DOE/RA/50378--T1

DE82 018739

Executive Summary

Feasibility Study For Alternative-Fuels Production: Fluidized-Bed Gasification Of Rice Hulls

Contract No.
DE-FG07-80RA878

Submitted To:

U.S. Department Of Energy
Idaho Operations Office
550 Second Street
Idaho Falls, Idaho 83401

Submitted By:

American Rice, Inc.
3000 Buller, P.O. Box 2587
Houston, Texas 77252

March, 1982

TABLE OF CONTENTS

p

PREFACE

This report is a condensation of A Feasibility Study for Alternate Fuels Production: Fluidized-Bed Gasification of Rice Hulls, a study conducted by American Rice, Inc., Houston, Texas with Energy Resources Co., Inc. of Cambridge, Massachusetts under U.S. Department of Energy Contract No. DE-FG07-80RA50378.

PROJECT SUMMARY

This study examines the feasibility of constructing an alternate fuel production facility using a rice hull fuel currently being generated at the American Rice, Inc. (ARI) processing facility in Houston, Texas. The demands for energy at the existing plant closely match the potential energy outputs which can be produced from the quantities of alternate fuels available.

It was found that fluidized-bed gasification of the rice hulls which produces a low BTU gaseous fuel and a char by-product has the greatest potential for meeting the energy demands of ARI. The char by-product produced is potentially a marketable item, although no market has been developed to date. The low BTU gaseous fuel can be used to produce various forms of useable energy.

The proposed plant, to be located within the ARI facility, would consume 340 tons a day of rice hulls, the projected average daily output of the existing facility. It would produce 5.17 megawatts of electric power; 30,000 pounds per hour of process steam and and 84 tons a day of char. This output would completely fulfill ARI's steam and electricity demands with an additional 1.9 megawatts of electricity available for sale to the local power company.

The estimated total installed cost of the proposed plant is $8,787,000. The estimated return on investment is 36.8%, assuming natural gas costs and char marketing revenue predictions hold true.

p

BACKGROUND

ARI is an agricultural processing and marketing cooperative owned by and serving 1,800 farm families located in the rice producing areas of Louisiana and Texas.

ARI produces two primary products: regular white milled rice and parboiled rice. By-products of the milling process include rice hulls, bran, broken kernels and brewers' rice.

Rice hulls represent twenty percent of the weight of paddy (unmilled) rice. Use of or disposal of this low-value by-product has frequently proved difficult because of the tough, woody, abrasive nature of the hulls, their low nutritive properties, resistance to weathering, great bulk and high ash content.

The ARI processing facility is located in the City of Houston, Texas and has annual sales of $200 million.

Joining ARI as a sub-contractor in the study was Energy Resources, Inc. (ERCO) of Cambridge, Massachusetts. ERCO has extensive experience in the development, design and construction of alternative fuel production facilities. Through its combined in-house capabilities, including a pilot plant test facility and analytical services laboratory, ERCO was able to provide technical assistance to ARI.

In recent years, with improving technologies and processes, the milling and treating of rice has grown in both sophistication and scale. Today's milling process requires more energy than in the past. This is especially true in the parboiling process where paddy rice is steeped in hot water and exposed to steam to completely gelatinize the starch, then dried to a storable moisture content and milled. This increased energy requirement places rice processors in the position of becoming larger energy users at a time when industry finds political and economic pressures to decrease their use of our nation's energy.

Faced with the prospects of continually escalating natural gas prices or, worse, possible unavailability of this primary fuel at any price, ARI began its investigation by comparing the value of rice hulls as a fuel to number two or number six fuel oil, natural gas and coal. Satisfied that the caloric value was adequate and the cost of the fuel much less than the compared fossil fuels, the objectives of this study were set:

(1) Determine that the use of rice hulls as fuel would provide the highest rate of return on this by-product.
(2) Select the most efficient technology available in the conversion of rice hulls to energy.
(3) Establish the impact of the resulting char product on the project.
(4) Economic feasibility of the system.

