DOE/MC/28202 -- 5195
(DE96004476)

Gasification Product Improvement Facility (GPIF)

Final Report

September 1995

Work Performed Under Contract No.: DE-AC21-92MC28202

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
CRS Sirrine, Inc.
Greenville, South Carolina

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September 1995

Gasification Product Improvement Facility
Fort Martin Station, West Virginia
Jacobs-Sirrine Job No. 16N25706

Gasification Product Improvement Project

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1.0 EXECUTIVE SUMMARY

At present time, America's reliance on foreign oil imports is greater than ever, and the volatile Eastern Europe and Middle East show no signs of easing tensions. Hence, the potential for loss of a major portion of the nation's heretofore abundant fossil oil based energy supply is as tenuous as it has ever been.

This coupled with increasing world pressure to reduce air emissions from energy related industries provides a "double-barreled" reason for the United States to seek to reduce the high cost associated with Integrated Gasification Combined Cycle (IGCC) in general, and coal gasification in particular.

The gasifier selected for development under this contract is an innovative and patented hybrid technology which combines the best features of both fixed-bed and fluidized-bed types. DB Riley, Inc., and Jacobs-Sirrine Engineers have formed a team to develop and commercialize this technology, called PyGas™ meaning Pyrolysis Gasification. PSI Power Serv's (formerly PSI Technology) role has been in an environmental assessment and technology developmental research capacity. PyGas™ is well suited for integration into advanced power cycles such as IGCC. It is also well matched to hot gas clean-up technologies currently in development. Unlike other gasification technologies, PyGas™ can be designed into both large and small scale systems.

It is expected that partial repowering with PyGas™ could be done at a cost of electricity of only 2.78 cents/kWh, more economical than natural gas repowering.

It is extremely unfortunate that Government funding for such a noble cause is becoming reduced to the point where current contracts must be canceled. However, this is the reality of the current situation regarding this particular contract.

We are grateful to those at METC who made a valiant, though futile attempt to reincarnate a smaller version of the PyGas™ gasifier at the Wilsonville, Alabama site.

We continue to hold onto the hope that eventually, funding to do a PyGas™ pilot plant will be forthcoming with a new approach and new contract at some time in the future and at a place as yet undefined.

2.0 CONTRACT OBJECTIVE

The DOE Fossil Energy Program has a mission to develop energy systems that utilize national coal resources in power systems with increased efficiency and environmental compatibility. The Gasification Product Improvement Facility (GPIF) project was initiated to provide a test facility to support early commercialization of advanced fixed-bed coal gasification technology at a cost approaching $1,000 per kilowatt for electric power generation applications. The project was to include an innovative, advanced, air-blown, pressurized, fixed-bed, dry-bottom gasifier and a follow-on hot metal oxide gas desulfurization sub-system. To help defray the cost of testing materials, the facility was to be located at a nearby utility coal fired generating site. The patented PyGas™ technology was selected via a competitive bidding process as the candidate which best fit overall DOE objectives.

3.0 SIGNIFICANT FACILITY DESIGN EVOLUTION SUMMARY

The GPIF project contractor is Jacobs-Sirrine Engineers (formerly CRS Sirrine Engineers, Inc.). Project Team members as sub-contractors included DB Riley (formerly Riley Stoker Corp.) and PSI Power Serv (formerly PSIT Co.). The project relationship is shown in the following figure :

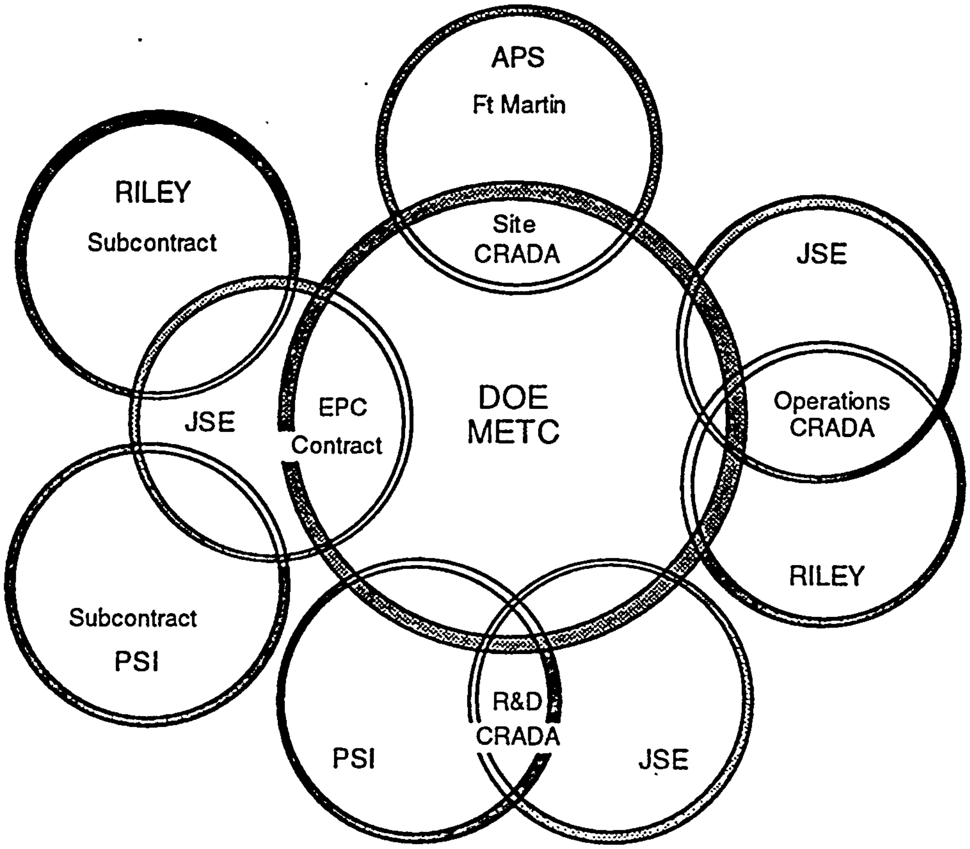


Figure 1 GPIF - A Government, Utility, and Industry Partnership

Of the nine tasks associated with Phase I of this project, the first four were completed, Task 5 was deleted, and Task 6 was partially completed.

3.1 TASK 1 NATIONAL ENVIRONMENTAL POLICY ACT DOCUMENTATION

A Topical Report entitled "Environmental Report" was prepared by the Project Team and issued to the DOE/METC in March, 1993. Subsequently, an "Environmental Assessment" was completed, leading to an Environmental Impact Statement and finding of No Significant Impact (NEPA Permit) for this facility.

3.2 TASK 2 WORK PLAN

A detailed "Work Plan" was developed for the performance of Phase I in accordance with the contract requirements. This plan was critiqued, reissued, and accepted by the DOE/METC.

3.3 TASK 3 PERMIT INFORMATION

The Project Team developed a comprehensive listing of potential permits, certificates, and inspection requirements for this project. Meetings were held to determine which potential requirements were applicable to this facility, those that could be included in the utility host's existing permit base, and those that could be handled by letter exemption or waiver.

3.4 TASK 4 CONCEPTUAL DESIGN

A complete conceptual design of the gasifier sub-system and the infrastructure required for the gasifier and the hot gas cleanup system was completed, reviewed, revised, and resubmitted several times during the third and fourth quarters of 1993 and first quarter of 1994. Final acceptance by DOE/METC of a topical report titled "Conceptual Design Report" was received in February, 1994. A completed Revision-0 design package was included in the "Conceptual Design" report. Completion of this significant project segment was a pre-requisite to initiation of the detailed design effort.

Concurrent with conceptual design was re-estimating facility capital costs and the development of the commercialization plan.

3.5 TASK 5 BENCH-SCALE TECHNICAL CONCEPT STUDIES

This task was deleted by the DOE/METC technical project manager in order to redirect greater technical emphasis on the facility design. Parallel work under a different contract (CRADA No. 94-021) effectively eliminated the need for the original concept studies effort identified in this task.

3.6 TASK 6 DETAILED CONSTRUCTION DESIGN

Significant effort on this task was expended by the Project Team from March, 1994 up to cancellation of the contract. Following are the most significant facility design evolutionary issues :

3.6.1 OPERATING PRESSURE CHANGE FROM 600 to 400 psig

The gasifier was originally 6 ft.-6 in. diameter with a normal operating pressure of 600 psig. The design pressure was 770 psig. The gasifier was also specified to operate at a minimum pressure of 200 psig. Coal throughput was to be 6 tons per hour at 600 psig operating pressure, and 2 tons per hour at 200 psig.

