SECTION THREE

DELIVERABLES REQUIRED BY DOE

3.1 Preliminary Facility Design

3.1.1 Assessment of Technological State of All Processes Being Considered

Task A & B - Identify, Characterize Needs and Available Technologies

Currently, in the Parboil Process ARI uses approximately 35,000 MCF natural gas per month to produce process steam and to dry processed rice. Electrical power is required throughout the plant in the milling operations, as well as in the white rice and parboil processes. The energy demands of the existing facility are as follows:

1. Process steam - 30,000 lbs/hr at 100 psi.
2. Hot Air - 32 MMBtu/hr at 300° to 700° F.
3. Electric Power - 3264 KW

The process steam will be used in the parboiling operation and no condensate returned. The hot air will be used in a number of direct contact rotary dryers. The existing boilers and dryers are presently designed for natural gas firing only. The electric power is used throughout the plant for the operation of processing equipment. No plans for future expansion or increased energy demands are being considered.

ARI currently faces both Federal and State pressure to curtail their use of natural gas like other industries, and even if gas is available for industry use, the cost to ARI may be prohibitive. The need to find an alternative energy source is paramount.

The most economical and obvious potential source of future energy for ARI lies with rice hulls – a byproduct of current ARI milling operations. Rice hulls constitute about 20 percent of the weight of rough rice that is processed and therefore represent a significant amount of material. ARI regularly generates 340 tons per day of rice hulls which corresponds to a heating value of 151 MMBtu/hr. The efficient use of the heating value of this byproduct can result in ARI becoming a self-sufficient energy user.

The value of this byproduct is cyclical at best. At times a market can be found and some value recovered, but often rice processors are faced with a difficult waste disposal problem in getting rid of the rice hulls. The solution is usually landfill or direct burning – solutions that are becoming environmentally unacceptable. Table 3.1.1-1 outlines the potential uses of rice hulls and what the future might hold for each.

The exhibit outlines so many uses for rice hulls that it seems disposal would not be a problem. In most instances, technology is not the governing factor; rather, it is a combination of economics, social and political considerations, and marketing information and techniques which govern the potential for each.

For instance, where urban settlements grow in close proximity to rice mills, the pollution caused by open burning of hulls becomes socially unacceptable, and political and legal restrictions prevent continuation of the original process of disposal. Economics of suitable pollution-free burning may be too costly, as is the transport of the bulky hulls to remote locations. Thus a new process with new technology may become necessary.[2]

---

[2] Houston, ed., <u>RICE: Chemistry and Technology</u>, p. 339.

TABLE 3.1.1-1

RICE HULL USES

POTENTIAL USE OF RICE HULLS	OUTLOOK
As feedstock to produce furfural.	Size of this market is small as substitutes are available.
Mixed with bran and sold as feedstock for livestock.	Mixing of hulls with bran is done to "get rid" of hulls - hulls lower the nutritive and commercial value of feed - therefore, a more desirable use of hulls is justified.
As an adjunct to prevent caking in fertilizers.	Fertilizer value is small.
As a polishing abrasive.	Some applications represent potential markets, substitutes available, and transportation, storage costs limiting.
As landfill.	Environmentally unacceptable. Regulations currently being promulgated.
As loose insulation material.	Applications are limited and substitutes available. Would need to be treated to meet building code requirements.
Fuel - direct burning	Environmentally unacceptable.
Fuel - Pyrolysis (gasification).	Realistic approach to utilize "waste product" to generate a gaseous fuel in an environmentally acceptable manner.

In the not-too-distant future, rice processors will be faced with the problems of where to get their energy and how to get rid of their rice hulls. Processors, to just dispose of the hulls, will be forced to find or create a market for their waste product. However, their increasing energy demand has created for them a potential market singly efficient, economical and advantageous - themselves - a chance to meet their energy needs with their own waste products.

The project team has concluded that the most feasible use of the rice hull byproduct is as a fuel for the reasons described above and summarized in Table 3.1.1-1.

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, fluidized-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. These various technologies are discussed in detail in Task C.

Task C - Develop Preliminary Technical, Economic Screen

The process team has performed a comprehensive review on the available energy technologies and has concluded that fluidized-bed gasification combined with the appropriate boiler, furnace or electric power generation cycle and the associated emissions controls strategies offers the most capable, efficient and demonstrated system.

The use of the fluidized-bed gasification process produces a low Btu fuel which offers a wide variety of energy production schemes. The fuel can be used directly in a conventional boiler for steam generation, combusted in a furnace to produce hot air for process drying, and can be used as a fuel in an electrical power generation cycle in which the waste heat can be captured for use in process drying. The versatility helps to make the use of a fluidized-bed gasification process the optimum process for the conversion of the rice hull fuel from both technical and economic standpoints. A technical and economic comparison of the processing options is discussed below.

Direct Combustion

The direct combustion of agricultural residues can be divided into four processing categories:

- suspension burners
- fluidized-bed combustors
- multiple-chamber combustors
- single-chamber combustors

The direct combustion systems are in general inexpensive systems compared to the gasification systems, although they present serious technical difficulties in the combustion of rice hulls. The difficulties common to all four types of direct combustors are summarized below.

Direct combustion systems typically operate at temperatures above the high silica ash fusion point resulting in the agglomeration or slagging of the ash. Due to the high ash content of the rice hulls, 22%, this slagging can result in serious operational difficulties in trying to remove the agglomerated ash from the combustion chamber. The combustion temperature can be kept below the ash fusion temperature of 1700°F using large amounts of excess air and resulting in larger more expensive combustion chambers and boilers. In addition, high pressure steam cannot be generated which could be used for the production of electricity in a steam turbine. Erosion of the walls of the combustor and boiler at accelerated rates will also be 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 system include unacceptably high particulate content in the flue gas, and other associated fugitive emmissions problems associated with the ash handling Other specific advantages and disadvantages of the direct combustion systems are described below.

Suspension burners can either be operated with an independent fire box separate from a boiler or retrofitted directly onto a boiler fire box. Suspension burners are similar to pulverized coal boilers in that they require relatively fine particles which are mixed with air and burn in suspension. Suspension burners are relatively inexpensive but require a dry, finely divided fuel. In order to make the rice hull fuel acceptable to these burners the hulls will have to be ground, thus adding an additional processing step and expense to the preparation of the feedstock. Although this burner could be fitted directly to a boiler for steam generation, for the reasons sited in the preceeding paragraph this was not found to be the technologically best suited for the conversion of rice hulls.

In fluidized-bed combustion, sand or another material is used to provide a heat reservoir and a well-mixed zone for combustion. Some form of feed preparation is required in order to produce a feed particle size that is compatible with fluidization, or else feed material will not be evenly distributed. Ash from combustion can be removed directly from the bed or from the gas stream once it has left the bed. The most serious constraint of fluidized-bed combustion is the large excess air requirement. Because of ash-softening temperatures in the range of 1700°F for some agricultural residues, enough excess air must be added to keep the combustion zone temperature below the ash-softening point. If the bed temperature is allowed to rise above the ash-softening point the bed will agglomerate and clinker, destroying its capability of producing a well-mixed combustion zone. The amount of excess air required will increase the mass flow to the boiler and drop the gas temperature that the boiler "sees," derating the boiler.

Single and multiple-chamber combustion use essentially identical principles. The fuel is initially partially combusted under starved-air conditions, producing a combustible gas. In a single-chamber combustor, this gas is burned above the grate or pile with over-fire air. In a multiple-chamber combustor the combustible gas is ducted to a second chamber in which complete combustion occurs. The purpose of the second chamber is to separate the gasifying and main combustion functions in order to minimize ash carryover and allow good control of combustion temperatures. These types of combustors can operate at temperatures below the ash-softening or fusion points of agricultural residues, but this is achieved by using a low initial air flow per unit of feed. Therefore, a large surface area is required in the initial combustion or gasification zone. This low air-to-fuel ratio limits the maximum size of the unit that can be shop-fabricated to about 25 tons per day of feed. Therefore, a large installation will require several units each with their own feeding systems, ash removal system, and particulate control. While multiple trains allow for good turndown ratio by removing single units from service, the economies of scale are limited.

Gasification Processes

Steam can be produced by direct firing of low Btu gas in a conventional water wall boiler. A low Btu burner can be fitted to the boiler which will sustain continuous combustion without the aid of a natural gas pilot.

The major types of gasification systems that can produce a low Btu gas that can be used firing a boiler, producing a hot gas for process drying, or using for electrical power generation are:

- o moving bed, gravity
- o moving bed, mechanical agitation
- o grate, traveling grate, or multihearth
- o fluidized-suspension bed, feed materials as carrier
- o fluidized bed, inert carrier

The type of gasification reactor will affect feed moisture content, feedstock variety, ash removal, particle size of feed, and turndown ratio and response. Each of the gasifier types will be discussed below in light of system requirements.

A simple moving-bed gasifier utilizes gravity to move the material through the reactor system. Feed material to be gasified is introduced at the top of the reactor. Air is blown through the reactor. Typically, a combustion zone exists near the bottom of the bed. The heat release in the combustion zone is carried upward toward the incoming feed, devolatilizing and gasifying it. The gasification products are carried off by the inert components of the air stream, the oxygen having been consumed in the combustion zone. The ungasified portion of the feed falls into the combustion zone where it is burned to provide the heat for the gasification reactions. The resulting ash is usually removed through the bottom of the bed.

In general, moving-bed gasifiers are limited to dry feedstocks; surface moisture in the feed may cause plugging or bridging of the reactor. Feedstocks such as straws, which tend to clump and bridge without constant agitation, are also difficult feedstocks for moving-bed gasifiers to handle. Since the gas must be produced at sufficient back pressure for use in the existing boilers, introduction of feedstock into the moving bed must be accomplished through a pressure seal in order to avoid leakage of noxious gas and particulates. In order to effectively utilize the entire reactor volume, care must then be taken to ensure that the feed is evenly distributed over the entire bed cross section; this may become difficult depending on the size and arrangement of the feed ports in a large-scale reactor.

Since low air velocities are used in a moving-bed reactor, particle carryover from the bed is usually not significant, and indeed may meet regulatory restriction on particulates downstream of the boiler. A mechanical particulate collector upstream of the boiler and/or a filtering device downstream of the boiler can provide adequate particulate removal, if necessary. However, particulate loading in the raw gas is unacceptably high if the gas is to be used in a gas turbine.

Perhaps the most serious drawback of a moving-bed gasifier is the unit's slow response time to demand. While a moving-bed system can achieve a 6:1 turndown ratio if enough parallel units are provided, the response of an individual unit to changes in demand is a function of the reactor volume. A large quantity of feedstock is in the moving-bed reactor at any time. Without changing gas composition, i.e., changing the air-to-fuel ratio in the reactor, there will be a lag time in the response of the reactor to demand change for gas that is proportional to the ratio of the mass feed rate divided by the mass of feed residing in the reactor.

For large units the response of the reactor may become increasingly poor as the reactor is turned down, since the amount of feed being introduced to the reactor is much less than the quantity of feed contained in the reactor.

The same restriction and drawbacks that apply to the moving-bed gasifier also apply to any moving-bed gasification system in which the flow of materials is enhanced by mechanical devices such as the vibrating grate or screw. The use of mechanical agitation of the reactor space may allow introduction of feedstocks that would not be permissible in a gravity-flow moving bed because of solids handling problems. However, the use of mechanical agitation does not significantly improve the moisture limitations or increase the types of feedstocks which may be processed.

Since mechanical, moving parts are being exposed to high temperatures in reducing conditions in the bed with this type of reactor, the expected lifetime of the agitating components may be quite short. This is probably not due to the materials of construction used, since nickel alloys are probably adequate for the type of service involved, but rather the problem will occur in the shaft seals because of the introduction of abrasive particulates at high temperature.

Gasification systems that utilize a grate fall into two different categories:

- starved-air combustion on a fixed or traveling grate; and
- grate and rabble arm combinations for moving material, such as a multihearth.

Starved-air combustion is very similar to complete combustion in a stoker-fired furnace. The major difference is that the amount of air is controlled so that only a small portion of the feed material is consumed by combustion. This releases enough heat to allow the gasification of the remainder of the feed. The combined combustion/gasification can occur at one or multiple zones.

A multihearth gasifier uses a series of stacked grates which are swept by mechanical arms. Air is introduced at the bottom of the unit and gas flows upward; feedstock is introduced at the top. The operation of the unit is very similar to a moving-bed gasifier except that a solid mass of feed material does not exist in the reactor. Instead, the reactor consists of a series of trays. The feedstock is introduced at the top, is heated to the point at which it starts to devolatilize and gasify, and the ungasified portion of the feedstock is combusted in the bottom zones.

Since mechanical agitation is used to move the feedstock, most moisture contents are acceptable. However, feed material which is below a minimum size will fall through the grating; therefore, only pelletized or large pieces of feed material can be porcessed successfully. Fines will rapidly fall through the system and not be completely gasified.

Power consumption of a grate-type gasifier may be significant. The rabble arms of a multihearth require a substantial amount of power, mainly due to the size and weight of the arms themselves. The pelletizing operation that would be required for gasifying agricultural residues on a grate may be considerable, especially if the material needs to be dried before pelletizing. This will depend greatly on the residue being processed.

While reliability of a pelletizing operation and gasification on a horizontal grate arrangement is probably quite good, multihearth furnaces and gasifiers are notorious for mechanical problems due to the exposure of the rabble arms to high temperatures. Neither system will be compact. Multihearth furnaces are relatively large compared to other gasification systems. While a traveling grate gasifier would be relatively compact, space will be required for the pelletizing (and perhaps drying) operation, as well as storage capacity for the pelletized feed.

The final category of gasification reactions is the fluidized bed. Fluidization describes the phenomena which occur in which a gas is passed upward through a bed of granular material. Initially, air simply percolates through the bed, but as the air velocity and volume increase, 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 velocity of the air increases further, the solid material is entrained in the air. Fluidized-bed gasification units can be divided into two distinct categories, depending on the granular material used. Granular material used for the bed can be composed of the feedstock itself, i.e., residual char and ash, or an inert material such as a sand may be used. The fluidized-bed gasification system recommended herein uses sand as the fluidizing medium. The use of sand has the following advantages over a fluidized bed in which the feed is merely suspended in fluidization, or in which feedstock ash is used as the fluidizing medium:

- higher fluidization velocities and throughputs can be utilized;
- larger feed particles can be fluidized;
- fine-particulate emissions from the bed are much less of a problem, since they are not allowed to form to an appreciable extent; and

- changeover or mixtures of feedstocks can be more readily handled without having to worry about changes in bed composition.

The advantages of fluidized-bed gasification over combustion and fixed-bed gasification are outlined below:

Gasification over Combustion

- Environmental
  - Particulates more controllable
  - Trace metals remain in ash/char
- Operational
  - Bed temperature below slagging temperature
  - Better load following characteristics
  - Produces transportable and storable energy
  - Power generation possible at reduced cost
  - Can utilize existing gas or oil boilers
  - Lower excess air requirements

Fluidized-Bed Gasification over Fixed-bed Gasification

- Accepts higher and more variable moisture in feedstocks
- Better load following
- For a given size:
  - smaller physical space required
  - larger throughput
- More precise control of:
  - energy output
  - operating conditions
- No moving parts in reactor
- More even feed distribution
- Wider range of feedstock acceptability

Task D - Select Process Most Suitable

For the reasons presented in Task C, fluidized-bed gasification (FBG) was found to be the process most suitable for this application. The gasification or pyrolysis of rice hulls to produce a useable energy form to replace the current use of natural gas or oil promises increased operating flexibility, environmental advantages, and reduced operating risks at a comparable or even lower life cycle cost than direct firing. The advantages of the FBG process over the other process options discussed in Task C 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. Localized hot spots exceeding the slagging temperature of the rice hull feedstock 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, troublefree 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 the 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 <u>clean</u> 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 particularly 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 thereby creating possible additional environmental and siting problems.

14. Under existing synthetic or alternative fuel programs, more financial assistance in the form of loan guarantees, purchase agreements or price guarantees will be available for gasification systems. This will provide two direct advantages for the gasification system. The project economics will be enhanced and secondly, and even more important, it will provide for the sharing of some technological and operating uncertainties of the gasification system.

The selection of the processes downstream from the gasifier will be largely an evaluation based on the ARI plant energy demand profile and economic considerations.

The steam requirements can be met by combusting the low Btu gas in a conventional type of boiler. Since the existing boilers currently in use are old and their expected useful life is short, retrofitting these units for low Btu gas combustion is not recommended. A new low Btu gas direct fired boiler is the most economical and efficient process for steam generation.

The hot gas required for process drying must be clean and transmit no odor or color to the rice being dried. The process currently in use is direct drying in which natural gas is fired directly into the dryer and the hot products of combustion come in direct contact with the rice. Due to the particulate loading of the low Btu gas stream it was felt that this would not be a good fuel for firing directly in the dryers. Pilot plant studies were conducted to determine if this direct firing was actually a problem, and the results will be discussed in Task F of this section. If the low Btu gas cannot be fired directly it is feasible to combust the fuel in a furnace and use a heat exchanger section to heat up ambient air to the required dryer temperatures. It is also possible to use hot exhausts from other processes, i.e. gas engines, for process drying.

Electric power can be generated using the low Btu gas as a fuel. The two most common generation cycles are gas engines and gas turbines. The gas engine produces greater amounts of electric power with less waste heat available per Btu input. Gas turbines produce less electric power per Btu input with more heat available in the exhaust stream.

The gas engine and gas turbine electric power generation processes were evaluated on an economic and technical basis as they would be applied to meet the ARI energy demands. Flow diagrams and capital and operating costs were developed for both processes and used in the economic evaluation. The results will be discussed in later sections.

Task E - Confirm Technical Performance in Lab or Pilot Plant Tests

The objectives of the pilot plant testing were as follows:

1. Confirm the technical feasibility and advantages of fluidized bed gasification of rice hulls.
2. Study the effects of variations in operating conditions on product yields and quality.
3. Generate char under various operating conditions for use in the marketing study.
4. Test the feasibility of using hot flue gases directly in the rotary drying of whole rice.
5. Confirm the environmental feasibility of the process.
6. Generate all necessary data for a complete plant design.

The pilot plant tests were conducted at the ERCO Pilot Plant in Cambridge, Massachusetts. The unground rice hull feedstock used in the testing was supplied by ARI and was a part of the actual material being generated in the rice processing. Approximately seven tons of the rice hull feedstock was used in the first round of pilot plant testing conducted in December 1980, to generate char and generate plant design data. Another three tons of material was used in March 1981 to gather additional environmental data and run direct drying studies.

The equipment arrangement remained unchanged throughout the American Rice tests conducted to date. As shown in Figure 3.1.1-1, a positive displacement blower supplied fluidizing air to the plenum of the reactor through a startup burner which is used only to preheat the bed before commencement of solids feeding. The burner is fired by methane which has been boosted in pressure over that available from the utility. After startup, the fluidizing air continues to flow through the burner assembly at a zero firing rate. The bed material within the reactor is an aluminum oxide refractory sand having a particle size chosen to allow well-defined fluidization. The fluidizing air passes from the plenum through the fluidizing grid, or distributor, into the bed to react with the fuel solids which have been introduced into the bed via the solids feed system. The reactant and product gases cause fluidization of the bed, and the resulting excellent thermal and chemical homogeneities.

The feed system begins with a one cubic yard feed hopper which empties through an adjustable screw feeder onto an inclined conveyor belt. The solids feed rate is manually controlled by this varispeed screw feeder. The conveyor lifts the solids to a chute through which the solids fall, entering a rotary valve which prevents back leakage of the pyrolysis gases from the reactor. An exhaust hood was installed over this feed station to prevent fugitive emissions from escaping into the plant. After the solids pass through the rotary valve, they enter a screw conveyor, or screw feeder, which introduces the solids into the lower extremeties of the reactor's fluidized bed.

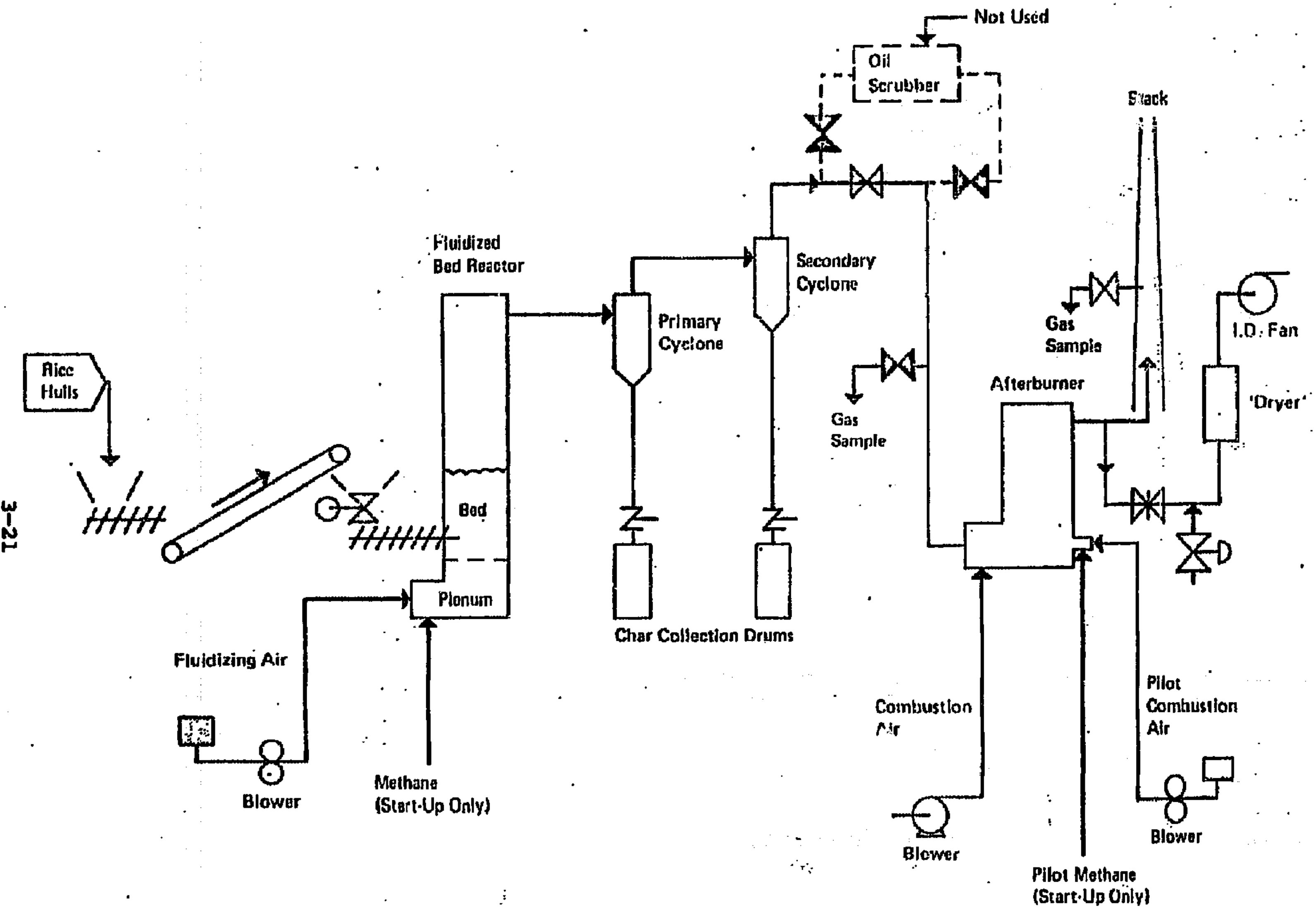


Figure 3.1.1-1: Pilot Plant FBG Flow Diagram

Upon entering the 20-in. diameter reactor, sufficient amounts of solids burn, or oxidize to bring the temperature of the components entering the reactor up to the bed temperature and to provide the energy of pyrolysis necessary to convert the remainder of the unburned solids into the desirable products of pyrolysis (char, oil, and low-Btu gas). The velocity of the gas through the bed causes an elutriation of the char/ash product so that the gas, solids, and vapor phases all pass from the reactor into the cyclone bank.

The cyclone system consists of a primary, low efficiency cyclone in series with a secondary, high efficiency cyclone, and has the purpose of separating the char/ash product from the gas-vapor stream. The solids exit the cyclone diplegs, passing into the char collection drums where they are removed from the process in batch and stored.

The gas-vapor exiting the cyclones are ducted to a mixing section where combustion air is added to the low-Btu fuel gas by means of a centrifugal blower. The mixture then enters an afterburner vessel where combustion takes place. The products of combustion exit the afterburner, which is itself an adiabatic device, and are immediately sprayed with a water injection nozzle to reduce their temperature to a value which can be tolerated by the stack. Finally, the cooled products of combustion exit the building through a carbon steel stack.

A small slip stream of the afterburner flue gases are drawn off and cooled to approximately 600° with ambient air for use in a direct contact dryer. The dryer was designed and made by ARI to simulate the actual drying operations in their plant. Small batches of wet rice are loaded into the dryer and the hot gases are passed from the rotating drum directly contacting the wet rice.

Task F - Analyzed Test Results/Needs

The pilot plant testing results confirmed the technical advantages of the fluidized-bed gasification system discussed in Section 3.1. 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. In addition, the feedstock was easily transported using conventional hardware, and the gaseous products displayed excellent combustion characteristics.

Four test runs were completed for a range of gasifier temperatures from 1083°F to 1604°F. During these runs, the necessary operational variables were recorded to generate heat and material balances and other necessary process design data. The char produced under each condition was saved for use in the marketing study. A summary of the operating conditions is given in Table 3.1.1-2.

The raw data collected was reduced to a common, coherent form that allows correlation of variables and observation of relationships. Mass and energy balances were then developed using the first and second laws of thermodynamics, which state that in any given process, mass and energy are conserved.

The closure of mass balances for the pilot plant tests averaged better than 95 percent which is well within the limits of experimental error and indicates good data measurement. The small discrepancies are attributed to inaccuracies in bulk mass measurements, and mass flows of the gas, oil and water vapor which are most difficult to measure. Elemental

TABLE 3.1.1-2

ERCO PILOT PLANT OPERATING CONDITIONS

RUN DATE	STEADY DURATION (HRS)	BED TEMPERATURE (°F)	FEED RATE (1) (LBS/HR)	CHAR PRODUCTION (LBS/HR)	CHAR ASH (%)
12/8/80	2.7	1083°	865.9	284.2	67.4
12/11/80	3.5	1260°	703.3	191.6	71.6
12/4/80	2.8	1431°	488.7	135.8	78.0
12/12/80	4.0	1604°	435.7	99.5	93.4

(1)Unground rice hull feed is 22.1 percent ash, 9.4 percent ash and 7809 Btu per pound on a dry ash-free basis.

mass balances were performed in order to look for any trends which may have consistently caused any errors in the mass flows, but none were found. This analysis confirms that the errors were random experimental errors. The mass flows were then adjusted to fully close the mass balances. This manipulation is necessary to allow for a consistent analysis of the energy balances.

Energy balances were developed from the experimental measurements and applying the principle of conservation of energy. The latent and sensible heats and the heat of combustion of the inputs and products of the gasifier, plus the system heat losses, were cataloged for data run. The closure of the energy balances averaged better than 90 percent, again within the limits of experimental error. The heat balances were then closed by normalizing the latent heat values of the products, which were determined experimentally and are the most likely source of experimental error. Refer to Section 3.1.2 for a typical mass and energy balance developed by these procedures.

The product mass and energy yields were plotted as a function of reactor temperature, and are discussed below. Using these trends, it will become possible to predict product heat and energy splits at a given temperature, and will allow us to determine the optimum design reactor temperature for the proposed plant.

The mass and energy yields of the char product, given in Figures 3.1.1-2, 3 & 4 show sharply decreasing yields with increasing bed temperatures. By plotting the ash-free char yield (Figure 3.1.1-3) it becomes apparent that at the higher

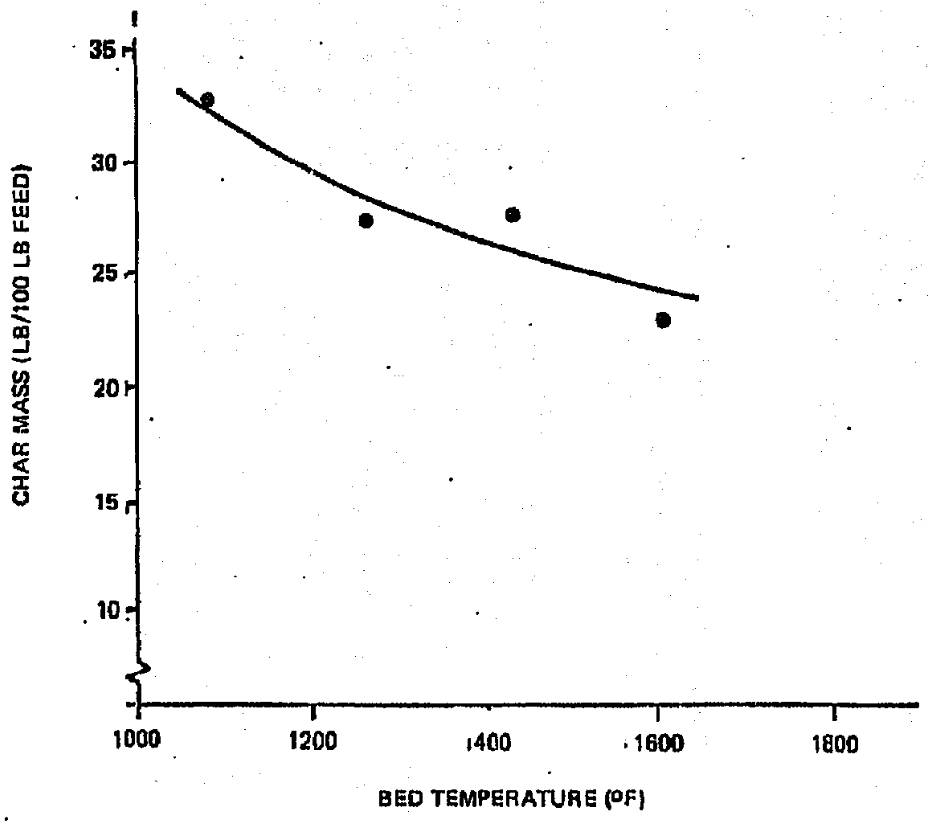


Figure 3.1.1-2 Char Mass Yield vs. Temperature.

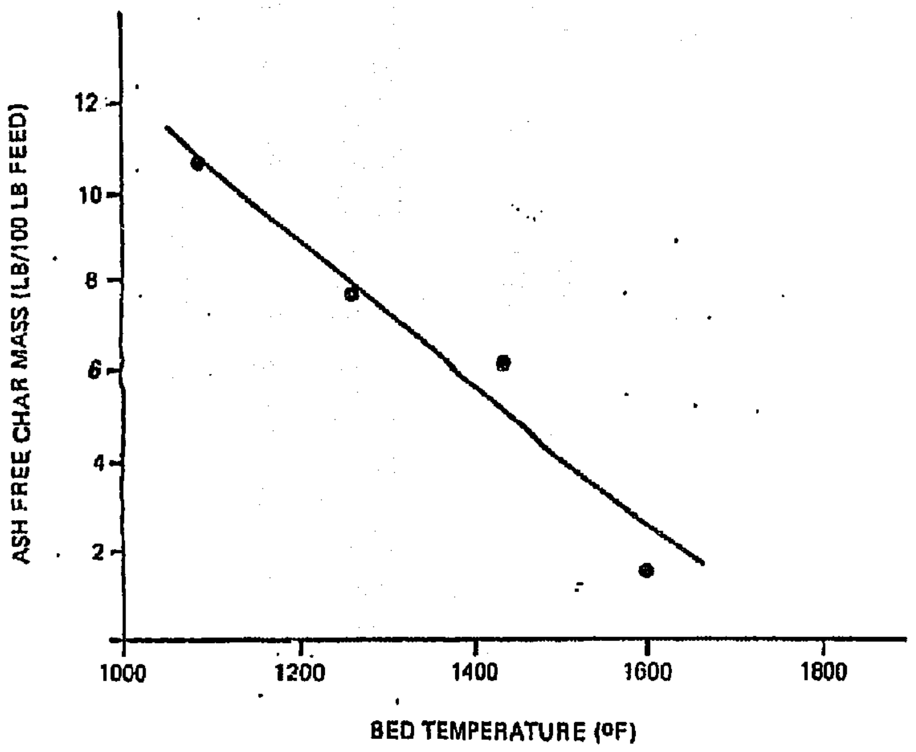


Figure 3.1.1-3 Ash Free Char Mass Yield vs. Temperature.