THE STUDY

At one time, most of the hulls produced by rice processors were used as fuel in steam plants which provided mechanical power for rice mills, but cost factors, cleanliness, lack of technology to meet regulatory compliance and the ready availability of natural gas and electricity have led to the discontinuation of this practice. Currently, a small percentage of rice hulls is used in the production of furfural. Some hulls are pulverized and sold as stock feed filler and lesser amounts are used for poultry litter and livestock bedding. During lulls in the market for hulls, they are often dumped in sanitary landfills.

The value of this by-product is cyclical at best. During those periods when a market cannot be found, processors are faced with a difficult waste disposal problem in getting rid of the rice hulls. Landfilling and open burning are becoming environmentally unacceptable and the economics of hauling the bulky hulls to remote locations or incincerating them purely to reduce volume are becoming increasingly burdensome.

Various markets for rice hulls were studies. Those included:

* As feedstock to produce furfural.
* Mixing with rice bran and sold as feedstock for livestock.
* As an adjunct to prevent caking in fertilizers.
* As a polishing abrasive.
* As landfill.
* As loose insulation material.
* As fuel.

In view of the limited potential of the marketability of rice hulls for the other uses and their excellent fuel values, the study team concluded that the most feasible use of the by-product is as a fuel to produce energy.

TECHNOLOGIES CONSIDERED

The process options (technologies) available which use rice hulls as a fuel source are divided into two basic groups: direct combustion and gasification (pyrolysis). Various process options are available within each basic group; for example, direct combustion processes include suspension burners, fulidized-bed combustors, multiple-chamber combustors and single-chamber combustors. Gasification technologies available include gravity and mechanical agitation moving beds, grate or multihearth, fluidized suspension bed and fluidized-bed.

The direct combustion systems are in general inexpensive systems compared to the gasification systems but present serious technical problems in the combustion of rice hulls.

Direct combustion systems typically operate at temperatures above the high silica ash fusion point, resulting in the agglomeration or slagging of the ash. The combustion temperature can be kept below the ash fusion temperature by using large amounts of excess air which results in larger, more expensive combustion chambers and boilers. Erosion of the walls of the combustor and boiler at accelerated rates are a common problem in direct combustion systems in which the highly erosive silica ash is in direct contact with the boiler walls. Other common problems of direct combustion systems include unacceptably high particulate content in the flue gas and other associated fugitive emissions problems with the ash handling.

In order to make the rice hulls acceptable to suspension burners they have to be pulverized, thus adding an additional, expensive processing step to the preparation of the feedstock.

The most serious constraint of fluidized-bed direct combustion is the large excess air requirement: enough excess air must be added to keep the combustion zone temperature below the ash-softening point or the bed will agglomerate and clinker, destroying its capability of producing a well-mixed combustion zone.

Single and multiple-chamber combustors use essentially the same principles. The fuel is initially partially combusted under air starved conditions, producing combustible gasses. These gasses are burned in the same chamber in the case of the single-chamber system or ducted to a second chamber in the multiple-chamber system in which complete combustion occurs. A low initial air flow is used but this requires a large surface area in the initial gasification zone, resulting in the maximum shop-fabricated unit being able to use only twenty-five tons of fuel a day.

While multiple trains allow for good turndown ratio by removing single units from service, the economies of scale are limited.

SYSTEM SELECTION

The major types of gasification systems that can produce a low BTU gas that can be used to fire a boiler, producing a hot gas for process drying, or for electrical power generation were studied and the fluidized-bed gasification system was found to be the process most suitable. The gasification of rice hulls to produce a useable energy form promises increased operating flexibility, enviornmental advantages and reduced operating risks at a comparable or even lower life cycle cost than direct firing.