This 600 psig operating pressure was higher than gasifiers had previously designed for or built by DOE/METC. Design conditions for many components, such as lock hoppers, lock hopper valves and the fuel feed system exceeded design conditions for those components used on previous and contemporary gasifiers. The high pressure design, therefore, required development work for some support equipment, with associated higher cost, in addition to the development work required for the gasifier vessel itself.

A process air compressor for this high pressure was available, but pushed the limit of available equipment. The required motor horsepower was very high, nearly 7000 horsepower. This exceeded the electrical capacity for motor start up without the addition of a low voltage starter.

In December 1994, the gasifier normal operating pressure was reduced to 400 psig, with the 200 psig minimum pressure still required. This was done to limit equipment development work to the gasifier itself and to control cost of auxiliary systems. This pressure reduction allowed use of support equipment with design conditions at levels used on previous DOE/METC gasifiers. Design pressure was also reduced to 660 psig. The lower normal operating pressure reduced the normal coal throughput to 4 tons per hour. Reduced pressure and lower coal feed rates reduced the process air compressor size, with motor horsepower being reduced to 3000 horsepower. The reduced voltage starter was still required, however. Capacities of other support equipment, such as coal and limestone handling, product gas cyclone, and the HRSG, were decreased due to the new lower coal throughput. An equipment cost reduction resulted for this specification change.

3.6.2 · OPERATING PRESSURE CHANGE FROM 400 to 325 psig

After the scope and design conditions for the gasifier and the support equipment was firmed up, the project cost estimate was updated. When the estimate update was completed, the cost had increased much above the contract cost. A list of potential cost saving scope reductions was developed, which would still allow testing the PyGas™ technology. Scope changes which would not allow scaleup to a commercial unit were not considered. Operating pressure reduction to 325 psig was one of several scope reductions selected. Several other scope reductions were also required to reduce the cost below the original contract estimate level.

Other scope reductions selected were:

Reduce the gasifier diameter from 6 ft. 6 in. to 5 ft. 0 in.

Delete use of a separate limestone system to remove sulfur from the product gas during the gasification process itself.

Replacing the HRSG with a product gas incinerator, without heat recovery, and a package boiler to supply gasifier process steam.

Reducing the gasifier diameter reduced the building size. The combination of reducing the gasifier diameter and reducing operating pressure to 325 psig, decreased the anticipated total coal throughput to 2 tons per hour. The combination of reduced pressure and coal through put reduced the process air compressor motor to less than 2000 horsepower. That eliminated the need for a costly reduced voltage starter. In addition, all other motor horsepower requirements were reduced, as were piping and valve sizes.

The separate limestone storage and feed system was deleted. In addition, wet oxidation of ash was replaced with a lower cost dry ash handling and storage system.

The original HRSG concept was to recover heat from the incineration of the product gas and send the resulting steam to Fort Martin. This required an expensive high pressure boiler, a long high pressure steam pipe connecting to Fort Martin, and the use of high quality boiler feedwater obtained from Fort Martin. By using a simple incinerator to burn the product gas, the expensive HRSG and steam piping were eliminated. A less expensive small package boiler was added to provide the steam required for the gasification process.

3.6.3 REROUTING OF PIPE BRIDGE TO FT MARTIN

The original concept was to route the utility bridge from the East end of the gasifier structure, passing north of the existing settling ponds, and cooling tower No. 2, then turning South to run between cooling tower No. 2 and Unit No. 2 powerhouse.

Detailed design development revealed numerous underground services in the area between Unit No. 2 and cooling tower No. 2. Most of the underground services were large circulating water pipes or electrical duct banks. The nature of the project did not allow for these to be relocated. Utility bridge foundation location and span length became a major engineering and cost hurdle.

In addition to the design considerations, Allegheny Power Systems (APS) indicated that the utility bridge in the original location would preclude access to the cooling tower No. 2 circulating water pumps, as well as other major equipment that require periodic attention. APS requested that an alternate route be used.

In response to the objections of APS and to control cost, an alternate route was proposed. The alternate route maintains the portion of the original route along the North side of the settling ponds. The new segments turned the utility bridge South between the East end of the settling ponds and the West side of cooling tower No. 2. The bridge then continued to the river bank and then turned East along the river bank to Unit No. 2.

As project cost became a problem, a lower cost alternate route was searched for. As part of this effort the bridge routing was again scrutinized. An investigation into the feasibility of locating the bridge on the South side of the lagoons, along the river bank was begun. This investigation was not completed before work on the project was stopped, however, since its distance was some 350 ft. less, it is reasonable to expect that it would have provided significant savings.

3.6.4 DESIGN PRODUCT GAS TEMP. CHANGE FROM 1100° F to 1500° F

The original product gas design temperature at the gasifier outlet was 1100° F. A combination of water and steam spray was to be utilized to achieve desired exit gas temperature. As reliance on spray water cooling of the product gas became more of a design issue, the desire not to spray water into the product gas stream had to be evaluated against the cost of high temperature piping. Projections were that the maximum product gas outlet temperature could even exceed 1800° F under some conditions. Calculations for the required length of the spray pipe revealed that about 60 ft would be required. This length presented building size problems. In addition there were concerns about possible water droplets entering the product gas cyclone causing erosion of the cyclone wall and possible solids deposition concerns. The decision was then made to increase the product gas outlet design temperature to 1500° F. This temperature was chosen because valves required around the lock hoppers were known to be available at such design temperatures. The plan was to cool the product gas as much as possible in a length of 10 ft. under the extreme conditions. Normally little or no cooling would be required. Gasifier operating variables would be limited to not exceed 1500° F at the end of the cooling spray pipe, if the cooling capability in 10 ft. would otherwise result in temperature exceeding 1500° F.

During the development of the estimate discussed in 3.6.2 above, the product gas pipe designed for 1500° F design temperature was found to be very expensive. Both high alloy pipe and refractory lined pipe were considered. One of the cost saving items then selected was to reduce the product gas design temperature to 1100° F. The gasifier diameter and coal through put reductions had the effect of reducing product gas temperature to less than 1100° F for normal operation. Only in extreme operating conditions would the product gas temperature exceed 1100° F. A cooling spray pipe designed for 50° F gas temperature reduction was included in the scope. This allowed a maximum gasifier product gas outlet temperature of 1150° F. Gasifier process variables would be limited to prevent higher temperature if 50° F reduction still resulted in temperatures higher than 1100° F. Only very minor limitations were expected to control the temperature in this scenario.

3.6.5 GPIF STATE AIR PERMIT REQUIREMENTS

The original scope of the GPIF included a flue gas duct from the GPIF to Fort Martin. GPIF flue gas was to tie into the Fort Martin Unit No. 2 precipitator inlet duct. The GPIF was considered part of the Fort Martin system, and therefore was to be covered by the existing Fort Martin permit.

The GPIF would gasify the same coal being burned by Fort Martin. Flue gas from incineration of GPIF product gas would pass through the Fort Martin precipitator and stack. Steam generated from the GPIF product gas would be supplied to the Fort Martin system. The PyGas™ process using the original concept of limestone mixed with coal feed, was expected to use low sulfur coal as well as remove most of the coal's sulfur. The result would be less SO_2 emission with GPIF operating than with GPIF not operating.

Discussions by DOE/METC with the State of West Virginia resulted in the requirement for a state air permit. The most serious impact was the requirement for a SO_2 scrubber and the schedule delay for construction.

The SO_2 scrubber added capital cost scope to the project without being covered by additional dollars added to the contract. In addition, no construction work was allowed by DOE/METC until the permit was issued.

It is logical to the Project Team that small research facilities such as the GPIF should not require commercial scrubbers. It is unclear why other facilities such as Wilsonville, Alabama have been able to be constructed without the requirement of SO_2 scrubbers, while in Maidsville, West Virginia, the opposite was the case.

3.7 TASK 7
TASK 8
TASK 9

The Site Preparation/Construction, Pre-Operational Test planning and testing tasks had not yet started at the time of project cancellation.