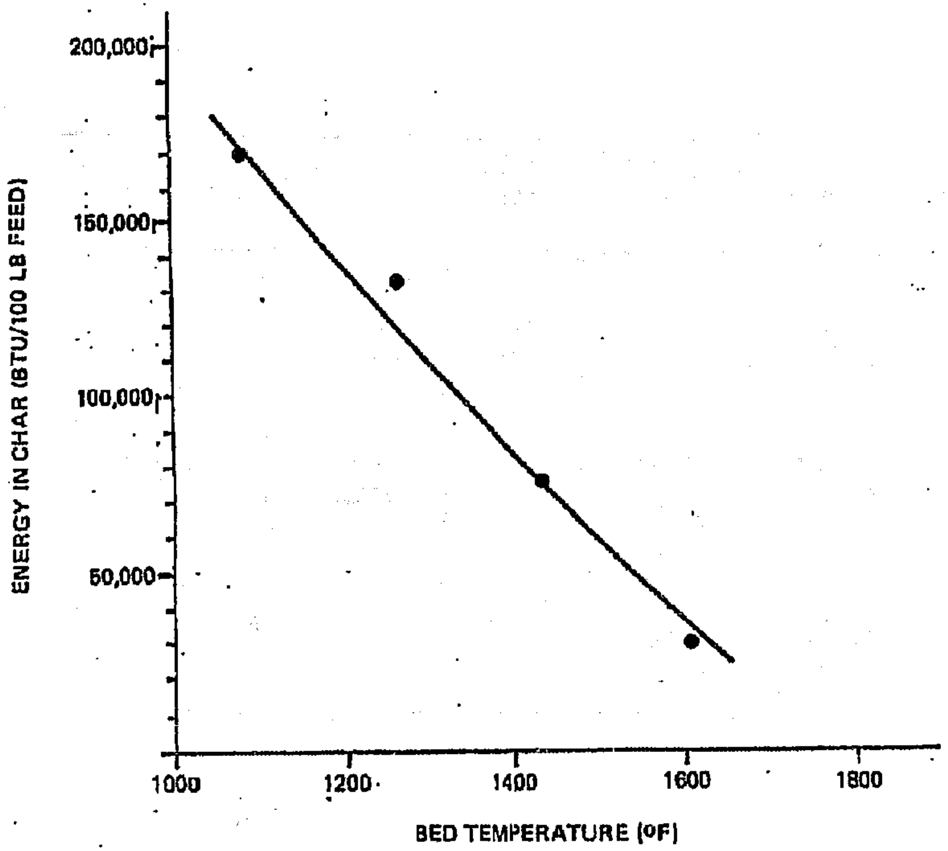


Figure 3.1.1-4 Char Energy Yield vs. Temperature.

temperatures, carbon or organic component of the char is almost completely removed. Reactor temperatures higher than 1600°F were not run to prevent any possible ash or silica slagging problems within the bed. This yield data will be important in evaluating all of the marketing possibilities for the char by-product.

The pyrolytic oil mass and energy yields, Figures 3.1.1-5 &6, also displayed decreasing trends with increasing reactor temperatures. This oil exits the reactor and remains in the gaseous state unless it is removed by scrubbing. These yields are important design criteria in the design of a scrubber, if it is required, or in adding to the heating value of the gaseous product stream.

The mass and energy yields of the gaseous product amount, Figures 3.1.1-7,8 show increasing trends with increasing bed temperature. The energy yield of the gas, which includes latent and sensible heats, appears to be tapering off at the elevated temperatures, indicating that the heating value of the pyrolytic gas is decreasing. This trend is shown in Figure 3.1.1-9 which plots the heating value of the pyrolytic gas in Btu/SCF as a function of bed temperature. The heating value of the combined pyrolytic gas and oil is also given, and will be an important design parameter.

Figure 3.1.1-10 plots the combined energy yield of the gas, oil and vapor stream as a function of bed temperature. The energy yield begins to taper off at higher temperatures as you would expect due to the decrease in the heating value of this stream shown in Figure 3.1.1-9. This combined stream will be used in fixing the boiler for steam generation and combusted for use in process drying.

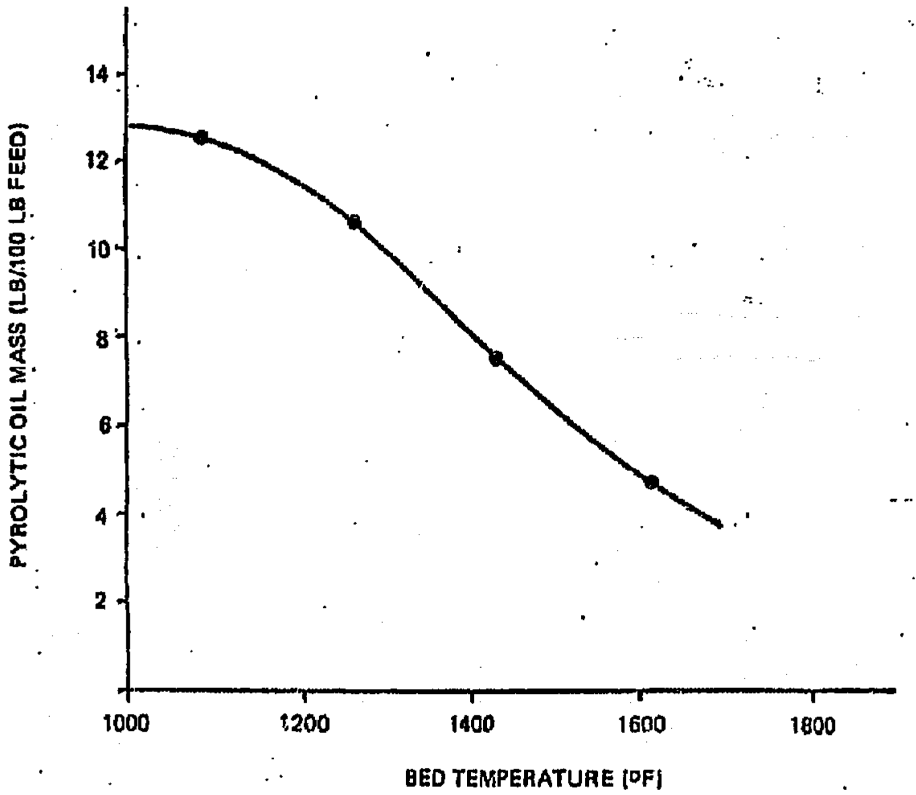


Figure 3.1.1-5 Pyrolytic Oil Mass Yield vs. Temperature.

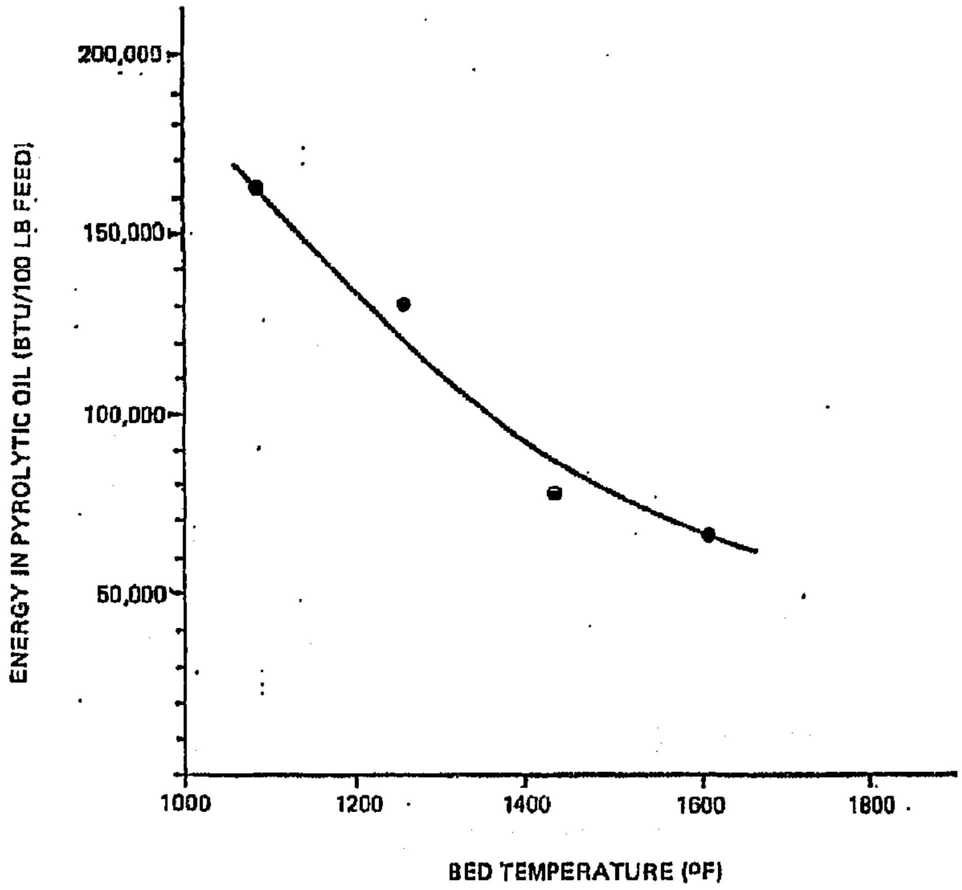


Figure 3.1.1-6 Pyrolytic Oil Energy Yield vs. Temperature.

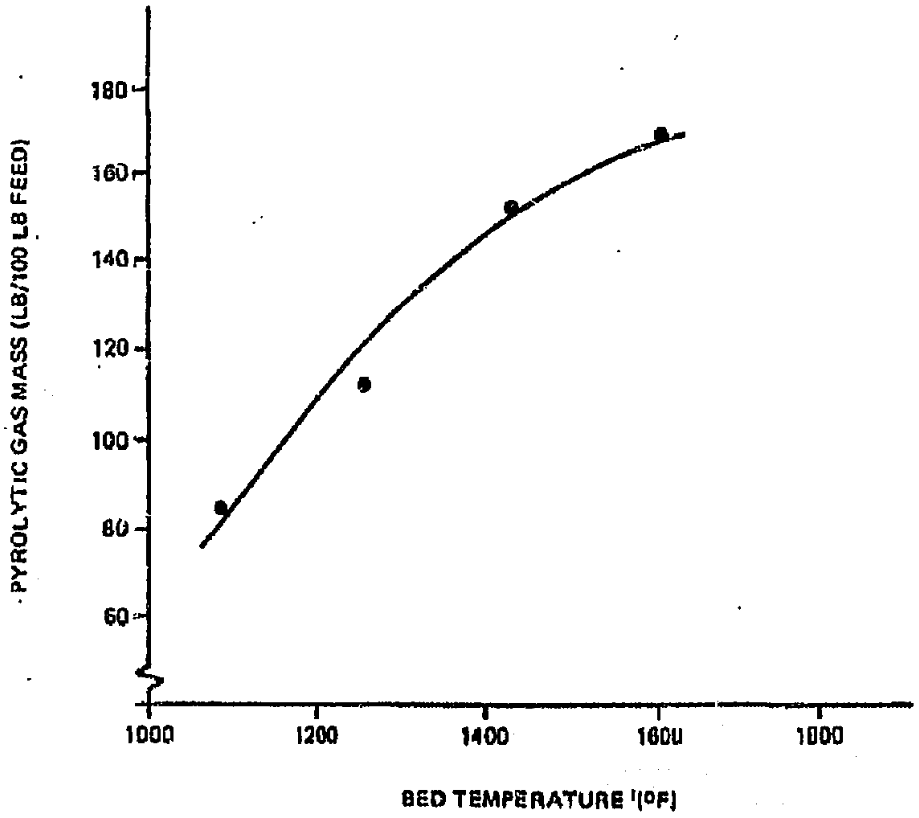


Figure 3.1.1-7 Pyrolytic Gas Mass Yield vs. Temperature.

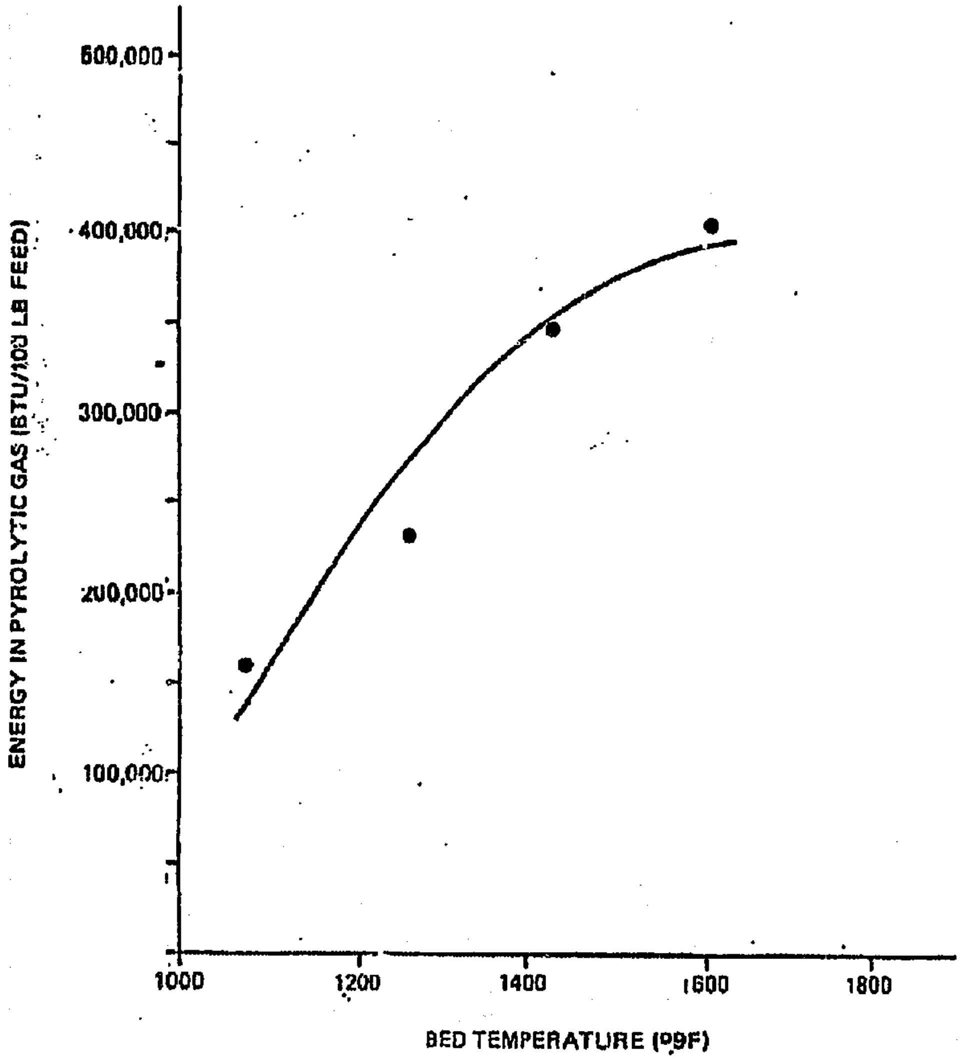


Figure 3.1.1-8 Pyrolytic Gas Energy Yield vs. Temperature.

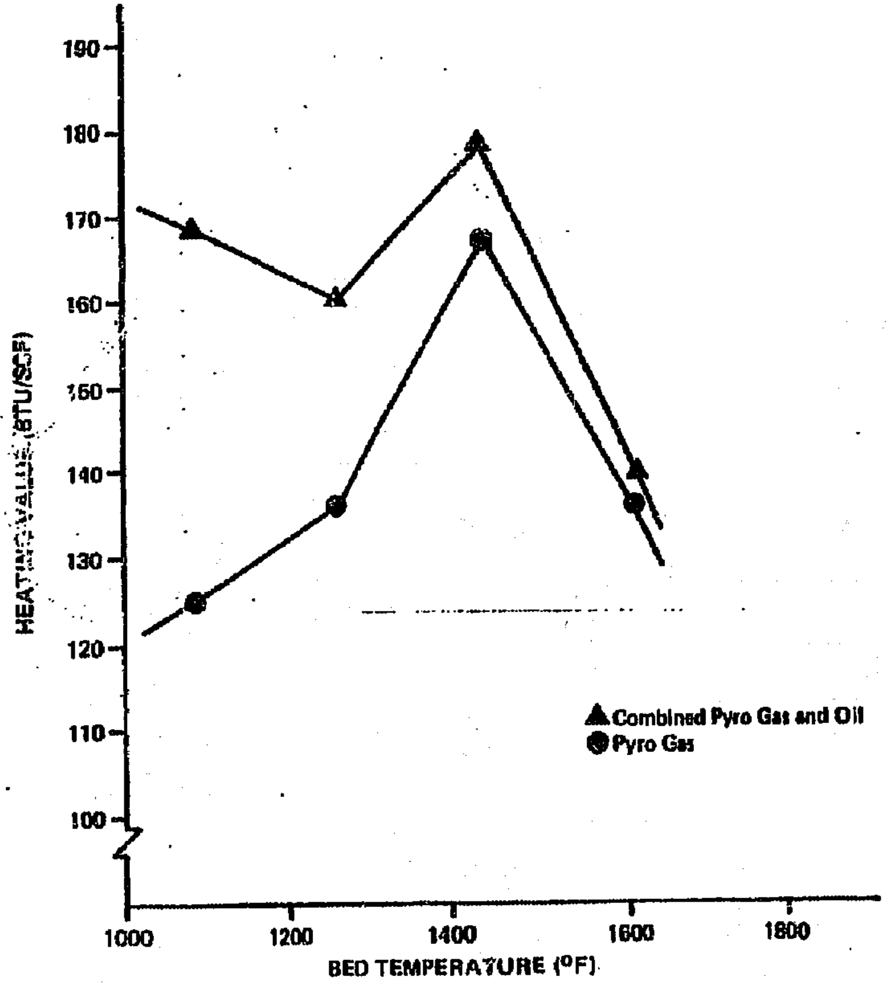


Figure 3.1.1-9 Heating Value of Gaseous Product vs. Temperature.

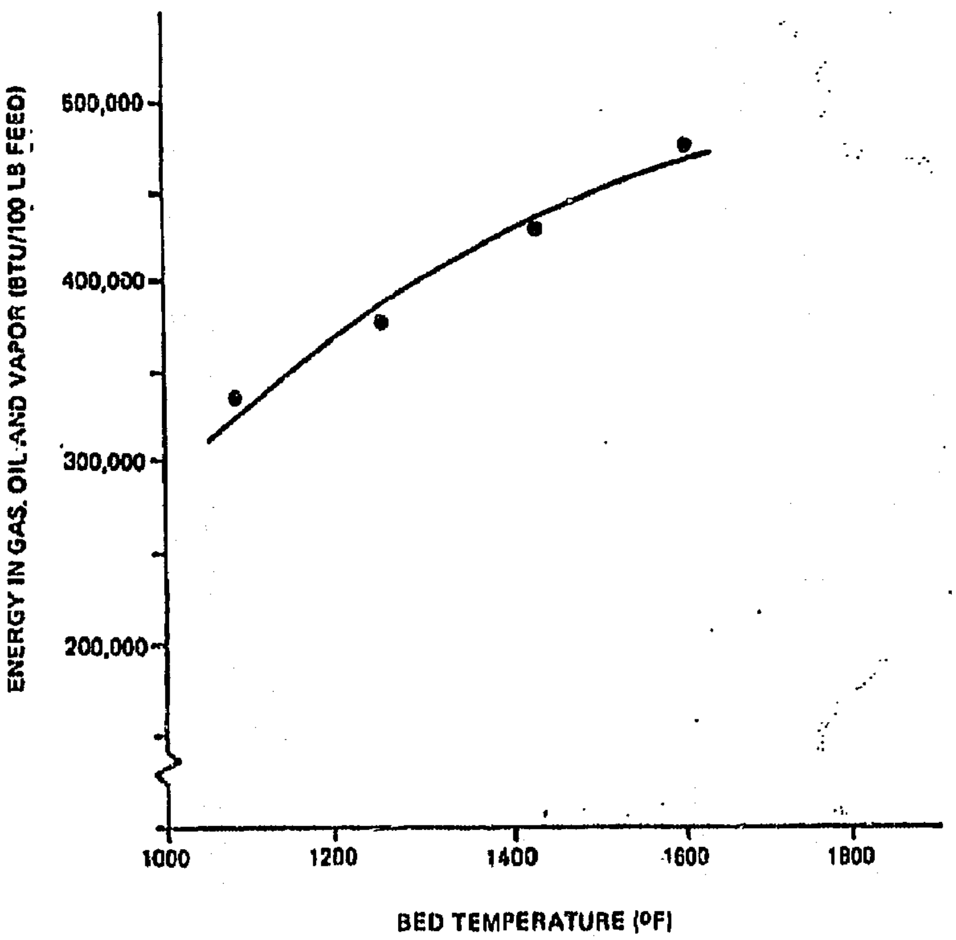


Figure 3.1.1-10 Energy Yield of Gaseous Product vs. Temperature.

Two days of testing with the direct contact rotary dryer were conducted and the results indicated that the high ash loading of this stream may present a problem in the contamination of the whole rice. The samples dried in the pilot plant dryer were returned to the ARI laboratory for odor, taste and color analysis. Although no odor or taste problems were found, it was felt that the ash may impart undesirable color to the rice. Although the evidence was not conclusive against the use of this flue gas stream in process drying, it would be best to take the conservative approach in the plant design and implement the necessary process changes such that hot air, not flue gas, would be delivered to the dryers.

The pilot plant testing further confirmed the environmental advantages of the FBG process. The afterburner flue gas was monitored during the tests and the potential sources of fugitive emissions identified. The results of these studies are given and discussed in the environmental section, 3.6.

Task G - Finalize Selection of Process

The pilot plant tests have further confirmed the feasibility and advantages of the FBG process combined with the appropriate steam, hot air or electric power generation options. The selected processes are shown functionally in Figure 3.1.1-11 and described in the ensuing paragraphs.

The unground rice hulls are fed to the fluidized bed gasifier which partially oxidizes the feed producing a char, oil and gaseous product. The char is then separated from the other products and stored before being transported off-site. The combined gaseous products, including the oil fraction are then used in the energy generation processes.

In Option 1 the combined low Btu gas and oil stream is split with a part being fed to 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 operations.

In Option 2 part of the combined gas and oil product are combusted in a boiler for steam production, and the remainder used for electrical power generation. The oil is removed from the low Btu gas before the gas is fired in an engine which is used to generate electric power. The hot exhaust gases are available for process drying operations. The use of a gas turbine for power generation would be functionally similar to the gas engine with different electrical output and capital cost.

p

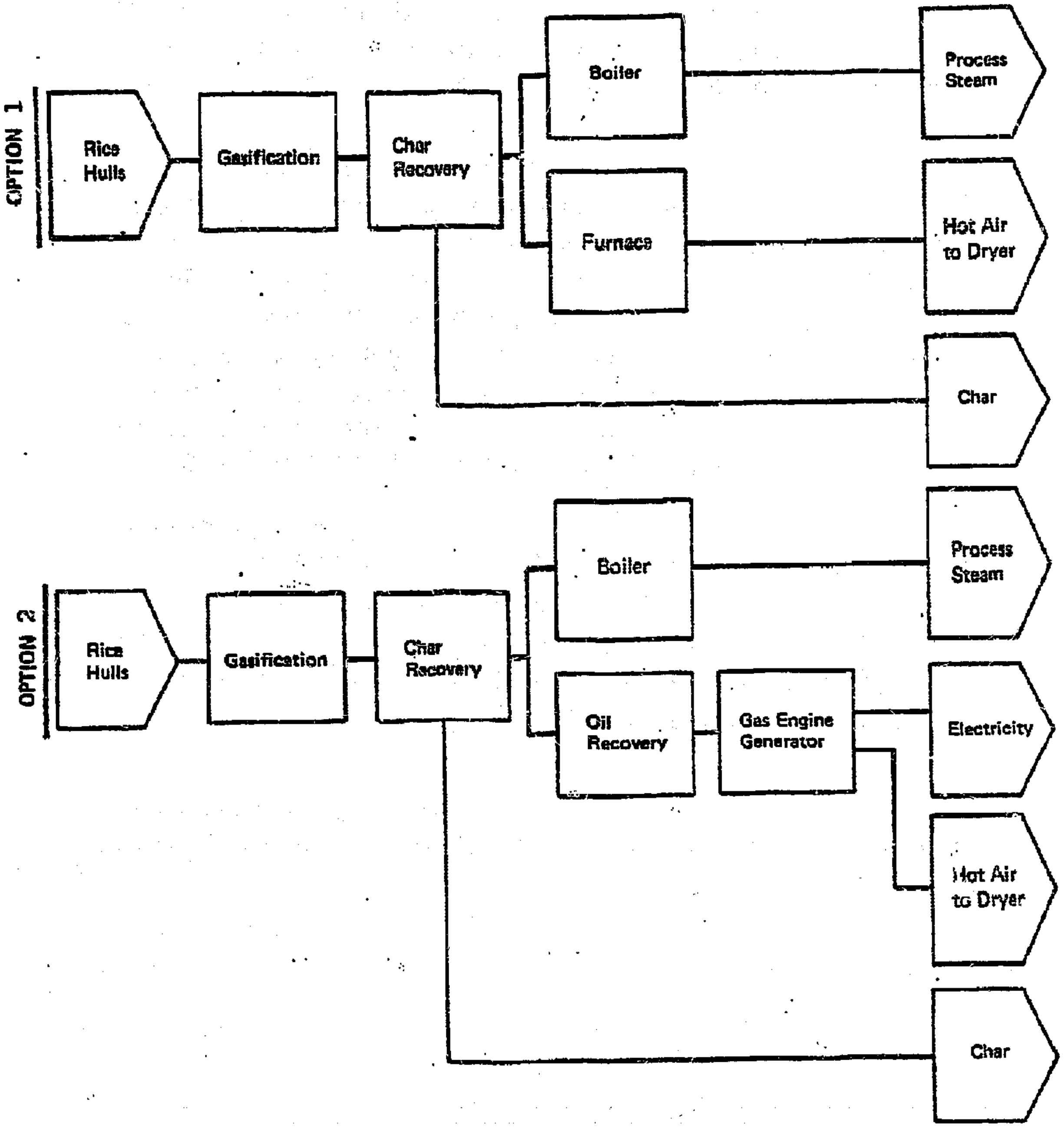


Figure 3.1.1-11 Simplified Process Flow Diagrams.

3.1.2 Detailed Information on Process Selected

Task A - Define Scale, Operating Specifications, etc.

The scale of the plant is based on the ARI rice hull production rates and energy demands as described in Section 3.1.1 Task A. Basic flow schemes were developed based on the pilot plant data and expected efficiencies of the various downstream processes, as previously shown in Figure 3.1.1-11. This basic flow scheme was used as a basis for the detailed engineering analysis carried out in Tasks B-D of this section.

Tasks B & C - Develop and Analyze Engineering Information Based on Tests and System Needs.

The primary function of the plant design is to reduce the natural gas dependency and hence operating or energy costs of the rice manufacturing process. This can best be accomplished by maximizing the combined gaseous product energy yields in the rice hull fluidized-bed gasifier. Reviewing the pilot plant energy yield data from Figure 3.1.1-10 we can see that the combined gaseous product energy yield is maximized at the higher bed temperatures around 1600°F. A more careful examination of this Figure shows that the energy in the gaseous product produced at a 1600°F bed temperature is 40 percent higher than that produced in a 1100°F bed.

The only constraint to operation at higher bed temperatures is that we continue to produce a gaseous product which can be reliably combusted in a conventional pilot-less low Btu gas burner. This means that the gas quality must remain above 120 Btu/Scf, say 130 Btu/Scf to be conservative.

Using the data in Figure 3.1.1-9 and realizing that the contribution of the oil to the gaseous product heating value is smaller at higher temperatures, we can conclude that the product gas produced at a bed temperature of 1700°F will no longer have the required heating value. In our design if we allow for a deviation of 10 percent from the normal feed rate and the feed rate at 1700°F is chosen as maximum deviation on the low side, using the feed rates found in the pilot plant tests, we conclude that the safe design reactor bed temperature is approximately 1530°F.

The heating value of the gas produced at this reactor temperature is 150 Btu/Scf, and should prove to be a fuel which can be easily combusted in a boiler, furnace or gas engine.

This analysis assumes that the quality of char produced at the various temperatures will not have a significant impact in its marketability. The char produced at 1530°F has an ash value of approximately 85%, and the mass of char to be handled is minimized at this higher temperature.

Using the results from the pilot plant tests discussed in Section 3.1.1, a heat and material balance was developed for the 1530°F gasifier. The balances are given in Table 3.1.2-2, based on a 100 lb per hour rice hull feed rate.

The inputs and products for the three most feasible processes are summarized in Table 3.1.2-2. In both cases all of the rice hulls are gasified at 1530°F in the FBG. In option 1 the low Btu gaseous fuel is burned in a boiler to produce the 30,000 pph of steam required, and the remainder of the gas is burned in a furnace and passed through a heat exchange section to produce hot air for process drying.

TABLE 3.1.2-2

GASIFIER MATERIAL AND ENERGY BALANCE

Reactor Bed Temperature 1530°F
Reactor Heat Value 7809 Btu/lb Dry, Ash Free
Feedstock Moisture = 9.4%, Ash = 22.1%

MASS BALANCE - GASIFIER (lb/hr)	IN	OUT
Feed (with moisture and ash)	100.0	
Air	112.9	
Char (85% ash)		24.9
N.C. Gas		161.6
Oil		5.9
Water		20.1
Particulate		0.4
Total	212.9	212.9

ENERGY BALANCE - GASIFIER (Btu/hr)	IN	OUT
Feed HV	53.49×10^4	
Water Latent		0.91×10^4
Water Sensible		0.90×10^4
Losses		1.07×10^4
Char Sensible		0.71×10^4
Char HV		6.15×10^4
Oil Sensible		0.26×10^4
Oil HV		7.07×10^4
N.C. Gas Sensible		3.93×10^4
N.C. Gas HV (150 Btu/SCF)		32.49×10^4
Total	53.49×10^4	53.49×10^4

TABLE 3.1.2-2

PROCESS OPTIONS FOR RICE HULL CONVERSION

Case	Description	Inputs Rice Hulls (TPD)	Inputs City Water (GPM)	Inputs Electricity (kw)	Products (TPD/MMBtu/hr) Char	Products (TPD/MMBtu/hr) Oil	Products (TPD/MMBtu/hr) Steam	Products (TPD/MMBtu/hr) Hot Air	Products (TPD/MMBtu/hr) Electricity (kw)
1	Boiler/ Furnace	340	100	720	85 (17.7)	--	360 (35.7)	2350$^{(1)}$ (32.0)	--
2	Boiler/ Turbine	340	200	1620	85 (17.7)	13.5$^{(2)}$ (13.5)	360 (35.7)	2350 (32.0)	2820
3	Boiler/ Gas Engine	340	200	1000	85 (17.7)	13.5$^{(3)}$ (13.5)	360 (35.7)	1900 (26.3)	5167

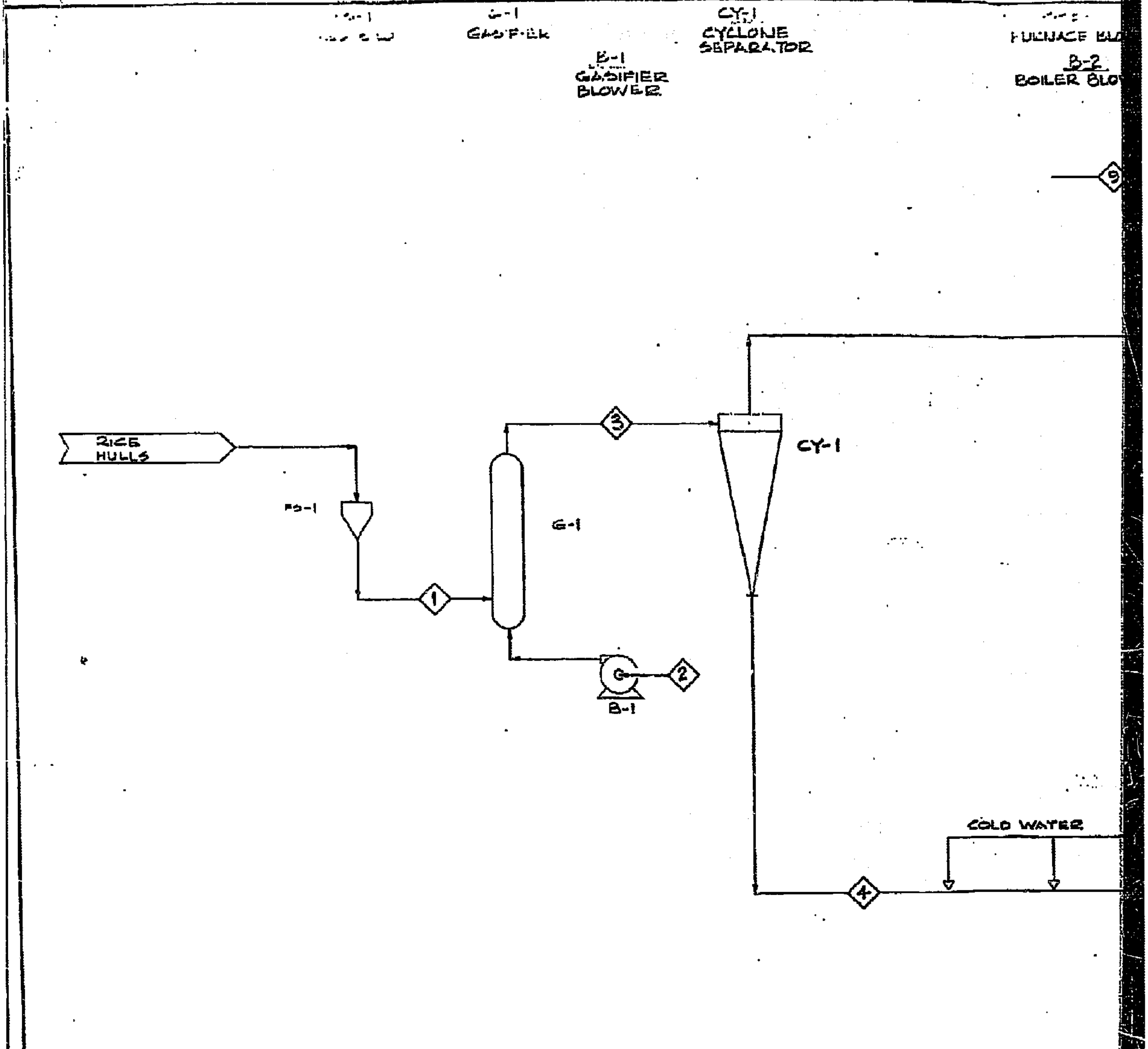
In Case 2 the low Btu gas produced in the FBG is used to fire a boiler to produce steam, and the remainder of the fuel used for electric power generation via a gas turbine. The oil scrubbed from the gas stream can be returned to the gasifier and burned, thus increasing the gasifier output and eliminating the need for storage and transporting the oil. The scrubbed gas is then compressed and used as a fuel in the gas turbine which produces electric power, and the hot flue gases are then used for heating an air stream which is used in the drying operations.

