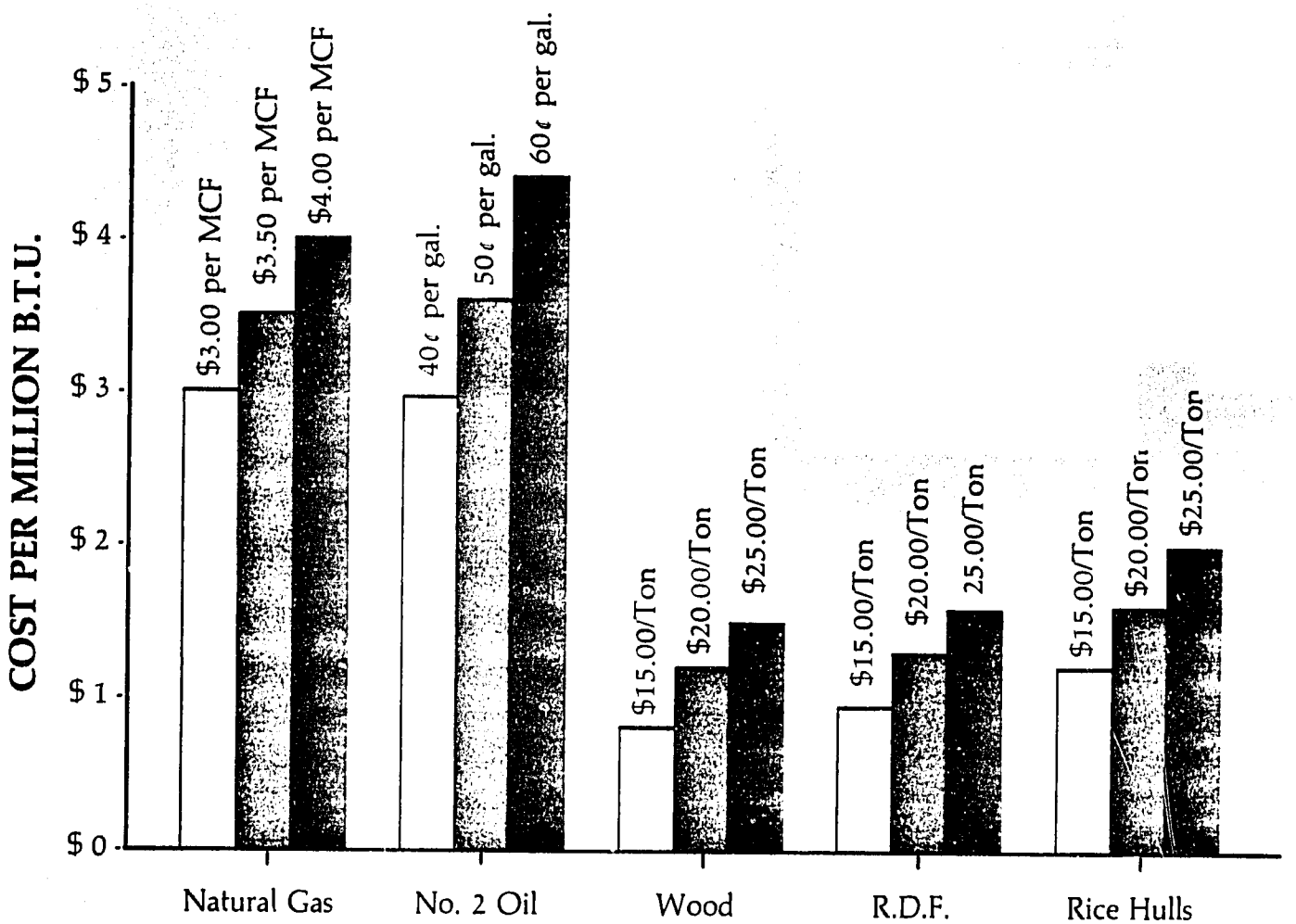
The Burner is today's best answer in selecting a user-friendly, highly efficient solid fuel burner for installation in a wide variety of commercial, institutional and industrial applications. It is compatible with a wide variety of boilers, kilns and heat exchangers, and can be used in most cases to convert existing hardware to solid fuels even if the existing fuels are oil or natural gas. It represents a major technological step forward in the burning of abundant, cheap fuels that heretofore were not economically or efficiently usable.

NOTE: Due to the uniqueness of the burning process and the high operational temperatures, the Burner has been able to meet or exceed all local and state air quality standards.

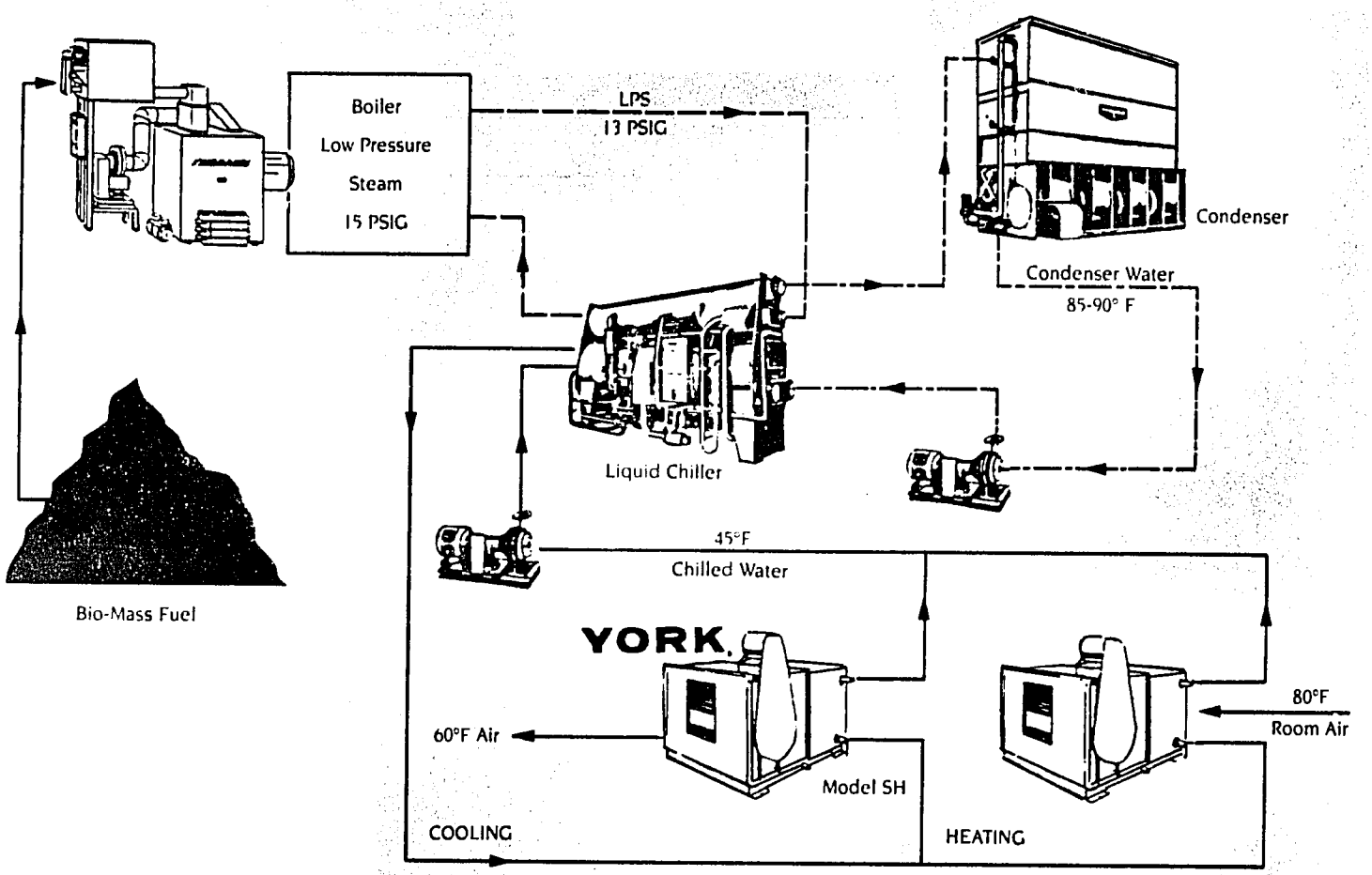
Fuel Cost Comparison Chart

FUEL COST COMPARISONS

PER MILLION B.T.U.