However, the following illustrates what was anticipated for the test plan and sequence :

Table 1

GPIF TEST PLAN

- Start with Coke Breeze
- Eastern Bituminous Coals
- Test Other Coals
    - Mid-Western Bituminous
    - Western Sub-Bituminous
    - Lignite Coals
- Full Complement of Input/Output Data
- Sulfur, Alkali, Ammonia Measurements

Table 2
GPIF TEST SEQUENCE

- Independent Pyrolyzer
- Integrated Pyrolyzer/Fixed-Bed
- Parametric Testing

The time-line of the project, re-direction of technical and installation emphasis by DOE/METC, and a variety of developments which impeded progress can readily be seen in the following major deliverables and a summary of events tables :

Table 3
Major Team Deliverables

Mar 93	TASK 1	ENVIRONMENTAL REPORT ISSUED
Mar 93	TASK 2	WORK PLAN ISSUED
Jun 93	TASK 3	PERMIT INFORMATION ISSUED
Feb 94	TASK 4	CONCEPTUAL DESIGN REPORT ISSUED
Jun 94	TASK 4	SANITATION SYSTEM REPORT ISSUED
Oct 95	TASK 6	REV-1 PROCESS DESIGN BASIS ISSUED

Table 4
Summary of Major Events

Jun 91	Mon Power Site Access Agreement
Sep 92	EPC Contract Award
Mar 93	Task 1 - Environmental Report Issued
Jun 93	JSE/DB Riley Teaming Agreement Reached
Feb 94	Task 4 - Conceptual Design Complete
	Gasifier Diameter from 5' to 6.5'
	Phase 1 Cost Estimate from $24.8 to $27.8-mil
Mar 94	Environmental Assessment/Finding of No Significant Impact Issued (NEPA)
Jun 94	METC Core Team Interactive in Concept Design
Jul 94	CRS Sirrine Acquired by Jacobs Engineering Group
Sep 94	Revised Concept Design Completed
Oct 94	METC Project Team Formed/Operations Responsibility
Dec 94	State WV Decision Requiring GPIF Air Permit
	Construction Start Delayed from Jun 95 to Oct 95
	Design Pressure Changed from 600 psig to 400 psig
Jan 95	Independent Cost Review
Feb 95	Flue Gas Desulfurization Added to Scope
	Rev - 0 Process Design Basis Completed
	Pipe Bridge to Ft. Martin Rerouted
Mar 95	Air Permit Application Submitted
Apr 95	JSE/Riley Executed Commercialization Agreement
	25% Design Review Completed
May 95	Design Basis Pressure Reduced to 325 psig
	Gasifier Diameter Reduced from 6.5' to 5'
	Design Temperature Changed from 1100°F to 1500°F
	Project Costs Revised
Aug 95	Termination Notice Received
	Rev-1 Process Design Basis Completed
Sep 95	Termination Cost Proposal Submitted
Oct 95	Final Technical Report (25 Page) Submitted

4.0 PyGas™ TECHNOLOGY ADVANTAGES

A DOE/METC internally generated report confirmed that fixed-bed systems have the highest potential thermal efficiency of all gasification concepts. This is because more of the Btus go to the Brayton thermodynamic cycle and less to the Rankine thermodynamic cycle than any other gasification process.

BASIC PyGas™ GASIFIER TRAITS

In this hybrid dual-stage gasifier, virtually all of the hydrogen and carbon in the coal is converted into fuel gas, which can then be combusted in highly efficient gas turbines and/or conventional boilers arranged in combined cycle configuration.

The stages of the hybrid PyGas™ gasifier process are depicted in the following process schematic :

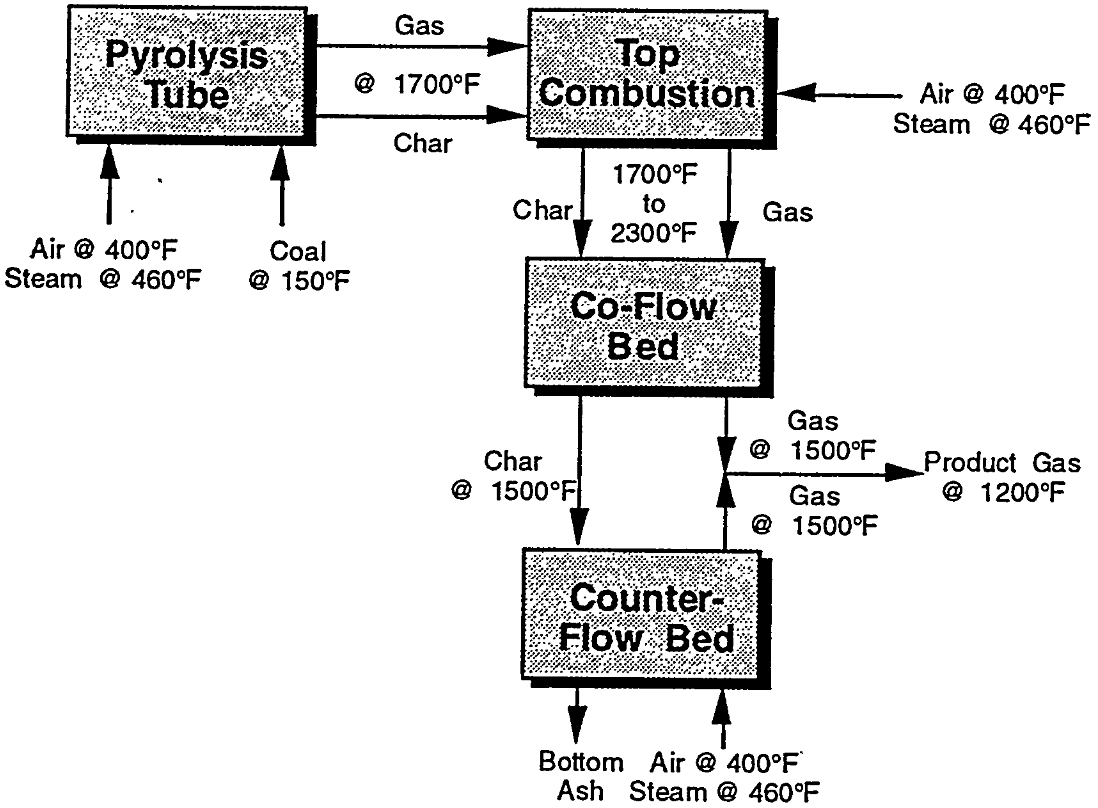


Figure 2 PyGas™ Process Schematic

The purpose of the first stage of the PyGas™ gasifier is to de-cake eastern bituminous coals within a fluidized-bed pyrolyzer. This process overcomes the capacity reductions and operational difficulties commonly associated with agglomerating tendencies of caking coals in conventional fixed-bed gasifiers.

It is now apparent that even caking coals can be rendered non-caking in a fluidized-bed pyrolyzer tube (pre-treatment). This stage also offers the additional benefit of tar destruction due to a combination of residence time, elevated temperatures, and steam injection.

Once rendered non-caking, the coal char overflows the pyrolyzer tube and falls into a fixed-bed below. As is commonly done in fixed-bed gasifier applications using low swelling coals, coke, and char, gasification is achieved by introducing air and steam via a rotating grate. Bottom ash carbon content can thus be controlled to the low levels acceptable to industry and the environment.

4.1 VIABILITY OF THE PyGas™ GASIFICATION CONCEPT

There exists significant data to cofirm the viability of the two major components which comprise the PyGas™ gasifier, and the use of limestone as a sulfur capture agent. These attributes are considered essential to achieving the DOE/METC GPIF project low cost objective of $1000/kW.

4.2 IMPORTANT PROCESS CHEMISTRY

Initially, C. Lowell (Wormser Engineering) et al and subsequently, Foster Wheeler Development Corp. demonstrated as high as 95% sulfur retention by the use of limestone injection with the coal into a "slug flow" pyrolyzer operated at 1600°F and of the same geometry as the one used within the PyGas™ gasifier vessel. Since the PyGas™ coal gasifier operates at from 1300°F to 1600°F in its rapid devolatilization pyrolyzer section, it is expected that the limestone will directly react, and subsequently form calcium sulfide while in the pyrolyzer section of the PyGas™ gasifier. Once CaS is formed along with char in the pyrolyzer, it is further expected that control of the gasifier operating temperature at the top of the gasifier by combusting pyrolysis gases will not adversely affect the CaS solids since both the METC MGas and the KRW kinetic rate models predict very rapid endothermic gasification and temperature drop to the vicinity of 1500°F within a very short distance within the upper solids bed. Similarly, it is believed that the lower PyGas™ operating temperatures in the gasifier solids bed region (lower than typical fixed-beds) will allow the CaS to remain or oxidize to $CaSO_4$ since the grate area operates in an oxidizing atmosphere.