The feasibility of using all of the gas produced by the gasifier in the gas turbine and then "cogenerating" steam and hot air from the flue gases was considered. It was found that the waste heat available was not sufficient to both produce the necessary steam and hot air, thus this option was not given further consideration.

In option 3 the gasifier products are used to fire a boiler to produce the required steam and the remainder of the gas fed to a gas engine for electric power generation. The oil is scrubbed from the gas stream being fed to the engine and is burned to produce hot air which will supplement the hot engine flue gases in meeting the dryer requirements. The electric power generated by the engine is in excess of that used by the plant, and the excess will be sold back to the power company.

Task D - Finalize Preliminary Facility Engineering Information

This section describes the processes and equipment in detail for each of the three process options. Refer to the Process Flow Diagrams, Figures 3.1.2-1, 2 & 3, and Equipment Lists in Appendix A for detailed engineering design documents.



DESCRIPTION	RICE HULL FEED	GASIFIER AIR	GASIFIER PRODUCT	HOT CHAR	CHAR PRODUCT	PYROLYSIS GAS TO BOILER	PYROLYSIS GAS TO FURNACE	BOILER AIR	FURNACE AIR	PROCESS STEAM	HOT AIR TO DRYERS	BOILER FLUE GAS	BOILER FEEDWATER	FURNACE FLUE GAS
STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TEMP (°F)	60°	60°	1583°	960°	200°	960°	960°	60°	60°	338°	710°	350°	60°	400°
FLOW (LBS/HR)	28593	31,986	60 317	7058	7053	17402	35 864	26837	170,702	30,000	225,000	44239	32,000	206,566
FLOW (ACFM)	60.5	6978	–	8.8	8.8	10258	21848	5854	51934	—	110,367	15029	—	74,978
ENTHALPY	151.55	0	145.24	19.48	17.74	41.34	85.17	0	0	35.7	57.6	8.28	0	17.9
PRESS. (PSIA)	—	14.7	16.7	—	—	16.0	16.0	14.7	14.7	114.7	15.5	15.0	40.0	15

NOTES:

1) UNGROUND RICE HULL FEED ASSUMED TO BE 22.1% ASH AND 9.4% MOISTURE WITH 7809 BTU/LB ON A DRY ASH-FREE BASIS

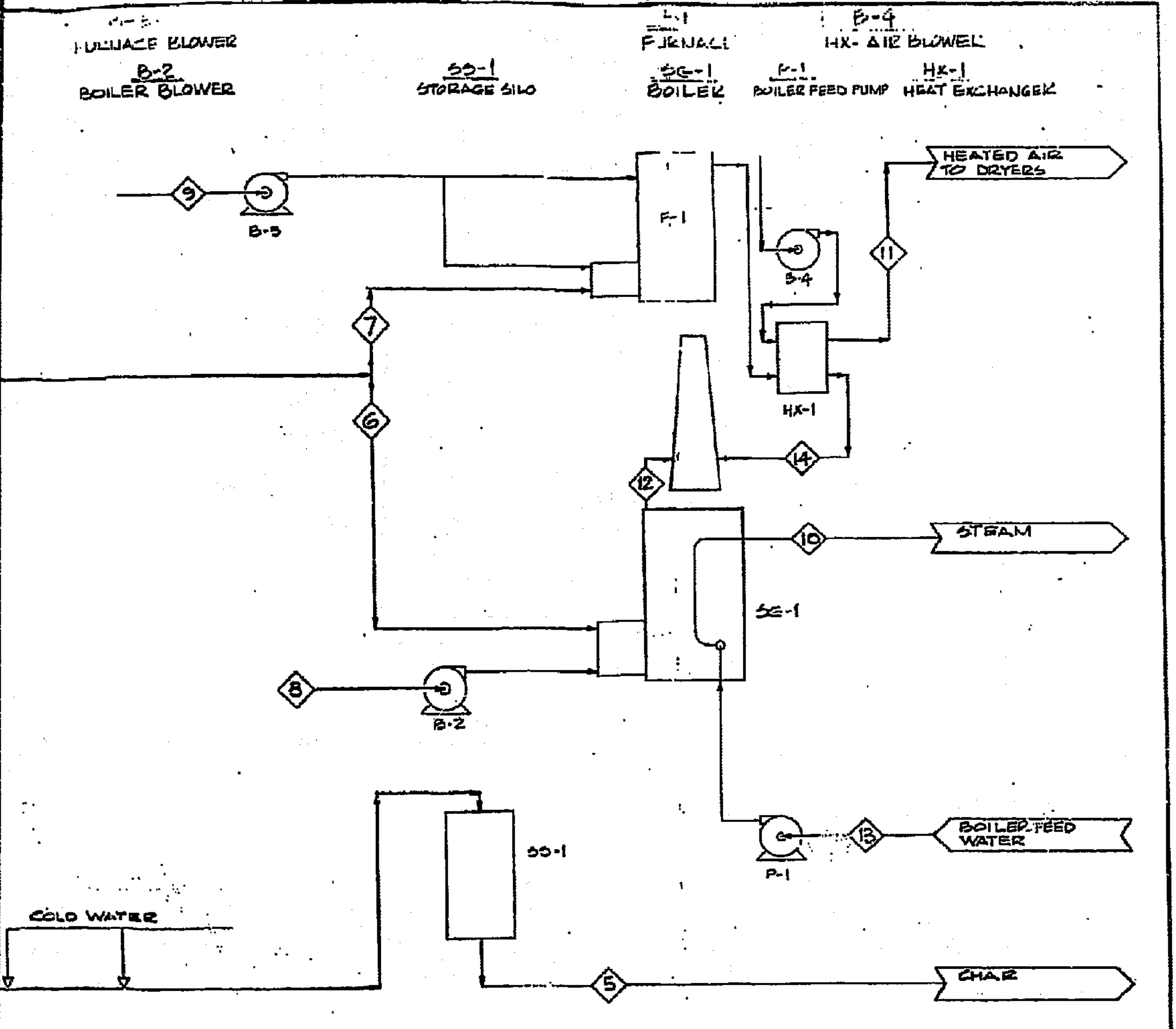


FIGURE 3.1.2-1
(Option 1)

REV	SHEET	DESCRIPTION	DATE	APPD

PROPRIETARY AND CONFIDENTIAL

EXCEPT AS OTHERWISE AGREED IN WRITING, THE INFORMATION AND DESIGN DISCLOSED HEREIN ARE THE PROPERTY OF ERCO AND MUST NOT BE COPIED OR DISTRIBUTED OUTSIDE ERCO EXCEPT TO AUTHORIZED PERSONS WITHIN A GENUINE NEED TO KNOW AND BY THE USE HEREOF ACKNOWLEDGE ERCO OWNERSHIP AND AGREE TO MAINTAIN THIS INFORMATION AND DESIGN IN STRICT CONFIDENCE.

DRAWN LM	DATE 7/81
CHECKED	DATE
APPD DA	DATE
APPD MFG	DATE
APPD STRESS	DATE
APPD MECH	DATE
APPD PROCESS	DATE
APPD PROJ TKK	DATE 7/81
RELEASED	DATE

REVISION STATUS OF SHEETS	REV
	SH

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES.

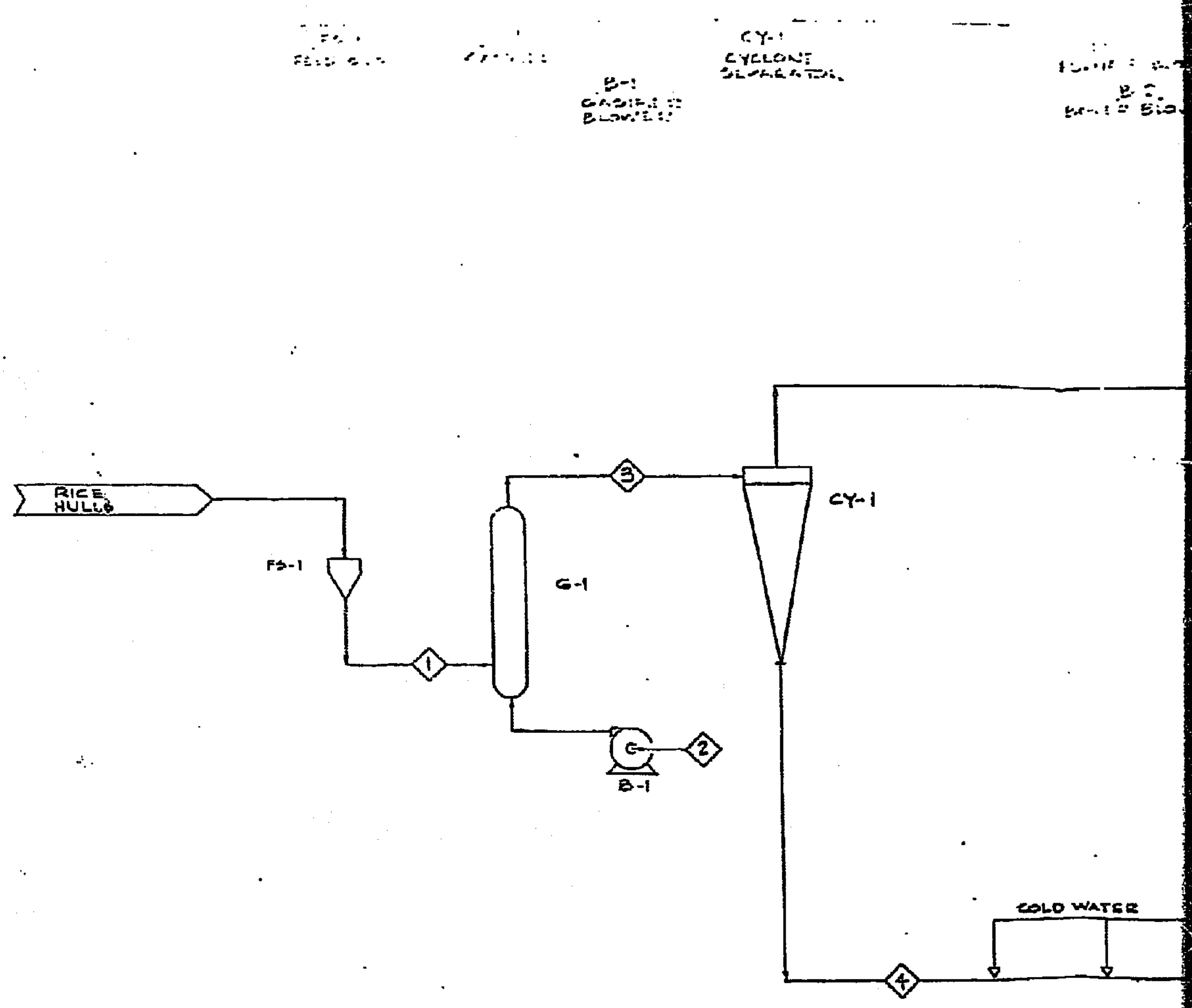
NEXT ASSY | USED ON

ERCO ENERGY RESOURCES CO. INC.
185 ALEWIFE BROOK PARKWAY
CAMBRIDGE, MASSACHUSETTS 02138

TITLE
PROCESS FLOW DIAGRAM
AMERICAN RICE INC.
HOUSTON, TX

SIZE	DWG NUMBER	REV
D	6150-001	0

SCALE | WEIGHT | SH OF



DESCRIPTION	RICE HULL FEED	GASIFIER AIR	GASIFIER PRODUCT	HOT CHAR	CHAR PRODUCT	PYROLYSIS GAS TO BOILER	PYROLYSIS GAS TO [illegible]	BOILER AIR	[illegible] GAS	PROCESS STEAM	GAS TURBINE AIR	BOILER FLUE GAS	BOILER FEEDWATER	HOT AIR TO DRYER	OIL
STREAM No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TEMP (°F)	60°	60°	1550°	950°	200°	950°	950°	60°	150°	550°	60°	350°	60°	710°	150°
FLOW (LB/HR)	25,998	31,465	60,319	7053	7053	17,472	35,564	25,657	[illegible]	30,000	175,994	44,289	33,[illegible]	225,000	1124
FLOW (ACFM)	66.5	6778	—	8.8	8.8	14,358	21,268	5654	—	—	38,805	15,023	—	16,527	—
[illegible]	151.55	0	145.94	19.45	17.74	41.94	85.17	0	32.78	35.7	—	5.53	0	57.6	15.49
PRESS (PSIA)	—	14.7	16.1	—	—	16.0	16.0	14.7	14.7	114.7	14.7	15.0	40.0	15.5	24.7

NOTES:
1) UNGROUND RICE HULL FEED ASSUMED TO BE 22.1% ASH AND 9.4% MOISTURE WITH 7849 BTU/LB ON A DRY ASH-FREE BASIS
2) ELECTRICITY PRODUCED BY GAS TURBINE, 2820 KW (9.62 10^6 BTU/HR)

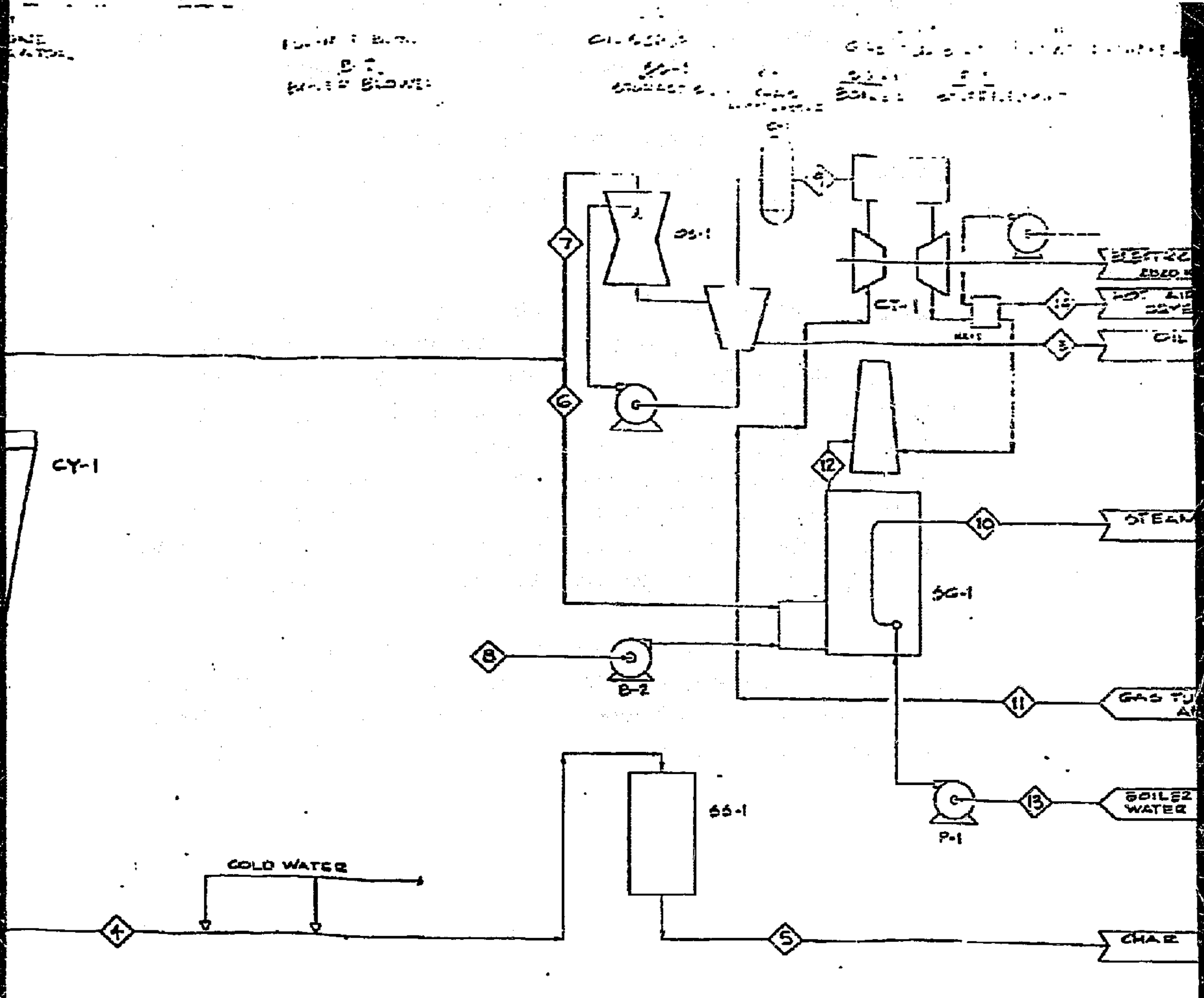


FIGURE 3.1.2-2
(Option 2)

BOILER FLUE GAS	BOILER FEEDWATER	HOT AIR TO DRYER	OIL
12	13	14	15
350°	.60°	710°	150°
44288	27,000	825,000	1124.
.5623	—	1.5227	—
228	0	87.6	13.49
15.0	40.0	15.5	[illegible]7.

ERCO

PROCESS FLOW
AMERICAN ZIC
ELEC. POWER

615

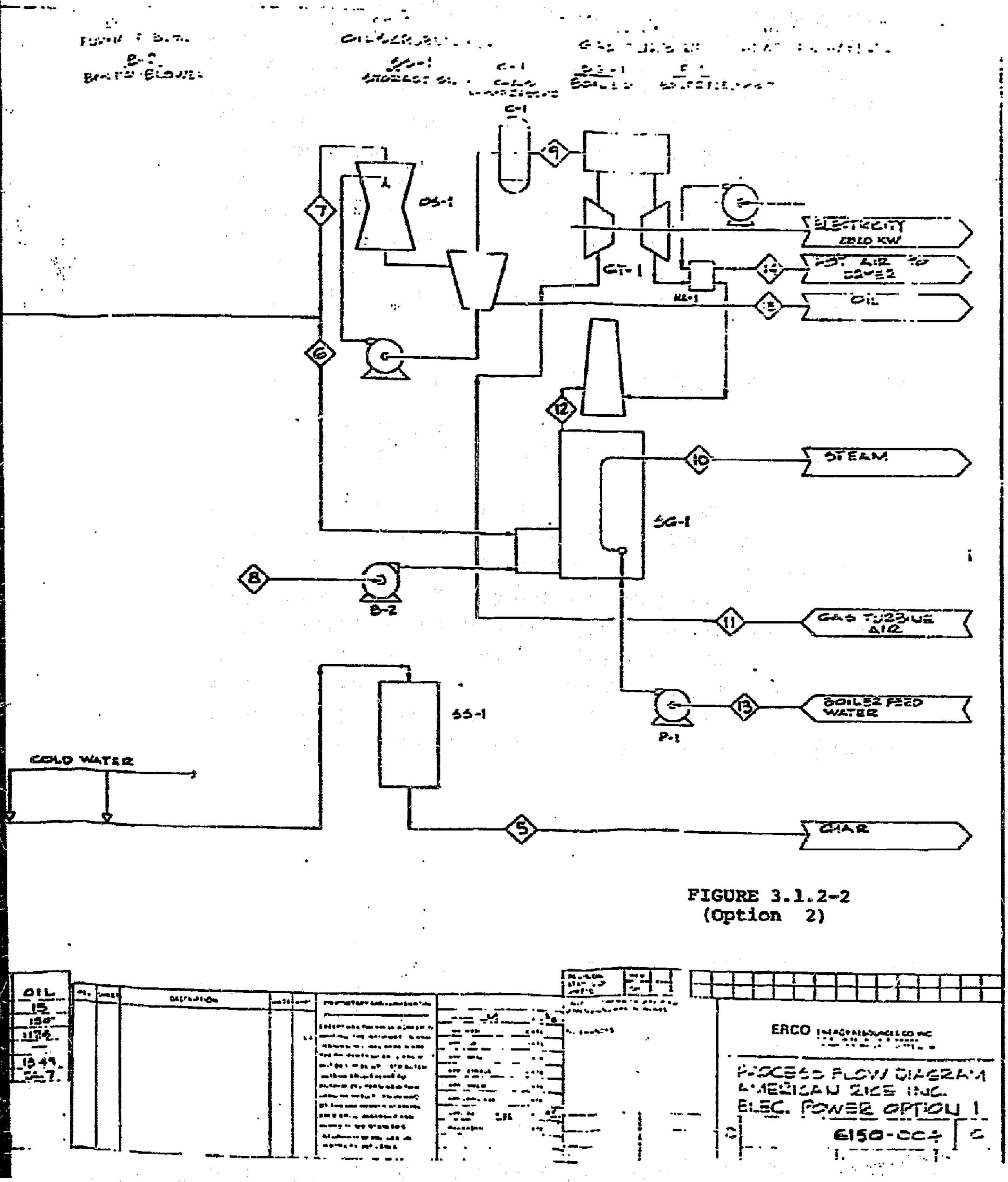
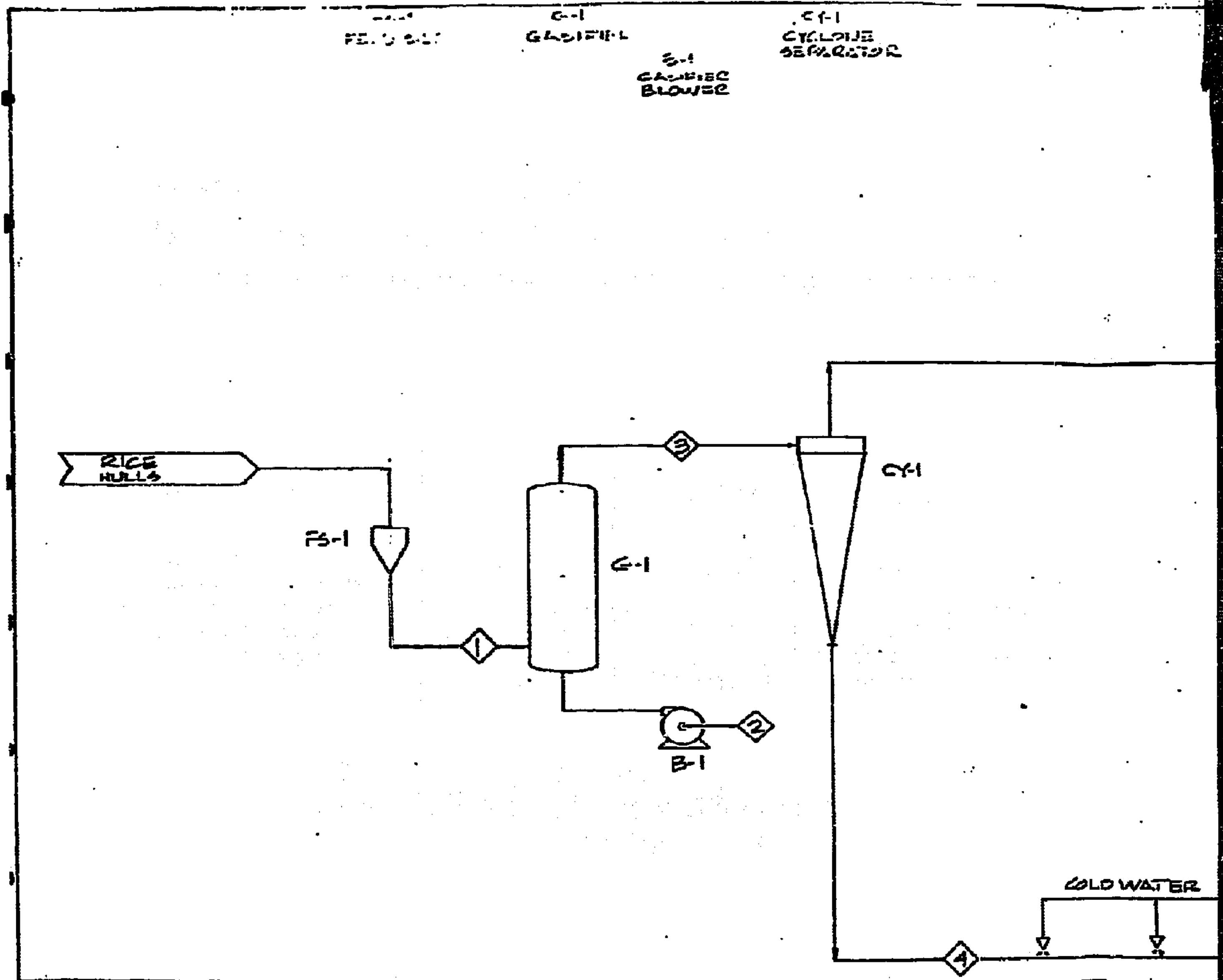


FIGURE 3.1.2-2
(Option 2)



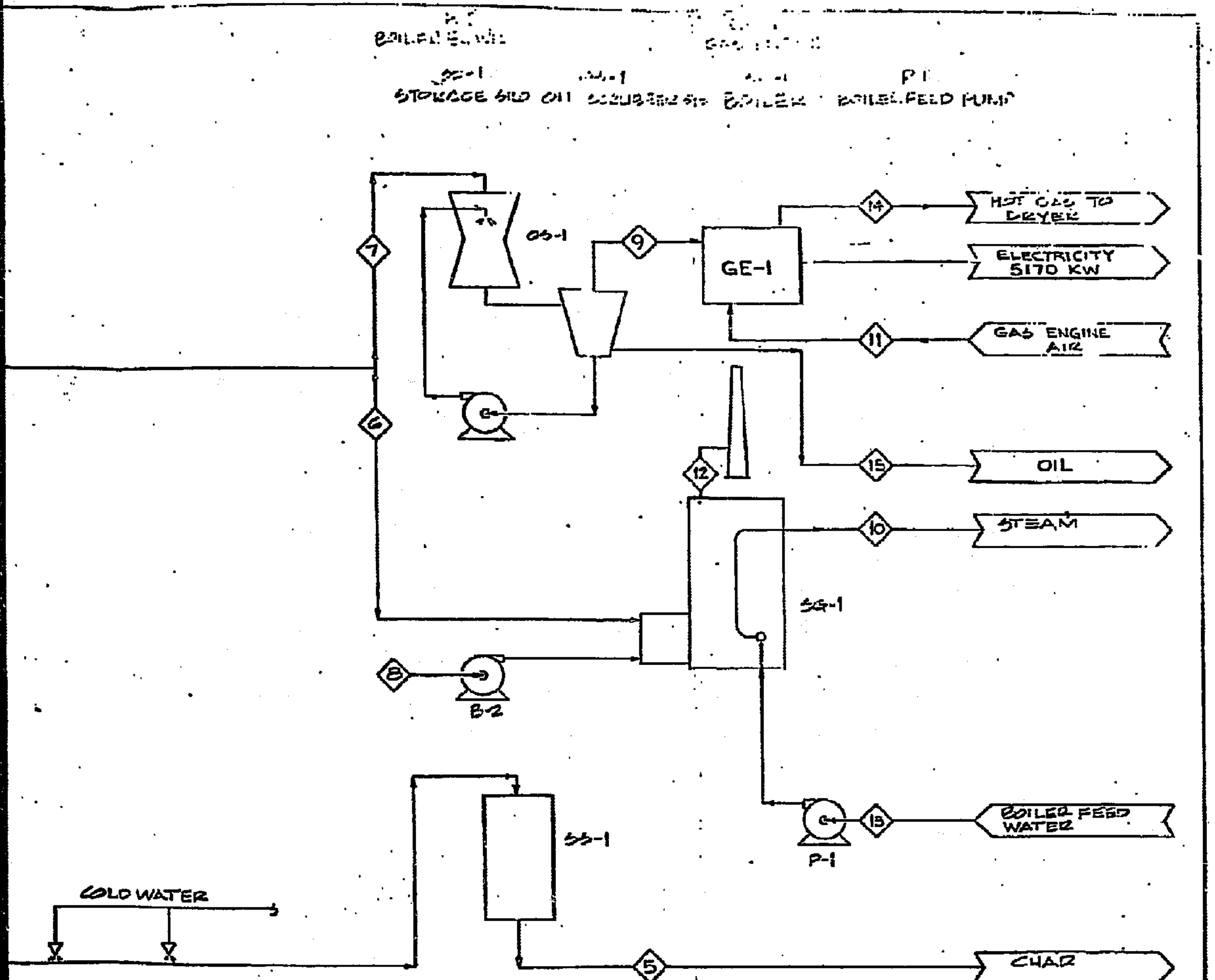
DESCRIPTION	RICE HULL FEED	GASIFIER AIR	GASIFIER PRODUCT	HOT CHAR	CHAR PRODUCT	PRODUCT GAS TO BOILER	PYROLYSIS GAS TO [illegible]	BOILER AIR	L.C. GAS	PROCESS STEAM	GAS ENGINE AIR	BOILER FLUE GAS	BOILER FEEDWATER	HOT GAS TO DRYER	OIL
STREAM Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TEMP (°F)	60°	60°	1980°	960°	200°	960°	960	60°	150°	338°	60°	350°	60°	700	150°
FLOW (LBS/HR)	28 393	31,986	60 519	7053	7058	17402	85 [illegible]	26837	37085	32 200	121,500	42.39	32,000	158585	1124
FLOW (ACFM)	605	6978	—	85	98	10538	21848	5854	9484	—	21,000	15028	—	71285	—
ENTHALPY (10⁶ BTU/HR)	151.55	0	165.26	19.63	17.74	41.84	85.17	-	62.99	35.7	-	3.29	0	26.39	15.49
PRESS (PSIA)	—	14.7	14.7	—	—	16.0	16.0	14.7	15.0	114.7	14.7	15.0	400	15.5	24.7

NOTES:

1) UNGROUND RICE HULL FEED ASSUMED TO BE 22.1% ASH AND 9.4% MOISTURE W/7809 BTU/LB ON A DRY ASH FREE BASIS

2) ELECTRICITY PRODUCED BY GAS ENGINE, 5170 KW (17.6×10^6 BTU/HR)

REV	SHEET	
A	1	UPDAT
0		



T GAS RYER	OIL
14	15
00	150*
8585	1124
7285	—
26.39	(9.49
6.5	24.7

Figure 3.1.2-3
(Option 3)

REV	SHEET	DESCRIPTION	DATE	APPD
A	1	UPDATE: GAS ENGINE WAS ...	7/8/..	DW
D				

PROPRIETARY AND CONFIDENTIAL

EXCEPT AS OTHERWISE AGREED IN WRITING THE INFORMATION AND DESIGN DISCLOSED HEREIN ARE THE PROPERTY OF ERCO AND MUST NOT BE COPIED OR DISTRIBUTED OUTSIDE ERCO EXCEPT TO AUTHORIZED PERSONS HAVING A GENUINE NEED TO KNOW AND BY THE USE HEREOF ALL WHO SO RECEIVE IT AGREE TO MAINTAIN THE INFORMATION AND DESIGN IN STRICT CONFIDENCE

DRAWN LM DATE
CHECKED DATE
APPD DATE
APPD MFG DATE
APPD STRESS DATE
APPD MECH DATE
APPD PROCESS DATE
APPD PROJ DWL DATE
RELEASED DATE

REVISION STATUS OF SHEETS REV SH

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES

ERCO ENERGY RESOURCES CO INC

PROCESS FLOW DIAGRAM
AMERICAN RICE INC
ELECTRIC POWER OPTION 2

D 6150-005 A

SCALE SHEET 1 OF 1

A. Fluidized Bed Gasifier System - The gasification process is common to all three options being considered. Unground rice hulls are delivered by ARI from their bulk storage silos to a gasifier feed silo. This silo, at 1450 ft^3, provides a surge capacity of 25 minutes and includes a closed top with internal duct control unit to prevent fugitive emissions. Additional features include bridge breakers, a load cell for level indication, discharge slide gate, and carbon steel construction. The feed flows by gravity onto a weigh belt which controls the feed rate to the gasifiers. The weigh belt is designed to cover a wide range of feed variations from 35 to 120 percent of the design flow. The feed is then split into two equal streams, one for each gasifier, and transported by bucket elevator to a second flow splitter which results in a total of four equal feed streams. The bucket elevator is designed to deliver up to 20 percent above the design feed rates, and is totally enclosed to prevent any fugitive emissions. The feed, now split into four equal streams, flows by gravity into rotary air locks, four required, which discharge into four screw feeders which feed the gasifiers. The rotary air locks and screw feeders are designed to handle a maximum flow of 200 percent of the design value. This will allow the continuous operation of a gasifier at the design level in the event that one feeder is off line. The rotary air locks are designed to prevent any back leakage of hot gases from the gasifier. The screw feeder delivers feed directly into the gasifier and is designed to withstand a maximum temperature of 1600°F.