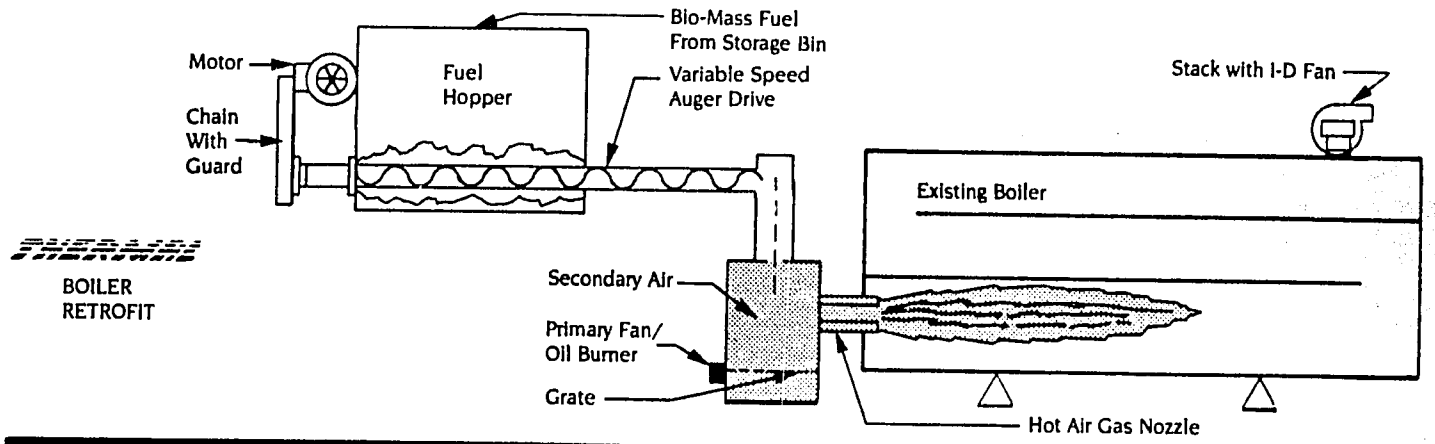


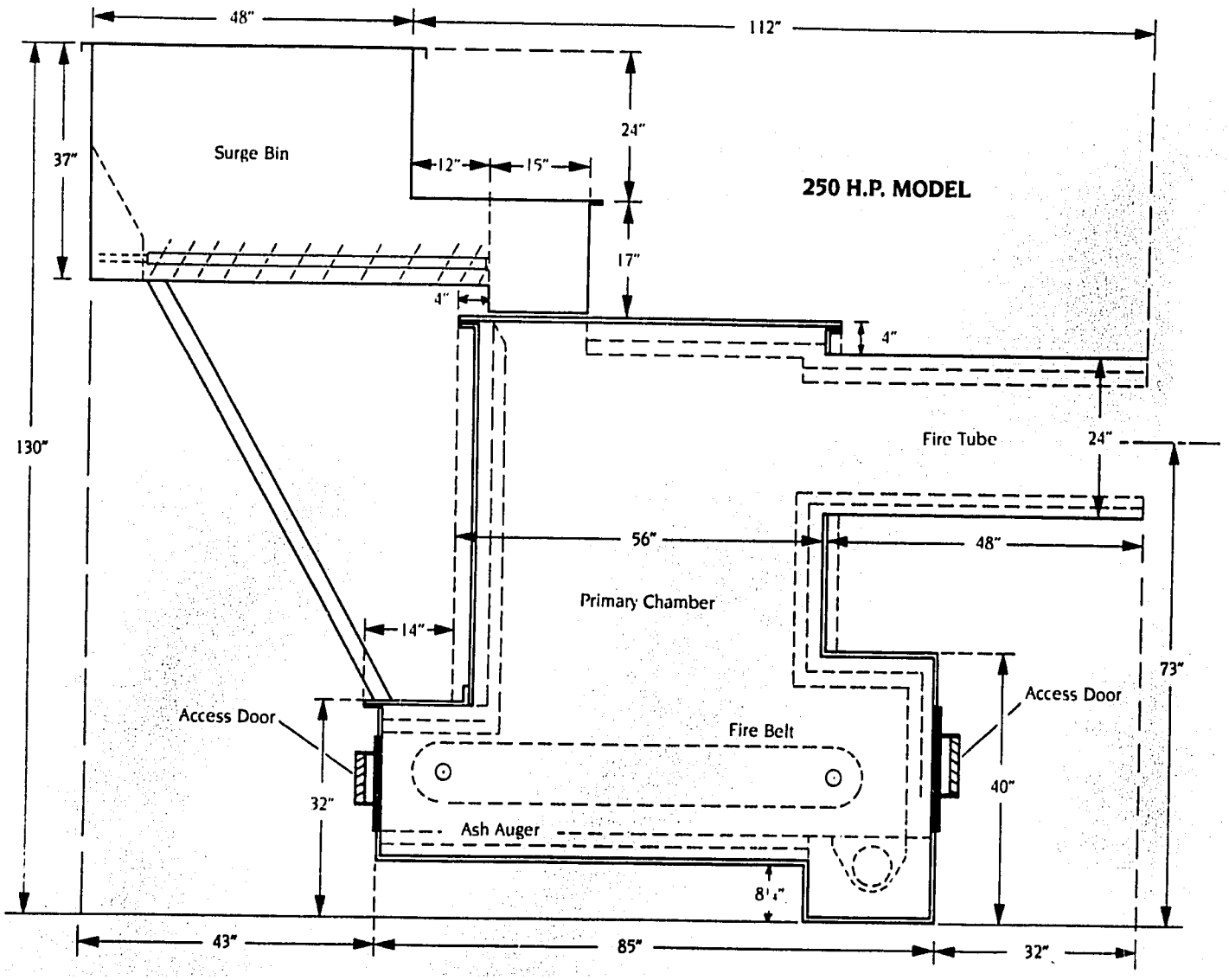
Heat and Air Conditioning



WASTE CONVERSION SYSTEMS INC.