J.M. Eakman (Exxon Research) et al identified that alkali metal gasification catalysts increase the rate of steam gasification, promote gas phase methanation, and minimize agglomeration of caking coals in a slugging pilot scale unit whose geometry was very similar to that of the PyGas™ proprietary gasifier pyrolysis section.

C.Y. Wen (West Virginia University) et al concluded from their entrained-bed coal gasification modeling that the effect of total pressure was increased carbon conversion at any steam to fuel ratio. They also concluded that increasing oxygen to fuel ratios increased carbon conversion at any operating pressure and at an optimum steam to coal ratio. The existence of an optimum steam to fuel ratio is important, because one can obtain the same carbon conversion at a lower oxygen feed by maintaining optimal steam to fuel ratios in the 0.4 to 0.5 range. Moreover, their carbon conversion efficiencies considerably exceeded that required by the pyrolyzer section of the PyGas™ gasifier indicating that acceptably high carbon utilization may be expected thereby minimizing conventional fixed bed gasification air and steam requirements.

H.S. Muralidhara (West Virginia University) et al concluded from their study that after initial pyrolysis, kinetic reaction rate increases in direct proportion to calcium content of the coal. This may prove valuable to the PyGas™ proprietary gasification process and may serve to explain in part why C. Lowell et al achieved greater than 50% carbon utilization during carbonization. As catalysts like calcium and potassium increase the reaction rate, endothermic reactions continue to lower the exit gas temperature. The 1600°F threshold, previously thought to be the practical kinetic limit of coal gasification reactions may be lowered toward 1200°F by such catalytic effects.

D.E. Woodmansee et al (General Electric) found that the efficiency of converting coal enthalpy to cold gas fuel value increased by 4% when the steam/air mass ratio was reduced. This is consistent with the PyGas™ concept of pyrolysis and cracking control by air flow with minimization of steam injection.

E. J. Nemeth et al (U.S. Steel Corporation) pilot scale results showed that the desulfurization of coal-derived gas at 1500 to 1770°F is feasible. They found that desulfurization of the hot reducing gas initially exceeded 97% removal of H_2S with dolomite.

C.Y. Wen et al (West Virginia University) stated that the understanding of coal pyrolysis is very important in view of the potential of the process to take advantage of (1) the phenomena of rapid pyrolysis and (2) obtaining higher yields of gaseous hydrocarbons by the application of pressure and hydrogen atmosphere. It was also stated that pilot plant studies of Union Carbide showed that release of gaseous hydrocarbons is improved significantly under high partial pressure of hydrogen. The char-gas reactions that take place during the second stage following the pyrolysis reaction may be classified into two distinct categories, namely volumetric reactions and surface reactions. Thus, diffusion is an important step in heterogeneous char-gas reactions. Higher hydrogen partial pressure improves the carbon conversion in the first stage of fast pyrolysis. For this reason, the PyGas™ process provides for the introduction of steam into the pyrolysis section of the gasifier along with the coal, limestone, and air.

If in the char-oxygen reaction (burning of char), the temperature and/or the particle size decrease substantially, the reaction may proceed toward the chemical reaction control regime, and it may take place uniformly throughout the internal pore surfaces of the particles. This observation may allow the PyGas™ gasifier to operate at lower steam to coal ratios in the gasifier combustion zone without experiencing the ash melting problems of conventional fixed bed gasifiers.

Wen observed that very little study has been done on the relative reactivities of different coal-chars in char-steam reactions. These works concluded that carbon-steam or char-steam reaction is chemical reaction controlled for smaller carbon/char particles (roughly <500 micron) and at temperatures up to 1800°F. At these conditions, the reaction occurs uniformly throughout the interior of the pore surfaces of the solid particles.

Wen also concluded that the phenomena of pyrolysis, particularly that of rapid and flash pyrolysis are yet to be understood well. The GPIF would have corrected this deficiency.

4.2.1 IN-SITU SULFUR REMOVAL

The fluidized-bed processing of coals having 3 to 5 percent sulfur content in the presence of limestone and dolomite has demonstrated capture of 88 to 95 percent of all sulfur released. Much of the captured sulfur is in the form of calcium sulfide (CaS). Retention of sulfur in this form has proven much more difficult within fixed-bed processes, probably due to the release of sulfur dioxide at elevated temperatures. Studies on the oxidation of CaS by Lynch and Elliot and Tones-Ordannes demonstrate that at high temperatures (greater than 2,500°F), complete oxidation occurs releasing SO_2 and producing CaO. At temperatures below 2,000°F, sulfate was produced in small amounts. In the intermediate range (2,100 to 2,300°F), the conversion of CaS oscillated rapidly between the formation of oxide and the sulfate. Rehmat conducted a study of these reactions for dolomite and limestone over the range of 1,500 to 1,900°F and up to 400 psig. Greater levels of sulfation were reported for dolomites (83 to 100 percent) than for limestone's (18 to 34 percent). The fixed-bed combustion zone in the PyGas™ process must be carefully controlled with a test objective to minimize sulfur release. Substantial sulfur retention is anticipated within the PyGas™ process.

4.2.2 CONTROL OF FUEL NITROGEN RELEASE

The volatile fraction of coal bound nitrogen is known to be released as hydrogen cyanide and ammonia in coal gasification processes. Control of the amounts of these compounds which are formed will be attempted by the utilization of controlled combustion, adding air within the gasifier vessel. This must also be a test objective. It is known that elevated temperatures reduces the formation of these species. The extent of molecular nitrogen formation from fuel bound nitrogen must be weighed against the inherent inefficiencies brought about by adding air to the pyrolysis gas before such operation can be considered sufficiently effective for commercial viability.

4.3 INHERENT ADVANTAGES OF THIS PROCESS COMPARED WITH AVAILABLE COMMERCIAL TECHNOLOGIES

The single most important inherent advantage of this system configuration is that the two most costly equipment areas in the existing power plant, the boiler and steam turbine, are both utilized at near full capacity. Precedence for operating a fully fired combined cycle (both the combustion turbine and the existing boiler are fired, and the existing boiler utilizes turbine exhaust gas) has been set nearly thirty years ago at such utility installations as West Texas Utilities San Angelo Station, and Oklahoma Public Service Company's Horseshoe Lake Station, both of which are combined cycle installations which utilize a fired boiler. Since the boiler island represents the largest cost of a coal fired power plant (typically 25% of the equipment cost), it makes more sense to utilize it rather than to pay to demolish it, or even more costly, to replace it with another type of boiler.

4.4 RELATED PyGas™ PROCESS CHEMISTRY MODELING

The PyGas™ coal gasifier employs several related and critically important process chemistries:

The pyrolyzer section rapidly drives off approximately 50% of the coal weight in the form of gaseous volatiles by pneumatically injecting the raw coal into the preheated pyrolyzer cone at from 1300° F to 1800° F. This "rapid pyrolysis" process has been proven successful in overcoming previous concerns of sticky tar formation which results in agglomeration in conventional fixed-bed gasifiers. The reason is that instant subjection of the coal to temperatures which exceed the point at which tar can exist in liquid form result in their devolatilization to gaseous form and even cracking with sufficient residence time.

Pneumatic introduction of crushed limestone along with the crushed coal into the rapid devolatilization pyrolyzer section of PyGas™ allows the $CaCO_3$ to react with H_2S to form CaS.

The introduction of additional top air into the PyGas™ gasifier elevates the temperature to approximately 2300° F (depending upon the specific ash fusion characteristics of each coal). This causes the tar vapors to crack and liberate additional sulfur to form additional H_2S, then endothermically react to form additional H_2 & CO.

This results in two distinct advantages:

1. The tars liberate sulfur which would otherwise not be captured by hot gas cleanup systems, and
2. The troublesome tar and carbon-black thermophoresis related pluggages downstream of the gasifier can be avoided.

As the hot coal gas then passes cocurrently down through a char laden partially fixed/partially fluidized-bed (manometer effect), endothermic gasification reactions serve to both rapidly consume available carbon, and to cool down the bed allowing previously volatilized alkali to condense onto and potentially be tied up by added or naturally occurring aluminosilicates in the ash. Any available carbon remaining in the ash is subsequently gasified above the rotating grate in the usual fixed-bed coal gasifier method using typical steam to coal ratios (but at considerably reduced mass flows) initially for oxidation, and then both temperature control and gasification.