Fluidization describes the phenomena which occur in which a gas (air) is passed upward through a bed of granular material. This granular material can be the feed stock itself, i.e., residual char and ash, or an inert material such as sand. The bed material recommended as a result of this study is an aluminum oxide sand. Initially, air simply percolates through the bed, but as the velocity and volume of air increases, a point is reached at which the granular material is lifted and the entire mass takes on the boiling appearance of a fluid. Ultimately, as the velocity of air increases further, the sand is entrained in the air.

To begin gasification, the bed is preheated with natural gas prior to the commencement of fuel solids (rice hulls) feeding. Upon entering the reactor, a sufficient amount of hulls burn to bring the temperature of the hulls entering the reactor up to the bed temperature and to provide the energy of pyrolysis necessary to convert the remainder of the unburned hulls into the desired products (char, oil and low BTU gas). At this point, the reactor is self-sustaining and the start-up fuel supply is shut off. The velocity of the air through the bed causes a separation of the char/ash product so that the gas, solids and vapor phases all pass from the reactor into the cyclone bank.

Char is collected in the cyclone bank and the low BTU gas and oil vapor exiting the cyclones are ready for transmission to the boiler combustor.

The advantages of the fluidized-bed gasifier process over the other process options are further explained below:

1. To direct fire rice hulls efficiently, large amounts of excess air are required leading to localized hot spots or overheating at temperatures exceeding the slagging temperature of rice hulls. This condition will cause the formation of eutectics, which over time will destroy the furnace or heat exchanger zone. The lower excess air requirements of the gasification process reduce the size of the blower and, thereby, the capital and operating cost of the system.

2. By operating at a lower and constant temperature throughout the reaction zone, gasification will prolong the life of the reactor vessel and allow for continuous, trouble-free operation.

3. The gasification reaction can occur equally as well utilizing either ground or unground hulls, thereby allowing for significant savings in utility and maintenance costs of the grinding facilities. Direct combustion, however, requires ground hulls to operate most efficiently.

4. The use of fluidized bed gasification permits a smaller physical sized plant and thereby easier and cheaper installation.

5. The gasification option permits a variable mix and composition of energy products: gas, oil, and char can be produced in varying quantities and at desired physical and chemical properties to match the needs of the user. For instance, the char product produced through gasification reaction can be very well controlled as to carbon content - a predominant determinant of its market value. Whereas, in a combustion system, the char produced is essentially the same chemically and physically across operating conditions.

6. The fluidized bed gasification system can accept a broad range of feedstocks, different from rice hulls, without appreciably affecting the performance of the system.

7. There are no boiler tubes or constrictions in the gasification reactor which rice hulls can impinge upon or erode.

8. The gasification reaction can provide a clean gas for use in dryers, and/or gas engines at varying temperatures, thereby replacing other expensive and vital energy needs currently met through the purchase of natural gas or electricity from outside sources.

9. The fluidized bed gasification system provides for better load following with a quicker response time to changes in energy demand and unmanned, automatic control.

10. Existing gas or oil-fired boilers can be used by retrofitting the burners for low BTU gas.

11. Gasification systems commercially built to provide gas for steam production and/or drying can readily be retrofitted at much less expense and in a lot less time for the production of electrical power. Furthermore, such retrofitting can be performed in stages as power needs grow and change over time.

12. Particulate emissions from the gasification system are much more acceptable, i.e., lower than the comparitive direct fired system. This is especially important in a non-attainment area, where offsets may be difficult or expensive to obtain.

13. Trace metals existing in the feedstocks will stay in the ash or char product in the gasification reaction whereas they will vaporize in the combustion reaction, creating possible additional environmental and siting problems.

PILOT TESTING

The pilot plant tests were conducted at the ERCO Pilot Plant in Cambridge, Massachusetts. Ten tons of rice hulls were supplied by ARI which were a part of the actual material being generated in the rice processing.

The pilot plant testing results confirmed the technical advantages of the fluidized-bed gasification system. Excellent bed temperature control, no ash slagging problems, quick load response times, low emission levels, and the production of a transportable and combustible form of energy are among the process advantages confirmed in the testing.