Boiler Retrofit/Dimensions

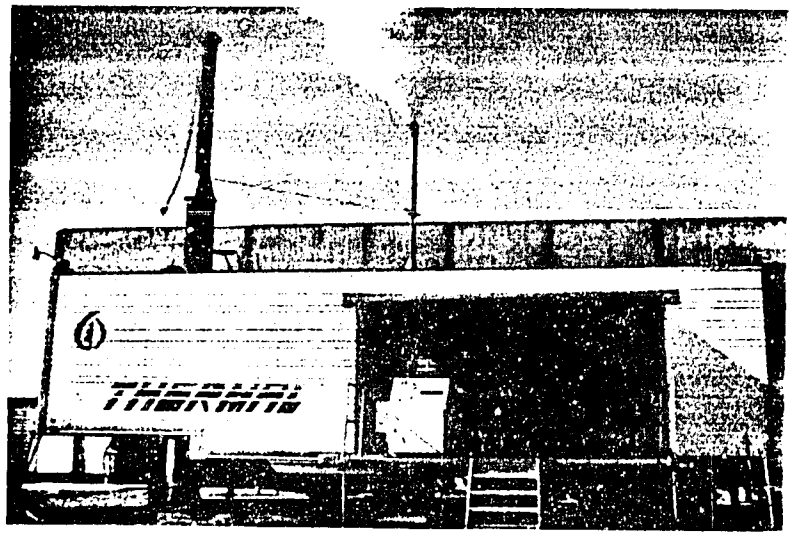




(See reverse side)

	WOOD WASTES	*MUNICIPAL WASTES Pellets Derived From:	AGRICULTURAL/ POULTRY WASTES
FUEL SOURCES	Sawdust Wood Chips Planer Shavings Hogged Wood (Logs/Branches) Wood Pellets	RDF (refuse derived fuel) Garbage Pellets Sewer Sludge** **(under development) Rubber Tires	Sugarcane Bagasse Coconut Shells/Husks Rice Hulls Coffee Hulls Alfalfa Pellets Sugar Beet Pulp Turkey/Chicken Manure Animal Manure

	COMMERCIAL	INDUSTRIAL	MUNICIPAL	RESIDENTIAL
APPLICATIONS **HEATING** **CO-GENERATION** **AIR CONDITIONING**	Warehouses Greenhouses Office Buildings Hotels/Resorts Airplane Hangars Shopping Centers Auto Dealerships	Processing Distilleries Bottling Plants Laundries Food Processors Tire Recapping Brick Kilns Desalinization Plants Lumber Kilns Agricultural Drying	Housing Authorities Schools Hospitals Government Buildings Prisons Civic Centers Recreational Facilities	Apartment Houses Condominiums Swimming Pools Spas Driveways/Walks



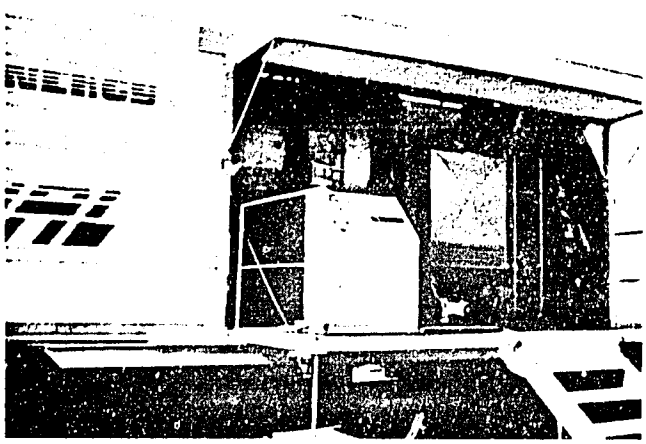
45' Mobile Unit

WASTE CONVERSION MOBILE DEMONSTRATION SYSTEM

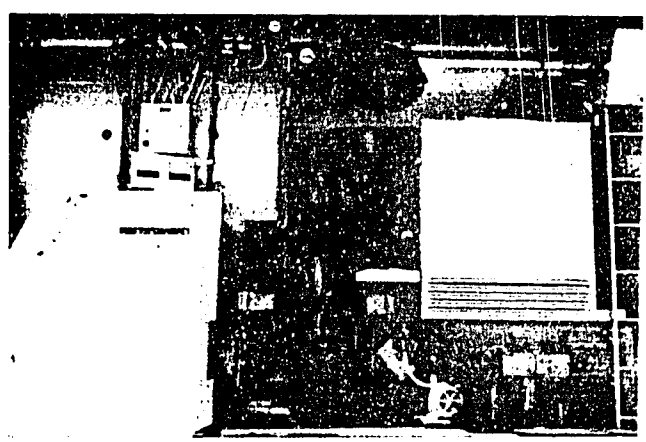
The Thermal Burner Mobile Demonstration System represents an investment in excess of $150,000. It provides potential users with a working demonstration of how cleanly and efficiently it converts R.D.F. (refuse derived fuel) or any of the other industrial or agricultural waste products readily available — into an economical source of energy that can produce steam, air conditioning and electric power.

The demonstration system contains a 150 HP Thermal Burner, Scotch Marine Boiler, computerized controller, fuel feed and ash removal systems.

It is a valuable on-site sales tool for our distributors. At various trade shows and expositions, it demonstrates the substantial reduction in gas and oil energy costs that can be achieved by potential users while helping to solve the local community waste problem.



View of Observation Deck and Computerized Controller



View of Thermal Burner and Boiler

AMOLAB
(ANALYTICAL MOBILE LABORATORY)

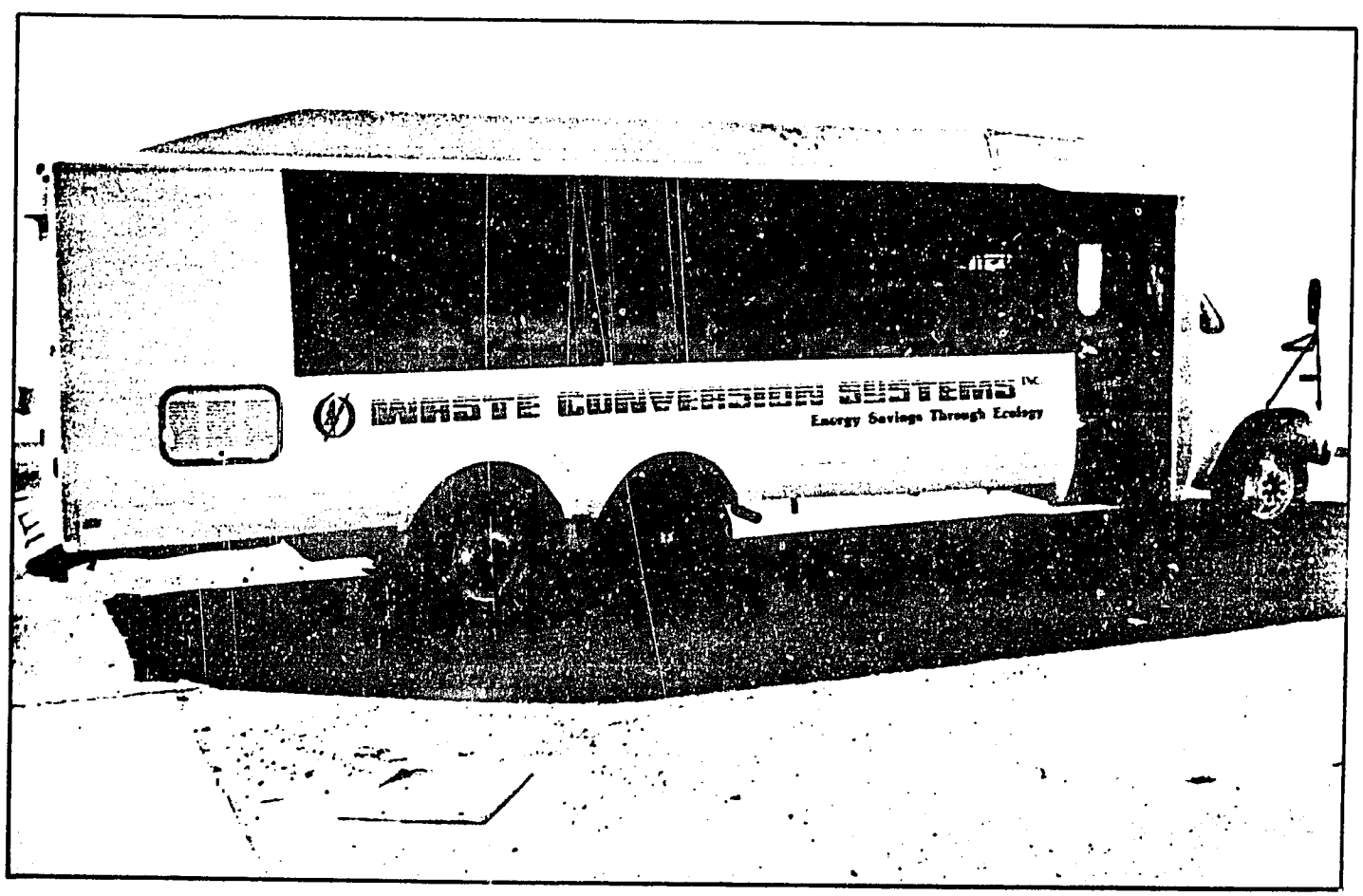
Waste Conversion Systems, Inc. has designed and built a unique state-of-the-art mobile analytical and development laboratory for on-site testing of solids, liquids and gases. When burners are monitored stack gases are separated in a Gas Chromatograph into the component parts, which are introduced automatically into an Ion Trap Detector (mass-spec) for "finger printing." The "finger prints" are automatically transferred to a computer for identification. The computer compares the "finger prints" in its library of over 42,000 compounds and when two "finger prints" match, the name of the matching compound is given. This process is repeated for each of the compounds present in the stack samples. Thus, we are constantly aware of the content of stack emissions and can optimize burning conditions to eliminate any unwanted emissions, if present.