Each fluidized bed gasifier is a 55 sq. ft. by 27 feet high vessel lined with a high temperature abrasion resistant refractory. A specially designed distributor plate is provided near the bottom of each vessel for even distribution of fluidizing air. The bed material within each reactor is a refractory sand having a particle size chosen to allow well-defined fluidization.

The reactors include above bed start-up burners which pre-heat the reactor during start-up.

Air required for fluidizing the gasifier bed is provided by positive displacement blower. One blower is supplied with each gasifier and each includes inlet and outlet silencers, inlet filter, relief valve, a bypass loop to contorl the output, and TEFC motor. Each blower is rated at 8650 SCFM at 10 psi.

The products of the gasifier flow into a cyclone separator which separates the solid char from the low Btu gas. Once again two cyclone systems are provided, one for each gasifier. Each cyclone system consists of high performance 304 ss cyclones manifolded in a quad arrangement. The cyclones are lined with an abrasion resistant refractory. The char discharge of each cyclone system flows through a high temperature, cast ss rotary air lock and discharges into a cooling screw conveyor.

The hot char is cooled to 300°F by means of a water spray, which removes 1.7 MMBtu's/hr. The cooled char is then transported by a bucket elevator into a 25,000 cu. ft. storage silo. The char storage silo provides storage for approximately 1½ days and includes a dust collector to eliminate fugitive dusting, bridge breakers and an unloading screw conveyor. This silo will be located outside of the building in an area which will have easy access to the existing ground transportation loading facilities.

Each gasifier can operate at the design temperature with variations of plus or minus 25 percent of the design feed flow. Wider variations of the feed flow can be accommodated by operating the gasifier at different temperatures, with higher feed rates resulting in lower bed temperatures and a different product split. The product splits have been developed in the ERCO pilot plant over a range of bed temperatures from 1000 to 1600°F.

B. <u>Boiler System</u> - A specially designed package boiler is used for combusting the low Btu gaseous fuel and producing 30,000 pph of 100 psig steam. The burner is designed for combustion of the low Btu fuel without the use of a continuous pilot flame. This burner can also burn natural gas for start-up or other upset situations. The package boiler is designed to accommodate the lower flame temperatures and longer flame lengths produced by the combustion of this fuel. The boiler package includes an economizer to maximize the overall efficiency (85 percent is expected), a burner management control package, and combustion air blower.

The boiler feed water treatment consists of a water softener designed for 100 percent make-up, 70 gpm, with a standby unit to allow continuous operation during the regeneration cycle. The treated water is then preheated in a heat exchanger using waste heat from the flue gas cooler or boiler blow down.

The preheated feed water is then deaerated in a jet-tray deaerator using process steam. The deaerator has a capacity of 150 cu. ft. allowing for a 15 minute residence time. The boiler feed water enters the feed pumps which pressurize the feed water before entering the boiler. A piped in backup pump is supplied to insure continuous operation.

The boiler flue gas contains particulate (TSP) and low levels of SO_2, NO_x, and CO. The use of a fabric filter dust collector is required to remove the particulate before the flue gas is discharged. The dust collector is designed for 17,000 ACFM and will reduce the particulate level to approximately .006 grains/ACF before the flue gas is discharged to the stack. A detailed discussion of the air control requirements is presented in a separate report.

C. <u>Furnace System - Option 1</u> - The remainder of the low Btu gaseous fuel, 85 MMBtu/hr, is available to meet the process drying requirements. This is accomplished by firing the low Btu gas in two 45 MMBtu/hr refractory lined furnaces. Low Btu burners designed for operation without a continuous pilot fire the fuel and combustion plus dilution air into the furnaces. The furnace is designed to allow for the high mass flow rates and provides enough residence time for complete combustion of fuel. This package also includes the combustion/dilution air blower, designed for a furnace exit temperature of 1500°F. The hot flue gases then enter the heat exchange section of the furnace in which ambient air is heated to 700°F, for use in the direct drying operation. Each air to air heat exchanger includes a bypass loop with controls to maintain a fixed air outlet temperature under varying ambient air conditions and demands. The system includes ambient air blowers, each rated at 25,500 ACFM, complete with inlet silencers and filters, which pressurize the air before it is heated and delivered to the dryers. The hot air distribution system is not included with this package.

The hot flue gases are further cooled in a cooler/preheater in which the excess heat can be used for preheating the boiler feed water. The flue gases are then passed through a pulse jet type fabric filter dust collector before being exhausted to the stack. The dust collector is rated at 75,000 after and reduces the particulate level to .003 grains/ACF.

D. Option 1 Special Systems - The gasifier, boiler and furnace systems will be housed in a common steel sided building, to be designed and constructed specifically for this application. The building will be complete with foundation, HVAC system, control room and access ways. The only equipment not included within the building will be the char storage silo, boiler and furnace fabric filters and the stack.

E. Electric Power Generation - Option 2 - In Option 2 the remaining low Btu gas is used to fuel a gas turbine which produces 2.82 MW of electric power, as shown in Figure 3.1.2-2, the process flow diagram. The gaseous product is first sent to an oil scrubber in which the gas is cooled and the pyrolysis oil and ash blow-by are removed. The gas is fed to a venturi scrubber which sprays a fine mist of scrubbing fluid (water) through the gas. After the scrubber the gas is accelerated through a cyclonic separator where the denser mists and particulates are separated from the gas. The liquid mists flow to a settling tank where the oil and water separate. The water is cooled in a heat exhcanger and pumped back to the venturi spray system. The heat, 6.5 MMBtu/hr, is used for preheating the boiler feed water or combustion air. The collected oil, 13.5 MMBtu/hr heating value, is then pumped back into the gasifier where it is burned, increasing the output of the gasifier.

Other possible uses for the pyrolysis oil are being explored, although it is felt that the oil should be used on site since it presents storage and transportation problems due to its high viscosity.

The cooled low Btu gas is then compressed in a screw type compressor to 60 psi before it is fed to the gas turbine. In the gas turbine the compressed gas is burned in the combustion chamber and the hot flue gases are expanded in the turbine and exhausted to the heat exchange section which heats ambient air to 710°F for process drying. The work produced by the turbine is used to power the air compressor mounted on the same shaft and to generate electric power. The gas turbine is complete with the generator, switchgear and transformer.

F. <u>Electric Power Generation - Option 3</u> - In option 3 the remainder of the low Btu gas, 85 MMBtu/hr, is sent to a gas engine/generator for electric power generation. Refer to Figure 3.1.2-3. The gaseous product is first sent to an oil scrubber as described in option 2 above. The oil collected in the scrubber, 13.5 MMBtu/hr heating value, is then burned in a small furnace to generate hot air for use in the process dryers.

The clean non-condensible gas is then fed to the gas engine where it is combusted with ambient air. The gas engine is a four cycle, spark ignited, water cooled reciprocating engine specially designed for burning low Btu gaseous fuel. The gas engine comes complete with generator, switchgear and transformer. The hot engine exhaust gases are then available for use in the process drying.

The complete system, with the exception of the char storage silo, boiler fabric filter and stack, will be housed in a common building as previously described in Section D.

Instrumentation and Process Control

Appropriate instrumentation and process controls are identified based on the performance criteria of the proposed plant, the conceptual design, and the equipment specifications. The proposed instrumentation and control loops are illustrated in Figure 3.1.2-4, Option 1.

The major control loops control the following operating variables:

- rate of feedstock delivered to the feed silo from storage bins.
- feed rate to gasifiers
- volume of fluidization air delivered to gasifiers
- rate of cooling water delivered to char cooling screw
- flow rate of low Btu gas to the boiler
- flow rate of low Btu gas to the furnace
- product steam flow/pressure
- product hot air temperature and flow

The rate at which rice hull feedstock is delivered from the storage bins is controlled by the level of the feedstock in the gasifier feed silo.

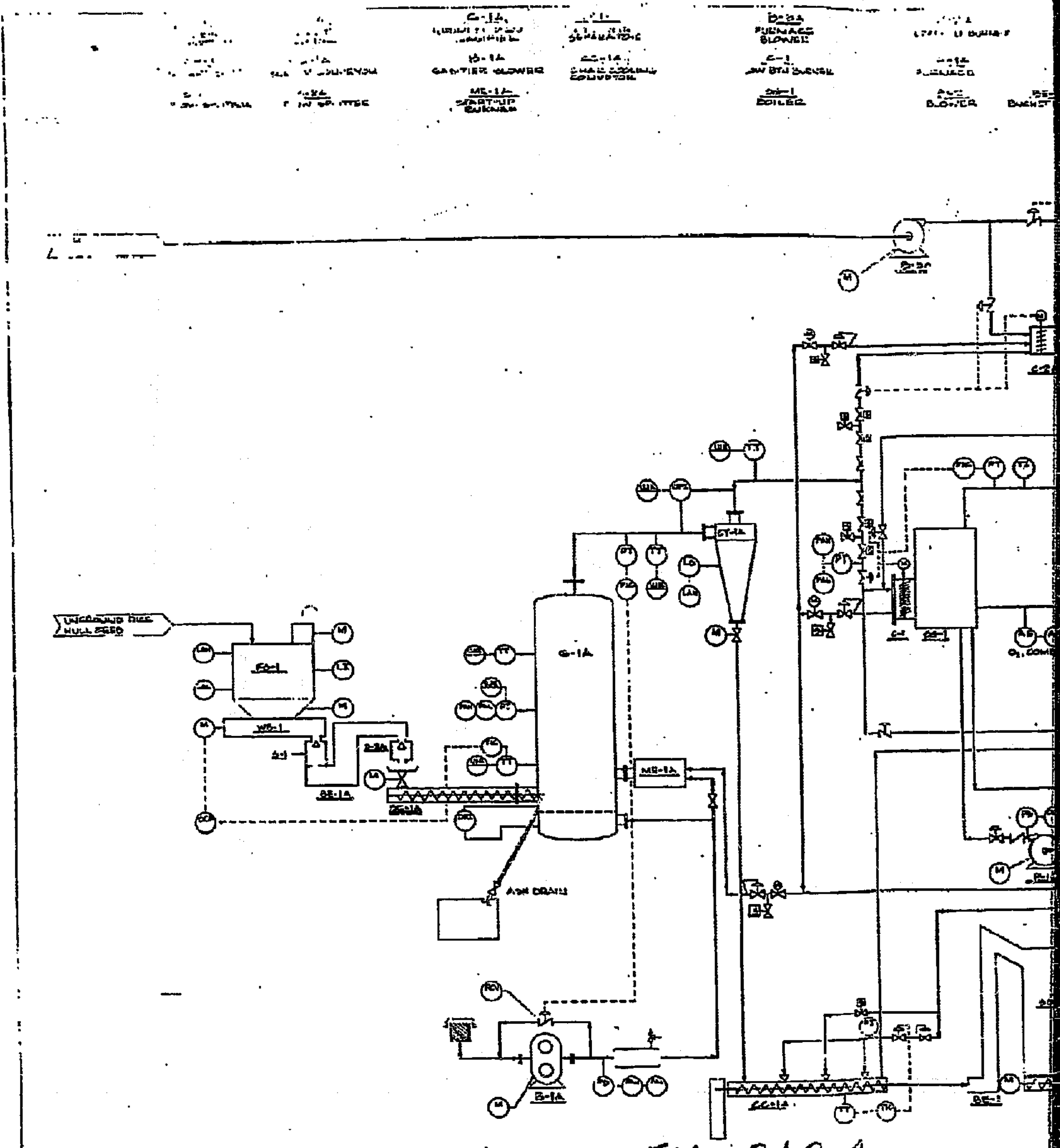

G-1A
B-1A
GASIFIER BLOWER
ME-1A
START-UP BURNER
SEPARATOR
CC-1A
CHAR COOLING CONVEYOR
B-3A
FURNACE BLOWER
SB-1
BOILER
BLOWER
UNGROUND RICE HULL FEED
FO-1
WS-1
SC-1A
CY-1A
ME-1A
ASH DRAIN
CC-1A
BE-1
O_2 COMB

FIG. 3.1.2-4

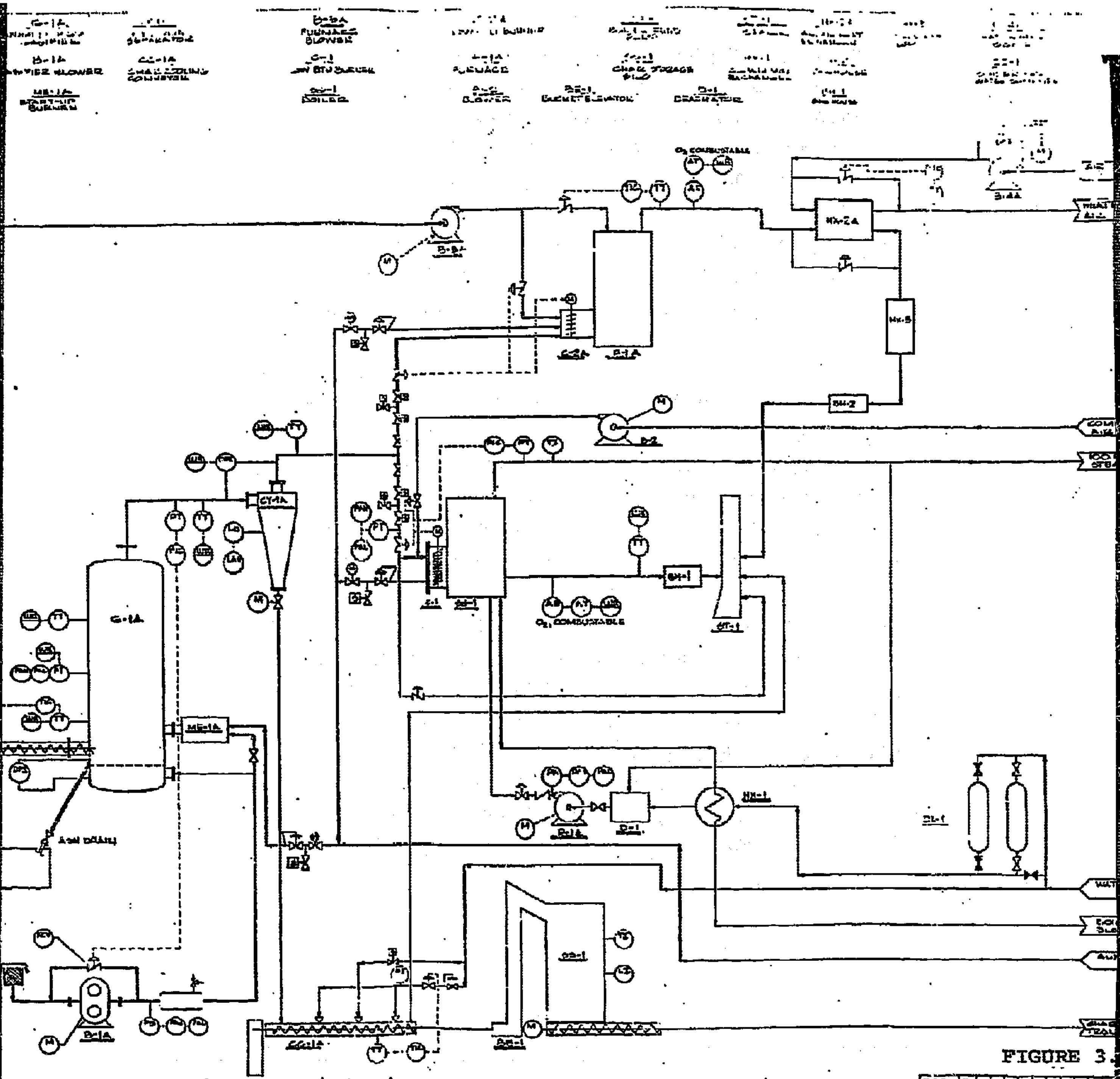


FIGURE 3.

FIG. 3.1.2-4

ERCO

AMERICAN
P&I DIAG.
RICE HULL

615

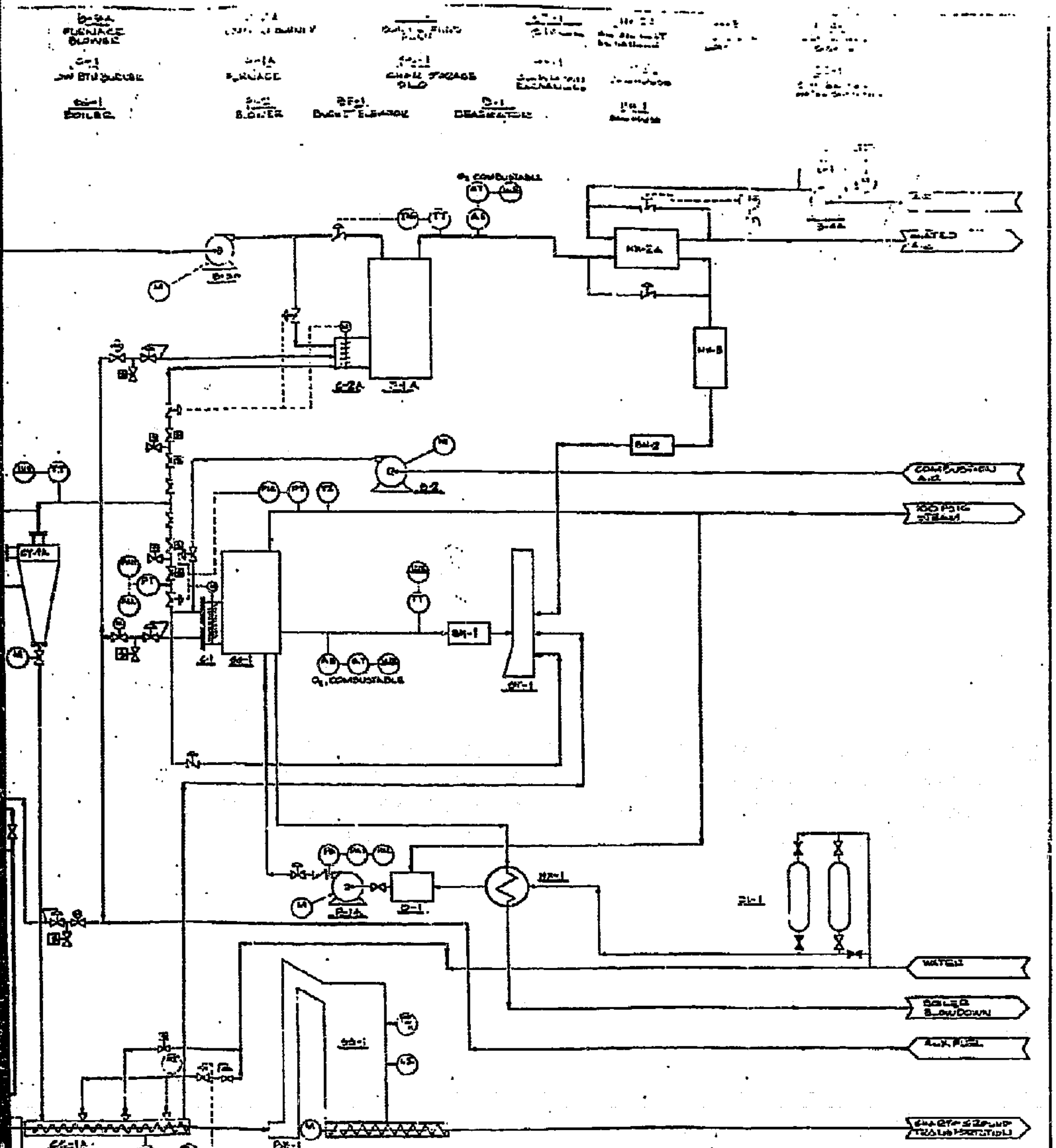


FIGURE 3.1.2-4

3.1.2-4

ERCO

AMERICAN RICE INC
P&I DIAGRAM
RICE HULL GASIFIER

6150-002

The feedrate of rice hulls to the gasifier is adjusted to maintain the desired gasifier reaction temperature. An increase in feedrate results in a decreased air-to-fuel ratio which decreases the temperature in the bed.

The flow rate of fluidization air to the gasifier is adjusted to maintain a constant gasifier exit pressure. The last two control loops described are interactive in the sense that the product of each loop affects the input variable of the other. The amount of rice hulls fed to a gasifier will, in part, determine the amount of gas produced and the pressure at the gasifier exit. The volume of fluidization air delivered to the gasifier will, in part, determine the air-to-fuel ratio and the temperature of the bed.

The amount of water sprayed into the char cooling screw is controlled in order to keep the temperature of the char leaving the screw at less than 300°F.

The boiler output is controlled by the outlet pressure which varies with steam demand. The outlet pressure is maintained at 100 psi by changing the firing rate of low Btu gas into the boiler.

The product hot air flow rate is maintained at a constant value by controlling the bypass air flow around the blower. The temperature of the hot air is maintained at a constant value by controlling the heat exchanger air bypass flow rate.

The control logic associated with option B is identical in the gasifier and boiler sections. In the electric power generation process, there are controls on the scrubber water makeup flow and on the air-flue gas heat exchanger. The scrubber makeup water is controlled by maintaining a constant level in the settling tank using a level control device. The air-flue gas heat exchanger controls are the same as those associated with the furnace, in which the air flow rate and hot air temperatures are controlled.

3.1.3 Alternative Fuel Production Schedule and Displacement of Oil and Gas

Tasks A-C - Develop Fuel Production and Oil and Gas Displacement Schedule

The fuel production schedule for the proposed plant was developed based on the pilot plant yield data previously presented. An on line factor of 90% was used, and is the goal of the proposed plant. The FBG process produces both a low Btu gaseous fuel and a char fuel. The gaseous fuel latent and sensible heat values were used in determining the magnitude of the energy output shown in Table 3.1.3-1. The heating value of the combined ash/char, 2500 Btu/lb at 85% ash, was used in determining the char energy output. It is possible that the char will not be used as a fuel, depending on the actual market, and will not be considered as an energy source.

The amounts of oil and gas displaced by the fuels produced are also given in Table 3.1.3-1. The displacement figures assume that the low Btu fuel can be used as efficiently as either oil or natural gas and that all of the gas produced will be used.

TABLE 3.1.3- 1

Projected Displacement of Oil and Gas Based On Alternative Fuel Production Schedule For Rice Hull Pyrolysis (1)

Alternative Fuels Produced	Energy Output (MMBtu/hr)	Equivalent Oil (2) (BBLS/yr)	Equivalent Natural Gas (3) (MCF/yr)
Combined Gaseous Product	126.51	172,088	949,910
Char Product	19.43	26,430	145,890

(1) Based on an on-line factor of 90% and 340 TPD feed rate.

(2) For fuel oil, 35° A.P.I., 138,000 Btu/BBL.

(3) For natural gas at 1050 Btu/SCF.

3.1.4 Raw Material Support Requirements

Tasks A-D - Determine Support Material Requirements and Identify Needs

The major material inputs to our process are (1) unground rice hull feedstock, and (2) city water for steam generation and other miscellaneous uses. Note that there will not be a significant increase in the plant water demand since we are replacing existing steam generators. Electricity is required for operation of motors and controls and a small amount of compressed air is needed for instruments and other miscellaneous uses.

All of the products from the proposed plant except the char will be used on site and require only plant distribution. Access to ground transportation is required for transporting the char to its final market.

The rice hulls will be required at a rate of 340 TPD and storage for approximately a one day supply is desired. These storage silos are already in existence at the facility with a storage capacity in excess of one day.

The projected city water and electric power demands are summarized in Table 3.1.2-2. The existing water mains and drains can be tied into and will accommodate the new facility. The compressed air, with a projected usage of 35 CFM at 150 psi, will be generated on site by a small electrical compressor.

In option 1 power lines to accommodate the 720 Kw demand will have to be tied into the new plant. In options 2 and 3 power will be generated at the new plant and distributed within remainder of the existing facility. In addition some excess power may be sold back to the utility company.

3.1.5 Assessment of Sale/Distribution or Use of Production

Task A - Characterize Fuel Output

A. Gas Product

The low Btu gas produced in the FBG process is a valuable fuel byproduct. The Btu value of the fuel varies with reactor temperature as previously shown in Figure 3.1.1-9, and the gas composition is at the various temperatures as given in Table 3.1.5-1. The primary consideration in evaluating the gaseous product is the heating value of the gas since this gas will be used as a fuel.

Due to the on site energy demand, the low Btu gas will be consumed in its entirety at the existing plant site. Since the energy is being consumed in the process which is generating the rice hull fuel, as long as the fuel is being produced on site there will also be an on site energy demand and market for the low Btu gas.

B. Char Product

The primary byproduct from the proposed alternative fuels production which will not be consumed on site is the rice hull char. Extensive testing was performed on the char produced in the pilot plant in conjunction with the marketing study. The composition of the char produced varies with reactor temperature as shown in Table 3.1.5-2. With increasing reactor temperature the ash content of the char also increases, and the fixed carbon content decreases. The heating value of the char on an ash and moisture-free basis was found to be constant for the char produced.

One char sample was selected for additional analysis, since the results from this sample can be applied to the other samples. The char produced at the 1604°F bed temperature was used in the analysis since it was closest to the actual design temperature of 1530°F. The additional analysis was quite extensive such that a complete marketing study could be conducted. A description of the detailed testing and results is discussed in the following paragraphs.

TABLE 3.1.5-1

NON-CONDENSIBLE PYROLYSIS GAS COMPOSITION (VOLUME %)

BED TEMPERATURE (°F)	GASEOUS COMPONENT							
	CO_2	H_2	C_2	O_2	N_2	CH_4	C_3	CO
1083°	15.90	2.63	0.26	0.89	56.43	3.53	0.59	19.77
1260°	12.96	4.92	0.35	0,87	54.87	4.52	0.11	21.39
1431°	14.00	7.92	0.39	1.12	49,23	5.86	0.45	21.03
1604°	13.69	6.82	0.09	0.78	55.51	4.90	0.34	17.87

Table 3.1.5-2

RICE HULL CHAR COMPOSITIONS AT VARIOUS BED TEMPERATURES

Bed Temperature (°F)	Ash (%)	Volatiles[1] (%)	Fixed Carbon (%)	Heating Value (Btu/lb)[2]
1083	67.4	6.7	26.0	14304
1260	71.3	5.1	23.6	15842
1431	73.3	6.5	20.2	12165
1604	93.4	3.3	3.3	13349

1. Volatiles defined as those components driven off up to 1800°F.
2. Ash and moisture free basis.

RCRA Analysis

The dominant federal legislation affecting the storage, handling, transportation, and disposal of solid byproducts from pyrolysis and combustion processes is the Resources Conservation and Recovery Act of 1976 (RCRA). The RCRA legislation, once implemented, will establish a relatively uniform set of requirements for the nation because few states will have regulations more stringent than those proposed by EPA. For now, the RCRA program is embodied in Proposed Rules published in the Federal Register, May 14, 1980.

Under the Proposed Rules, solid wastes or byproducts are grouped into three categories: (1) hazardous wastes; (2) non-hazardous wastes; and (3) special wastes. Wastes may be classified as hazardous for any of the following reasons:

- The waste or byproduct is "listed" as hazardous due to known environmental hazards.
- The waste or byproduct fails EPA-proposed tests in the following areas:
  - i. Toxicity
  - ii. Ignitability
  - iii. Reactivity
  - iv. Corrosivity

The rice hull char leachate was well under the established toxicity limits tested for under this legislation, as shown in Table 3.1.5-3.RCRA toxicity tests were not conducted for pesticides and herbicides since these compounds would have been destroyed in the FBG reactor. No test procedures have been established for ignitability, reactivity and corrosivity of solid materials, hence none were conducted. Based on the pilot plant experience in handling, storing and transporting the char no reactivity, corrosivity or ignitability has been observed. It is our experience that the char is essentially chemically inert. In conclusion, the char produced from FBG of rice hulls was found to be a non-hazardous waste as defined by the present RCRA legislation.

2/3/81

Table 3.1.5-3

TOXIC SUBSTANCE ANALYSIS

Report Sheet
(µg/l)

Maximum Contamination Level		5,000	100,000	1,000	5,000	5,000	200	1,000	5,000
ERCO ID	Client ID	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
56-40	RICE HULL FIBER CHAR	20	<100	<0.5	<5	15	<0.2	<5	<0.5

If the customer has any questions regarding analyses, he should refer to samples in question by their ERCO ID#.

Toxicological Effects of Solid Wastes or Byproducts

Toxicological effects of solid wastes were evaluated by the use of a battery of EPA Level-1 health and ecological effects tests. The health effects tests used for toxicological evaluations were the Salmonella/Microsome Mutagenesis Assay (Ames Test), Rabbit Alveolar Macrophage (RAM) Test, CHO Clonal Assay, and Acute In Vivo Test in rodents. The ecological effects tests conducted were the Freshwater Algal Bottle Assay with Selenastrum Capricornatum, Acute Static Bioassays with the fathead minnow and water flea, and the Soil Microcosm Test. The results of these tests are summarized in Table 3.1.5-4 and discussed below. Refer to Appendix B for the complete test reports.

The Ames Test is used to identify substances which as mutagens or carcinogens pose a serious health risk to those exposed to the substance. This test measures the ability of a substance to induce mutations in the Histidine Biosynthetic Pathway of Salmonella Typhamurium. The rice char was found to be non-mutagenic in all strains at all concentrations tested, and hence presents no mutagenic health threat to those who come in contact with the material.