Four test runs were completed for a range of gasifier temperatures from 1083° F to 1604° F. The optimum safe design reactor bed temperature was found to be approximately 1530° F. The gas produced at this temperature has a heating value of about 150 BTU/SCF, a fuel which can easily be combusted in a boiler, furnace or gas engine. The char product at 1530° F. has an ash value of approximately 85%, and the mass of char to be handled is minimized at this temperature.

Variations in char composition were obtained at different reactor bed temperatures with fixed carbon percentages ranging from 26.0% at 1083° F to 3.3% at 1604° F.

A complete Resources Conservation and Recovery Act (RCRA) analysis was run on the char which showed that the by-product is essentially inert and non-hazardous. Toxicological, ecological, organic and inorganic tests comfirmed the RCRA analysis.

PLANT DESIGN OPTIONS

The versatility of the fluidized-bed gasification provides a number of options in satisfying the energy requirements of ARI: steam for processing, hot air for drying and electrical power. For the purposes of the study, three options were selected as models and complete economic analyses were made of each. Subsequent to the completion of the study other options were considered and will be discussed in the Epilog.

The gasification process is common to all three options considered. Two fluidized-bed gasifiers, each being 55 square feet by 27 feet high vessels lined with a high temperature abrasion resistant refractory, receive the rice hulls at a rate of 340 tons a day and deliver 31,906 ACFM of low BTU pyrolysis gas to the system. Char is generated at the rate of 84 tons a day.

In Option 1 the combined low BTU gas and oil stream is split with a part being fed into a boiler in which it is fired to generate process steam. The remaining gaseous product is combusted in a furnace to produce hot air for use in the process drying operation.

In Option 2 part of the the combined gas and oil product is combusted in a boiler for process steam generation. The oil is removed from the balance of the gaseous product and the gas is used to fuel a gas turbine which, in turn, is used to power an electrical generator. The hot turbine exhaust gasses are available for process drying operations and the oil is returned to the gasifier.

Option 3 differs from Option 2 in that a gas engine replaces the gas turbine as the electrical generator power source. The electricity produced as an excess can be sold back to the local power company.

THE CHAR PRODUCT

A survey of potential users of rice hull char was undertaken. Potential users and markets have been identified and are being studied to determine interest and the liklihood of developing an economically viable market. At this time, most of the potential users contacted are still evaluating the char; however, there have been no formal commitments made by anyone to purchase the char or take the char until it is demonstrated that a constant composition product can be produced in reliable quantities.

It appears likely that there will be a market established for the char product. However, for the initial operating period of the plant, the planning will have to reflect the disposal of the char as a waste material until such time as certain marketing arrangements can be made.

ECONOMIC FEASIBILITY

In the study, the following areas were analyzed and reported in detail for the three options considered:

Capital Requirements and Operating Costs
Investment Analysis
Other Project - Related Costs/Benefits
Risk Analysis
Sensitivity Analysis

Option 3 was found to display the most positive economic results. Therefore, this report will focus on the analysis of that option.

BASIS FOR ANALYSIS

Number of Years in Project: 11
Debt Equity Ratio: .00/1.00
Insurance Rate: 2.0%
Investment Tax Credit: 18.0%
Tax Rate: 0.0%

Capital cost: $8,787,000
Operating Life: 10 Years
Tax Life: 10 Years
Construction Period: 1 Year (CY 1982)

Depreciation Method: Double Declining Balance to Straight Line
Plant Load Factor: 80%

RESULTS OF ECONOMIC ANALYSIS

Rate of Return on investment: 36.88
Rate of Return on Equity: 36.94
Payback Year: 1985

"Other Project-Related Costs/Benefits" refer to environmental, health, safety and socioeconomic considerations. These costs and benefits are of an intangible nature and would not be significantly different for any of the three options.