Minerals present in the ash are determined using an Atomic Absorption Spectrophotometer. The types of minerals present determine where the ash can be sold. A few of the many uses for ash are:

fertilizer	concrete	cinder block	roofing paper	asphalt	drainage
carbon paper	steel mills	wall boards	shingles	icy roads	ceramics

AMOLAB can analyze gram quantities of any type of fuel including toxic and hazardous materials allowing for the burning of these fuels under safe conditions.

AMOLAB is used internally to monitor newly installed burners and for demonstrations of the use of alternate fuels. It is also rented on a service basis to perform any analysis within the capacity of the instrumentation. Rates can be figured on the following basis: per assay, per hour, per day, or per week.



Discussion Draft

POWER SHORTAGES IN DEVELOPING COUNTRIES: MAGNITUDE, CAUSES, AND FUTURE PROSPECTS

Prepared by:

Office of Energy
Bureau for Science and Technology
U.S. Agency for International Development
Washington, D.C.

January 11, 1988

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EXECUTIVE SUMMARY

BACKGROUND

Recognizing that "energy shortfalls are causing a serious constraint to development in over half of all A.I.D.-assisted countries," the Committee on Appropriations of the U.S. House of Representatives requested a report from the U.S. Agency for International Development on the "magnitude of the crisis, its implications for future economic and social development and the potential for U.S. technologies and services to address this problem", including an assessment of "appropriate incentives for private sector participation...."

The rapidly accelerating problem of electric power in developing countries is of critical importance to the United States. As a key prerequisite for economic development, electric power is vital to efforts to improve living standards in the Third World and to satisfy the demands of their citizens within a stable political context. Also, the electric power market in developing countries provides significant trade opportunities for U.S. businesses.

PURPOSE AND REPORT ORGANIZATION

In response to the Congressional request, this report highlights the dilemma faced by developing countries and seeks to initiate a discussion about potential solutions and the appropriate role of the United States foreign assistance program. The specific purpose of the report is to assess the magnitude and causes of the present and future power problems in developing countries (Chapter 1), to identify the impacts of inadequate power supply (Chapter 2), to consider the importance of power development to the United States and to U.S. suppliers of goods and services (Chapter 3), and finally to provide strategies for power supply improvement and identify the role of the U.S. Agency for International Development (Chapter 4).

1. ELECTRIC POWER DEMAND AND SUPPLY OUTLOOK

Unlike recent trends in the United States and some other developed countries, consumption of electricity by developing countries is still growing faster than their overall economies. Between 1970 and 1982, electricity consumption in developing countries increased at an annual growth rate of over 8.6 percent, while the Gross Domestic Product (GDP) grew at 4.6 percent to 5.7 percent per year over the same period. Over the past twenty years, the ratio of electricity consumption to income growth was 1.4 to 1.6.

Although developing countries contain over 75 percent of the world's population, they consume only 18 percent of all electricity produced in the world and have only 19 percent of all power generation capacity. By comparison, in 1984 the United States had an electric power generation capacity of over 630 GW (trillion or "giga" watts), compared with 445 GW for all developing countries.

Per capita consumption of electricity in developing countries is far below that of industrialized countries. The average of all developing countries is 500 kWh (kilowatt hours) per capita per year, and for the lower income, A.I.D.-assisted countries the average is only 300 kWH per capita per year. In contrast, per capita electricity consumption is over 5,000 kWh per year in Western Europe and over 10,000 kWh in the United States. In general, over 80 percent of the rural population in developing countries does not have access to electricity.

Causes of the Power Problem

The fundamental causes of the power problems of developing countries relate to both the supply of and the demand for power. Briefly, these are the key issues:

- Power deficit. In most developing countries, current demand exceeds supply frequently resulting in unplanned power outages and the necessity fo industries to devote their resources to installing redundant, onsite generating plants.

- High transmission and distribution losses. In many countries, transmission and distribution losses from technical inefficiencies and theft are 20 to 30 percent, compared to 8 percent in developed countries.

- Inefficient operation of power plants. Due to improper maintenance and operation, power plants in developing countries are available for operation only 50-60 percent of the time compared with over 80 percent in the United States and other industrialized countries.

- Financial difficulties of electricity authorities. Although on average developing countries devote 25 percent of their public development budgets to electric power, electricity authorities in many countries are unable to raise, through electricity sales, cross subsidies or borrowing, sufficient capital to cover their investment needs. Uneconomic pricing requires substantial subsidies from the central governments for their operations.

- Shortage of skilled manpower. Most utilities in developing countries have been unable to attract and retain a sufficient number of good managers, engineers and technical personnel.

- End-use inefficiencies and lack of conservation. Both the equipment using electricity in developing countries and the manner in which is used are highly inefficient. Also, techniques and methods of conserving power have not been widely adopted.

Future Demand for Electric Power: Current Trend Scenario

If current trends in electric power consumption continue at the recent 8.6 percent annual growth rate, electricity consumption over the next twenty years in developing countries would increase five-fold by the year 2008. **This would require the investment of $4.79 trillion, or an average over $235 billion per year, compared with the $50-60 billion being spent currently.** Developing countries cannot sustain the financial and environmental impacts of such an expansion.

Future Demand for Electric Power: Alternative Scenarios

Recognizing the unsustainability of simply projecting current trends in electric power demand, the report analyzes three alternative scenarios of future demand growth. These alternative scenarios are intended to illustrate the potential range of future outcomes, giving the reader a general order of magnitude rather than a definitive estimate of future conditions. The alternative scenarios are based on the high and low projections for economic growth in developing countries by the World Bank and on rather dramatic reductions in the ratio of electricity consumption to income growth.

These alternative scenarios assume (1) significant efficiency improvements in existing and future power facilities, (2) sharp reductions in transmission and distribution losses, and (3) considerable improvement in the end-use efficiency of electricity consuming equipment and devices. Under this approach, the ratio of electricity to income growth is reduced in stages from its current level of 1.4 down to as low as 0.9 by the year 2000 and beyond (0.9 is slightly less than the ratio being experienced in the United States today).