Table 3.1.5-4

Summary of Toxicological Tests on Rice Hull Char

Test	Result LD50 or LC50(1)	Level of Toxocity
Salmonella/Microsome Mutagensis (Ames Test)	-	negative
Acute *In Vivo* Rodent Toxicity Assay	3.0g/kg	low
CHO Clonal Assay	205 µl/ml	low
Rabbit Alveolar Macrophage Cyto Toxicity Assay	200 µg/ml	low
Algal Bottle Assay	56.5%	moderate
Fathead Minnow	38.5%	low
Water Flea	24.6%	low

(1) Mean Lethal Concentrations or Dose

The RAM Test provides a method for analyzing the potential toxicity of inhaled substances. A low level of toxicity was found for the char sample, indicating that no serious health threat is posed by the inhalation of this substance. The CHO Clonal Assay is used for evaluating the potential toxicity of a substance to mammalian cells in a culture. The test results also showed a low level of toxicity, indicating that the char has a low level of toxicity to mammals. The acute In Vivo Rodent Assay is used in evaluating the toxicities due to pure chemicals as well as complex mixtures. This test, since it is conducted on whole living animals, allows a reliable interpretation of test results and the possibility of drawing conclusions about the potential hazard of the char to human health. Again a low level of toxicity was observed, indicating that human exposure to the char is only mildly toxic.

The ecological effects tests are used in evaluating the toxic effects caused by the discharge of pollutants in the water supply of the plant and animal life. The Algal Bottle Assay is used to assess the toxic effects of the effluent discharge from the rice hull char on freshwater green alga. The char had a moderate level of toxicity on the alga, with a mean lethal concentration of 56% using an aqueous extract as described in Appendix B. The char had a low level toxic effect on the animal life as indicated by the fathead minnow and water flea tests.

The soil microcosm test was conducted in order to evaluate the possible detrimental effects which land filling or open storage of the char would have on the microcosms in the soil. The char did not have any disruptive effect on the dynamic equilibrium state established by the soil microcosms, and furthermore no evidence of degradation of the char was observed. These results indicate that the char is inert with respect to the soil microcosms.

In conclusion, the toxicological tests conducted in the char were encouraging. In almost every test the char was found to display a low level of toxicity, confirming its inert nature and increasing the marketing potential of the char.

Organic Analysis

EPA Level 1 organic analysis was conducted on the char in order to identify the organic compounds contained in the char, and thereby better identify any possible detrimental characteristics of the char. The total organic levels found were quite low. 0.04%, as shown in Table 3.1.5-5. The compounds found, also listed in Table 3.1.5-5, are those expected from incomplete combustion and are typical of those found in non-harmful substances like charcoal. This analysis helps to confirm the low level of toxicity found in these tests.

Inorganic Analysis

A complete inorganic analysis was conducted using spark source mass spec as defined in the EPA Level 1 inorganic analysis. The complete results are given in Appendix B, which also gives the levels of the unburned rice hulls. No high levels of toxic metals were found, confirming the RCRA analysis.

TABLE 3.1.5-5

ORGANIC ANALYSIS OF RICE HULL CHAR (1)

I. GC/MS Data

Compound	Estimated concentration (µg/g)
Benzoic acid	5.2
Fluorenone	3.4
Phenanthrene	9.5
Anthraquinone	1.3
Fluoranthene	9.5
Pyrene	8.2
Chrysene/ benzo(a)anthracene	1.3

II. Gravimetric and TCO Data

TCO	1.8 mg
Grav.	0.1 mg
Total TCO + Grav.	1.9 mg
Conc.	0.4 mg/g
Total organics/ entire sample	16.4 mg/g
%organics in entire sample	0.04

(1) Taken from Level 1 Organic Analysis Report, 6/19/81, prepared by Energy Resources Co., Environmental Sciences Division.

Task B - H - Identify Potential Uses, Identify Processing Needs, Quantities Needed and Produced, Compile Assessment

These tasks will be discussed in detail in Section 2.2.3, the market/use analysis section, in which potential market uses will be analyzed in detail.

3.1.6 Procurement of Equipment Schedule

Task A - Identify In-Place System Components and Specify Equipment Needed

The equipment lists previously developed and given in Appendix A list the major equipment specifications for the equipment which will be purchased for the proposed plant. Detailed equipment specifications were made for all major equipment and vendors contacted. Prices, delivery dates and other specific requirements were obtained for each piece of equipment.

Task B - Compile Information and Develop Schedule

Deliveries for the specified equipment ranged up to 24 weeks for the longest lead items, with most items having deliveries of 14-16 weeks. The deliveries for each item are given in Appendix A.

3.1.7 Management Plan for Project Leading to Commercialization

Task A - Outline Scope of Work

The work breakdown leading to the completion of the proposed facility consists of engineering, equipment procurement, site and building erection, equipment installation and start-up phases. Subcontractors will be required in the following areas: (1) site preparation, (2) building erection, (3) equipment installation, (4) miscellaneous installation including electrical, utility connections and instrumentation. In-house work will include the detailed design engineering, project management and start-up engineering.

Task B - Develop Constraints and Project Timing

Each major activity identified in Task A will require certain constraints in order to prevent delays in the project schedule. The engineering requirements are such that two to three engineers and a designer must be available during the first three months of the project to provide the necessary detailed engineering design to proceed with the remaining phases of the project. The major constraint to the equipment procurement schedule is that payment terms be worked out, the project budget adhered to, and the equipmnet specifications be released on time by the engineering group. Possible constraints to the site preparation and building erection will include subcontractor selection and payment terms, labor relations, weather conditions, and timely release of engineering documents. Problems associated with equipment installation will be minimized if the delivery and site preparation schedules are maintained.

In all cases delays in the completion of previous tasks will directly effect the schedule of all subsequent tasks. Hence emphasis will be placed on maintaining the initial schedules such that delays will not be transferred into the remainder of the project schedule.

Tasks C & D - Identify Resources Available, Develop CPM Chart and Finalize Scope of Work

Using the equipment delivery schedules, projected manpower requirements and subcontractor time estimates a preliminary CPM chart was developed for the proposed project, as shown in Figure 3.1.7-1. The critical items are identified and their relation to the overall project timing shown.

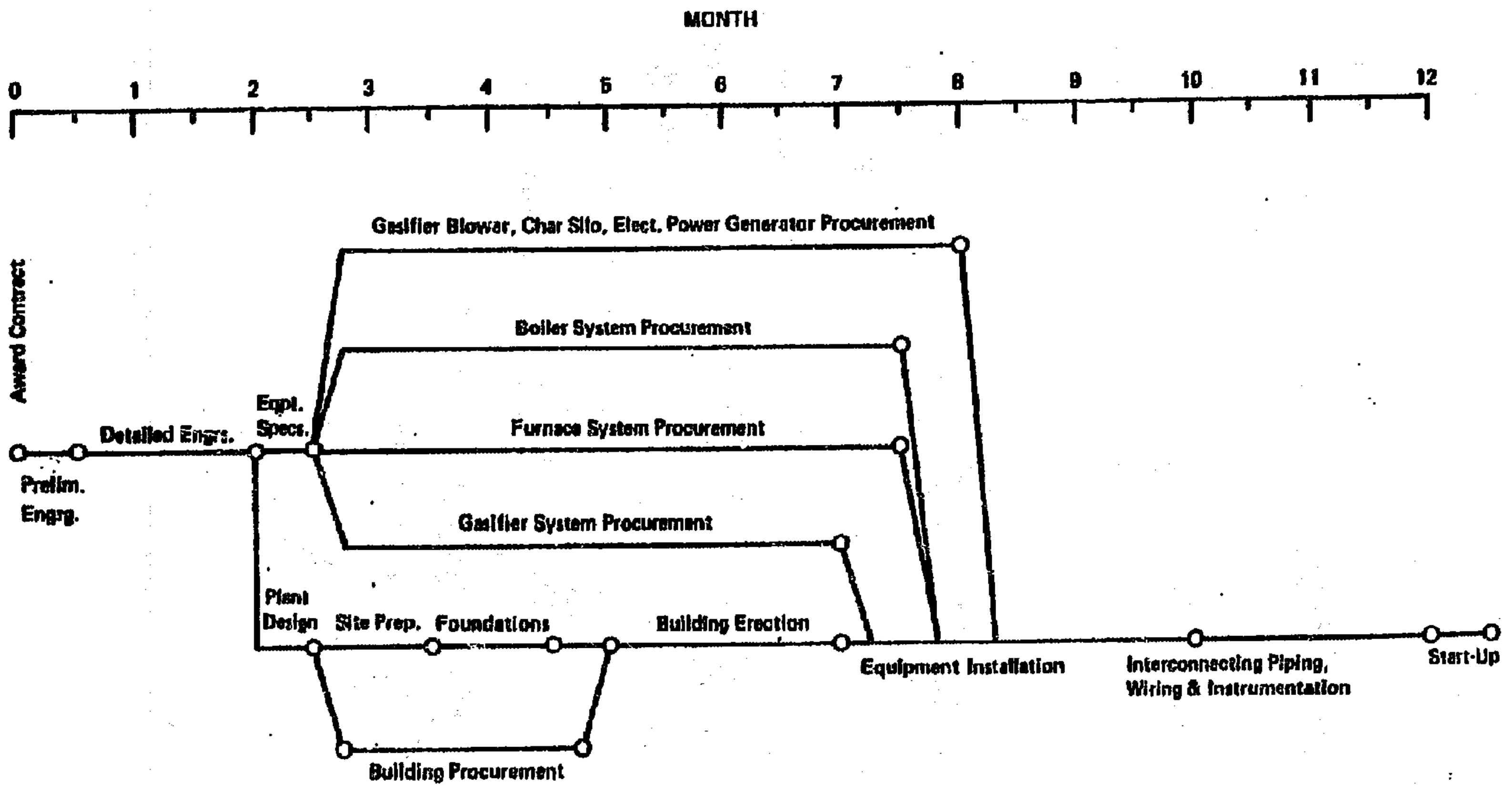


Figure 3.1.7–1. CPM Chart for Proposed FBG Plant.

Task E - Develop Manpower Needs and Budget

Cost estimates were developed for all three of the process options being considered for more detailed economic analysis. In-house manpower requirements, travel requirements, consultants, subcontractors and other direct costs were estimated and used with the equipment cost estimates given by the vendors in developing budgetary cost figures. These estimates are based on previous experiences on jobs similar to the proposed project. The total costs for the three process options are given in Section 3.2.1 which gives capital and operating cost estimates.

Task F & G - Identify and Contact Potential Subcontractors for Project

The subcontractors required for this project fall into the following basic areas: (1) site preparation and foundations, (2) building erection, (3) equipment installation and (4) interconnecting piping, ducts, and wiring. Each of these areas will require one or more subcontractors, depending on the specific task.

Local contractors were contacted in the Houston area related to the above tasks. In addition subcontracted services supplied by major equipment vendors were also considered. For example, the supplier of the furnace can also provide complete installation services for the furnace and all associated equipment such as the blower, heat exchanger and interconnecting duct work. It was found that in many cases allowing the major equipment suppliers to provide subcontracted services was more economical and effective. For the smaller items like the electrical and instrument installation local subcontracted services presently being employed by the existing plant may be employed.

Task H - Finalize Management Plan

A proposed project schedule was developed using the information gathered in the previous tasks. Figure 3.1.7-2 shows the proposed project schedule, and projects a mechanical completion time of 12 months from award of contract.

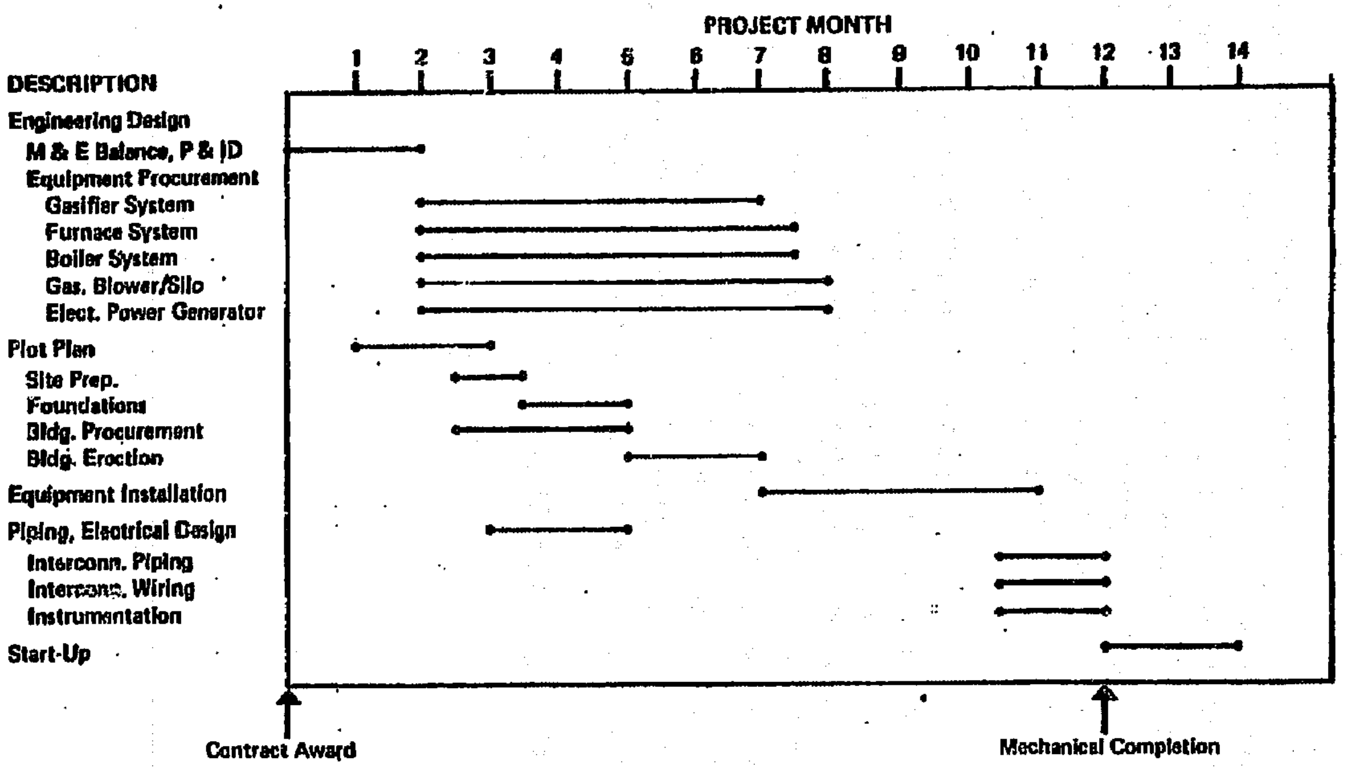


Figure 3.1.7–2. Project Schedule for Proposed FBG Plant.

3.1.8 Assessment of Uncertainty of Commercial Applications and What Needs To Be Done

Task A-C - Identify and Quantify Risks, and Identify Options

The technical risks of the proposed plant have been kept to a minimum by taking advantage of the previous experience in design and operation of FBG plants. In addition the purchased systems will be carefully evaluated to minimize possible technical risks and to insure expected lifetimes of at least ten years.

The process control instrumentation has also been carefully selected to minimize upset conditions which could result in component failure. These controls will give advanced warning and automatically shutdown the process in proper sequence before damage can occur. Some of the additional risks which have been considered and the solutions to the problems are discussed below.

The gasifier front end system consists of the solids feed systems to deliver the feed to the reactor. It is possible that plugs could develop in this system which could result in loss of feed and/or the overloading of drive motors. The easiest solution to prevent the interruption of normal operation is to employ a dual feed system to each gasifier with each rated to handle 100% of the gasifier feed rate. This arrangement will allow for continuous operation while corrective action is being taken.

The gasifier vessel is designed for continuous trouble-free operation, with generous access openings to allow for any possible maintenance. Some possible problems which may be encountered in the gasifier are the fusing of bed material, refractory erosion and distributor plate blockages. The bed fusion problem is the result of misoperation and corrective action can be employed in the process operations.

The vessel shall be designed to allow for the changing of bed material during operation by providing the necessary drains. Premature failure of the refractory lining can be avoided by allowing for the highly erosive conditions encountered in fluidized bed applications. In the event that the refractory fails prematurely, the vessel shall be designed to allow for easy access and repairs. Risks associated with the failure of the distributor plate can be minimized by proper design methods. In summary many of the potential risks associated with the gasifier vessel can be minimized by employing a good vessel design. The previous experiences gained by ERCO in these areas will insure this end.

The down stream ducting and cyclones will not pose any risks beyond possible refractory erosion and blockages. These problems will be kept to a minimum by employing good design practices and careful monitoring of the operations.

The down stream boiler and furnace or electrical power generation equipment will be purchased from reliable sources which have had experience in the combustion of low Btu gas. The boiler operation should be highly reliable since similar installations have had good operating histories. In addition major risks are avoided since these package boilers are designed to code and include all of the necessary safety features. A high erosion rate due to the high silica ash in the gas and glazing of the refractory linings can be potential risks associated with the operation. The boiler linings shall be designed to allow the high erosion rates, and the glazing shall be eliminated by keeping the combustion temperatures below the glazing point of the silica. It is also possible that an upstream upset could cause the interruption of the supply of low Btu gas and hence cause the loss of steam generation capability. This risk can be avoided by using a boiler which can also fire on natural gas and pipe in natural gas for emergency use.

The furnace is also a highly reliable system, similar to one which ERCO has had in operation. The potential risks associated with erosion and glazing can be handled in a manner similar to those associated with the boiler.

The electrical power generation equipment, both gas engine and gas turbine, are proven technologies and have a high level of reliability. Low Btu gas has been used to fire these systems and no problems have been found for this application, although it is still a relatively new application.

3.1.9 Contingency Plan Formulation

Tasks A-C Formulate Monitoring, Develop Budget and Implementation Plan

The possible risks identified in the operation of the proposed plant have been discussed in the previous section. The problems will manifest themselves in the form of complete or partial equipment failure or production of off spec products. The plant will be continuously monitored by keeping process log data sheets which will indicate trends in operation and all breakdowns. These log sheets will monitor key parameters for each component at intervals such that a potential failure can be predicted and a contingency plan can be implemented on a timely basis.

Contingency plans have been formulated for various events and included in the operation manual for the system. In general small failures and process problems can be corrected by following the directions in this manual. Major process or equipment problems which may develop will require additional analysis by qualified engineers. It is felt that with the proper engineering assistance and implementation of the proper corrective procedures complete component failure can be avoided.

In most cases the costs associated with insuring a minimum of risks have been incorporated in the original design and equipment costs of the system. For example, the gasifier front end feed system will include a back-up since each feed line can handle the complete feed rate. This conservative design philosophy is common to all areas of the process in which potential risks have been identified.

To allow for unexpected problems 3% of the capital cost has been included in the annual budget for the proposed plant under "maintenance" costs. This amount will be enough to cover all contingencies associated with the operation, including replacing of motors, repair to refractory and other equipment failures which may occur.

3.2 Economic and Financial Analysis

3.2.1 Capital Requirements and Operating Costs

Task A: Project Specification

Capital requirements and operating costs are presented for the three options discussed previously in this report. In Option 1, rice hulls are gasified in an FBG and the low-Btu gaseous fuel is combusted in a boiler for steam generation and also a furnace for making hot air for process drying. In Option 2, the low-Btu gas is fed to both a boiler and a gas turbine for electrical power generation. Option 3 is identical to Option 2 except a gas engine is used for electrical power generation. Refer to Figures 3.1.2-1, -2, and -3 in Section 3.1.2 for detailed PID's of the process options.

Tasks B and C: Outline Other Considerations and Facility Costing

Environmental, site, product demands, and fuel availability issues have all been addressed for the proposed processes. These issues are discussed in detail in other sections. In summary, no offsets need to be purchased to comply with the environmental regulations, and the costs for the Best Available Control Technology (BACT) are included in the capital costs. The optimum site for the proposed plant was found to be within the existing ARI facility in Houston, Texas and the costs reflect this selection. Costing for the products was based on current on-site fuel costs, and the by-product values are discussed in a later section.

Table 3.2.1-1 presents the capital requirements for each option. Included are equipment purchased and installation costs as well as indirect costs incurred during construction.

This estimate does not include, however, administrative charges, corporate overhead allowances and working capital requirements.

The investment amounts for each option were established by calling on vendors for equipment cost assessments.

TABLE 3.2.1-1

CAPITAL COSTS
(In Thousands of 1981 Dollars)

CAPITAL COSTS	OPTION 1	OPTION 2	OPTION 3
Equipment	4,884.0	6,672.7	7,690.1
Installation	390.0	405.4	405.0
Indirect	693.7	691.9	691.9
Total Plant	5,967.7	7,770.0	8,787.0

TABLE 3.2.1-2

FIXED OPERATING EXPENSES
(In Thousands of 1981 Dollars)

	OPTION 1	OPTION 2	OPTION 3
Labor[a]			
Supervisor	$ 40,000	$ 40,000	$ 40,000
Maintenance and Operator	$261,630	$261,630	$261,630
Total Labor	$301,630	$301,630	$301,630
Maintenance Material	$264,000	$264,000	$264,000
Utilities (stand-by)	--	100,000	100,000
Miscellaneous	50,000	50,000	50,000
Total Fixed Operating Costs	$615,630	$715,630	$715,630

[a] Supervisor: $40,000 p.a.
Maintenance and Operator labor:
5 first-class stationary engineers @ $32,000 p.a.
4 third-class stationary engineers @ $25,400 p.a.
Overtime is figured into annual salaries.

TABLE 3.2.1-3

VARIABLE OPERATING EXPENSES[a]
(In Thousands of 1981 Dollars)

	OPTION 1-3[b]	
Rice Hulls		
Feed Rate	340 ton/day	
Unit Costs	$5/ton	
Operating Time	292 days	
Total Costs p.a.		$496.4
Char Disposal		
Production Rate	84.6 ton/day	
Disposal Costs	$5/ton	
Operating Time	292 days	
Total Costs p.a.		$123.5
Total Variable Operating Costs		$619.9

[a] Annualized cost data are based on an 80% load factor (292 days of 365 days).

[b] The variable operating costs are the same for each option.

Operating costs are subdivided into a fixed and a variable portion. Fixed operating costs comprise those expenses that are incurred regardless of short-term changes in operations. In this case, they are labor, maintenance materials, utilities' stand-by charges and an allowance for miscellaneous expenses. Table 3.2.1-2 shows estimated fixed operating costs for each option based on current labor and utility costs in the Houston, Texas area.

Variable operating costs are incurred only when the plant is operating. They include feed costs for rice hulls and the expenses for disposing of the produced char for option 1; where electricity is not generated by the plant, expenditures for power needs are also a variable cost. Table 3.2.1-3 itemizes the variable cost estimates for the ARI facility. Underlying is a capacity of 365 days and a load factor of 80 percent. Under each option the variable operating costs are the same because feedrates and unit costs are expected to be equivalent.

Operating costs were arrived at by reviewing the literature, client discussions and engineering judgment. The numbers have adequate contingencies figured in.

Project revenues are generated by the production of steam, hot air and electricity. Revenues are different under each option depending on the degree to which power needs are covered internally.

The unit prices were determined by taking the current market value for each energy category in the Houston, Texas area as a proxy. Table 3.2.1-4 exhibits estimated revenues for each option. The calculations assume an 80 percent load factor or 7000 hours of operation per annum.

TABLE 3.2.1-4

REVENUES
(In Thousands of 1981 Dollars)

	OUTPUT PER OP. HOUR	UNIT PRICE	REVENUE[a] (per annum)
Option 1			
Steam	30,000 pph	$4.87/p	$1,023.9
Hot Air	34.7 MMBtu/hr	4.00/MMBtu	972.7
Total Revenues			$1,996.6
Option 2			
Steam	30,000 pph	$4.87/p	$1,023.9
Hot Air	34.7 MMBtu/hr	4.00/MMBtu	972.9
Power	1,202 kW/hr	0.04/kW	335.9
Total Revenues			$2,332.5
Option 3			
Steam	30,000 pph	$4.87/p	$1,023.9
Hot Air	34.7 MMBtu/hr	4.00/MMBtu	972.7
Power	5,170 kW/hr	0.04/kW	1,449.3
Total Revenues			$3,445.9

[a] Assumes 7008 hours of operation, i.e., 80% of capacity.

To carry out a meaningful analysis, a number of general economic parameters as well as project-specific variables need to be defined. Table 3.2.1-5 contains a list of these factors. Those needing further explanation are discussed below.

American Rice, Inc. is an agricultural cooperative and as such is not subject to income taxes. Thus, the income tax rate equals zero for this project, too.

The investment tax credit rate amounts to 20 percent of that part of the total plant investment which is not structure related. To account for this, an 18 percent rate has been applied to the total plant investment as shown in Table 3.2.1-1.

The Double Declining Balance method for depreciating the plant has been chosen as the most appropriate one, assuming no terminal value at the end of the estimated operating life of 10 years. General inflation is expected to run at 10 percent per annum. For energy-related items, such as opportunity costs for utilities' products, a rate of 15 percent per annum was determined. Historically, prices for energy-related goods and services rise approximately 50 percent faster than prices of the overall market basket.

Construction of the plant is planned to start in January 1982 and to last for 1 year. Short-term interest on construction loans is estimated at 14 percent per annum.

All computations are based on an 80 percent effective production rate (292 days of 365 days). The initial investment, the operating costs, the project revenues, and the parameters outlined above form the basic inputs for the investment analysis that follows in Section 3.2.2.

TABLE 3.2.1-5

MACROECONOMIC PARAMETERS, TAX AND FINANCIAL ASSUMPTIONS

Inflation		
Operating Expenses	- Fixed	10% p.a.
	- Variable	15% p.a.
Revenue		15% p.a.
Interest	- Short Term	14% p.a.
Tax	- Income Tax Rate	0.0% p.a.
	- Investment Tax Credit Rate	18%
Insurance	- Based on Plant Investment	2%
Depreciation	- Method: Double Declining Balance	
	- Operating Life	10 years
Salvage Value		0
Construction Period		1 year
Construction Starting Date		1/1/82
Plant Startup Date		1/83
Plant Effective Capacity		7,008 hours 292 days p.a.

3.2.2 Investment Analysis

Tasks A and B: Modeling Analysis and Assessment of Facility

This section assesses the economic impact of recycling rice hulls to produce readily usable energy sources. The analysis is divided into two parts: the first passage defines a common unit of measurement based on which the economic impact of the three options can be examined and compared. Only the option with the most positive economic results will be further analyzed in a second part where the sensitivity of the project's economic viability is tested towards varying key assumptions.

Various methods exist to compare alternative investment opportunities. In this analysis, the criterion used is an internal rate of return computation, titled return on investment. Discounting the project cash flows at the internal rate of return will yield a net present value of zero. Thus, the higher the rate, the more attractive the project from an economic viewpoint.

The cash flows are calculated before compensation of capital supplies, thus not making them subject to change owing to the financing arrangement chosen.

For the base case analysis the most likely point of a range of uncertain events is selected for the calculations. Sensitivity analysis explores the degree of uncertainty intrinsic to the calculated rate of return. The assumptions of each key parameter are varied across a predetermined range and the impact on the rate of return measured.

The cost, financial, tax, and economic assumptions described above comprise the base case. Appendix B contains detailed information on each option, including sources and uses of funds statement, a balance sheet, an income statement, all projected over the expected life of the project. Table 3.2.2-1 finally displays a summary of the base case for each option.

These data, and particularly the summary in Table 3.2.2-1, clearly indicate that Option 3 yields a significantly higher return than Options 1 and 2. The return on investment amounts to 36.8 percent for case 3 as opposed to only 21.4 percent and 23.1 percent for cases 1 and 2.

Thus, on economic grounds, option 3 is superior over the other two facility alternatives. They should be excluded in favor of option 3 which yields the most benefits to the interested parties.

The following sections of the Economic and Financial Analysis include only option 3 since they would not change the attractiveness of option 1 vis-a-vis the two other alternatives.

3.2.3 Other Project-Related Costs/Benefits

Tasks A and B: Identify Other Costs and Modeling Assessment

The socioeconomic costs and benefits created by this alternative source of energy are discussed in Section 3.6, Environmental, Health, Safety and Socioeconomic Consideration. These costs and benefits are of an intangible nature and a concrete value has not been assigned to them. This is the reason why they have not been directly entered into the investment analysis. It is clear, however, that option 3 remains the most desirable one even when including these imponderables, because they are not significantly different for any of the three alternatives.

3.2.4 Risk Analysis

The return on investment calculated in Section 3.2.2 only applies if the assumptions outlined in Section 3.2.1 for the various parameters occur as stated. However, because each variable is uncertain and calculated only for the most probable case, deviations can be expected.

The following section identifies and discusses the main sources of risk inherent in the American Rice, Inc. energy generating facility. Section 3.2.5 in turn will include a sensitivity analysis which is a quantification of the risks outlined and qualitatively analyzed below.

Tasks A-E: System Supply and Market Reliability, Environmental Constraints and Risk Measurement and Adjustment

Although there are risks linked to almost every input variable, they can be categorized into five main groups: uncertainty in the magnitude of plant investment; uncertainty in fuel costs; uncertainty in operating costs; uncertainty in the economics for char disposal; and uncertainty in the market prices (including inflation) of produced energy.

Capital Cost - A careful analysis of the equipment required to build the system within the planned timeframe resulted in an estimate of an initial capital investment of $8.787 million. Even though equipment costs were assessed by

TABLE 3.2.2-1

SUMMARY FINANCIAL PROJECTIONS

OPTION 1

PRESENT VALUE CALCULATIONS-NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cash Flow Bar	-5898.1	1019.4	877.3	1102.9	1370.1	1685.8	2058.1	2496.5	3011.8	3616.8	4326.0

Rate of Return on Investment:	21.41
Rate of Return on Equity:	21.43
Payback Year:	1987
Total Cumulative Cash Flow Bar:	15666.8

OPTION 2

PRESENT VALUE CALCULATIONS-NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cash Flow Bar	-6079.7	1554.8	1382.3	1696.4	2066.0	2500.0	3009.2	3605.8	4303.9	5120.1	6073.5

Rate of Return on Investment:	23.06
Rate of Return on Equity:	23.06
Payback Year:	1987
Total Cumulative Cash Flow Bar:	23232.4

OPTION 3

PRESENT VALUE CALCULATIONS-NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Cash Flow Bar	-9712.7	4007.1	2890.8	3433.6	4066.1	4802.5	5659.4	6655.8	7813.9	9159.0	10720.5

Rate of Return on Investment:	36.88
Rate of Return on Equity:	36.94
Payback Year:	1985
Total Cumulative Cash Flow Bar:	49496.0

calling on potential suppliers, there is a chance that the market situation will change between now and the time when the actual purchases are made and prices for such items increase/decrease. This would result in a change in capital costs and thus in the overall profitability of the project.

Another factor that could potentially impact the magnitude of the initial investment is construction delays. The time schedule presented in this study has been established using best engineering judgment. Nevertheless, unforeseeable events such as strikes, natural catastrophes, etc. could disrupt the construction timetable and result in delays. The ensuing impact on plant expenditures could significantly disrupt the economics of the project.

<u>Fuel Costs</u> - There are two main sources of risk associated with fuel costs: one related to availability, the other to price changes.

Rice hulls are the main source of fuel supply for the facility in question. Because rice hulls are produced by ARI during the process of upgrading rough rice, hulls should be readily available as long as ARI operations keep up planned rice production. Fuel supply, therefore, is exposed to little uncertainty and presents a relatively minor risk.

In contrast, price changes for rice hulls largely depend on the demand situation for this commodity. Section 3.1.1 and Table 3.1.1-1 discuss the potential uses of rice hulls. The past changes in the value of rice hulls show it to be rather volatile. However, even though opportunity costs can be expected to fluctuate, it is unlikely that any of the present uses places a higher value on rice hulls than gasification does. Thus the downside risk from this source is rather low.

Operating Costs - This cost category comprises maintenance, labor, utilities stand-by, and miscellaneous expenses. The last three expense items (labor, stand-by and miscellaneous) are fairly predictable in nature and thus bear limited risk. Maintenance costs are to a large extent a function of system reliability. If the plant runs as expected, maintenance costs will be within close proximity of the base case assumptions. There are, however, a number of reasons why the system could not operate as smoothly as predicted. There are two specific areas that contribute to this uncertainty. One is the system technology per se, the other is lack of inexperience in operating the plant in question. While the latter should only be a temporary phenomenon and would disappear as the operating staff slides down the experience curve, the former is potentially more serious in nature.