The main sources of "risk" inherent in the project can be categorized into five main groups:

1. Uncertainty of the Magnitude of Plant Investment. This could be caused by price changes in the equipment or by delays in construction.

2. Fuel Costs. This refers to the rice hulls and identifies two risks: one related to availability, the other to price changes. Fuel supply presents a relatively minor risk. Even though the cost (value) of rice hulls may escalate, it is unlikely that any of the present uses places a higher value than gasification does.

3. Operating Cost. The primary risk here is the maintenance cost which could be affected by the technology, i.e., it's failure to function to design load factors. A secondary risk could be lack of experience of the operations personnel.

4. Char Value. Char has the potential to influence the attractiveness of this project significantly. Risk is limited on the downside because of the rather conservative scenario adopted for this cost and, it could conceivably become a valuable product as markets are developed.

5. Energy Products (Steam, Hot Air and Electric Power). Any hikes in natural gas and electricity costs beyond the expected annual inflation rate of 15 percent will improve the economics of the project, whereas lower increases will diminish it.

The risks outlined are considered normal for new, alternative energy technologies. These risks are stressed because fluidized-bed energy systems are relatively capital-intensive and a substantial financial commitment is required. A payback period of four to five years leaves the invested capital to the caprices of an uncertain future for rather a long time.

The "sensitivity analysis" examined how changes in the input variables (risks) can influence the return on investment. The following table summarizes the sensitivity analysis. In each case the degree of sensitivity refers to the impact caused by the parameter while the degree of uncertainty refers to the probability of change actually occurring.

SENSITIVITY ANALYSIS SUMMARY

PARAMETER	DEGREE OF SENSITIVITY	DEGREE OF UNCERTAINTY
Capital Cost	High	Low
Rice Hull Cost	Moderate	Low
Maintenance Cost	Low	Moderate
Char Value	Low	High
Power Value	Moderate	High
Power Yield	High	Low
Energy Inflation	High	Moderate

At face value, the expected return on investment of 36.9% appears to be a fair return. However, the project is attractive to ARI only if the risk-adjusted rate of return is higher than that which could be earned by investing the capital in alternative opportunities. From the sensitivity analysis it can be elicited that under a bad case scenario, the rate could drop to as low as 10%. Even though this case is unlikely to occur, it illustrates that there is a substantial downside to this project. From a purely economic perspective ARI should make the investment only if (a) the return is higher than the corporation's cost of capital, and (b) there are no projects with higher risk-adjusted rates of return.

EPILOG

Following the completion of the study, ARI assessed its priorities and came to some new conclusions. A closer look at the Public Utility Regulatory Policies Act (PURPA) indicated that the best return on investment can be gained by converting as much energy as possible to electrical power. Concern was felt about the efficiency of available scrubbers in cleaning the low BTU gasses sufficiently for use in eigher a gas turbine or gas engine. ARI was also concerned about the char disposal problem; both the time required to establish markets and the large volume of product to be handled.

Economic analyses were completed on two new options. One included a scaled down system using only 100 tons per day of rice hull fuel to produce only the 30,000 pounds per hour steam required at the processing plant. The second system would use 300 tons a day of rice hulls to produce steam. The required 30,000 pounds per hour would be extracted for processing and the balance would be used in a steam turbine which would drive a gernerator to produce electricity. An excess of 3.5 megawatts would be available for sale to the local power company.

Finally, these two options were combined and the project structured into two phases with the understanding that while the objective was the full scale plant, construction of Phase I would allow for proving the technology and developing the char market at a reduced capital outlay.

The economics of Phase I show a before tax return on investment of 36.6% based on a capital outlay of $3,200,000, annual operating costs of $400,000 and a net zero value of the char.

To add the equipment necessary to complete Phase II, an additional $7,000,000 capital outlay is required, plus an additional operating cost of $231,000. Again using a zero char value, the before tax return on investment is projected to be 37.7%.

As was the case with the original study, the projected rates of return must be risk-adjusted to establish the true economic feasibility of the project. This study is now in progress.