These projections suggest that from an existing level of 445 GW of capacity in developing countries by the year 2008 generation capacity could increase to between 1150 GW (an annual growth rate of 3.71 percent) and 2008 GW (an annual growth rate of 5.8 percent). These projected growth rates are considerably lower than the 7 percent per year rate projected by the World Bank for 1985 to 1995 or the 8.6 percent per year used in he current trend scenario..

Based on these scenarios, **the projected financial cost of the new generating capacity and its related transmission and distribution facilities would be between $800 billion for the low growth scenario and $1.7 trillion for the high growth scenario.** If, however, no improvements in end-use efficiency, transmission and distribution losses and generation plant utilization occurred (i.e. the ratio of electricity consumption to income growth was 1.4 from 1988 to 2008, instead of declining to 0.9) the investments required would be $1.6 trillion for the low income growth scenario and $3.9 trillion for the high income growth scenario!

2. THE IMPACT OF ELECTRIC POWER SHORTAGES

While not sufficient unto itself, the availability of reliable electric power is a key component of the infrastructure necessary for economic development in the Third World. Expansion of the agricultural and industrial sectors, in particular, depends heavily on electricity to perform productive functions. Currently in most developing countries, the industrial sector dominates electricity consumption, accounting for over 60 percent of total electricity use.

As these nations modernize, electricity use in the commercial and residential sectors is rising sharply, and in some countries has outstripped industrial sector consumption. Electrical services in the form of lighting, heating, cooling, and labor saving devices add to the quality of life and the productivity of individuals and their families and, consequently, are in high demand in developing countries.

Also, most developing countries have adopted aggressive plans for rural electrification in an effort to decentralize their populations and to distribute the benefits of economic growth and electric services. Electricity has direct benefits in rural areas on health through its us in refrigeration of vaccines and food. Electricity also permits the introduction of lighting and small-scale, labor saving devices for rural production and consumer convenience. These programs are endangered if developing countries cannot obtain the financial resources for decentralized, rural electrification.

Electricity and Economic Development

Even though power supply capacity in developing countries has increased significantly over the past two decades, the demand for electrical services has risen more rapidly. **Consequently, many developing countries now face critical power shortages of over 10 percent of their generation capability.** In Pakistan, for example, over the past five years, power shortages have been over 25 percent of the peak demand. In India, power shortages of over 10 percent are common throughout the country with some states experiencing shortages of power of up to 40 percent.

These power shortages and unmet demands for power result in significant economic problems. In Pakistan, for example, load shedding in the industrial sector alone has led to a 1.8 percent decrease in Gross Domestic Product and a 4.2 percent decrease in the

country's foreign exchange earnings. In India, the current 10 percent average supply cut to the industrial sector is estimated to cause an annual production loss of over $6 billion -- equivalent to 12 percent of the country's industrial output. Also, the unreliability of power supplies has caused serious losses of agricultural production, especially in those areas dependent upon electrical pumps for irrigation.

Environmental Impacts of Electric Power Systems

A massive expansion of electric power production in developing countries based on current trends threatens environmental damage to developed, as well as developing countries. Projections of power supply expansion show enormous increases in hydropower and steam thermal (mainly coal) facilities. Large-scale hydropower plants often require the relocation of sizeable populations and permanent alteration of river basin ecosystems. Coal-fired power generation has historically been associated with the emissions of particulate materials, sulfur dioxide, oxides of nitrogen and other pollutants from related mining, cleaning, generating and storage operations. The specter of global climatic change looms over any substantial expansion of coal burning plants. Shifts in climatic zones, a rise in atmospheric temperature, a rise in sea level and other disruptive impacts may result from growing concentrations of carbon dioxide and other by products of fossil fuel use.

Systematic planning, conservation and utilization of new technologies offer opportunities to significantly mitigate the massive environmental impacts anticipated by following the current trends that concentrate primarily on the expansion of generating capacity.

Financial Dilemma

Developing countries, due to inadequate economic growth rates and substantial debt burdens, clearly lack the financial resources needed to satisfy the $4.79 trillion demand projected under the current trend scenario.

To achieve the significant growth in their power sectors experienced to date, the developing countries have had to devote an average of 25 percent of their capital improvement budgets to the electrical power sector. Further proportional increases in

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the power-sector budget are unlikely since they are likely to cause negative impacts on other important sectors, such as health care services, education, and transportation. Already the poorer developing countries spend $8 per capita annually on power for every dollar spent on education or health.

Under the alternative scenarios, even with significant conservation measures, developing countries will require roughly $800 billion to $1.7 trillion in additional capital for power sector investment in new generating capacity and related transmission and distribution equipment over the next 20 years -- an average of $40-85 billion per year. This does not include any expenditures on rehabilitating or replacing existing power plants or on conservation measures.

The report projects that multilateral and bilateral development agencies can be expected to provide, by the year 2008, from 20 to 40 percent of the needed capital for the alternative scenarios. The report assumes that through pricing and operational reforms the electric utilities and central governments could raise an additional 20 percent of the required capital from domestic revenues. Given the withdrawal of private financial institutions from the international lending market and given that their participation in power sector lending usually requires significant guarantees by the borrowing country or other third party, no projection was made for their future participation, although some level of participation can be expected on a case by case basis.

Combining external and internal capital flows still leaves a substantial shortfall of funds -- $350 million for the low growth scenario and $1,065 billion for the high growth scenario -- needed for new generating capacity.

3. IMPORTANCE OF THIRD WORLD POWER DEVELOPMENT TO THE UNITED STATES

The power situation in developing countries directly concerns the United States in several ways:

- Foremost is a humanitarian concern for the living conditions of people in these countries, their employment opportunities, and prospects for achieving sustainable economic development.

- As an essential ingredient for economic growth, sufficient supply and efficient use of electric power is critical in the efforts of the U.S. to encourage developing countries to shift from aid recipients to trading partners.

- Power shortages that have induced public demonstrations and riots have sociopolitical implications affecting the stability of governments and their ability to respond to citizen needs.

- The power market in developing countries provides a major opportunity for U.S.suppliers of equipment and services to increase their export sales.

Importance for U.S. Trade

The Committee on Appropriations specifically asked for an analysis of the potential for U.S. technologies and services to address the power problems of developing countries. The report projects the total export market for power generation, transmission and distribution equipment and related services to range from $367 to $908 billion over the next twenty years, depending on the growth scenario. The largest equipment submarkets will be for boilers, steam turbines, and hydroturbines; the largest service submarkets will be in construction and project management.

The competitiveness of U.S. suppliers in the power industry, however, has dramatically declined in recent years. **U.S. exports now represent less than 10 percent of the total power generation exports to developing countries, down from 17 percent just 5 year ago and down from over 20 percent in the late 1970's.** With the inclusion of transmission and distribution equipment, total U.S. power industry exports to developing countries are currently below the $2 billion mark, compared with Japanese exports to developing countries of $3.7 billion.

If current trends persist, the U.S. share of developing country power market sales will be limited to about 5 percent of the estimated export potential through the end of the century. Reversing the trend is possible if incentives can be developed to assist U.S. suppliers. Also, because of a weakened dollar, U.S. products are becoming more competitive with equipment sold by European and Japanese manufacturers. The

restricted availability of export financing for U.S. companies, however, remains a problem.

The U.S. position could also be improved by targeting incentives toward those technologies and services where U.S. suppliers have a competitive edge, such as high-temperature gas turbines, coal emission control, atmospheric fluidized-bed boiler systems, transmission and distribution equipment, conservation equipment and services, and end-use efficient electrical equipment and devices. Furthermore, US. has an edge in project management services and in independent power production through renewable and cogeneration technologies due to our recent domestic experience with these under the Public Utility Reform and Pricing Act (PURPA).