Even though various in-depth pilot and feasibility studies have been conducted for the case under consideration, an increase in maintenance costs due to either inexperience in the system's operations and/or system unreliability cannot be entirely eliminated. Particularly during the initial phases of operation, unfavorable deviations from the base case assumptions are not abnormal. The base case assumes an inflation rate of 10 percent per annum for operating costs, which is the expected average inflation rate for the Houston area over the life of the project. Since inflation has a large corresponding impact on any cash flow stream, a relatively minor deviation of the general inflation rate can have a very large effect on the magnitude of operating costs. At present, it is very difficult to evaluate a rate of inflation beyond a relatively short period of time, which adds further to the uncertainty of this expense item.

Char Value - Uncertainty regarding the char market is very limited on the downside because the base case assumes a rather conservative scenario for this expense. Because of the characteristics of char, as described in Section 3.3.2, it could conceivably become a product for which a buyer is prepared to pay a substantial amount of money. Thus, char has the potential to influence the economic attractiveness of this project significantly.

Energy Products - The items included here are steam, hot air, and power. There are two possible sources of uncertainty associated with these products, namely marketability and price changes.

Marketability and price of a product are closely interlinked since usually the former can be expressed as a function of the latter, i.e., the lower the price the higher the marketability of the product. In this case, however, ARI constitutes a captive market for the energy output of the system and, hence, the fundamental marketing risk is somewhat limited.

The base case takes the market price in the Houston area as a proxy for steam, hot air, and power prices and adds an annual expected inflation of 15 percent. Any hikes in energy prices beyond this mark will improve the economics of the project, whereas lower increases will diminish it. Should alternative public power, steam, and hot air supply become less expensive than marginal production costs at the plant, then, from the perspective of American Rice, Inc., a switch is advisable and a shutdown of the facility economical. The overall financial viability of this project is greatly dependent on the market price of the sources of energy produced. Uncertain market prices, of course, materially enhance the riskiness of the project.

Summary

The above is an inventory of potential power of risk affecting this project. Not included are risks that fall under the force majeure category. The most notable are changes in the environment, such as a modification of the regulatory setting. Concluding, the risks outlined are considerable as is normal for new, alternative energy technologies. These risks are further stressed because fluidized-bed energy systems are relatively capital-intensive and a substantial financial commitment is required. A payback period of 4-5 years leaves the invested capital to the caprices of an uncertain future for rather a long time.

3.2.5 Sensitivity Analysis

Tasks A and B: Modeling Assessment, Analyze and Compile Results

In the previous section various sources of risk have been identified and discussed. This section now examines how the return on investment is influenced when the input variables are changed. To make such a comparison possible, an extensive analysis was conducted, a synopsis of which is displayed in Figures 3.2.5-1 and -2. (Guidelines for using the graphs are given further on in this section.)

Table 3.2.5-1 presents a summary of the results of the sensitivity and risk analysis. The degree of sensitivity on its own does not suffice to evaluate the calculated return. Rather, each parameter needed to be examined as to the probability of a change in base case assumptions actually occurring. As an example, even though a change in the capital costs has a high impact on the return on investment, such a change has a low probability of occurring, downgrading the overall risk from that source.

From this aggregate perspective, the most significant changes in base case assumptions are expected to originate from the power value parameter and the energy inflation parameter.

As exhibited in Table 3.2.2-1, the expected return on investment from this project is 36.9 percent. At face value, this appears to be a fair return. However, the project is attractive to ARI only if the risk-adjusted rate of return is higher than what could be earned by investing the capital in alternative opportunities. From the sensitivity graphs, it can be elicited that under a bad case scenario, the rate could drop to as low as 10 percent. 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.

TABLE 3.2.5-1

SENSITIVITY ANALYSIS SUMMARY

PARAMETER	DEGREE OF SENSITIVITY[a]	DEGREE OF UNCERTAINTY[b]
Capital cost	High	Low
Rice hull cost	Moderate	Low
Char value	Low	High
Maintenance cost	Low	Moderate
Power value	Moderate	High
Power yield	High	Low
Energy inflation	High	Moderate

[a] Measures the relative sensitivity of return on investment to change in parameters base case assumptions.

[b] Indicates the probability of a change in parameter base case assumptions.

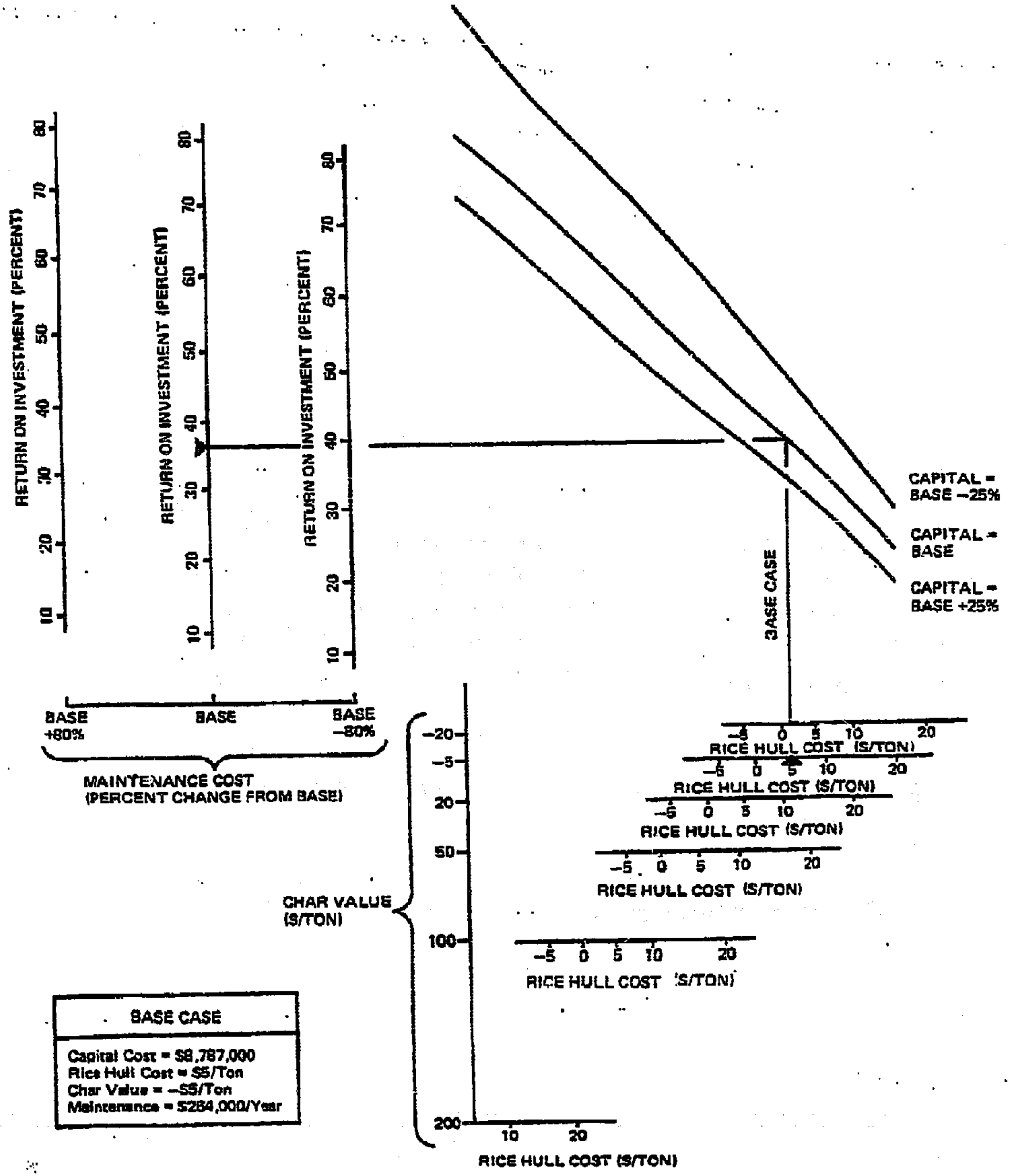
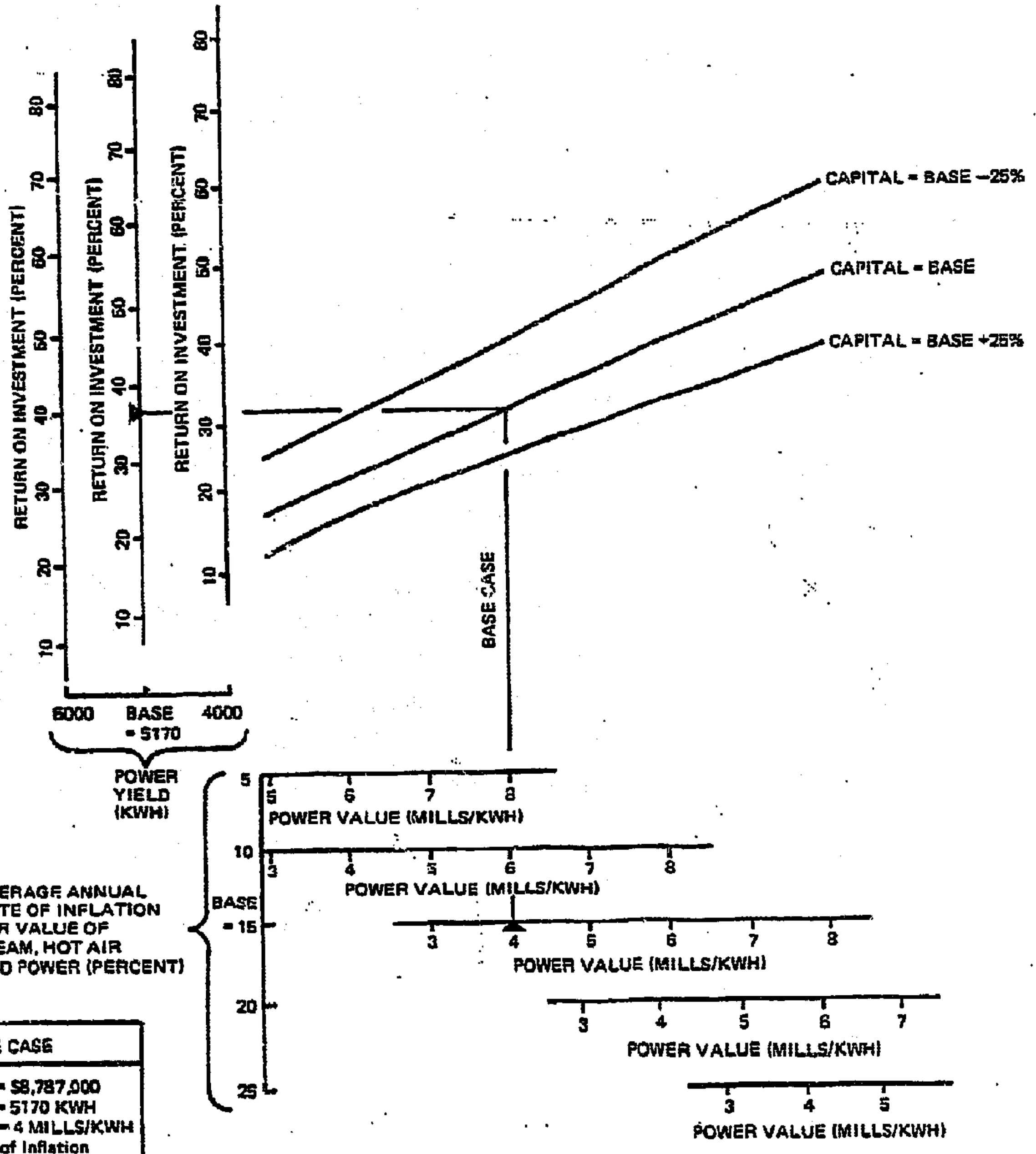


Figure 3.2.5–1. Sensitivity of Return on Investment to Rice Hull Cost, Char Value, Maintenance Cost and Capital Cost.



BASE CASE

Capital Cost = $8,787,000
Power Yield = 5170 KWH
Power Value = 4 MILLS/KWH
Annual Rate of Inflation
Applied to Value of Steam,
Hot Air and Power = 15%

Figure 3.2.5—2. Sensitivity of Return on Investment to Changes in Power Value, Inflation Rate, Power Yield and Capital Cost.

How to Use Sensitivity Graphs

The graphs serve as tools which permit one to measure the return on investment under different case scenarios. They can be used in two ways:

1. The return on investment is determined by attaching values to each parameter.
2. The return on investment is held fixed at a given level and the values of the different input variables necessary to achieve the desired return on investment are computed.

Both the singular and cumulative effect that these changes in base case assumptions have on the return on investment may be obtained in this manner.

The following is an example to illustrate the use of the figures:

I. Situation (from Figure 3.2.5-1)	Change from Base Case
Char value = $20/ton	+ $25/ton
Rice hull costs = $10/hr	+ $5/ton
Capital base = 125%	+ 25%
Maintenance costs = 20% of base case	- 80%

To determine the return on investment:

1. Start with point 20 on the char value scale.
2. Move over to corresponding rice hull cost scale and stop at point 10.
3. Trace perpendicular to the line capital = Base +25%.
4. Head perpendicular to the left to the scale for return on investment, titled "Base - 80%" at the bottom.
5. Read return on investment: approximately 35% in this case.

3.3 Market/Use Analysis

3.3.1 Gas Product

The low Btu gas produced by the gasification of rice hulls represents a valuable fuel source. The most important property of the gas is its heating value, as previously discussed in Section 3.1.5. The FBG is designed to maximize the total heat output of the gaseous fuel by operating at 1530°F and producing a gas with a heating value of approximately 150 Btu/SCF. The low Btu gas composition was monitored during the pilot plant testing and is known over a range of reactor temperatures from 1000°F to 1600°F.

Although the market potential for this fuel may be large, it was found that all of the fuel can be used on site to replace natural gas currently being consumed. The direct use of the fuel at the existing site offers many economic advantages over selling the fuel on the market such as: (1) eliminates transportation costs which will be relatively high due to the large volume per Btu of gas (2) eliminates the need to clean, cool and compress the gas before storage and transporting. This can be an expensive operation due to the large volumes of the gas. (3) Adjustments to existing boilers would have to be made to accommodate the low Btu gas which again is an additional expense and may result in derating the existing boiler or power generator.

The potential uses of the gas at the existing site are for use as fuel for steam generation, process drying, and electric power generation. These options were discussed in detail in the design section. It was found that the use of this low Btu gas directly as a fuel source for process drying was not feasible based on tests conducted at the pilot plant. These tests included the actual drying of wet rice in a rotary dryer using hot flue gases produced by the combustion of the low Btu gas.

In conclusion the current demand for energy at the existing plant has created the ideal market for the low Btu gas produced by the rice hull gasification. As long as the plant is operating and generating the alternative fuel source there will be a demand for the low Btu gaseous fuel in the production of steam, hot air, and electricity.

3.3.2 Char Product

A survey of potential users of rice hull char generated at the American Rice facility in Houston, Texas, is currently underway. ERCO's fluidized-bed system would be used to gasify the 340 tons of rice hulls generated daily at American Rice. This system would produce usable energy in the form of a low Btu gas that would satisfy ARI's energy needs for steam and hot air or electricity. As a result of this process, the by-product char would be formed. Unlike the low Btu gas, ARI would have no use for the char product.

Potential users and markets of the char product have been identified and are being surveyed to determine interest and the likelihood of developing an economically viable market. The char is storable and transportable; therefore, the locus of feasible users of char depends on the transportation methods and costs available. The higher the market price that could be expected from the char, the farther it could be transported profitably.

The char product has been tested and analyzed for potential markets. Samples of the rice hull char and summaries of the analytical tests performed on the char have been sent out to potential users.

At this time, most of the potential users contacted are still evaluating the char. There has been a lot of interest shown in 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 char can be produced in reliable quantities.

Task A - Identify Product

The char byproduct was generated at the pilot plant at various gasifier temperatures and detailed analysis performed on the char. The results of the analytical tests were given in Section 3.1.5. These results were summarized and sent to potential users to aid in the marketing study.

Task B - Develop Market Profile (Technical, Geographic Constraints)

As stated earlier, the char can be stored and transported so the potential markets investigated were not limited to the immediate vicinity of the American Rice facility. In fact, several of the companies surveyed were not only outside the Houston area, but they were in many different parts of the country.

At this time it is not possible to estimate the size of the potential market for the rice hull char since no previous market has been established. It is felt that once the char becomes available and is used the market potential will expand greatly as will the price of the char. The market may also be cyclical depending on the demand of the final product.

The market potential and size will also depend greatly on actual end use. The potential markets are given in Task C and the approximate sizes of each market can be estimated from Table 3.3-1.

Task C - Identify Users and Substitutes or Competitive Products

Through literature searches companies were identified that have in the past or are presently involved in the marketing and sale of products similar to the char product. Some of the potential uses for the char are listed in Table 3.3-1.

The high carbon content char is produced at lower reactor temperatures, while the low carbon char is produced at higher reactor temperatures. Chars of both high and low carbon contents were produced at the pilot plant and sent to potential users for analysis.

Task D - Develop Product - Market Economics

At this point, there has not been a price formulated for the char product. As in the case of the low Btu gas, the price or value of the char cannot exceed the equivalent value of whatever the char would be replacing. Pricing strategy for the char product is being compiled and analyzed.

Task E - Survey Potential Users and Arrange Field Tests

Potential users of the rice hull char have been identified and surveyed. The proposed project plan and analytical background was presented and comments received.

Several companies were identified in literature searches that had previously been involved in the marketing and sale of a product called "Opal Black" which was also a processed rice hull ash. Through phone conversations with representatives of one of these companies, it was learned that "Opal Black" was only on the market a short time because there was an interruption in their supply of rice hulls. They were selling the rice hull ash in truck load quantities and believe the product is efficient and that there is a viable market for it. They have been looking for someone to build a plant that would generate the rice hull ash, because they believe they have the necessary knowledge to market the char. The technical director for this company is willing to exchange their information and knowledge and also mentioned the possibility of their receiving a "finder's fee" for marketing the char. Depending on the price, there are four major markets they know of.

TABLE 3.3-1

POTENTIAL USES FOR RICE HULL CHARS

I. HIGH-CARBON CHAR

A. Rubber filler and anti-skid agent
B. Asphalt or floor surfacing additive
C. Carbon-paper ink extender
D. Soil amendment
E. Water purification agent, i.e. filtration, coagulation and absorption agent
F. Silicon carbide and silicon tetrachloride manufacture
G. Steel manufacturing
H. Aluminum alloying agent

II. LOW-CARBON CHAR

A. Refractories: porous silica, adobe and lime-silica types
B. Silica glasses
C. Carriers for catalysts, insecticides and fungicides
D. Abrasives: in tumble-cleaning; polishing agents, soft-grit blasting materials, and in handsoaps or toothpastes
E. Oil absorbents, sweeping compounds, oil spill combatants
F. Sodium silicate manufacturing
G. Anti-caking component in fertilizers
H. Suspension agent for porcelain enamels, paint
I. Dehydrating or deodorizing agent
J. Hydraulic cement
K. Agricultural mulches

One of them is a replacement for medium thermal carbon black, as a semi-reinforcing filler by the rubber industry. Due to increasing costs of natural oil and gas, from which carbon blacks are made, it is becoming increasingly important to find economic substitutes for carbon blacks.

Other companies surveyed are testing the char for possible application as a concrete or asphalt filler. It is believed that the addition of a silica ash to concrete would produce a high acid-resistant concrete that could be used in food processing plants.

Chemical companies contacted have expressed a definite interest in purchasing the char product; one, in particular, has inquired about the price structure, shipping point and freight classification for the rice hull char. Another chemical company stated that one possible use they are testing is that of a tacifier or extender, which would be used to make rubber sticky.

A company that is involved in the sale and disposal of fly ash was contacted. They have expressed interest in purchasing the char; however, they are still evaluating the sample that was sent to them.

One company surveyed stated that they are actively pursuing a char source with a high carbon content to use as an alloy with aluminum. Because the flexibility of the fluidized-bed system allows most any carbon content to be specified, it was possible to supply them with a sample of char having a carbon content of 25%. They are also still evaluating and testing the char.

The possibility of using the char in agricultural mulches and compost is also being investigated, and potential users in this area were contacted and given samples of char. One such person surveyed is presently composting rice hulls in a big settling pond to produce a soil conditioner which he bags at a bagging facility on his property and markets. However, he is concerned that he will not be able to continue and receive rice hulls from various facilities in Houston, in that he anticipated that all of the mills would, in the future, turn to utilization of the hulls to produce energy for their process. As a result, he saw his future as not taking and disposing of the hulls but taking and disposing of the char produced from their utilization. He is willing to negotiate a contract to receive the char. He has indicated that his facility is capable of handling 40 truck loads a day, each truck carrying about 15 to 20 tons.

Task F - Pilot Runs to Generate Raw Materials

Information was gathered from potential users on the quantities of char required for testing purposes and the physical and chemical properties desired.

The rice hull char contains high levels of silica. The flexibility of the fluidized-bed system allows most any carbon content or quality to be specified. Depending on the carbon content, the char can be either black or white. Char with different carbon contents has been requested for testing purposes and varying applications.

Task G - Procure Necessary Feedstocks and Perform Pilot Plant Char Generation

Feedstocks similar to those used in the planned commercial scale production facility were provided by American Rice to ERCO's pilot plant to be used to generate the specified char samples.

Samples of the rice hull char were then gathered, tested and analyzed chemically and physically. Sulfur content, particle size distribution, trace metal content, ash content, and toxicity were measured.

The federal legislation affecting the storage, handling, transportation, and disposal of solid by-products from pyrolysis processes is the Resources Conservation and Recovery Act of 1976 (RCRA). Once this legislation is implemented it will establish a uniform set of requirements for classifying solid wastes or by-products. Under the proposed rules as outlined in the December 18, 1978 Federal Register, the rice hull char samples tested can be categorized as non-hazardous wastes.

The other alternative to selling the char would be to dispose of it as a waste product in the most environmentally safe method and as economically as possible.

Industrial waste disposal companies in the Houston area were contacted to determine transportation and disposal methods available to handle the approximately 80 tons of rice hull char expected to be generated daily at American Rice. One disposal company estimated that three or four truck loads would be required to haul off this amount of char allowing for 25 tons of char per load. At this time they have a large, tentative site that would be used for waste disposal of various non-hazardous materials such as fly ash, flue gas sludges and rice hull ash. They are presently in the process of getting the necessary permits and locating participants for their disposal project. A sample of the rice hull char and the testing results showing the char is non-hazardous were sent to them. It is believed that this disposal company could handle the expected output of char; however, they were unable to give us any information on the cost of their disposal methods at this time.

Other disposal companies in the Houston area were contacted and given information about the rice hull char along with char samples. There appear to be no problems in locating a disposal firm to carry off the char if it becomes necessary to dispose of it as a waste product, especially since the char has been proven to be non-hazardous. At this time we are still waiting for information from the disposal companies on their disposal prices.

Task H - Collect and Prepare Char in Proper Quantities; Ship to Potential Users

Char samples were collected as required in containers for shipping to potential users.

In most instances 8 oz. samples were requested; however, certain companies did request larger amounts. The samples were clearly labeled and delivered or mailed in a timely manner.

Task I - Develop and Monitor Field Tests; Compile Field Reports

Field tests were conducted by each potential customer depending on the specific application being considered. The field testing included actual use of small quantities of the char in various processes. The actual tests conducted were preliminary in nature, with most potential customers wanting large quantities from the actual plant before they could conduct complete tests and make a commitment. In some cases the field tests indicated that the application was not suitable, thus further defining the potential market.

Task J-K - Perform User Survey and Assess Marketability of Char Based on Potential Pricing Terms

The potential market for the char has been defined based on the user survey and field testing. Due to the preliminary nature of the study, firm commitments have not been made by any users until the process is on line and the product is actually available. The value of the byproduct can be estimated using the extremes for price definition. In the worst case we can assume that the char will be sent to a landfill for disposal. Based on existing costs for landfilling rice hulls and preliminary estimates from disposal companies based on the char samples they have evaluated we can expect disposal costs to be approximately $5 to $10 per ton F.O.B. the proposed plant. The highest price found to date for rice hull char being made in Italy and sold in Europe is $250/ton in small quantities. A conservative estimate of the value would be to take an initial value of minus $5/ton and increase the average value to $10/ton after the market has been developed.

At the present time it is hard to predict the value of the char because no existing markets have been developed for this product. It is also expected that the value will vary depending on the actual usage, and the value will in general increase once the market has been developed. The sensitivities of the system economics on the char value are shown in the financial Section 3.2.5, where it was found that the char value has a low degree of sensitivity on the return on investment. However, It should also be noted that the low degree of sensitivity is coupled with a high degree of uncertainty.

Task L - Determine Market Breadth and Formulate Marketing Plan

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

3.4 Siting Considerations

Task A - Identify Constraints

Many contraints were considered in the evaluation of proposed sites for the new plant. The issues of land ownership, right-of-way, environmental regulations, water availability, transportation of both feed stock and byproducts, distribution of plant outputs, availability and permitting requirements were all addressed in the site selection process.

The issues of land ownership and right-of-way become largely economic considerations since using land currently owned by ARI would reduce or eliminate costs associated acquiring land and right-of-ways. Environmental regulations associated with the proposed plant are discussed in Section 3.6.1 and it was found that the only potential emmission problem is with particulates (TSP). Since some areas within the state of Texas and within Harris County are non-attainment for particulates, a site selected within one of these areas would most likely require the purchase of an off-set to operate in one of these areas. The water requirements for the proposed plant are given in Table 3.1.2-2 and range from 100 to 200 gpm. A water supply adequate to meet this demand must be secured at the plant site.

Transportation of both feedstock and char to and from the plant site is an important consideration. The site shall be selected to minimize the transportation costs. In addition the presence of a railroad line on the existing site would offer advantages. Proximity to the user of the steam, hot air, or electricity is also of key concern and the distribution costs of these commodities must be kept to a minimum. The costs associated with connecting the new plant to utilities such as electricity, water, sewers and natural gas should be considered, especially if a remote site is selected.

The permitting requirements required for the construction of the proposed plant are:

City of Houston Building Permit, or other city,
if not in Houston
Texas Air Control Board (TACB)

Permits required for operation are:

Texas Air Control Board (TACB)
City of Houston Department of Public Works
Fire and Safety Inspection
Texas Department of Labor and Standards -
Boiler Division
Houston Lighting and Power Co. - Purchased Power
Service

Another consideration in the selection of the site is the availability of land which meets all of the other constraints. This is an important consideration since the existing plant is within the City of Houston and available land close to this site is at a premium.

Finally the advantages associated with locating the new plant close to or within the existing facility are a constraint in the site selection. The advantages include access to existing maintenance and personnel facilities, good communications with the existing plant and other items associated with better integration with the existing plant.

Task B & C - Develop Feasibility Screen and Identify Sites to be Considered. Screen and Analyze

Of the constraints identified in Task A the most important in the selection of the proposed site are those with the largest financial implications. The capital and right-of-way costs associated with purchasing new land can have a profound influence in the selection of the site, hence it would be best to use land already owned by ARI if it is available and satisfies the other constraints presented.

Another primary consideration in the selection of the new site is that the transportation and distribution costs be kept to a minimum. Locating the facility close to both the existing feedstock storage tanks and to the parboil plant where the steam and hot air are used should be given careful consideration.

The above critical siting constraints have reduced locus of possible sites to those within ARI owned land and those close to the parboil and storage facilities. Reviewing the plot plan of the existing ARI facility available lands with adequate size, approximately 10,000 sq. ft. were given further consideration.

The available sites were further screened for their proximity to the storage and parboil facilities. A site was found available adjacent to the existing storage tanks and within approximately 500 ft. of the parboil plant. No other available sites were found within the existing plant which were closer to storage and parboil plant.

More detailed information was obtained on this proposed site including access to ground transportation, applicable environmental regulations, permitting requirements and availability. The proposed site is shown in Figure 3.4-1.

The proposed site was an excellent fit with the identified constraints. The access to both truck and rail transportation allows for easy transporting of the char byproduct away from the site to the market. The existing loading facility can be easily integrated into the proposed plant. The new plant will be within less than 50 ft. of the feedstock storage, thus minimizing the costs of feedstock delivery. The steam and hot air produced will be piped less than 500 ft. to the parboil plant where they will be used.

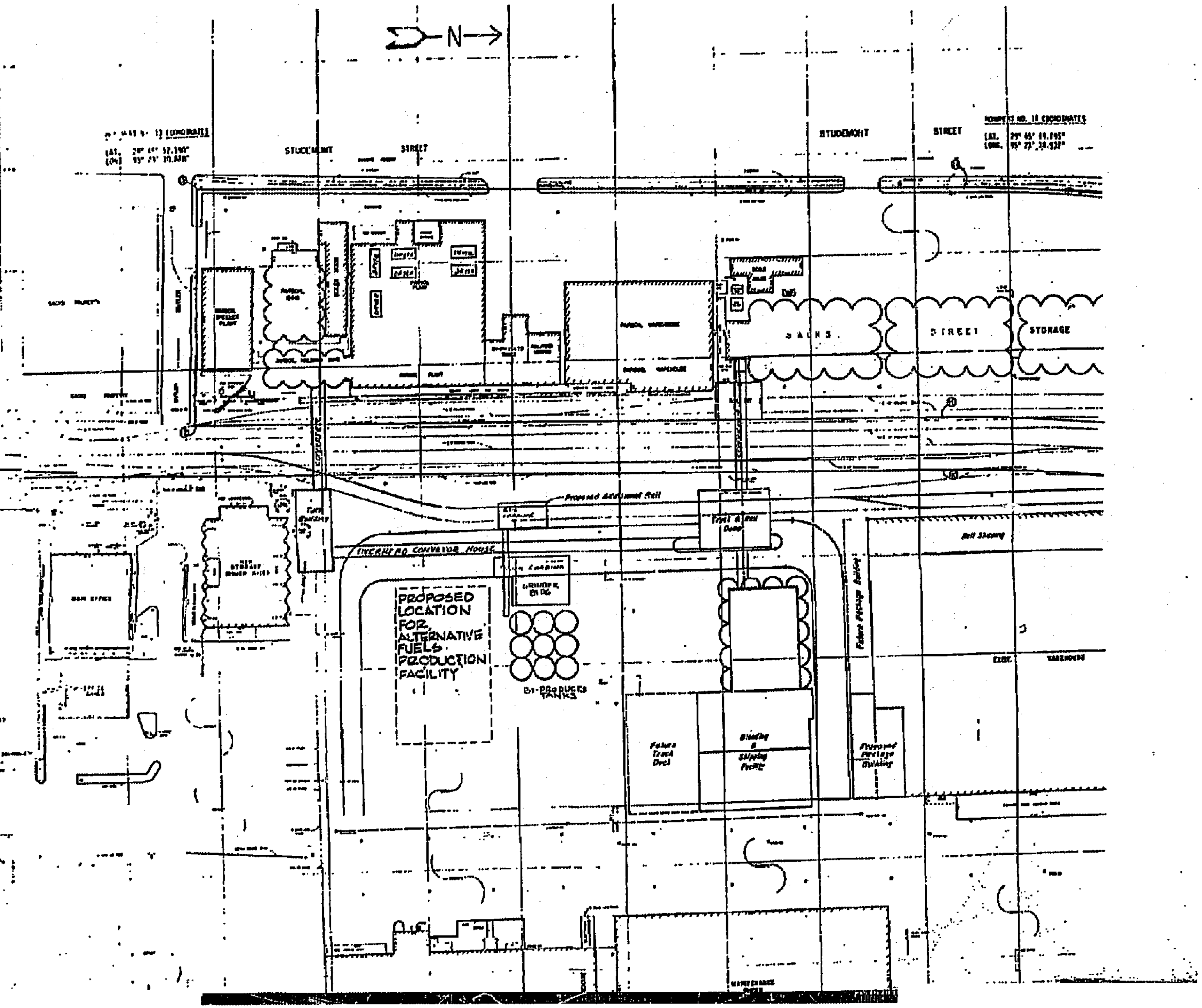
A review of the local regulations for Harris County shows that the proposed site is not in a non-attainment area, and the plant should not have any difficulties in meeting the other environmental regulations. Sufficient water is available for the new site which will cause an increased demand of only 25 to 100 GPM. The proximity to existing utilities is excellent. Power, water and sewer lines can easily be tied into the new plant.