The lower solids bed is also expected to capture the remaining sulfur fraction as it becomes released during gasification as CaS and subsequently (with adequate temperature control) allow the CaS to oxidize to $CaSO_4$ since it operates in the typical fixed-bed gasifier oxidizing manner.

The expected gasifier exit temperature from PyGas™ is approximately 1200°F to 1500° F, which is nearly ideal for hot gas cleanup systems which require raw gas temperatures above 1200° F. The control of PyGas™ raw gas exit temperature to match precisely the required zinc based sulfur sorbent operating temperature range may be accomplished in two ways:

1. Water spray mist injection is contemplated to both cool the PyGas™ exiting raw gases and maintain sufficient gas moisture levels as needed in the sulfur absorber vessel. Unlike the limits of singularly fired combined cycle plants which have unfired HRSG's, compressor surge margin limitations can be maintained irrespective of coal gas moisture in the dual fired combined cycle arrangement. This is because not all of the turbine air bled to the gasifier need be returned to the turbine combustor. This is the result of the plant arrangement having both a booster air compressor, and an auxiliary air compressor for dual combined cycle firing of coal gas.

2. Since it is well known that most coal ash contains calcium and potassium based compounds which produce catalytic endothermic gasification reactions, exit raw gas temperatures from the PyGas™ gasifier may be driven below its anticipated 1500°F level toward 1200°F. The test facility is expected to reveal just how far such gasification reactions can be driven. Its results may then dictate whether zinc ferrite, zinc titanate, Z-sorb, or other hot metal sorbent is optimum.

The bottom ash from PyGas™ is expected to contain less than 5% residual carbon and 50% to 100% sulfur removal in the form of CaS and fully oxidized $CaSO_4$, along with unreacted residual $CaCO_3$. Obviously, sufficient sulfur capture would obviate the need for separate hot gas cleanup.

Significant effort has been given to this continuing process, including the development of a mathematical model to determine the appropriate operating conditions within the PyGas™ gasifier vessel using both the METC-MGAS and KRW kinetic rate limitations.

The preliminary results of this modeling effort are included herein. They have also been presented at and published by the American Society of Mechanical Engineers (ASME) under the title "THE PyGas™ PROCESS, AS MODELED BY DOE-MGAS & KRW KINETIC RATE EQUATIONS".

These most significant developments showed conclusively that adding a pyrolyzer such as contemplated by the PyGas™ gasifier increases the gasifier yield by avoiding liquid phase tars, as well as by quickly consuming 50% of the coal in a relatively small fluidized bed vessel operated in the "slug flow" regime.

If all that the PyGas™ gasifier ever did was to condition caking coal to avoid agglomeration, it would no doubt be considered very successful. However, the PyGas™ gasifier can potentially perform several additional process benefits in the gasification of coal. These include cracking tar, condensing volatilized alkali, preventing coal fines carryover from the gasifier, producing raw gas at temperatures ideal for hot gas cleanup systems, and handling coal of any expected moisture content with no adverse affect on gasifier exit temperature.

Additional air is specifically introduced at the top of the gasifier to further reduce cyanide and ammonia levels as well as to raise its operating temperature sufficiently to crack the tars driven to gaseous form during pyrolysis. To do this requires only to add air until the gasses at the top of the PyGas™ gasifier reach approximately 2300 F. The specific coal inorganic fraction fusion characteristics will dictate more precisely the top gas operating temperature just as it does for conventional fixed-bed gasifiers.

Since the last stage of the PyGas™ coal gasification process is that of carbon gasification, the raw gas exit temperature will always be very close to the optimum for metal oxide types of hot gas cleanup systems, in the 1200°F to 1500°F range. This is a decided advantage as opposed to either the molten slag bottom entrained bed gasifier types which produce raw gas too hot for hot gas cleanup systems, and conventional fixed-bed gasifiers whose raw gas product is often too cold depending on how much coal moisture had to be evaporated hence cooling down its exiting temperatures.

Irrespective of coal moisture content, the PyGas™ gasifier's raw gas exit temperatures remain nearly constant at near optimum hot gas cleanup temperatures. Conventional fixed-bed gasifiers which have no control over raw gas exit temperatures affected by incoming coal moisture and associated tar condensation will create significant difficulty for hot gas cleanup system control.

Based upon the repeated past successes of pyrolyzers (sometimes called "carbonizers") built and operated by several U.S. Government agencies as well as independent private organizations, and owing to the simplicity of merely placing such a device within the confines of a fixed-bed air-blown coal gasifier vessel in such a manner that gravity alone is necessary to move the products of pyrolysis into the conventional gasifier, a decision by the DOE to accept the PyGas™ gasifier as "ready for pilot scale testing" would be quite reasonable.

4.4.1 THE PYROLYZER

Pyrolysis is the chemical change created by the addition of heat in a reducing atmosphere. Gasification is the phase change from solid to gas also produced by the addition of heat also in a reducing atmosphere. As coal enters any gasifier, it must be heated to gasification reaction temperatures. During heating, volatiles (i.e. CO, CO_2, H_2, H_2S, & NH_3) and condensable hydrocarbons (referred to as tars) are released. The release of the volatile products is directly affected by the heating conditions. As coal is heated, its volatiles form bubble-cell structures throughout the coal. Under rapid heating conditions (10^4 °F/sec), the expansion of the volatiles within the bubbles quickly reach high enough pressures to "break" the bubbles and escape before the coal particle expands. However, as the heating conditions decrease to under 10^3 °F/sec, the coal particles swell before the pressure within the "volatile bubbles" is high enough to rupture the "bubbles". The phenomenon of tars forming a sticky surface coating on coal results in adjacent particles "sticking" together and forming an incipient clinker. This phenomenon is known as agglomeration. Air and steam pass around such agglomerated lumps following a path of least resistance. This bypassing results in a diminished gasification reaction since the air and steam cannot reach the unreacted coal contained within the agglomerated lump. When this happens, channeling occurs within a gasifier and its productivity and efficiency quickly diminish.

Rapid devolatilization occurs in the PyGas™ pyrolyzer section. The rapid heating liberates the tars in gaseous form rather than tacky liquid form. Thus, the agglomeration characteristics of highly caking coals from most eastern American bituminous seams becomes irrelevant.

The PyGas™ pyrolyzer resembles the pyrolyzers used by the United States Bureau of Mines to devolatilize various coals by a process sometimes called "carbonization". In addition to identifying their empirical relationships, reports produced by Wormser Engineering, Inc. and West Virginia University were reviewed to model the pyrolyzer performance. A major objective of PyGas™ is the rapid devolatilization and maximization of carbon conversion in the pyrolyzer. This, in turn, minimizes air and steam requirements needed to gasify the remaining carbon (char) in the fixed bed gasifier section. Volatiles released, and thus carbon conversion, can be higher than ASTM test indications of weight loss of caking coals as a result of rapid devolatilization. The US Bureau of Mines notes that bituminous coal volatile yield peaks at approximately 1300° F if rapid heating is applied. On the other hand, if the heat rate is slowed down, the volatile yield becomes proportional to pyrolysis temperature. Peak weight loss of the coals was then compared with the test data with the determination of the volatile content of coal by ASTM standards.

Cases for several different air-to-coal ratios at the top of the gasifier were developed. Limiting the amount of air added resulted in the ability to reach upper zone temperatures of 2300° F without the addition of steam to the top of the gasifier. As more air is added to the top of the gasifier, additional steam must be added to keep temperatures from exceeding 2300° F. As the air-to-coal ratio at the top of the gasifier increases, total steam-to-coal ratio to the gasifier also increases. As the air-to-coal ratio to the top of the gasifier increases, the amount of air needed for lower bed gasification decreases. The total mass flow of air for pyrolysis and gasification remains relatively constant over the range of upper area air-to-coal ratios. Investigation of carbon conversion indicates that as the amount of top air increases, the carbon conversion in the upper bed increases and the requirement for lower bed carbon conversion decreases. The amount of moisture in the product gas changes and the higher heating value of the product gas also varies markedly as a function of top air-to-coal ratio. As the amount of air to the top of the gasifier increases, steam needed to maintain gasifier peak temperatures also increases. The result is a gas with a large amount of moisture and a low heating value. It is, therefore, apparent that peak performance should be gained by operating the PyGas™ gasifier with minimal amount of steam to gasify the coal. The model was also applied to determine the gas constituents exiting the pyrolyzer, exiting the upper gasifier bed, exiting the lower gasifier bed, and finally the combined raw product gas.