If the declining trend in market share is reversed, the report projects that U.S. suppliers could secure 8 percent of the export market through the year 2008, or from $46.4 to $62 billion.

4. STRATEGIES FOR POWER SUPPLY IMPROVEMENT

Given that the traditional approach to electric power shortages, i.e. expansion of generating capacity, is not sustainable, what strategies can developing countries pursue?

Policy Approaches

Policy reforms can play a major role in improving the quality of electricity supply, increasing the efficiency of electricity use, and alleviating adverse environmental impacts.

- Pricing Policy. Electricity prices in many developing countries are administered prices fixed by the government to achieve sociopolitical and equity, as well as,economic objectives. Consequently, artificially low electricity prices result in excessive and wasteful consumption patterns. Developing countries need to find politically acceptable approaches to raising prices to reflect the true capital and operational costs of supply.

- Energy Conservation Policy. Few developing countries have adequately considered the substantial impact that enacting energy conservation policies

and strategies can have on providing additional power while reducing the need for expensive new generating capacity. Conservation policies on the generation, transmission, distribution and end-use of electricity should be developed and enacted.

- Private-Sector Participation Policy. In almost all developing countries the private sector plays little or no role in the power sector. Policies to increase private-sector participation can inject much needed competition, appropriate pricing , efficient management, and private financial investment.

- Environmental Policy. Developing countries will have to confront the critical issue of environmental degradation resulting from activities in the power sector. Explicit policies for environmental protection should be adopted that set forth goals for environmental protection and enhancement, and procedures for evaluating impact and weighing trade offs.

Institutional Approaches

Existing institutional structures in most developing countries are not well matched to the present and future power situation, which will require innovative approaches, an emphasis on conservation, involvement of the private sector and more efficient operation. Approaches to institutional development in developing countries will be needed in the following areas:

- Utility management improvements. System planning should recognize the importance of adequate training and staff development, and of rational management objectives based on efficiency and productivity.

- Privatization of parastatal utility functions. Privatization of existing and future generating, transmission and distribution activities offer opportunities for significant improvements.

  Research and development. The use of innovative, environmentally acceptable technologies will require an indigenous capacity for research and development.

- Strengthening power-sector financing institutions. Given the shortage of capital, attention should be paid to developing specialized, domestic and foreign sources of financing for the power sector.

- Strengthening institutions related to conservation and end-use efficiency. Within the context of a national energy conservation policy, developing countries need to establish an integrated approach combining engineering, management and financial aspects of electricity conservation and end-use efficiency.

Technological Approaches

Increasing efficiency and power output can be achieved by technological improvemen in the power sector, as discussed below:

- Power plant performance improvement. Significant improvements in the order of magnitude of 10 percent in power plant performance can be accomplished through cost effective plant rehabilitation and improved operation.

- Transmission and distribution loss reduction. Technical fixes, which do not require advanced technologies, and attention to the theft problem can significantly reduce transmission and distribution losses at relatively insignificant expense.

- End-use efficiency improvement. The introduction of recent improvements in motors, lighting, air conditioning and refrigeration can, it is estimated, reduce end use consumption of electricity by up to 30 percent.

- Load management. In developing countries where peak demand grows at considerably faster rates than average load, load management -- reduction of peak loads, development of off-peak loads and the transfer of loads from on-peak to off-peak periods -- presents an attractive opportunity for reducing the need for additional generating capacity.

- Cogeneration. Combining the generation of thermal energy and electricity allows industrial and large commercial users to use the waste heat from

power generation for process or other thermal needs and reduce their total energy costs.

- New generation technologies. There are a wide variety of conventional and nonconventional generation technologies that can be used in developing countries to reduce environmental impacts, to utilize indigenous fuel resources and to use renewable resources.

Private-Sector Approaches

Directly involving the private sector in the power development of Third World countries offers promising solutions to solving the power problems. The private sector has greater incentive and ability than the public sector to manage and operate efficiently and productively. Also, the private sector has potential access to private sources of financing that are unavailable to the state-owned utilities. In the limited instances where private companies are generating and selling power in developing countries, there is clear evidence of their greater efficiency and reliability.

Impact on Power Sector Expansion Requirements

To assess the impact of nongeneration approaches to the power-sector problem, the report analyzes specific, achievable performance goals for electric utilities and electricity consumers in developing countries. It appears quite feasible to achieve the following:

- 10-20 percent improvement in plant capacity;
- Reducing transmission and distribution losses from 25 percent to 15-20 percent; and
- Improving the end-use efficiency of electrical equipment and devices by 20-30 percent.

In contrast to the current trend projection discussed in earlier, the alternative scenarios that emphasize conservation can reduce the need for additional generation capacity to 1,000 to 1,760 GW.

Role of A.I.D. In Alleviating Power Shortages

The U.S. Agency for International Development should play a pivotal role in assisting developing countries to alleviate their electric power problems. Building upon its extensive experience, the Agency can make substantial contributions in the following areas:

Policy Dialogue

- Pricing policy. A.I.D. should focus its activities to induce pricing reform policies that reduce or eliminate uneconomic pricing and alleviate current and future demands for power.

- Conservation policy. A.I.D. should assist developing countries to develop and implement national energy conservation plans that address generation, transmission and distribution, and end-use consumption of power.

- Private-sector policy. A.I.D. should expand its current efforts to encourage the implementation of policies and practices that assist private-sector participation in the power sector.

- Environmental policy. A.I.D. should assist developing countries to develop, adopt and implement systematic policies, standards and practices for environmental management for power-sector activities.

Institutional Improvements

A.I.D., through the technical expertise it has available and the its proven ability to provide effective training, should focus particular attention to improving the electric utility institutions in developing countries. The Agency should concentrate its resources on the following:

- Improving utility management

- Assisting in privatization of parastatal utility functions

- Supporting research and development

- Strengthening power-sector financing institutions
- Assisting institutions involved with conservation and end-use efficiency improvements

Technology Transfer

A.I.D. should take the lead in coordinating federal activities to promote technology options in which U.S. businesses have special capabilities, such as power plant rehabilitation, transmission and distribution loss reduction, load management, cogeneration, conservation and end-use efficiency improvement, and environmental controls.

Private-Sector Development

A.I.D. should pursue various strategies to induce private-sector participation in the power sectors of developing countries. These are briefly outlined in this report and more fully discussed in the companion report on "Options to Increase Private Participation in Electric Power Development in A.I.D.-Assisted Countries." Initially, A.I.D. should focus on removing the policy and institutional barriers to private-sector participation in the power sector and on assisting the implementation of a limited number of potential projects to provide some actual experience with this innovative approach.

OPIC

15 - 25 million allocation from OMB to assist small US business abroad loans of $500K → 6m.

6 - 50m covered by guarantee program
11% rates; terms more generous than commercial banks.
can neg. 2-3 yr grace period, interest only.

say $100 investment; $50 from OPIC, 60-40 debt-eq. ratio
$40 of eq ~$25 from American, $15 from anywhere, even competitors or from host government.

loan guarantees are translated into commercial bank loans.
criteria: efficiency
joint ventures (incl. local partner)
this year is reauthorization year; 4 or 5 leg. proposals.
2 are imp: (1). Sp + Cong to make equity investments.
would allocate 25% i.e., OPIC would take 15% position.
(2) use loan funds to adapt technologies to LDC's
technology adaptation funds.

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51. Jack Williamson T.D.P.

52. J. Sullivan A.I.D.

vest operations, to reduce losses, and improve quality of their crops. The structured training and research are tailored to specific needs of participants so that they may better solve postharvest problems in developing countries.