TABLE OF CONTENTS

p

The estimated total installed cost of the proposed plant is $8,787,000. The estimated return on investment is 36.8 percent. However, due to the relatively high financial risks associated with alternative fuel production plants it is recommended that price guarantees for the char byproduct and loan guarantees be made available. With such assistance the commercial realization of the alternative energy plant is highly likely.

SECTION TWO

INTRODUCTION

2.1 Background

American Rice, Inc. (ARI) is an agricultural processing and marketing cooperative owned by and serving 1800 farm families located in the rice-producing areas of Louisiana and Texas. The ARI processing facility is conveniently located in the city of Houston, Texas and has an annual sales of $200 million.

Joining ARI as a subcontractor in this study is Energy Resources Co. Inc., (ERCO), a leader in fluidized-bed gasification technology. ERCO has the combined in-house capabilities including a pilot plant test facility, process/design engineering staff and analytical services laboratories, and will be providing technical assistance to ARI. ERCO has extensive experience in the development, design and construction of alternative fuel production facilities.

The work to be conducted in this study was described in the Technical Proposal submitted by ARI on April 25, 1980. The study followed the tasks described in this proposal and is reported in a similar task type fashion. Some of the proposed tasks resulted in more extensive study and analysis beyond the original scope of the proposal was conducted, whereas other tasks were found to be less important and given less emphasis as the project team felt warranted. In all cases the study was conducted within the overall goals and objectives proposed in the Technical Proposal.

2.2 The Feasibility Study Objectives

The purpose of this study is to evaluate the technical, economic and environmental feasibility of the construction of an alternative fuel production facility at the ARI plant. Included in this study the questions concerning the marketing of all byproducts generated by the facility were addressed.

To complete these objectives pilot plant testing was conducted to assist in the technical evaluation of the process options available. Various operating variables were studied and the results of the pilot plant testing used in developing more specific engineering design information where required. The byproducts generated during testing were used to assist in conducting the marketing survey.

Using the information developed above, process designs were developed for the options having the greatest feasibility. Based on these design concepts, equipment lists and specifications were generated and capital and operating costs for the processes developed.

The capital and operating costs were combined with the results of the marketing studies and used to determine the overall system economics and financial viability of the processes.

Marketing questions concerning the handling, transport and sale of the char product were investigated. Potential markets were explored by screening potential users and sending samples of the char byproduct to the interested parties.

The purpose of the environmental portion of the study was to assess the potential environmental impacts of the proposed processes and to identify all of the environmental regulatory and permit requirements. In doing so any constraints to the plant's design and operation were taken into account.

The results of the feasibility study will be reviewed by the management of ARI. The commercial viability of the proposed plant will then be determined. A favorable evaluation would allow full-scale design and construction to begin.

2.3 Rice and the Milling Process

Rice has long been one of the major foods of the world. In recent years, with improving technologies and processes, the milling and treating of rice has grown both in sophistication and scale. Today's milling process requires more energy than in the past. Together with the increasing cost and the decreasing availability of energy to industrial users, today's rice processor must be more efficient and constantly seek ways to save energy, not only to become more competitive, but in order to survive.

Figure 2.3-1 outlines a modern rice processing plant with parboil facilities. Parboiling is a process which advantageously affects the physical properties of the rice grain.

The demand for parboiled rice is growing rapidly and mills are expanding their parboil capacity. However, parboiling necessitates a much greater energy usage for cookers, steepers, and driers. Therefore, rice processors find themselves becoming larger energy users at a time when industry finds political and economic pressures to decrease their use of our nation's energy.

ARI produces two primary products: regular white milled rice and parboiled rice. Byproducts of the milling process include rice hulls, bran, broken kernels, and brewer's rice.