Table 5
Predicted Gas Compositions at Various Stages in the PyGas™ Gasifier
Using DOE - CCT4 Reference Coal Analysis
(volumetric percentages)

COAL GAS CONSTITUENT	PYROLYZER EXIT	UPPER GASIFIER EXIT	LOWER GASIFIER EXIT	COMBINED RAW PRODUCT GAS
CO	23.8	27.39	23.51	26.34
H_2	19.77	17.59	15.33	16.98
CO_2	3.94	1.8	6.08	2.95
H_2O	2.14	2.35	17.49	6.43
CH_4	4.70	0.00	0.00	0.00
H_2S	0.91	0.57	0.00	0.42
N_2	43.31	49.13	37.14	45.90
Tars	<1.0	<0.1	<0.1	<0.1
Alkali (ppmv)	<.1	<.1	<0.01	<0.01
Temp (°F)	1300	1500	1500	1500
HHV (Btu/scf)	198	151	134	144

4.4.6 TECHNICAL CONCLUSIONS

The PyGas™ coal gasification process promises to alleviate previous limitations in the type of coals that can be effectively gasified in an air-blown, fixed-bed gasification system.

1. Caking coals can be gasified without the adverse effects of sticky tars which have historically resulted in agglomeration in fixed-bed gasifiers.
2. It incorporates features to eliminate (by cracking) tar formations from exiting the gasifier and plugging downstream piping and equipment.
3. It provides a bed of ash on which volatilized alkali can condense and become retained by aluminosilicates either contained within or added to the coal ash.
4. By cracking sulfur containing tar formations, a previous concern of hot gas cleanup system sulfur bypass is eliminated.
5. High moisture containing coals can be gasified without lowering the gasifier exit temperature which could otherwise adversely affect the hot gas cleanup system, and without excessive exit gas moisture which can otherwise exceed turbine compressor surge margin limitations.
6. In contrast to slagging gasifiers, coals with high or low ash fusion characteristics can be gasified in this air-blown gasifier.
7. The exit temperature allows for optimum performance of the hot gas cleanup unit to remove sulfur compounds.
8. Utilized in concert with hot gas cleanup and a combination of rich/lean gas turbine combustion followed by NO_x reburning in fired retrofitted boilers, emissions of SO_2, NO_x, and CO_2 are expected to be the lowest ever achieved by an IGCC system.

The result is expected to be a clean, low-Btu gaseous fuel of approximately 150 Btu/scf at 1200° F, suitable for firing gas turbines, power boilers, and other combustion processes.

4.5 TECHNICAL/ECONOMIC ADVANCES

Historically, fixed-bed gasifiers have been less than successful when gasifying eastern U.S. highly caking coals. This is due to high free swelling coal's propensity to swell and form sticky tars and asphaltines resulting in agglomeration, overheating, and clinkering. Several gasifier manufacturers and researchers have attempted to mechanically break up such agglomerates in an "ex post facto" manner with water cooled stirrers. To date, none have adequately dealt with the phenomenon. Work done in 1963 by Lurgi for the Bureau of Mines on highly caking eastern bituminous coal clearly shows that conventional fixed-bed gasifiers experience coal throughput limitations of from 49% to 65% due to the caking characteristics of Pittsburg #8 coal. This resulted despite the use of a water cooled stirring device intended to break up incipient agglomerates. The remarks column for the 28 hour test duration identified overheating, porous coke in the discharge, blocked ash discharge, and large semi-fused clinker occurrences. Other fixed-bed coal gasifier manufacturers have experienced very much the same results when attempting to gasify highly caking coals. The PyGas™ gasifier is a novel approach aimed at preventing the thermal conditions which promote the agglomeration phenomenon such as that just described.

Since the PyGas™ gasification process is also intended to crack gaseous tars, it is expected to result in significantly less tar sulfur related sulfur bypass of the hot gas cleanup system, and far less concern for operational constraints relating to tar and carbon-black thermophoresis pluggage potential downstream of the gasifier than currently exists for current fixed-bed gasifiers.

The anticipated condensation of volatilized alkali onto the coal ash within the gasifier where it can be stabilized by the aluminosilicates in the ash represents yet another very substantial potential technological advantage of the PyGas™ coal gasification process.

Another potential technical advance of PyGas™ type of coal gasification process was demonstrated by Acurex under DOE contract. Less ammonia conversion to NOx was reported for low Btu gas combustion than for medium Btu gas. When combusted in a rich/lean mode, as much as 95% NOx reduction resulted. Additionally, when low Btu PyGas™ gasifier coal gas is also combusted in the burners of an existing retrofit/repowered boiler with turbine exhaust gas, a significant amount of NOx reduction by "reburning" can also take place. West Texas Utilities San Angelo plant demonstrated a 50% reduction in the NOx that had been produced by the gas turbine when operated in the fired gas turbine and fired boiler combined cycle mode.

Yet another potential technical advance which the PyGas™ gasifier would likely enjoy over other fixed-bed gasifiers is its consistently relatively moderate raw gas exit temperature (approximately 1200° F). Typical coal gasifiers cannot control their raw gas exiting temperatures due to the evaporative process of the entering coal's moisture which can vary daily with coal moisture content.

Carbon carryover from the PyGas™ coal gasifier is expected to be very low since none of the coal feed fines can bypass the gasification process as is the case with most fixed-bed coal gasifiers. Controlled agglomeration of fines within the gasification vessel is also possible since the whole decaking process is done within the gasifier vessel.

Existing boilers fired with high gas mass flows as would be the case for a fired combined cycle retrofit/repowered boilers with low Btu PyGas™ gasifier coal gas have the potential to produce more burner turbulence, better mixing and lower CO emissions.

The final technical advance is the potential ability of the PyGas™ gasifier to produce exit gas temperatures very near the optimum for hot gas cleanup systems. This is in contrast to the very hot slagging gasifiers which must either quench their gas (very inefficient), or indirectly cool their gas which shifts more heat to the less efficient Rankine thermodynamic cycle and away from the more efficient Brayton thermodynamic cycle.

Therefore, the PyGas™ gasifier coal gasification process claims the following potential advances :

POTENTIAL TECHNICAL ADVANCES

1. Operates even on eastern high caking bituminous coals.
2. Cracks tars for condensation and thermophoresis avoidance.
3. Liberates tar related sulfur promoting higher hot gas cleanup system sulfur capture.
4. Condenses and captures volatilized alkali with in-bed ash-aluminosilicate reactions.
5. When the low Btu PyGas™ gasifier coal gas is rich/lean fired in a gas turbine, then fired in a retrofit/repowered existing boiler on turbine exhaust gas, the an emission of rate less than 0.1 lb/mil-Btu of NOx is anticipated without an SCR.
6. High raw gas exit temperatures consistent with the needs of hot gas cleanup systems.
7. Low carbon carryover since coal feed fines cannot bypass the gasification process.
8. Not requiring significant raw gas cooling (with associated Btus going to the Rankine cycle) keeps more Btus in the more efficient Brayton cycle, achieving the highest cycle efficiency.

Relative to economics issues, following are the relevant issues:

1. The PyGas™ gasifier is air-blown thereby eliminating a very costly and energy intensive individual subsystem in the plant, the oxygen separation plant. A recent Destec ad indicated a $30-million oxygen separation plant is used by their process on an $80-million balance of system.

2. The PyGas™ gasifier is intended to be manufactured in the largest truck shippable shop fabricated vessel module; a size sufficient to produce 100 MWe in a combined cycle application.

3. The PyGas™ gasifier has only one moving part inside the vessel, the rotating grate.

4. The crushed coal feed system is pressurized far upstream of the gasifier which alleviates the requirement for a hot high pressure lock hopper valve since it operates in a 150° F environment.

5. Since the PyGas™ gasifier incorporates continuous pneumatic crushed coal feed, no valuable coal gas is wasted through a coal feed lock hopper vent system.

6. Fixed-bed gasifiers traditionally operate on sized lump coal. The PyGas™ gasifier uses crushed coal to 1/4 inch by zero. Therefore, it can operate on far cheaper "run of mine" coal feed.