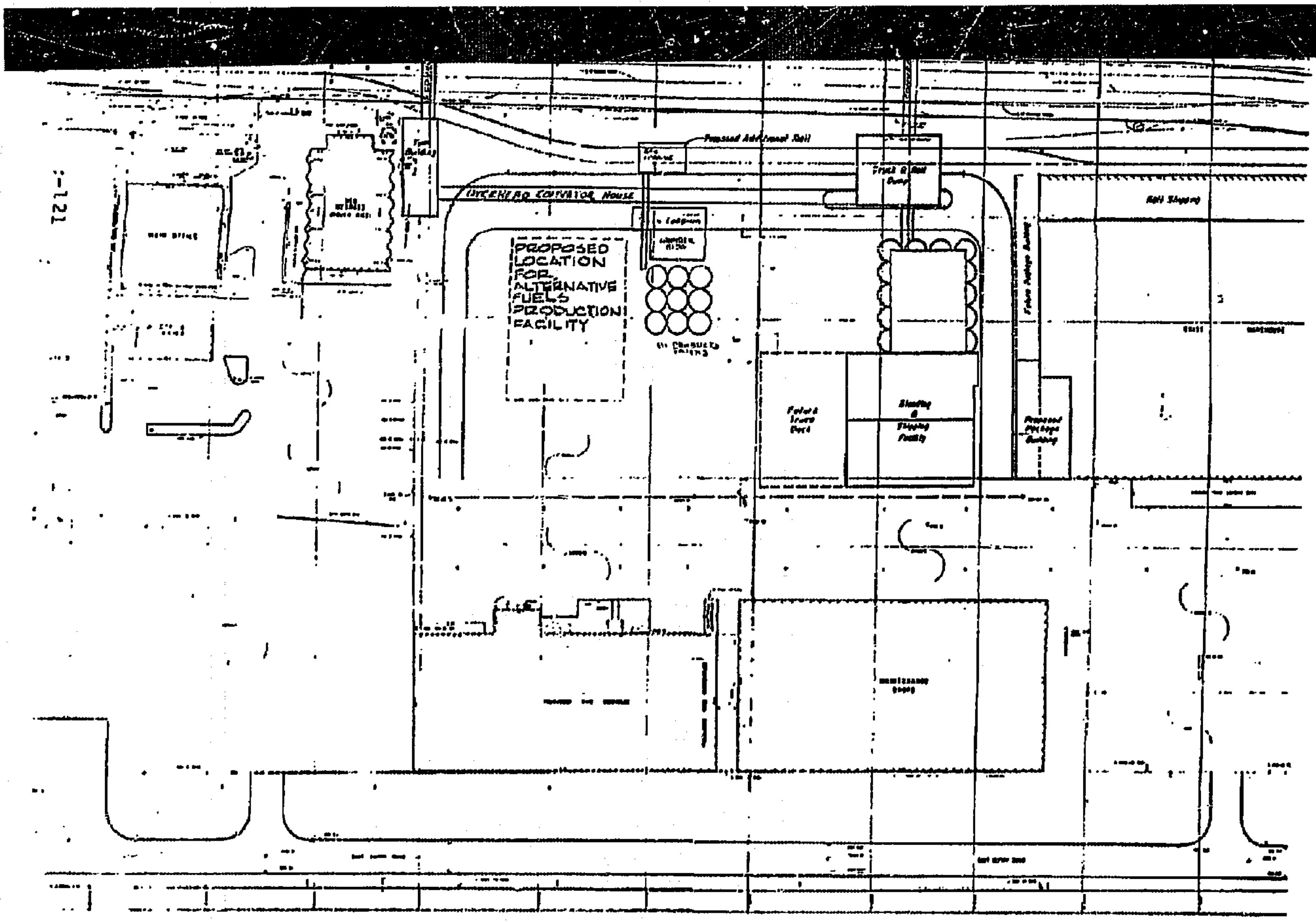
The permitting requirements for the proposed facility were discussed with the proper authorities and no problems exist in the prompt acquisition of these permits.

Task D - Develop the Plan/Profile

The site selected is located on 39.2 areas of land owned by American Rice about one mile from downtown Houston but within the city limits. Currently, the site is level with all utilities, roads, and other intrastructure in use or under construction. Ample room exists for the installation of new equipment and sufficient electrical power to operate the new equipment is located nearby. The system will be adjacent to the drying and parboiling facilities such that transportation of hot air and steam will be minimized. Refer to Figure 3.4-1.

The exact location of the proposed plant is shown in Figure 3.4-2, which shows the plant location related to the existing feed silos. Note that the layout is for Case 1 and for Case 2 and 3 the electric power generator equipment will be located in the area where the furnaces are shown. This layout indicates that the proposed site has adequate space to accomodate the proposed plant.


N
STUDEMONT
STREET
STUDEMONT
STREET
LAT. 29° 45' 19.795"
LONG. 95° 23' 38.937"
SACKS STREET STORAGE
Proposed Additional Rail
Truck & Rail Dump
OVERHEAD CONVEYOR HOUSE
GRINDER BLDG
PROPOSED LOCATION FOR ALTERNATIVE FUELS PRODUCTION FACILITY
BI-PRODUCTS TANKS
Future Truck Dock
Blending & Shipping Facility
Proposed Package Building
Future Package Building
Rail Siding
ELEC.
WAREHOUSE



ARI American Rice, Inc.

F' URE 3.4-1

PROPOSED LOCATION OF ALTERNATIVE FUEL PRODUCTION FACILITY

Other technical risks associated with the performance of the gasifier have been quantified in the pilot plant. The product splits and quality have been identified in the pilot tests. The composition of the gas and char products are now well known functions of the bed temperature and the gasifier performance can be reliably predicted.

The economic uncertainties associated with the operation of the proposed plant have been quantified using sensitivity analysis with respect to utility, raw material and byproduct cost variations. The results of this study are presented and discussed in Section 3.2.

The environmental risks of the proposed plant have been minimized in the plant design. The results of the pilot plant testing have been used to establish the environmental baseline, and the applicable regulations used to establish the allowable emission limits. The only emission problem associated with the FBG process is the particulate level in the flue gases. In the proposed plant design a baghouse, known for reliability of operation, was included to reduce emissions to acceptable levels. In addition a specially designed fugitive emission control system has been employed in the proposed plant. The levels of the other priority pollutants have been found to be within acceptable limits based on the pilot plant results, and hence little environmental risk expected from the proposed plant. A detailed discussion of the environmental control strategies is discussed in Section 3.6.

3.5 Alternative Fuel Resource Assessment

3.5.1 Resource Availability Assessment

Tasks A-B - Analyze Local Data and Assess Availability of Resource

The ability for ARI to depend on a reliable alternative fuel supply for the life of the proposed facility is essential. ARI plans on using waste rice hulls generated from their own processing facility in Houston. Due to the nature of the ARI cooperative, it also controls the raw material supply, whole rice, from which the waste is generated. The long-term availability of this resource seems very good.

Task C - Assess Alternative or Substitute Availability

There are many other sources of acceptable feedstocks available in the Houston area since it is one of the major rice processing areas in the country. Since the in-house availability is sufficient to meet the entire needs of the proposed facility, these other potential sources were not explored any further.

Task D - Determine Amount of Preparation Necessary

The alternative fuel, rice hulls, is acceptable for use in the FBG system in their "as received" condition and no additional preparation of the fuel is necessary.

3.5.2 Resource Reliability Assessment

Task A-B - Analyze Local Data and Available Technical Properties

The existing alternative fuel supply produced by ARI is of consistent size and quality for use in the FBG process. The in-house supplies are constant throughout the year because of their more than adequate storage capability. The technical properties including moisture and ash content and Btu value have been identified for the feedstock and all have been found to be acceptable to the FBG system.

Task C-D - Determine Effect of Handling, Etc., and Fuel Characteristics Variability

The fuel is currently being produced and stored on site and requires no additional treatment effort when fed to the FBG. Hence, no adverse effect will be felt on the product reliability. The existing fuel source has been sampled and analyzed and found to be acceptable in its "as received" condition for use in the FBG process.

3.6 Environmental, Health, Safety and Socioeconomic Assessment

3.6.1 Environmental Assessment

3.6.1.a Define Baseline Environmental Quality Schedule

Task A-D - Review, Compile and Report Baseline Data

An environmental analysis was performed relevant to the proposed processes and site recommended for the alternative fuel production plant. Using the detailed engineering information generated in Section 3.1.2, all of the potential environmental hazards were identified and quantified. The environmental impacts have been separated into two separate groups for this discussion: air and water discharges.

The gasification plant and all associated systems will produce various stack and fugitive emissions into the air. The stack will vent emissions from three sources, the boiler flue gas, the char cooling screw, and the furnace flue gas or power generator flue gas. The pilot plant studies characterized emissions from the gasification unit and from the afterburner or combustor. These values will be used to determine the emissions from the boiler and furnace or gas engine/gas turbine. The experience of similar ERCO plants and the charcoal industry indicates that the emissions from the char cooling contain negligible amounts of hydrocarbons or other pollutants, and this stream does not require further characterization.

The pilot plant work investigated the levels of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and total suspended particulates (TSP) in the emissions from the afterburner. Table 3.6.1-1 indicates those levels that were present in the flue gas. The low SO_2 emission is expected since the rice hull feed analysis indicated low sulfur concentrations, approximately 0.2%, and most of the sulfur remains in the char byproduct. The relatively high NO_x value, which was higher than those resulting from the gasification of their solid fuels, may be a result of a high afterburner temperature which can cause the formation NO_x. Temperatures in the afterburner were in excess of 2000°F, the upper limit of the readout device.

TABLE 3.6.1-1

AVERAGE AFTERBURNER FLUE GAS STACK EMISSIONS
IN FBG PILOT PLANT (1)

Compound	Flue Gas Concentration
SO_2	8 (ppm)
NO_x	250 (ppm)
CO	35 (ppm)
O_2	8.5(%)

(1) Based on data taken March 26, 1981, 1500°F FBG temperature.

The particulate content (TSP) of the low Btu gas was measured after the cyclone and found to be 0.8 grains/ACF, corresponding to approximately 350 lbs/hr for the full scale plant. This reading corresponds to a cyclone efficiency of only 95%, an efficiency which can be greatly improved with new high efficiency cyclones.

The proposed processes will have possible fugitive emissions from the gasifier feed rotary valves, feed surge hopper, and char loading facilities where the char is discharged from the storage silo to the rail car or truck. It is felt that these emissions can be completely controlled as described in Section 3.6.1.6.

The proposed plant will present a number of demands on the water supply. The demands associated with the boiler will be approximately 70 gpm, and will not differ from the current demand. The char cooling screw will require an additional 4 gpm of water spray for char cooling. In options 2 and 3 the scrubber will require a make up flow of approximately 50 gpm. The need for makeup is a function of gas entry and required exit temperature. This makeup includes any makeup required in the cooling loop associated with this operation. The gas engine is water cooled using a closed loop which requires only small amounts of makeup water.

The wastewater discharges will be primarily associated with the steam usage. These will consist of discharges from the parboil process associated with the steam usage, feed water treatment backwash discharge, and miscellaneous small cooling water discharges. The discharges will not differ from those currently being discharged and presently acceptable to the City of Houston. The discharges from the cooling screws will be in vapor form. Storm water, including all land and facility runoffs from the proposed site, will be discharged through storm drains. These discharges will not come in contact with any of the byproducts or feedstock and hence will not be contaminated.

3.6.1.b Evaluation of Environmental Standards and Constraints

Tasks A-C Determine and Assess Appropriate Regulations

All new construction or modification to existing equipment that causes air pollutants to be emitted must obtain a permit from the Texas Air Control Board (TACB). This permit is issued in accordance with State of Texas regulations as defined under Regulation VI, best available control technology (BACT), and federal regulations.

A meeting was held with the local TACB officials in Houston during which the expected emissions from the proposed plant were discussed. The SO_2 and NO_x emissions and water discharge were judged to be within the local, state and federal regulations. The total controlled emission from the new plant for TSP must be kept below 25 TPY to obtain an exemption from permitting procedures and public notification. The entire facility is allowed exemptions totaling 100 TPY uncontrolled and 50 TPY controlled emissions, and ARI has already used 14 TPY for a new conveyor system. In addition, the State of Texas requires that the TSP level in the stack be kept below 0.02 grains/ACF. TABC has already approved a rice hull burning facility in the City of Houston which uses a bag filter, to reduce the TSP levels. Based on this permit it is felt that our process will comply with regulation VI, BACT, if a bag filter is included for cleanup.

The federal regulations require that all new plants comply with the Prevention of Significant Deterioration (PSD) program. New sources of pollution are carefully reviewed and are given permits that delineate what increments of pollutants they can emit. The review, called a PSD review, can be required of all major sources in attainment areas.

The proposed facility is located in an attainment area for all pollutants, except ozone which is not emitted by the plant, and hence the proposed plant could be subject to PSD regulations. The gasification plant falls under one of 28 listed sources, a fuel conversion plant.

A major modification is a physical change in a major stationary source that would result in a significant net emissions increase of any regulated pollutant. A significant net increase is determined by first calculating the amount of the proposed increase. Then, it is necessary to quantify all of the source's emissions increases and decreases that occurred in the previous 5 years. Next, all of the changes in emissions are totaled and if the resultant net emission is larger than a specified amount, the modification is subject to a PSD review.

The specified amounts are called the _de minimis_ values. Table 3.6.1-2 gives these amounts for some pollutants. Modifications resulting in a net increase in emissions that is less than these values are not subject to a PSD review.

Because there are existing pollutant sources at the ARI facility, the proposed gasification plant becomes a modification of the existing facility, which means that there must be a significant net increase in emissions to warrant a PSD review.

TABLE 3.6.1-2

DE MINIMIS VALUES

POLLUTANT	_DE MINIMIS_ emissions rate (tons/year)
CO	100
NO_x	40
SO_2	40
Particulates	25

The federal regulations also require that all new sources be in compliance with the New Source Performance Standards (NSPS). These standards are primarily for larger sources as indicated in Table 3.6.1-3 in which the size limitations and latest regulations are given. The only area in which the NSPS regulations may apply is for stationary gas turbines, the proposed boiler and gas engine will be below the established limits. For stationary gas turbine there exists limits for SO_2 and NO_x as follows:

$SO_2 \leq 0.15\%$ at 15% O_2

and fuel $S \leq 0.8\%$

$NO_x \leq .0075 \times 14.4$ (Y&F) where Y = heat rate in KJ/WHR, and F = f(Fuel Used)

TABLE 3.6.1-3

NEW SOURCE PERFORMANCE STANDARDS (NSPS) SIZE LIMITATIONS

Type of Process	Minimum Size For Which NSPS Applies
boiler	250 MMBtu/hr
stationary gas turbine	10.7 gega J /hr (10 MMBtu/hr)
stationary gas engine	Greater than 350 cuin /cyl More than 8 cylinders, @ 240 cuin /cyl

The water discharge limitations established by the City of Houston apply to the proposed effluents since the effluents will be discharged in the city sewer system. The City of Houston has established maximum allowance for 13 metals, pH, oil and temperature, and periodically samples ARI's discharge.

3.6.1.c. Evaluation of Environmental Control Methods

Task A-C Determine System Needed, Develop Feasibility and Identify Control Technology

Based on a careful evaluation of the baseline data and applicable environmental regulations, additional control strategies will be required for the control of particulates (TSP) emitted by the proposed plant. Particulate can be removed from the flue gas using any of these four basic technologies: (1) mechanical collectors, (2) wet scrubbers, (3) electrostatic precipitators, (4) fabric filters.

The mechanical collector is a device which uses inertia to separate the particulate from the gas stream. In our process we are already using one such collector, the multicyclone, for removal of the larger particles up stream of combustion equipment, and the use of an additional mechanical collector will not be effective in removing remaining smaller particulates before discharging the flue gas.

Scrubbers are compact inertial collectors in which a water spray is used to separate the particulate from gas stream. The collection efficiency is proportional to the flue gas pressure drop across the collector, with a high efficiency collector as required in this application requiring a high gas pressure drop, perhaps 25 in water gage. The major disadvantage of this system is that the collected particulates leave the scrubber as a slurry or sludge and represent a large disposal problem.

Electrostatic precipitators are highly efficient devices which electrically charge and remove the particulate from the gas stream. The major disadvantage of this device is the high capital cost as compared to the other control technologies. In addition this device is highly sensitive to particle resistivity and careful evaluation of the ash will be needed before this system can be employed.

Fabric filters collect solid particles by passing the dirty gas through a cloth which the particles cannot penetrate. These devices are highly efficient, capturing 99% with particles down to submicron size, and able to operate at temperatures up to 500°F depending on the fabric used. The pressure drop is typically 2 to 4 in water gage. The major advantages of this technology are the low capital and operating costs and high dependability. In addition this technology, unlike the other three, can operate under wide variations in the flow rate without affecting the removal efficiency.

In summary the fabric filter is the process best suited for this particulate control application. It offers a lower capital and operating cost while demonstrating high removal efficiency. Using this technology the TSP emission levels will comply with all state and federal environmental regulations. A PSD permit will not be required and the plant will comply with the State of Texas Regulation VI. In addition this is well proven technology which has already been approved by the Texas Air Control Board as the BACT for use in a rice hull burning facility in the Houston area.

3.6.1.d Assessment of Gross Quantities of Effluent

Task A - Predict Impact of Each Effluent

The fabric filter was determined to be the best control technology for the removal of TSP from the flue gas. This technology offers an efficiency of approximately 99% for the loading and size distribution expected in this application. The incoming flue gas to the fabric filter will contain approximately 120 lbs/hr of ash assuming we use high efficiency cyclones with 98% efficiency and that all of the residual carbon is burned off.

Data generated in the pilot plant was sent to a cyclone manufacturer and he found that an efficiency of 98% was obtainable with a 10 in. water gage pressure drop. Using a 99% fabric filter efficiency the emission levels are 1.2 #/hr in the exiting flue gas which corresponds to a loading of approximately .003 grain/ACF in the flue gases. The expected total mass flow rates of the pollutants emitted in the stack from the proposed facility are listed below in Table 3.6.1-4. This table is based on the levels found in the pilot plant testing, and using the BACT for removal of TSP.

TABLE 3.6.1-4

TOTAL STACK EMISSIONS FROM PROPOSED FACILITY

Species	Total Annual Mass Flow (TPY)	Approx. Conc.
SO_2	4	8 ppm
NO_x	118	250 ppm
CO	17	35 ppm
Particulates (TSP)	5	.003 grain/ACF

Based on these emission levels, the proposed plant should have no problem gaining the approval of TACB, and this was confirmed in the meeting held with this agency. The plant will not be subject to a PSD review since the emissions will be below the de minimis values including the 14 TPY of TSP which are already being emitted by ARI. The NSPS regulations will also not apply to the proposed plant since its size is below the minimum level.

3.6.1.e. Modeling Predictions of Impacts

The environmental impacts of the proposed plant will be kept to a minimum using the BACT previously described. Employing these technologies the predicted emissions levels will be within the local and federal regulations. The water discharges will not be different from the existing levels, and the increase in air emissions as listed in Table 3.6.1-4 is almost negligible by present standards. An assessment of the emission levels indicates that the environmental impacts will not be significant and will not cause a significant deterioration of the air, water or land in the area of the proposed plant.

3.6.1-f. Special Considerations

Fugitive emissions which may be emitted from the proposed facility will be controlled using the appropriate control strategies described below. The fugitive gas emissions from the gasifier feed system will be controlled by venting all of the enclosed solids handling equipment through a common ID fan which will discharge into the combustion chamber of the furnace or boiler, in which all of the fugitives will be incinerated and exit to the fabric filter for further cleaning. A system similar to this has been employed in other FBG plants and has been found to be effective in eliminating all fugitive emissions.

Discharging the char from the storage silo to trucks or rail cars for ground transportation can result in possible fugitive dusting. Although the char was found to be non-hazardous by RCRA testing and was also found to have low toxic levels, it is still desirable to minimize the fugitive emissions due to the black color and light density of the dust. These factors could result in an undesirable appearance and have undesirable effects on the surrounding community. To prevent this possible emission source the use of enclosed conveying systems which are vented through dust control fans can be used. It is also possible to pneumatically convey the char into tank cars for ground transportation. Experience at the existing plant and other similar plants shows that pneumatic conveying to enclosed tank cars can completely eliminate any fugitive emission problems and it is the recommended technology for this application.

3.6.2 Socioeconomic Effects

3.6.2.a Employment and Fiscal Impacts

The proposed alternative fuels plant will have small positive socioeconomic impacts on Houston. These impacts comprise employment impacts and fiscal impacts on the City of Houston.

Houston, Texas has a population of 1,594,086 (U.S. Census 1980). The total labor force in Houston is 1,501,100 (July 1981) with a 5% unemployment rate.

The existing ARI facility presently employs approximately 500 workers. The proposed plant will create openings for 11 workers. The annual wage for the new employees will range from $15,000 to $25,000, which is close to the average annual wage for the other workers at the facility, and close to average annual pay for the City of Houston. The construction manpower requirements will create work for an average of four men over a 10 to 12 month period. No problems are anticipated in filling these new jobs due to the large labor force existing in the area; and no measureable impact will be felt by the local municipality.

No special federal, state, or local socioeconomic requirements apply to the proposed facility, and no special land use restrictions apply to this site.

3.6.3 Health Effects

3.6.3.a Identify All Applicable Regulations and Local Data

The proposed plant has been designed to minimize any possible detrimental health effects to the workers and surrounding community. Potentially harmful health effects to the workers in the plant may result from accidental contact of the low Btu gas produced by the FBG process, or from exposure to the char byproduct. The applicable regulations for this type of facility are defined by the Occupational Safety and Health Administration (OSHA) in the general industrial standards, section 1910 of the Code of Federal Regulations. In addition, emissions from the proposed facility may expose the community and local environment to these materials. The applicable health regulations for these emissions are those environmental regulations enforced by TACB for the emissions.

The allowable employee exposure levels for inert nuisance dusts, as defined by OSHA in section 1900.1000, Table 2-3 of CFR are 5 mg/cm respirable dust (<10u) and 15 mg/cm total dust. It is felt that the dust in consideration is non-toxic and only "nuisance" dust. In order to confirm this, extensive testing was conducted on the char as described below.

The char was subjected to a battery of EPA level-1 health and ecological effects tests, organic and inorganic chemical analysis. The results, described in detail in Section 3.1.5, show that the char had a negative response to the Ames test, low levels of toxicity in other tests, and was found to be non-hazardous in the RCRA tests. The Ames test results indicate that the char is not mutagenic or carcinogenic, the RAM and CHO tests indicated a low level of toxicity if inhaled or ingested. In vivo testing also confirmed the low toxic level of the char. The organic analysis indicated low levels of potentially harmful organics and the inorganic tests showed low levels of heavy metal compounds.

The ecological effects tests indicated that the char has low levels of toxicity on the aquatic plant and animal life. In addition, the char was found to be inert with respect to the soil microcosms.

The analyses of the low Btu gas produced by the gasifier given in Table 3.1.5-1 show that extremely low levels of heavy organics are contained in this gas. This is expected since equilibrium favors the conversion to CO and other smallmolecular weight compounds. Due to the high levels of CO in this gas, approximately 20%, caution should be observed so that personnel do not come in direct contact with the gas. OSHA regulations define the allowable 8-hour time weighted average for CO in CFR Table 7-1 as 9,000 mg/cm.

The heatlh effects on the surrounding community are evaluated by the Texas Air Control Board (TACB). This evaluation will be made largely on the environmental emissions produced by the plant, and no problems are anticipated in complying with these environmental regulations, as stated in the previous section.

3.6.3b Describe and Demonstrate Control Measures

The potential routes to exposure of the workers to the char are by directly contacting the substance or inhaling the char dust. The risks of this exposure are minimized by keeping the char in contained vessels, by using a pneumatic unloading system, by employing adequate fugitive emission control strategies, and employing an adequate building ventilation system. In the event that it becomes necessary to handle the char, precautions should be taken to minimize exposure. These precautions include wearing protective clothing on exposed areas and using a dust or gas mask.

Exposure to the low Btu gas will occur only during upset conditions. If an upset occurs, then corrective measures will be taken to stop any leaks, and special precautions will be taken during this time including wearing gas masks to prevent unnecessary exposure. Again, the fugitive emission control system will limit accidental exposures.

To prevent any potential health risks to the surrounding community, emissions will be minimized using the best available control technology (BACT) as described in Section 3.6.1c.

In summary, the plant has been designed to minimize occupational and public exposures to any potentially hazardous agents. In addition, the plant will be well equipped with the necessary protective devices to prevent health risks if an accident occurs.

3.6.3c Special Considerations

The existing plant presently uses natural gas for a fuel in the direct drying of white rice. It is proposed that the low Btu fuel produced by the gasifier be used to replace the natural gas in these drying operations. It is imperative that the use of the gas in the drying process present no potential health risks if used in this direct contact dryer. The gas could be combusted and used directly to dry the rice or combusted and then fed to a heat exchanger which would heat ambient air for use in the dryers. The first option presents the risk of odor or health problems because the combustion products of the low Btu gas will directly contact the rice. Pilot plant tests were conducted using a rotary dryer in which the Low Btu gas was combusted and then passed through the dryer. The rice which was dried by this process was then returned to the laboratory at ARI where color, odor, and taste tests were conducted. The results of these tests indicated that the gas imparted no noticeable taste or odor to the rick, although the rice was slightly discolored due to the fly ash carryover in the hot flue gas. The project team concluded that the gases could not be used directly due to the fly ash content of the gas, and also any risks associated with possible taste or odor contamination in the full scale plant would be eliminated. Based on this recommendation, a heat exchanger was employed in design option 1 which uses the hot products of combustion to heat air to the desired temperatures for process drying. The net effect is a reduction in process efficiency, the heat exchanger being approximately 60% efficient, and an increase in the installed plant cost by as much as $200,000.

3.6.4 Safety Effects

3.6.4a Identify Local and State Regulations

The applicable safety regulations have been identified for the proposed plant. These regulations include the OSHA

General Industrial Standards which are enforced by the state and the building construction regulations which are enforced by the public works department of the City of Houston.

The OSHA safety regulations are defined in the Code of Federal Regulations, Chapter XVII. The applicable regulations include design requirements for walking-working surfaces, means of egress, personal protective equipment, general environmental controls, medical and first aid, fire protection, machinery guarding, materials handling, and electrical codes. The building construction requirements include electrical codes, and plumbing and sewage codes.

3.6.4b Description of Control Methods to Meet Requirements

The appropriate steps will be taken to assure that all of the applicable safety regulations will be adhered to. The design teams will incorporate the necessary safety design features into the building and equipment designs as required by OSHA. This will include the proper equipment layout design to insure adequate access to equipment and exits, proper design of catwalks and ladders, proper design of exhaust ventilation, and fugitive emission control system, and proper equipment design to insure machine guarding.

A comprehensive operational safety and health management program will be implemented for the proposed plant. This program will be constantly monitored and enforced by the full time safety director at the existing plant and make use of the other in-plant safety personnel including a full time nurse. The program will include the development and adoption of safe operating procedures, development of a safety and health inspection and maintenance program, development of emergency procedures, including procedures for fire and explosion, and evacuation; an industrial hygiene program; on-site first aid; medical and rescue equipment; plant security requirements, and in-service training programs in occupational safety and health.

SECTION FOUR

CONCLUSIONS & RECOMMENDATIONS

The purpose of this study was to investigate the feasibility of the construction of an alternative fuel production facility using rice hulls, a waste product generated at the ARI plant in Houston, Texas. The existing plant has needs of steam, hot air and electricity, making it an ideal consumer of the various forms of energy produced from the proposed alternative fuel conversion plant. In this feasibility study all aspects of this proposed facility were evaluated and the following conclusions and recommendations made.

- The fluidized bed gasification (FBG) process combined with the appropriate steam and electrical power generation equipment has been selected as the optimum technology for this application. The FBG process was compared to other gasification and combustion processes and found to be the most viable process, based on economic and technical considerations.

- A fuel production schedule was developed for the proposed FBG plant and it was found that energy output of the plant is equivalent to approximately 172,000 BBLS/yr of oil or 950,000 MCF/yr of natural gas based on a 90% on line factor and pilot plant yield data developed in this study.

```
                    PROJECT ECONOMIC ANALYSIS

                       AMERICAN RICE PLANT
                             CASE-1

                          *** BASIS ***

             NUMBER OF YEARS IN PROJECT!  11
             DEBT TO EQUITY RATIO!   .00 / 1.00

             INSURANCE RATE =   2.0 %
             INVESTMENT TAX CREDIT =  18.0 %   TAX RATE =   0.0 %


   CASE-1
        CAPITAL COST               $5,672,000
        OPERATING LIFE  10 YEARS           TAX LIFE  10 YEARS
        CONSTRUCTION PERIOD  1 YEAR

     PLANT OUTPUT DATA
        STEAM      30 KPPH         $4.87/K-LBS         INFLATED 15%/P.A.
        HOT AIR    34.7 MMBTU/HR   $4.00/MMBTU         INFLATED 15%/P.A.

     FIXED OPERATING EXPENSE DATA
        LABOR                         $301,630 P.A.    INFLATED 10%/P.A.
        MAINTENANCE                   $264,000 P.A.    INFLATED 10%/P.A.
        MISC.                         $ 50,000 P.A.    INFLATED 10%/P.A.

     VARIABLE OPERATING EXPENSE DATA
        RICE HULLS       $5/TON    340 TONS/DAY        INFLATED 10%/P.A.
        CHAR DISPOSAL    $5/TON    84.8 TONS/DAY       INFLATED 10%/P.A.
        UTILITIES                     $192,000 P.A.    INFLATED 15%/P.A.

        DEPRECIATION METHOD IS DOUBLE DECLINING BALANCE TO STRAIGHT LINE
        PLANT OPERATES AT 80 PERCENT LOAD FACTOR
        OUTPUT IS IN THOUSANDS OF DOLLARS INFLATED AT RATES INDICATED
```

- Complete engineering analysis was performed on the proposed alternative fuel production facility. Process flow diagrams with heat and material balances, Process and Instrumentation Diagrams, Equipment Lists and layouts and all raw material support requirements were developed. This detailed analysis further confirmed viability of the proposed process from an engineering standpoint.

- A management plan was developed for the proposed project and an overall project completion schedule of 12 months developed. In this analysis equipment deliveries, manpower and subcontractor needs, site preparation, erection and installation schedule were determined and a CPM and overall project schedule developed.

- Complete capital and operating costs were developed for the three process options in consideration. A complete investment analysis was performed and returns on investment calculated for these options. The FBG process combined with a direct fired boiler producing 30,000 lb/hr of steam and a gas engine/generator producing 5.17 MW of electricity (Option 3) was found to have the highest return on investment of 36.8%. The complete installed capital cost for this process option was $8,787,000.

- A financial risk analysis was made for the proposed process and the sensitivity of the return on investment to those variables quantified. The power value and energy inflation parameters have the greatest potential impacts on the return on investment based on their moderate to high influence on both the degree of sensitivity and uncertainty.

- Due to the inherently high risk perceived by financial institutions for alternative energy systems similar to the FBG process proposed for this application, special financing arrangements may be required. The project team recommends that a price guarantee of $25/ton and a 90 percent loan guarantee for the plant be made available by the Department of Energy.

- A complete analysis was made of the potential site for the proposed plant and it was concluded that the optimum location for the proposed plant is on an available plot at the existing ARI facility. Using this site offers many economic advantages than other sites including reduced land costs and low transportation costs, i.e. close proximity to raw material and user, and is feasible from a technical aspect.

- Extensive testing was conducted on the char and it was found to be non-hazardous, by RCRA testing, and non-toxic based on Level 1 EPA toxicity analysis. Additional chemical and physical properties of the char have been identified and used to aid in the Marketing Survey.

- Potential markets for the char byproduct have been identified, samples sent to potential users and field studies conducted. There has been a great deal of interest shown in the char; however, there have been no formal commitments made by anyone to purchase the material until it is demonstrated that a constant quality char is produced in reliable quantities.

- It was concluded by the project team that the flue gas produced by the combustion of the low Btu gas could not be used directly for direct rotary drying of whole rice due to the high ash carryover in the gas. Based on this finding, it will be necessary to incorporate a flue gas to air heat exchanger in the plant designs which include process drying options.

- Environmental, Socioeconomic, Health and Safety baselines have been determined for the proposed plant. The applicable regulations have been identified and the necessary control strategies defined. It was found that a fabric filter is the Best Available Control Technology for the control of particulate emissions and will be employed in the process design as required. By adhering to the applicable regulations no adverse health or safety effects will be posed by the proposed process.