WHITE RICE - Rough rice, also called paddy, is cleaned through a series of machines to remove straw, dust, foreign seeds and other impurities. Next, the hulls are removed and separated from the kernels. The resulting product, brown rice, consists of the rice kernel, the germ and a coating of rice bran. The bran and germ are removed, leaving only white milled rice.

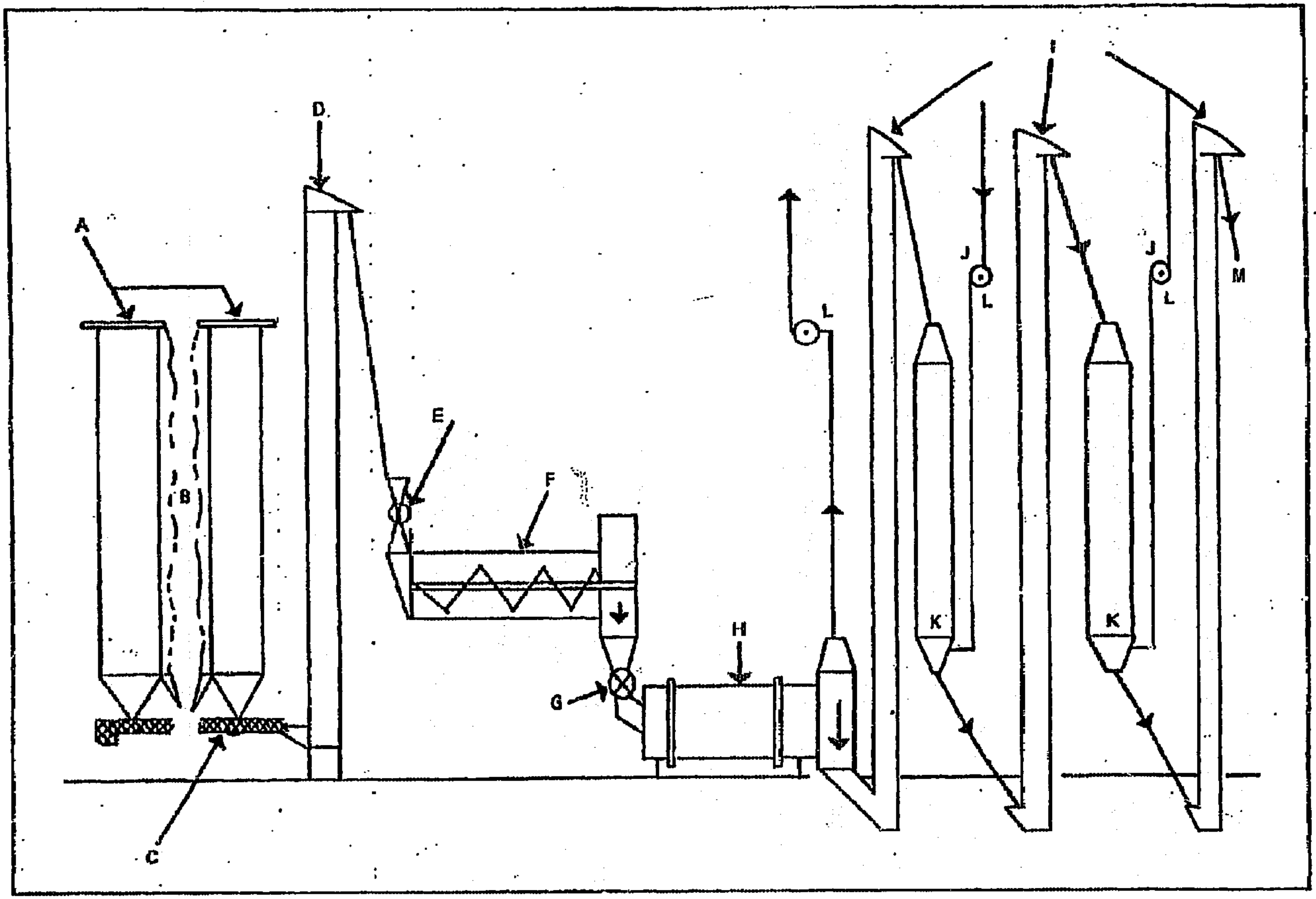

Figure 2.3-1 Modern Parboiling Plant

A. Raw Paddy. B. Soaking Tanks. C. Horizontal Conveyor. D. Raw Paddy Elevator. E. Inlet Rotating Valve. F. Continuous Steamer. G. Outlet Rotating Valve. H. Rotating Drier. I. Processed Paddy Elevators. J. Blower. K. Dryers. L. Air Heater. M. Processed Paddy.

During the transition from harvest to milled rice, some of the kernels are broken. Since the primary market is for whole kernel rice, the "brokens" and the brewers' rice (tiny chits of broken rice) are separated and stored for future use as described below.

PARBOILED RICE - The cleaning and milling of parboiled rice are similar to the white milling process with the following exception:

Following cleaning, paddy rice is soaked in hot water, drained and exposed to steam to completely gelatinize the starch. The rice is then dried in rotary dryers and milled in the conventional manner. Refer to Figure 2.3-1.

To summarize, the key advantages of parboiled rice are:

1. The elevated cooking temperatures destroy insects and eggs in the grain, creating a relatively sterile product.
2. Moisture content is controlled, making the grain less susceptible to relative humidity changes during storage.
3. The kernel is harder, creating a resistance to penetration of insects into the kernels.
4. Fewer grains are broken during milling.
5. Cooking quality is more uniform, fewer solids are lost into the water, and the cooked rice is not so sticky and gelatinous.

Parboiling before milling also allows some of the vitamins and minerals from the bran and hull to permeate the kernel, thus enhancing the nutritional value of the finished product.

SECTION ONE

SUMMARY

This study examines the feasibility of constructing an alternative fuel production facility using a rice hull fuel currently being generated at the American Rice, Inc. (ARI) processing facility in Houston, Texas. The demands for energy at the existing plant closely matched the potential energy outputs which could be produced from the quantities of alternate fuel available.