7. What may be the single most important economics issue of all is that the PyGas™ coal gasification process is suitable for and intended to retrofit/repower existing utility boilers without the need for pressure part modifications to the boiler. Since the boiler is the single most expensive piece of equipment in a utility generating station, making use of it rather than planning to demolish it in favor of a new boiler would save substantial costs.

8. The PyGas™ gasifier is expected to be sold to utility generating companies much like boilers and turbines have been marketed in the past. The repowering approach is always a lower cost one than for the utility to have to purchase energy "over the fence" at value added costs from a private owner/operator, because the existing facility's efficiency is substantially increased and most of the facility cost already exists making it largely already "sunk" and amortized.

4.6 THE REPOWERING OPTION CONCEPT

In a normal repowering setting (not the GPIF), a conventional heat recovery steam generator would be contemplated downstream of the combustion turbine to produce approximately 250°F turbine exhaust gas in the normal fashion except that it would be designed to produce saturated steam only. This would be necessary to make up for the lowered pulverized coal flame temperature when firing on turbine exhaust gas under fully matched combustion turbine and pulverized coal fired boiler conditions, and the attendant reduction in furnace performance (steam generation). Conversely, the additional gas mass flow over the superheater would then allow full steam temperature to be reached and full Rankine cycle efficiency to be maintained.

With proper attention to heat transfer duty within an existing power boiler, it is possible to utilize combustion turbine exhaust gas as a source of windbox oxygen while utilizing its existing steam generators on pulverized coal at loads consistent with the increased gas mass flow associated with turbine exhaust gas firing. Overall net efficiencies of power generation can exceed 42%.

The PyGas™ coal gasifier with its coal feed preparation system represents a major step toward small affordable modular coal gasification systems for the power generation industry. The single most notable feature of the full sized gasifier is its extremely compact module size relative to other competing coal gasification technologies. It will be designed as truck shippable modular vessels of approximately 100 MWe equivalent capacity (when utilized in the combined cycle mode).

The repowering process concept is to match an available combustion turbine size to the existing boiler size to maximize total IGCC efficiency without exceeding existing boiler/turbine operational limitations. While not within the scope of this project, this concept is postulated as one of several potential solutions to the new Clean Air Act. The host utility therefore, will have an interest in the consideration of extending the use of coal gasification (assuming test gasifier success) to simultaneously increase power generation efficiency by approximately 20% while reducing emissions. Two factors weigh heavily in this system matching effort:

1. Selection of combustion turbines whose exhaust gas oxygen content nearly matches the existing boiler's fired oxygen requirement at normal excess air levels minimizes dry stack gas losses.
2. As larger combustion turbines are considered, a point is reached where the gas mass flow through the existing boiler becomes excessive.

Assuming an eventual fuel firing switch (not included in this project) in the existing boiler from pulverized coal to low Btu/scf coal gas, a change in furnace performance must be recognized.

The lower emissivity of the coal gas flame results in slightly lower furnace absorptivity, and a higher furnace exit gas temperature. This in combination with higher than normal gas mass flow due to the use of turbine exhaust gas encroaches on superheater metal temperature limitations. One simple method of controlling this limit is to operate the existing boiler at slightly reduced output. How much lower than full steam flow operation of the existing boiler depends on its specific design and the capacity of other related equipment such as potential coal handling and storage limits. There is always a substantial gain in net power due to the gas turbine contribution.

4.7 CONCEPTUAL RILEY PyGas™ DESIGN

Figure 3 shows the general arrangement of the PyGas™ gasifier which evolved during the course of the conceptual design phase of the contract. While certain equipment design details have become better understood and developed, the basic apparatus remains as depicted in its original patent disclosures.

Coal, sorbent, air and steam are co-injected vertically upward into a carbonizer tube cone forming a jetting fluidized-bed. Recirculation of previously devolatilized char particles back down into the jet provides the heat source for rapid devolitilization of incoming raw coal particles. It also sufficiently insulates coal particles from one another, inhibiting tar based agglomeration. Maintenance of bed temperatures below the melting point of the coal's inorganic fraction also inhibits high temperature melted ash agglomeration.

While the whole issue of fines generation in the jetting fluidized-bed has been rigorously reviewed, the potential to control agglomeration within the slugging carbonizer tube has yet to be evaluated. Others have successfully controlled high temperature agglomeration (KRW) to produce gravitational separation of the inorganic coal fraction. The design incorporates the ability to test and determine the potential for PyGas™ to control fines elutriation by controlling char solids agglomeration.

The ability to raise top gas temperatures to assure complete gaseous tar cracking is also provided.

A separation annulus directs all flow in a downward direction to separate solids from the gaseous flow, and to assure well distributed flow characteristics as well as some gasification, depending on the gas temperature, solids residence time, and kinetic limitations of gasification reactions.

A conventional fixed-bed with reversible rotating grate provides sufficient residence time for char to become gasified by introducing air and steam under-grate in the same manner utilized for the past century to gasify coke and anthracite.

The potential for in-situ sulfur capture with concurrent sorbent feed is provided for in the design.

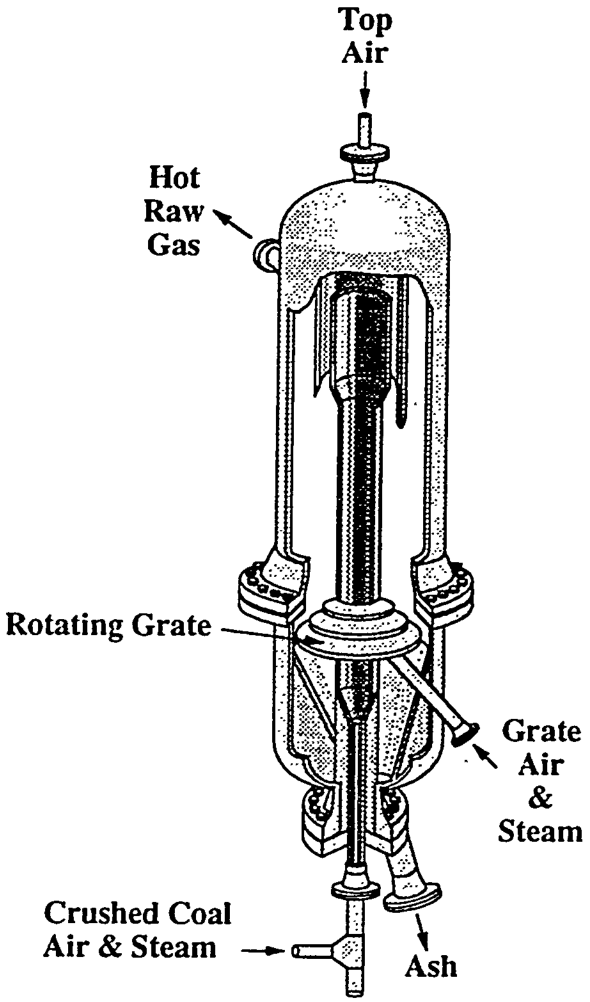


Figure 3 General PyGas™ Gasifier Arrangement

4.8 COMMERCIALIZATION APPROACH

4.8.1 MARKET DESCRIPTION

Virtually the entire existing coal fired utility market from 100 MWn on upward represents the potential market for the PyGas™ gasifier. Once demonstrated, it will compete very successfully with all of the various pulverized coal plants with scrubbers, circulating fluidized bed boilers (CFBC), and other integrated gasification combined cycles because it has at least twice the coal throughput of a fixed-bed Lurgi gasifier on caking coals, cracks tar vapors, condenses volatilized alkali, uses "run of mine" coal, does not bypass coal fines, and maintains ideal hot raw gas outlet temperatures consistent with hot gas cleanup system temperature limitations. The market share gained by this technology will be considerable because this technology is proprietary and patent protected (applied for worldwide).

Shop fabricated 50 to 100 MWe equivalent modules are intended to replace existing pulverizers which are usually of similar incremental sizing and numbers in utility applications. It was recognized by the utility industry long ago that redundancy was necessary for pulverizer application to coal fired utility boilers (note the "typical" 300 MW DOE reference plant example has some six (6) pulverizers). In like fashion, the utility industry has utilized a multiplicity of coal burners for individual boilers (although not shown, the 300 MW reference plant likely has from eighteen (18) to twenty-four (24) coal burners).