The faculty includes full-time scientists in the area of processing, with emphasis on rice and forages, and several cooperating specialists from various departments and research stations. The Division draws upon the experience of personnel in the LSU Agricultural Center and others with broad international experience for its short- and long-term training programs.

Facilities for research and training in postharvest technology are available at the Department of Agricultural Engineering and other units of the LSU Agricultural Center. A complete laboratory for grain quality work is available. This laboratory is equipped with rice grading equipment recommended by the U.S. Department of Agriculture; various types of moisture evaluation systems; typical grain processing equipment; precision apparatus for testing mechanical properties; and apparatus for cooking, texture evaluation, and color analysis. Special equipment for processing oriented research applications such as parboiling, continuous steaming of grain, and grain drying are also available for use by trainees of the Division.

Several items of equipment such as a microwave moisture determination system, a color sorter for grains, and a complete integrated small scale rice mill are included for procurement by the Division.

Research

Research activities, recently completed and ongoing, include:

* On-farm rice drying energy evaluation studies.
* Parboiled rice drying, utilizing microwave energy.
* Rice drying—a generalized drying model development and deep-bed simulation.
* High temperature drying and tempering effects on parboiled rice quality.
* Laboratory evaluation of rice parboiling methods for developing countries.
* Study of rice bran removal and color relationships.
* Mechanical and chemical conditioning treatments to accelerate drying of forages.
* Evaluation of changes in storage in mechanically formed hay packages.
* Evaluation of chemical treatment of low quality forage for quality enhancement.
* Chemical preservation of high moisture forages.

Training

Training programs at the Division include:

* Short-term training programs in all postharvest phases of grain crops; cleaning and sorting; grain drying; storage and pest control; grain pretreatments; milling; grading and quality control; handling; postharvest phases of forages such as mechanical and chemical conditioning; drying; and preservation.
* Long-term degree programs in the Department of Agricultural Engineering (MS and Interdisciplinary PhD). The areas of research that students may work in include: engineering aspects of processing; materials handling; crop drying; storage of grain crops; processing equipment; by-product utilization; grain properties; computer application/simulation; and rice/grain technology. In the area of forages, students/trainees may be involved in chemical/mechanical conditioning of forages; mechanical drying; quality enhancement of low quality forages; and preservation of high moisture forages.

The training programs, both short- and long-term, are specifically designed for host country applicability in order to provide the highest level of competence to trainees relative to problems likely to be encountered in developing countries. Research projects and problem areas from host country situations are the guide in formulating graduate study programs in the long-term category.

For training costs, assistance, and other relevant details, please request information from:

Postharvest Technology Division
International Programs
Louisiana State University Agricultural Center
P.O. Box 16090
Baton Rouge, Louisiana 70893
USA

International Programs
Macon D. Faulkner, Director

Louisiana State University Agricultural Center
H. Rouse Caffey, Chancellor

The Louisiana State University Agricultural Center follows a nondiscriminatory policy in programs and employment.

Postharvest Technology Division

INTERNATIONAL PROGRAMS

LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER

Postharvest Technology Division Louisiana State University Agricultural Center

The importance of rice and other cereal grains to the people of the world is well established, but increasing populations, especially in developing nations, place a great burden on the farming community. Improved postharvest techniques deployed along with improved quality and yields of crops will greatly alleviate hunger and food shortages, because controlling postharvest losses increases food availability. Rice has been singled out as the crop that would benefit most from programs to reduce postharvest losses. Based on estimates made by the International Rice Research Institute (IRRI), 1.3 billion people get more than half their food energy from rice.

Louisiana State University (LSU), during the last several decades, has been involved in worldwide agricultural research, training, and extension programs associated with rice and other subtropical crops. To strengthen this ongoing commitment the LSU Agricultural Center established the Postharvest Technology Division of International Programs to develop institutional and human resource skills in the area of rice and other subtropical crops. This division will complement well established programs in production of these crops by concentrating its activities on the postharvest aspects of rice, cereal grains and forages, crops common to Louisiana and many developing nations.

The Louisiana State University System and the LSU Agricultural Center

Louisiana State University System, a comprehensive university, is the land-grant university in Louisiana. The System is comprised of eight campuses located throughout the state. The campus entrusted with development of agricultural programs in the state, in conjunction with the U.S. Department of Agriculture and other agencies, is the LSU Agricultural Center, situated in Baton Rouge.

The LSU Agricultural Center is responsible for statewide research and extension functions of the LSU System. International Programs is one of the principal units of the Center, along with the Louisiana Agricultural Experiment Station and the Louisiana Cooperative Extension Service. Since the College of Agriculture, a unit of LSU in Baton Rouge, and the LSU Agricultural Center occupy the same campus, many of the Center's scientists hold joint appointments from both.

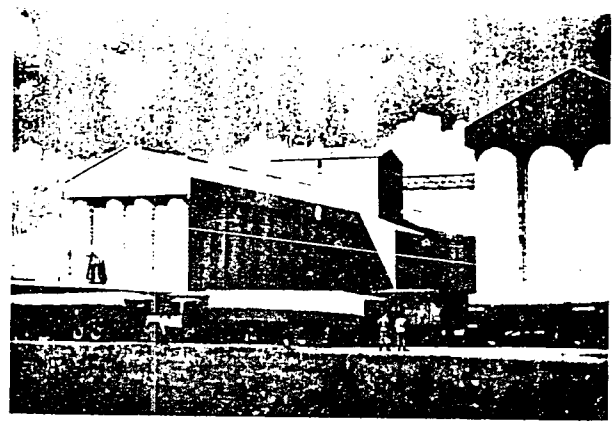
LSU Agricultural Center and International Programs

The University has more than 30 years experience in international programs. International programs implemented by the LSU Agricultural Center relate to many technical specialties. The Center has been involved internationally in institution building, participant training, and technical consultations in areas such as agricultural engineering, agricultural economics, management, agronomy, animal science, entomology, and horticulture.

The Center's scientists have served several countries, including Malaysia, Venezuela, Nicaragua, Indonesia, India, and Guyana. Many short-term programs have been completed in the Philippines, Thailand, Burma, Bangladesh, El Salvador, and Brazil. Some of the more recent work has been undertaken in Liberia, Sierra Leone, and Belize. The Center has committed a large qualified staff to service programs aimed at international agricultural development.

Louisiana has been a leading rice region of the United States for almost 100 years. The LSU Agricultural Center operates the largest and oldest rice research station in the United States. The Louisiana Rice Research Station, headquartered at Crowley, serves as a major source of research information for rice growers throughout the world. The international rice training programs at Crowley provide training to participants from many rice growing countries. The Agricultural Engineering Department of the LSU Agricultural Center, situated in Baton Rouge, is actively involved in rice postharvest research. The "LSU Dryer" or continuous flow rice dryer, developed in this department, is now in use all over the world. The Center has established the Postharvest Technology Division to develop expertise in similar technology through research and structured training.

The primary objectives of the Division are training and research in postharvest technology of rice, cereal grains, and forages; more specifically the specialized training of country personnel, assisting the faculty in solving postharvest problems, and conducting adaptive and applied research in postharvest technology of grains and forages. The Division also augments the current grain and forage postharvest technology programs of the Department of Agricultural Engineering and other departments of the Center. The main thrust



of the Division's programs and activities is to strengthen the capability of personnel from developing nations who are involved in grain and forage postharvest

what is domestic market for small integrated energy/byproduct biomass systems – PURPA, chemicals.

One major point: there is a huge potential market in LDC power and AID needs industry help in developing that market.