It was found that fluidized bed gasification of the rice hulls which produces a low Btu gaseous fuel and a char byproduct has the greatest potential for meeting the energy demands of ARI. The char byproduct produced is potentially a marketable item, although no market has been developed to date. The low Btu gaseous fuel will be used to produce various forms of useable energy.

The proposed plant, to be located within the existing ARI facility, would consume 340 tons per day of rice hulls, the projected average daily output of the existing facility. It would produce 5.17 MW of electric power; 30,000 lb/hr of process steam and 89 ton/day of char. This output will completely fulfill ARI's steam and electricity demands with an additional 1.9 MW/hr of electricity available for sale to the local power company. The proposed plant will comform to all local, state and federal environmental, health and safety standards applicable for this type of plant at the proposed location.

p

BY-PRODUCTS - Rice bran is high in protein, fat and crude fiber and is commonly used as a supplement in livestock feeds. Cooking oil can be extracted from rice bran but this is not done at ARI. Currently, only one mill in the U.S. has oil extraction capability.

Broken kernels are generally remixed with whole kernels to meet market quality criteria.

Brewers' rice is generally sold to breweries where it is used as a component in making beer.

Rice hulls represent twenty percent of the weight of paddy rice. Use or disposal of this low-value byproduct has frequently proved difficult because of the tough, woody, abrasive nature of the hulls, their low nutritive properties, resistance to weathering, great bulk, and high ash content.

At one time most of the hulls were used as fuel in the steam plants which provided mechanical power for rice mills, but cost factors, cleanliness, lack of technology to meet regulatory compliance and ready availability of natural gas and electricity have led to the discontinuation of this practice. Concurrently, a small percentage of rice hulls is used in the production of furfural. Some hulls are pulverized and sold as stock feed filler and lesser amounts are used for poultry litter and livestock bedding. During lulls in the market for hulls, they are often dumped in sanitary landfills.