Appendix A

EQUIPMENT LIST
AND
DELIVERY SCHEDULE

Energy Resources Company Inc.

EQUIPMENT LIST

CLIENT American Rice UNIT NAME Gasifier PROJ. MGR TKC PAGE 1 OF 5

CONTRACT NO. 6150 UNIT NO. DATE 4/27/81 REV 0 DATE

ITEM NO.	DESCRIPTION	Quantity	Delivery (weeks)	REMARKS
FS-1	Rice Hull Feed Silo	1	20	1458 cu ft w/bag filter and bridge breakers
WB-1	Feed Weigh Belt	1	14-16	5.0 - 17.0 TPH w/set point controller
BE-1A,B	Feed Bucket Elevator	2	12	8.5 TPH, 16' H
RV-1A-D	Feed Rotary Airlock	4	16	8.5 TPH, 1½ HP
SC-1A-D	Feed Screw Feeder	4	14	8.5 TPH, 3 HP, SS construction
G-1A,B	Fluidized Bed Gasifier	2	16	55 ft^2 x 27'H, refractory lined
ME-1A-F	Start-up Burner	6	16	2 MMBtu/hr, NG fired
B-1, A,B	Gasifier Blower	2	24	8650 SCFM @ 10 psi, I/O silencer
CY-1A,B	Cyclone System	2	14	14000 ACFM, quad, SS, refractory lined
RV-2A,B	Char Rotary Airlock	2	20	4.7 TPH, SS construction, 1 HP
CC-1A,B	Char Screw Conveyor/Cooler	2	16	4.7 TPH, w/water spray
BE-2	Char Bucket Elevator	1	18	9 TPH, 50' H
SS-1	Char Storage Silo	1	24	24,000 cu ft, w/unloading conveyor

Energy Resources Company Inc.

EQUIPMENT LIST

IENT American Rice　UNIT NAME Boiler　PROJ. MGR DKC　PAGE 2 OF 5
INTRACT NO. 6150　UNIT NO.　DATE 4/27/81　REV 0　DATE

ITEM NO.	DESCRIPTION	Quantity	Delivery (weeks)	REMARKS
C-1	Low-Btu Burner	1	20	45 MMBtu/hr, w/controls
B-2	Boiler Combustion Air Fan	1	20	6000 ACFM, included w/SG-1
SG-1	Package Boiler	1	20	30,000 PPH, 100 psi steam with economizer
P-1A,B	Boiler Feed Water Pump	2	12	70 gpm @ 150 psig, one spare
D-1	Feed Water Deaerator	1	12	40,000 pph, 150 cu ft.
DI-1	Boiler Feed Water Softener	1	12	70 gpm, one standby w/regenerant tank
BH-1	Boiler Bag House	1	16	17,000 ACFM, pulse jet

ERCO Energy Resources Company Inc.

EQUIPMENT LIST

CLIENT American Rice UNIT NAME Furnace PROJ. MGR RKC PAGE 3 OF 5
CONTRACT NO. 6150 UNIT NO. DATE 4/27/81 REV 0 DATE

ITEM NO.	DESCRIPTION	Quantity	Delivery (weeks)	REMARKS
C-2A,B	Low-Btu Burner	2	20	45 MMBtu/hr w/controls
F-1A,B	Furnace	2	20	Refractory lined
B-3A,B	Furnace Air Blower	2	22	22,500 ACFM
HX-2A,B	FG-Air Heat Exchanger	2	18	SS w/bypass and controls
B-4A,B	HX Air Blower	2	18	25,500 SCFM, 20 in w.c.
HX-3	F.G. Cooler/Preheater	2	18	20 MMBtu/hr
BH-2	Furnace Bag House	1	16	75,000 ACFM, Pulse Jet

Energy Resources Company Inc.

EQUIPMENT LIST

LIENT American Rice
ONTRACT NO. 6150
UNIT NAME Gas Turbine
UNIT NO.
PROJ. MGR DKL
DATE 4/27/81
PAGE 4 OF 5
REV 0 DATE

ITEM NO.	DESCRIPTION	Quantity	Delivery (weeks)	REMARKS
OS-1	Oil Scrubber	1	16	Venturi Type w/Cyclone Separator
T-1	Scrubber Recirculation Tank	1	12	2500 gal
P-2	Scrubber Recirculation Pump	1	12	1000 gpm @ 100 ft TDH
HX-4	Scrubber Heat Exchanger/Preheater	1	12	6.5MMBtu/hr, 325 ft^2
P-3	Oil Pump	1	12	5 gpm @ 100 ft TDH
C-1A-C	Gas Compressor	3	24	2750 SCFM @ 60 psi, screw type
GT-1A,B	Gas Turbine	2	24	1410 KW, 480V, complete
HX-5A,B	FG - Air Heat Exchanger	2	18	SS w/bypass and controls

[illegible] Energy Resources Company Inc.

EQUIPMENT LIST

CLIENT American Rice UNIT NAME Gas Engine PROJ. MGR DK PAGE 5 OF 5
CONTRACT NO. 6150 UNIT NO. DATE 4/27/81 REV 0 DATE

ITEM NO.	DESCRIPTION	Quantity	Delivery (weeks)	REMARKS
OS-1	Oil Scrubber	1	16	Venturi Type w/cyclone separator
T-1	Scrubber Recirculation Tank	1	12	2500 Gal
P-2	Scrubber Recirculation Pump	1	12	1000 gpm @ 100 ft TDH
HX-4	Scrubber Heat Exchanger/Preheater	1	12	6.5 MMBtu/hr, 325 ft^2
P-3	Oil Pump	1	12	5 gpm @ 100 ft TDH
GE-1 A,B	Gas Engine	2	24	2600 KW; watercooled, complete

```
                         PROJECT ECONOMIC ANALYSIS

                          AMERICAN RICE PLANT
                               CASE-3

                             *** BASIS ***

                NUMBER OF YEARS IN PROJEC.:  11
                DEBT TO EQUITY RATIO:   .00 / 1.00

                INSURANCE RATE =   2.0 %
                INVESTMENT TAX CREDIT =  18.0 %   TAX RATE =   0.0 %


PLANT
   CAPITAL COST                  $8,787,000
   OPERATING LIFE  10 YEARS                TAX LIFE  10 YEARS
   CONSTRUCTION PERIOD             1 YEAR

  PLANT OUTPUT DATA
    STEAM      30   KPPH          $4.87/K-LBS   INFLATED 15%/P.A.
    HOT AIR    34.7 MMBTU/HR      $4.00/MMBTU   INFLATED 15%/P.A.
    POWER      5170 KW/HR         $0.04/KWH     INFLATED 15%/P.A.

  FIXED OPERATING EXPENSE DATA
    MISC               $ 50,000/P.A.            INFLATED 10%/P.A.
    MAINT              $264,000/P.A.            INFLATED 10%/P.A.
    LABOR              $301,630/P.A.            INFLATED 10%/P.A.
    STD-BY CHG         $100,000/P.A.            INFLATED 10%/P.A.

  VARIABLE OPERATING EXPENSE DATA
    RICE HULLS         $5/TON   84.6 TONS/DAY      INFLATED 10%/P.A.
    CHAR DISPOSAL      $5/TON    340 TONS/DAY      INFLATED 10%/P.A.

    DEPRECIATION METHOD IS DOUBLE DECLINING BALANCE TO STRAIGHT LINE
    PLANT OPERATES AT 80 PERCENT LOAD FACTOR
    OUTPUT IS IN THOUSANDS OF DOLLARS INFLATED AT RATES INDICATED
```

CASH FLOW - NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
------SOURCES-------											
NET INCOME	-175.7	2214.5	1484.9	2308.9	3166.3	4082.7	5083.5	6080.0	7238.0	8583.1	10144.6
DEPRECIATION	0.0	1757.4	1405.9	1124.7	899.8	719.8	575.9	575.9	575.9	575.9	575.9
PAID IN CAPITAL	9537.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BUYOUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DEBT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.T. DEBT (OP. LOSS)	175.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL SOURCES	9537.0	3971.9	2890.8	3433.6	4066.1	4802.5	5659.4	6655.8	7813.9	9159.0	10720.5
---------USES--------											
P&E CPTL. EXPD.	8787.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DELTA WORKING CAP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DEBT REPAYMENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.T. DEBT REPAYMENT	0.0	175.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PRE-OP. COSTS	750.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIVIDENDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL USES	9537.0	175.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SURPLUS	0.0	3794.2	2890.8	3433.6	4066.1	4802.5	5659.4	6655.8	7813.9	9159.0	10720.5
CASH FLOW OPER.	-175.7	3796.2	2890.8	3433.6	4066.1	4802.5	5659.4	6655.8	7813.9	9159.0	10720.5
CASH FLOW PROJ.	-175.7	2038.8	1484.9	2308.9	3166.3	4082.7	5083.5	6080.0	7238.0	8583.1	10144.6
CASH FLOW P&E	0.0	1757.4	1405.9	1124.7	899.8	719.8	575.9	575.9	575.9	575.9	575.9
CASH FLOW INVEST.	9537.0	4007.1	2890.8	3433.6	4066.1	4802.5	5659.4	6655.8	7813.9	9159.0	10720.5
TOTAL COVERAGE RATIO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PROFIT AND LOSS - NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
TOTAL REVENUE	0.0	4106.1	4722.0	5430.3	6244.9	7181.6	8258.9	9497.7	10922.4	12560.7	14444.8
STEAM	0.0	1220.1	1405.1	1613.5	1855.6	2133.9	2454.0	2822.1	3245.4	3732.2	4292.0
HOT AIR	0.0	1159.1	1333.0	1532.9	1762.8	2027.3	2331.4	2681.1	3083.2	3545.7	4077.6
POWER	0.0	1727.0	1986.0	2283.9	2626.5	3020.5	3473.5	3994.6	4593.7	5282.8	6075.2
TOTAL OPERATING EXP.	0.0	1505.0	1655.4	1821.0	2003.1	2203.4	2423.7	2666.1	2932.7	3226.0	3548.6
FIXED	0.0	806.4	887.0	975.7	1073.3	1100.7	1298.7	1428.6	1571.5	1728.6	1901.5
VARIABLE	0.0	698.5	768.4	845.2	929.8	1022.7	1125.0	1237.5	1361.3	1497.4	1647.1
INSURANCE	175.7	175.7	175.7	175.7	175.7	175.7	175.7	175.7	175.7	175.7	175.7
OVERHEAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPERATING PROFIT	-175.7	2425.4	2890.8	3433.6	4066.1	4802.5	5659.4	6655.8	7813.9	9159.0	10720.5

DEPRECIATION	0.0	1757.4	1405.9	1124.7	899.8	719.8	575.9	575.9	575.9	575.9	575.9
EBIT	-175.7	668.0	1484.9	2308.9	3166.3	4082.7	5083.5	6080.0	7238.0	8583.1	10144.6

INTEREST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SHORT TERM INTEREST	0.0	35.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROFIT BEFORE TAXES	-175.7	632.9	1484.9	2308.9	3166.3	4082.7	5083.5	6080.0	7238.0	8583.1	10144.6

RECAPTURE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INVEST. TAX CREDIT	0.0	1581.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WORK INCENTVE CREDIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TAX LIABILITY	0.0	-1581.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PROFIT AFTER TAXES	-175.7	2214.5	1484.9	2308.9	3166.3	4082.7	5083.5	6080.0	7238.0	8583.1	10144.6

```
********************************************   BALANCE SHEET - NOMINAL DOLLARS   ********************************************
                     -------------------------------------------------------------------------------------------------------------
                       1982      1983      1984      1985      1986      1987      1988      1989      1990      1991      1992
                     -------------------------------------------------------------------------------------------------------------
INVENTORY               0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
CASH                    0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
GROSS BOOK VALUE     8787.0    8787.0    8787.0    8787.0    8787.0    8787.0    8787.0    8787.0    8787.0    8787.0    8787.0
AVAILABLE SURPLUS       0.0    3796.2    6687.0   10120.7   14186.7   18989.2   24648.6   31304.5   39118.3   48277.3   58997.8
TOTAL GROSS ASSETS   8787.0   12583.2   15474.0   18907.7   22973.7   27776.2   33435.6   40091.5   47905.3   57064.3   67784.8
  ------------ ..
CUM. DEPRECIATION       0.0    1757.4    3163.3    4288.1    5187.8    5907.7    6483.5    7059.4    7635.3    8211.1    8787.0
TOTAL NET ASSETS     8787.0   10825.8   12310.7   14619.6   17785.9   21868.5   26952.1   33032.0   40270.1   48853.2   58997.8
  -----------
SHORT TERM DEBT       175.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
DEBT                    0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  -----------
EQUITY               8611.3   10825.8   12310.7   14619.6   17785.9   21868.5   26952.1   33032.0   40270.1   48853.2   58997.8
  RETAINED EARNINGS  -175.7    2038.8    3523.7    5832.6    8998.9   13081.5   18165.1   24245.0   31483.1   40066.2   50210.8
  BUYOUT                0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  PAID IN CAPITAL    9537.0    9537.0    9537.0    9537.0    9537.0    9537.0    9537.0    9537.0    9537.0    9537.0    9537.0
  PRECONSTRUCTION    -750.0    -750.0    -750.0    -750.0    -750.0    -750.0    -750.0    -750.0    -750.0    -750.0    -750.0
```

```
                    ***  PRESENT VALUE CALCULATIONS -  NOMINAL DOLLARS  ***
                 ---------------------------------------------------------------------------------------------
                    1982      1983      1984      1985      1986      1987      1988      1989      1990      1991      1992
                 ---------------------------------------------------------------------------------------------
CASH FLOW DAR     -9712.7    4007.1    2890.8    3433.6    4066.1    4802.5    5659.4    6655.8    7813.9    9159.0   10720.5
DELTA SURPLUS-PAID -9537.0   3796.2    2890.8    3433.6    4066.1    4802.5    5659.4    6655.8    7813.9    9159.0   10720.5
   IN CAPITAL
                              ----------------------------------

                              RATE OF RETURN ON INVESTMENT:  36.88
                              RATE OF RETURN ON EQUITY:      36.94
                              PAYBACK YEAR:                   1985
                              TOTAL CASH FLOW DAR:         49496.0


                        ***   COST ANALYSIS - NOMINAL DOLLARS  ***

                                                   AVERAGE        PERCENT OF
                                                ANNUAL AMOUNT   TOTAL REVENUE
                   REVENUES
                          STEAM                        2252.0          29.73
                          HOT AIR                      2139.5          28.23
                          POWER                        3187.6          42.06
                                                       ------         ------
                   TOTAL REVENUE                       7579.0         100.00

                   OPERATING EXPENSES:
                       FIXED
                          MISC.                          81.6           1.08
                          MAINT.                        431.0           5.69
                          LABOR                         492.5           6.50
                          STAND-BY                      163.3           2.15
                                                       ------         ------
                       TOTAL FIXED                     1168.4          15.42

                       VARIABLE
                          RICE HULLS                    810.4          10.69
                          CHAR DISPO                    201.7           2.66
                                                       ------         ------
                       TOTAL VARIABLE                  1012.1          13.35
                                                       ======         ======
                   TOTAL OPERATING EXPENSES            2180.5          28.77
                   INSURANCE                            175.7           2.32
                   DEPRECIATION                         798.8          10.54
                   INTEREST                               3.2           0.04
                   TAXES                               -143.8          -1.90
                   PROFIT                              4564.6          60.23
```

CASH FLOW - NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
------SOURCES-------											
NET INCOME	-58.4	427.3	-173.9	262.0	697.4	1147.6	1627.6	2065.9	2581.3	3186.2	3895.5
DEPRECIATION	0.0	584.0	1051.1	840.9	672.7	538.2	430.5	430.5	430.5	430.5	430.5
PAID IN CAPITAL	5839.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BUYOUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DEBT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.T. DEBT (OP. LOSS)	58.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL SOURCES	5839.7	1011.3	877.3	1102.9	1370.1	1685.8	2058.1	2496.5	3011.8	3616.8	4326.0
---------USES--------											
P&E CPTL. EXPD.	5839.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DELTA WORKING CAP.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DEBT REPAYMENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.T. DEBT REPAYMENT	0.0	58.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PRE-OP. COSTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIVIDENDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL USES	5839.7	58.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SURPLUS	0.0	952.9	877.3	1102.9	1370.1	1685.8	2058.1	2496.5	3011.8	3616.8	4326.0
CASH FLOW OPER.	-58.4	952.9	877.3	1102.9	1370.1	1685.8	2058.1	2496.5	3011.8	3616.8	4326.0
CASH FLOW PROJ.	-58.4	368.9	-173.9	262.0	697.4	1147.6	1627.6	2065.9	2581.3	3186.2	3895.5
CASH FLOW P&E	0.0	584.0	1051.1	840.9	672.7	538.2	430.5	430.5	430.5	430.5	430.5
CASH FLOW INVEST.	5839.7	1019.4	877.3	1102.9	1370.1	1685.8	2058.1	2496.5	3011.8	3616.8	4326.0

TOTAL COVERAGE RATIO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

```
****************()**************************   PROFIT AND LOSS - NOMINAL DOLLARS   ********************************************
                     --------------------------------------------------------------------------------------------------------
                        1982     1983     1984     1985     1986.    1987     1988     1989     1990     1991     1992
                     --------------------------------------------------------------------------------------------------------
TOTAL REVENUE            0.0   1231.1   2736.0   3146.4   3618.4   4161.2   4785.3   5503.1   6328.6   7277.9   8369.6
     STEAM               0.0    631.3   1403.1   1613.5   1855.6   2133.9   2454.0   2822.1   3245.4   3732.2   4292.0
     HOT AIR             0.0    599.8   1333.0   1532.9   1762.8   2027.3   2331.4   2681.1   3083.2   3545.7   4077.6
TOTAL OPERATING EXP.     0.0   1146.0   1742.0   1926.7   2131.5   2358.5   2610.4   2889.9   3200.6   3544.4   3926.8
     FIXED               0.0    693.7    763.1    839.4    923.3   1015.7   1117.2   1229.0   1351.9   1487.0   1635.8
     VARIABLE            0.0    452.3    978.9   1087.3   1208.1   1342.9   1493.2   1660.9   1848.1   2057.3   2291.0
INSURANCE               58.4    116.8    116.8    116.8    116.8    116.8    116.8    116.8    116.8    116.8    116.8
OVERHEAD                 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
OPERATING PROFIT       -58.4    -31.7    877.3   1102.9   1370.1   1685.8   2058.1   2496.5   3011.8   3616.8   4326.0
   ----------
DEPRECIATION             0.0    584.0   1051.1    840.9    672.7    538.2    430.5    430.5    430.5    430.5    430.5
EBIT                   -58.4   -615.7   -173.9    262.0    697.4   1147.6   1627.6   2065.9   2581.3   3186.2   3895.5
   ----------
INTEREST                 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
SHORT TERM INTEREST      0.0      8.2      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
PROFIT BEFORE TAXES    -58.4   -623.8   -173.9    262.0    697.4   1147.6   1627.6   2065.9   2581.3   3186.2   3895.5
   ----------
RECAPTURE                0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
INVEST. TAX CREDIT       0.0   1051.1      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
WORK INCENTVE CREDIT     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
TAX LIABILITY            0.0  -1051.1      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   ----------
PROFIT AFTER TAXES     -58.4    427.3   -173.9    262.0    697.4   1147.6   1627.6   2065.9   2581.3   3186.2   3895.5
```

** BALANCE SHEET - NOMINAL DOLLARS **

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
INVENTORY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GROSS BOOK VALUE	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7
AVAILABLE SURPLUS	0.0	952.9	1830.1	2933.1	4303.2	5989.0	8047.2	10543.7	13555.5	17172.3	21498.3
TOTAL GROSS ASSETS	5839.7	6792.6	7669.8	8772.8	10142.9	11828.7	13886.9	16383.4	19395.2	23011.9	27338.0
CUM. DEPRECIATION	0.0	584.0	1635.1	2474.0	3148.8	3686.9	4117.5	4548.0	4978.6	5409.1	5839.7
TOTAL NET ASSETS	5839.7	6208.6	6034.7	6296.7	6994.1	8141.8	9769.4	11835.3	14416.6	17602.8	21498.3
SHORT TERM DEBT	58.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DEBT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EQUITY	5781.3	6208.6	6034.7	6296.7	6994.1	8141.8	9769.4	11835.3	14416.6	17602.8	21498.3
RETAINED EARNINGS	-58.4	368.9	195.0	457.1	1154.5	2302.1	3929.7	5995.6	8576.9	11763.1	15658.6
BUYOUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAID IN CAPITAL	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7	5839.7
PRECONSTRUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

B-9

```
                              ***  PRESENT VALUE CALCULATIONS -  NOMINAL DOLLARS  ***
                  ------------------------------------------------------------------------------------------------
                     1982      1983      1984      1985      1986      1987      1988      1989      1990      1991      1992
                  ------------------------------------------------------------------------------------------------
CASH FLOW BAR       -5898.1    1019.4     877.3    1102.9    1370.1    1685.8    2058.1    2496.5    3011.8    3616.8    4326.0
DELTA SURPLUS-PAID  -5839.7     952.9     877.3    1102.9    1370.1    1685.8    2058.1    2496.5    3011.8    3616.8    4326.0
   IN CAPITAL
                                  ----------------------------------

                                  RATE OF RETURN ON INVESTMENT:  21.43
                                  RATE OF RETURN ON EQUITY:      21.43
                                  PAYBACK YEAR:                   1987
                                  TOTAL CASH FLOW BAR:         15666.8


                                   ***   COST ANALYSIS - NOMINAL DOLLARS  ***

                                                          AVERAGE        PERCENT OF
                                                       ANNUAL AMOUNT   TOTAL REVENUE
                             REVENUES
                                     STEAM                  2198.5          51.28
                                     HOT AIR                2088.6          48.72
                                                            ------          -----
                             TOTAL REVENUE                  4287.1         100.00

                             OPERATING EXPENSES:
                                 FIXED
                                     LABOR                   492.5          11.49
                                     MAINT.                  431.0          10.05
                                     MISC.                    81.6           1.90
                                                            ------          -----
                                 TOTAL FIXED                1005.1          23.44

                                 VARIABLE
                                     UTILITIES               329.8           7.69
                                     RICE HULLS              785.6          18.33
                                     CHAR                    195.5           4.56
                                                            ------          -----
                                 TOTAL VARIABLE             1310.9          30.58
                                                            ======          =====
                             TOTAL OPERATING EXPENSES       2316.0          54.02
                             INSURANCE                       111.5           2.60
                             DEPRECIATION                    530.9          12.38
                             INTEREST                          0.7           0.02
                             TAXES                           -95.6          -2.23
                             PROFIT                         1423.5          33.20
```

```
                    PROJECT ECONOMIC ANALYSIS

                       AMERICAN RICE PLANT
                             CASE-2

                          $$$ BASIS $$$

            NUMBER OF YEARS IN PROJECT:  11
            DEBT TO EQUITY RATIO:    .00 / 1.00

            INSURANCE RATE =    2.0 %
            INVESTMENT TAX CREDIT =  10.0 %   TAX RATE =    0.0 %


PLANT: CAS
     CAPITAL COST                  $7,770,000
     OPERATING LIFE  10 YEARS             TAX LIFE  10 YEARS
     CONSTRUCTION PERIOD           1 YEAR

  PLANT OUTPUT DATA
     STEAM     30 KPPH             $4.87/K-LBS        INFLATED  15%/P.A.
     HOT AIR   34.7 MMBTU/HR       $4.00/MMBTU        INFLATED  15%/P.A.
     POWER     1202 KW/HR          $0.04/KWH          INFLATED  15%/P.A.

  FIXED OPERATING EXPENSE DATA
     LABOR                         $301,630 P.A.      INFLATED  10%/P.A.
     MAINTENANCE                   $264,000 P.A.      INFLATED  10%/P.A.
     STAND-BY                      $100,000 P.A.      INFLATED  10% P.A.
     MISC.                         $50,000  P.A.      INFLATED  10%/P.A.

  VARIABLE OPERATING EXPENSE DATA
     RICE HULLS         $5/TON     340 TONS/DAY       INFLATED 10%/P.A.
     CHAR DISPOSAL      $5/TON     84.6 TONS/DAY      INFLATED 10%/P.A.

     DEPRECIATION METHOD IS DOUBLE DECLINING BALANCE TO STRAIGHT LINE
     PLANT OPERATES AT 80 PERCENT LOAD FACTOR
     OUTPUT IS IN THOUSANDS OF DOLLARS INFLATED AT RATES INDICATED
```

```
***********************************************     CASH FLOW - NOMINAL DOLLARS     ****************************************
                         1982     1983     1984     1985     1986     1987     1988     1989     1990     1991     1992
------SOURCES------
NET INCOME               -80.0    738.9    -57.6    544.5   1144.4   1762.8   2419.4   3015.9   3714.1   4530.3   5483.7
DEPRECIATION               0.0    800.0   1439.9   1152.0    921.6    737.3    589.8    589.8    589.8    589.8    589.8
PAID IN CAPITAL         7999.7      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
BUYOUT                     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DEBT                       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
S.T. DEBT (OP. LOSS)      80.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
TOTAL SOURCES           7999.7   1538.8   1382.3   1696.4   2066.0   2500.0   3009.2   3605.8   4303.9   5120.1   6073.5
---------USES--------
P&E CPTL. EXPD.         7999.7      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DELTA WORKING CAP.         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DEBT REPAYMENT             0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
S.T. DEBT REPAYMENT        0.0     80.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
PRE-OP. COSTS              0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
DIVIDENDS                  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
TOTAL USES              7999.7     80.0      0.0      0.0      0.0      0.0      0.0
    ------------
SURPLUS                    0.0   1458.9   1382.3   1696.4   2066.0   2500.0   3009.2   3605.8   4303.9   5120.1   6073.5
CASH FLOW OPER.          -80.0   1458.9   1382.3   1696.4   2066.0   2500.0   3009.2   3605.8   4303.9   5120.1   6073.5
  CASH FLOW PROJ.        -80.0    658.9    -57.6    544.5   1144.4   1762.8   2419.4   3015.9   3714.1   4530.3   5483.7
  CASH FLOW P&E            0.0    800.0   1439.9   1152.0    921.6    737.3    589.8    589.8    589.8    589.8    589.8
CASH FLOW INVEST.       7999.7   1554.8   1382.3   1696.4   2066.0   2500.0   3009.2   3605.8   4303.9   5120.1   6073.5
    -----------
TOTAL COVERAGE RATIO      0.00     0.00     0.06     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
```

PROFIT AND LOSS - NOMINAL DOLLARS

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
TOTAL REVENUE	0.0	1438.9	3197.8	3677.4	4229.1	4843.4	5592.9	6431.9	7396.6	8506.1	9782.1
STEAM	0.0	631.3	1403.1	1613.5	1855.6	2133.9	2454.0	2822.1	3245.4	3732.2	4292.0
HOT AIR	0.0	599.8	1333.0	1532.9	1762.8	2027.3	2331.4	2681.1	3083.2	3545.7	4077.6
ELECTRICIT	0.0	207.8	461.7	531.0	610.6	702.2	807.6	928.7	1068.0	1228.2	1412.5
TOTAL OPERATING EXP.	0.0	1164.0	1655.4	1821.0	2003.1	2203.4	2423.7	2666.1	2932.7	3226.0	3548.6
FIXED	0.0	806.4	887.0	975.7	1073.3	1180.7	1298.7	1428.6	1571.5	1728.6	1901.5
VARIABLE	0.0	357.6	768.4	845.2	929.8	1022.7	1125.0	1237.5	1361.3	1497.4	1647.1
INSURANCE	80.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0
OVERHEAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OPERATING PROFIT	-80.0	114.9	1382.3	1696.4	2066.0	2500.0	3009.2	3605.8	4303.9	5120.1	6073.5
DEPRECIATION	0.0	800.0	1439.9	1152.0	921.6	737.3	589.8	589.8	589.8	589.8	589.8
EBIT	-80.0	-685.1	-57.6	544.5	1144.4	1762.8	2419.4	3015.9	3714.1	4530.3	5483.7
INTEREST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SHORT TERM INTEREST	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROFIT BEFORE TAXES	-80.0	-701.1	-57.6	544.5	1144.4	1762.8	2419.4	3015.9	3714.1	4530.3	5483.7
RECAPTURE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INVEST. TAX CREDIT	0.0	1439.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WORK INCENTVE CREDIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TAX LIABILITY	0.0	-1439.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PROFIT AFTER TAXES	-80.0	738.9	-57.6	544.5	1144.4	1762.8	2419.4	3015.9	3714.1	4530.3	5483.7

```
**********************************************     BALANCE SHEET - NOMINAL DOLLARS     **********************************************
                      ---------------------------------------------------------------------------------------------------------------
                        1982      1983      1984      1985      1986      1987      1988      1989      1990      1991      1992
                      ---------------------------------------------------------------------------------------------------------------
INVENTORY                0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
CASH                     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
GROSS BOOK VALUE      7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7
AVAILABLE SURPLUS        0.0    1458.9    2841.2    4537.6    6603.6    9103.6   12112.8   15718.5   20022.5   25142.6   31216.1
TOTAL GROSS ASSETS    7999.7    9458.6   10840.9   12537.3   14603.3   17103.3   20112.5   23718.3   28022.2   33142.3   39215.8
 -------------
CUM. DEPRECIATION        0.0     800.0    2239.9    3391.9    4313.4    5050.7    5640.5    6230.3    6820.1    7409.9    7999.7
TOTAL NET ASSETS      7999.7    8658.6    8601.0    9145.5   10289.9   12052.6   14472.0   17488.0   21202.1   25732.4   31216.1
 -------------
SHORT TERM DEBT         80.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
DEBT                     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 -------------
EQUITY                7919.7    8658.6    6601.0    9145.5   10289.9   12052.6   14472.0   17488.0   21202.1   25732.4   31216.1
  RETAINED EARNINGS    -80.0     658.9     601.3    1145.8    2290.2    4052.9    6472.3    9488.3   13202.4   17732.7   23216.4
  BUYOUT                 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  PAID IN CAPITAL     7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7    7999.7
  PRECONSTRUCTION        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

B-14

```
                              *** PRESENT VALUE CALCULATIONS -  NOMINAL DOLLARS  ***
                     --------------------------------------------------------------------------------------------------------
                       1982      1983      1984      1985      1986      1987      1988      1989      1990      1991      1992
                     --------------------------------------------------------------------------------------------------------
CASH FLOW BAR         -8079.7    1554.8    1382.3    1696.4    2066.0    2500.0    3009.2    3605.8    4303.9    5120.1    6073.5
DELTA SURPLUS-PAID    -7999.7    1450.9    1382.3    1696.4    2066.0    2500.0    3009.2    3605.8    4303.9    5120.1    6073.5
  IN CAPITAL
                                    ----------------------------------------

                                    RATE OF RETURN ON INVESTMENT:  23.06
                                    RATE OF RETURN ON EQUITY:      23.06
                                    PAYBACK YEAR: *                 1987
                                    TOTAL CASH FLOW BAR:         23232.4


                                     ***   COST ANALYSIS - NOMINAL DOLLARS  ***

                                                          AVERAGE       PERCENT OF
                                                        ANNUAL AMOUNT  TOTAL REVENUE

                               REVENUES
                                    STEAM                    2198.5        43.88
                                    HOT AIR                  2088.6        41.68
                                    ELECTRICIT                723.5        14.44
                                                             ------        -----
                               TOTAL REVENUE                 5010.6       100.00

                               OPERATING EXPENSES:
                                  FIXED
                                    LABOR                     492.5         9.83
                                    MAINT.                    431.0         8.60
                                    MISC.                      81.6         1.63
                                    STAND-BY                  163.3         3.26
                                                             ------        -----
                                  TOTAL FIXED                1168.4        23.32

                                  VARIABLE
                                    RICE HULLS                785.6        15.68
                                    CHAR                      195.5         3.90
                                                             ------        -----
                                  TOTAL VARIABLE              981.1        19.58
                                                             ======        =====
                               TOTAL OPERATING EXPENSES      2149.5        42.90
                               INSURANCE                      152.7         3.05
                               DEPRECIATION                   727.2        14.51
                               INTEREST                         1.5         0.03
                               TAXES                         -130.9        -2.61
                               PROFIT                        2110.6        42.12
```