- AID'S program: economic development
  - policy
  - technology transfer
  - institutional development
  - private sector

energy program - $200 million, focus on several countries Pale Egypt. also Phil, central America

Office of Energy

- The power problem
  - 50W — 3000W
  - effects on development
  - over the next 30 years 800 → 1,700 billion needed.
  - LDC power market - $367 - 908 billion

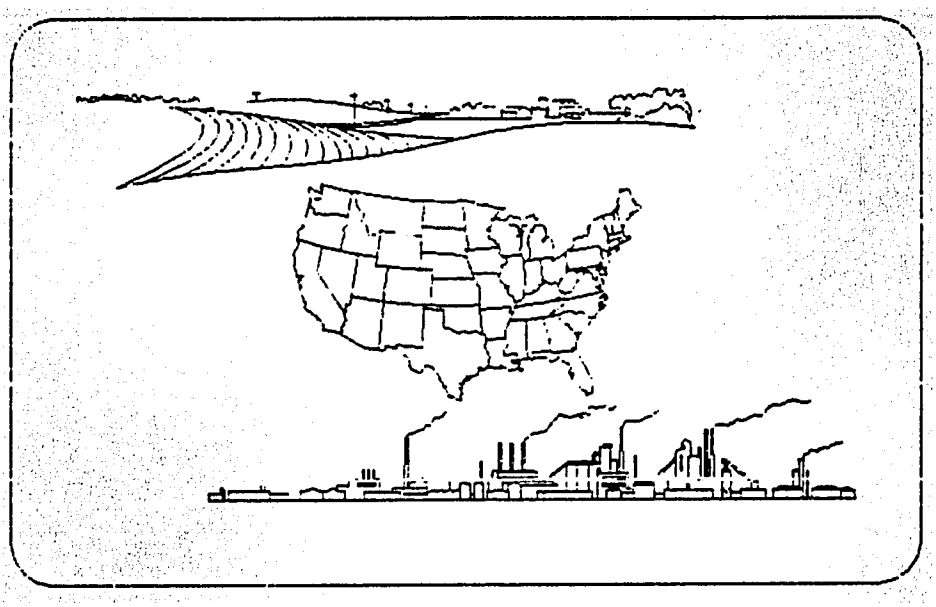
    U.S. exports now less than 10% of total power generation exp. down from 17% 5 years ago and down from 20% in late 1970's.

  total power exports below $2 billion, compared with Jap. $3.7 billion

- The solution
  - efficiency, technology, policy etc.
  - private sector -

- a challenge
  - AID role in assisting the private sector - prog. dev. options
  - status of the market opportunity - huge market, not activity
  - feedback to AID

RICE RESIDUE UTILIZATION TECHNOLOGY MARKET PROSPECTS: U.S. AND OVERSEAS



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Louisiana State University Agricultural Center
Baton Rouge, Louisiana

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AGENDA

Thursday, January 28

Morning Session: *"U.S. technologies and the scenario in developing nations" (session moderator:* Dr. Lakshman Velupillai, L.S.U.)

8:30	*Welcome Address*	- Dr. H. Rouse Caffey, Chancellor, L.S.U. Agricultural Center
8:45	*"The university role in integrating residue utilization into postharvest systems"*	- Mr. Macon D. Faulkner, Vice-Chancellor and Director, International Programs, L.S.U. Agricultural Center
9:00	*"How does the U.S. private sector interact with the goals of the U.S. foreign assistance program?"*	- Dr. James Sullivan, Director, Office of Energy, Science & Technology Bureau, U.S.A.I.D., Washington D.C.
9:30	*"The potential of agricultural residue utilization technology in improving economies"*	- Mr. John Shields, Manager, Office of Agricultural & Chemical Development, Tennessee Valley Authority, Muscle Shoals, AL
10:00	*"Rice Residue Utilization - The U.S. commercial offerings and new resources"* - a video presentation.	*- Postharvest Technology Division,* L.S.U. Agricultural Center, Baton Rouge, LA
10:30	COFFEE BREAK ** *Displays by participating companies/institutions* **	
10:45	*Technologies in the making* - new possibilities *(a) Rice bran as a potential source of higher value chemicals.*	- Dr. Robert Sayre, Research Chemist, Food Quality Research Unit WRRC, ARS USDA, Albany, CA.
	(b) Gas turbine cogeneration with agricultural residues	- Dr. Eric Larson, Princeton University, NJ
	(c) Gasification of rice hulls	- Dr. John Goss, University of California, Davis, CA
11:15	*"The developing country environment - risks and constraints"*	- Dr. Marcia Gowen, Bioenergy Systems & Technology Project, Office of Energy, Science & Technology Bureau, U.S.A.I.D., Washington D.C.
11:45	*Discussion*	
12:15	LUNCH	

Foreign Corrupt Practices Act.

Thursday, January 28th

Afternoon Session: *"The dynamics of creating consortia/joint ventures" (session moderators: Dr. Joseph Roetheli, TVA & Ms. Betsy Amin-Arsala, U.S.A.I.D.)*

1:30 *Group discussion*

Consortium group: Spokesperson - Mr. Willis Noland, Facilitator - Dr. Lalit Verma

Joint venture group: Spokesperson - Mr. Keith Lanneau, Facilitator - Dr. John Nye

The two groups will participate separately, one as a consortium and the other as a joint venture, addressing the following issues:

(a) What the U.S. industry has to offer in terms of technology.
(b) What is promising in the research areas?
(c) What are the international markets?
(d) What are the risks and constraints?
(e) How do we finance & support international ventures?

4:30 *Preparation of summary of findings by group spokesperson and the facilitator*

5:00 *Reception - L.S.U. Agricultural Center*

Friday, January 29

Morning Session: *"Group session findings, next steps?"*

8:30 *Presentation of "consortium" group summary - Mr. Willis Noland, President, Agrilectric Power Partners, Ltd., Lake Charles, Louisiana.*

8:50 *Presentation of "joint venture" group summary - Mr. Keith Lanneau, President, Helix International, Baton Rouge, Louisiana.*

9:10 *General discussion:*
I. Summary of risks & constraints
II. What are the next steps?

10:15 COFFEE BREAK

10:30 *Summary Comments*

10:50 *Summary comments*

11:15 *"Options for future use of PL480 funds"*

12:00 *Conclusion*

- Mr. Jack Williamson, U.S. Trade and Development Program, International Development Cooperation Agency, Washington D.C.
- Mr. John Aldonas, Office of Deputy Director for Government Affairs & Business Development, Overseas Private Investment Corp., Washington D.C.
- Mr. Robert Bostick, International Affairs Specialist, PL480 Program, Office of Management and Budget, Washington D.C.

Special thanks to

Dr. H. Rouse Caffey, Mr. Macon D. Faulkner, Dr. James Sullivan, Mr. John Shields, Dr. Robert Sayer, Dr. Eric Larson, Dr. John Goss, Dr. Marcia Gowen, Mr. Willis Noland, Dr. Lalit Verma, Mr. Keith Lanneau, Dr. John Nye, Mr. Jack Williamson, Mr. John Aldonas, Mr. Robert Bostick, Dr. Charles Schexnayder, Ms. Margaret Blackwell, Ms. Mary Margaret Bayot, Ms. Ann Evans, Ms. Mary Ann Hebert, Ms. Danielle Bayham, Ms. Gayle Gautreau, Ms. Ganelle Bullock, Ms. Kay Suggs, Mr. Ted Baiwin, Mr. Brett Ory, Dr. Harton Traylor, Ms. Betsy Amin-Arsaia, Dr. Joseph Roetheli, Ms. Jacqueline Broder, Mr. Wayne Barnier, Dr. Mary Jim Beck, Dr. Richard Strickland, Mr. Russel Lambert, Mr. Ronald Bailey and all others who assisted in numerous ways in this project.

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