The application of the PyGas™ gasifier modular vessels follows the very same time tested logic (the function of the PyGas™ gasifier and its coal preparation equipment are the same as the pulverizers and the coal burners of contemporary coal fired systems, so the concept of using several partially redundant modules is not new, rather, it is a logical adaptation to existing coal fired facilities). The statistical improvement to availability is quantifiable and has been previously developed.

It should be noted that since the addition of the PyGas™ gasifier results in lowering the maximum fireside gas temperature via the introduction of turbine exhaust gas to the windbox of the existing utility coal boiler, forced outages most commonly caused by local excessive temperatures to superheater and waterwall tubing are far less likely. Therefore, the use of this technology in retrofit of existing coal boilers will actually reduce existing superheater and waterwall tube failures. This is achieved by lowering the furnace gas temperature both by dilution with turbine exhaust gas and by reducing the firing rate of the existing boiler. The net effect remains significantly greater electric output at much increased efficiency due to the addition of a small gas turbine to the cycle.

The project team identified existing coal fired utility power plants as near term candidates for standardized PyGas™ gasifier application. While many consider conventional flue gas scrubbers as the economical solution to the emissions concerns of large coal fired utilities, such systems are expensive and adversely affect power plant efficiency by consuming significant quantities of power which would have otherwise been available to the grid. In effect, while reducing stack emissions, scrubbers return reduced plant electricity output for their significant expense.

Retrofitting and repowering existing coal fired power plants with the PyGas™ gasifier results in much lower emissions than currently available commercial scrubber systems plus very substantial increased power output for the same coal input for which the facility has already been designed.

The "Commercialization Plan" contemplated for this emerging product to serve a burgeoning power production market was developed with the recognition that first unit implementation looms as the greatest threat to timely introduction of this concept for widespread use in the cogeneration, independent power production, and utility industries.

Since additional development of the PyGas™ hybrid gasifier is currently needed before the economic goals of the project team can be realized, it is believed that the cogeneration, independent power production, and utility industries will not endorse it until such time that the improved gasifier is demonstrated.

There is solid justification for the consideration of the addition of PyGas™ gasifier systems to existing coal fired utility plants. The majority of the most costly of the capital cost items of the power plant already exist. These include coal receiving/handling/storage/reclaim, water sourcing/purification/treatment/disposal, electricity generation/conditioning/distribution, and the most costly of all, the boiler island itself.

Unlike other repowering strategies which require replacement of the boiler island, this approach presents a way to simply add on the PyGas™ gasifier system to the existing coal designed plant with minimum modification to the existing infrastructure. The result is also an approximate 15% to 20% increase in power output while simultaneously reducing the plant's stack gas emissions by well in excess of 90% for SO_2, NO_x, and particulates, and 15% to 20% for CO_2.

4.8.2 RILEY COMMERCIALIZATION SUMMARY

The PyGas™ Pilot Development Facility planned for the GPIF would provide the necessary data to prove the benefits of the PyGas™ process and scaling parameters to offer commercial sized plants. This is an absolute necessity in DB Riley's commercialization plans for the technology.

In market studies conducted by DB Riley and others, a majority of the old coal plants are under 300 MWe in size, with an average around 150 MWe. This is the target niche for DB Riley's commercialization efforts to repower using PyGas™ technology.

A key ingredient of the commercialization of the PyGas™ technology is data from a pilot plant facility to conclusively prove the process and allow scale-up to take place.

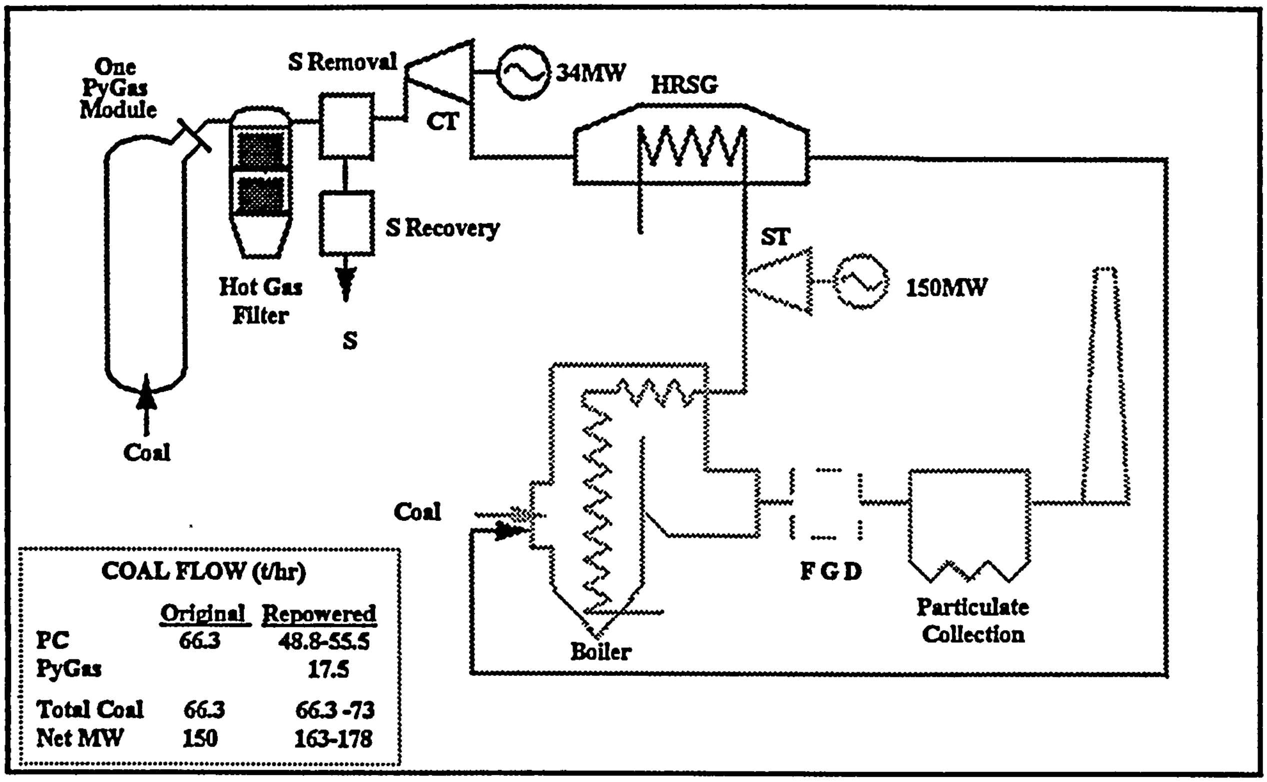
The following summarizes the overall commercialization plan for PyGas™ :

- A PyGas™ pilot development facility is essential for commercialization.
- The commercialization strategy is based on repowering existing coal-fired boilers less than 300 MWe, which account for the majority of units that will become repowering candidates by the turn of the century.
- Existing coal fired plants are more likely to repower with coal.
- Repowering will provide the experience base for entering the U.S. and foreign new capacity or "greenfield" power generation market.
- Full PyGas™ repowering costs are less than $1000/kW; 25-50% lower than other coal based technologies. Partial repowering with PyGas™ can be performed at less than $500/kW, which is less than most natural gas combined cycle facility capital costs.
- Cost of electricity of less than 3¢/kWh for partial repowering is more economical with PyGas™ than partial repowering with natural gas.
- This partial repowering strategy, which is well suited to PyGas™, is especially attractive during soft demand for added capacity. Partial repowering results in approximately 20% capacity growth, while full repowering adds 200% capacity growth.

PyGas™ modular gasification can provide a system that beats natural gas on a levelized cost of electricity analysis when partially or fully repowering small to moderate sized coal plants.

In several studies made by DB Riley, adding PyGas™ would provide very attractive systems at electricity costs less than 3 ¢/kWh when partially repowering existing coal fired utilities providing 10% to 50% MW growth and at 10% to 20% greater efficiency than the existing generating station.

In a fully repowered scenario, PyGas™ would provide a plant with 200% MW growth at a cost less than 3.5¢/kWh.



COAL FLOW (t/hr)

	Original	Repowered
PC	66.3	48.8-55.5
PyGas		17.5
Total Coal	66.3	66.3 -73
Net MW	150	163-178

Figure 3 Partial IGCC Repowering With PyGas™

4.8.3 COMMERCIALIZATION PLAN

The PyGas™ technology is a patented process and apparatus. These patents have been transferred from Jacobs-Sirrine Engineers Inc. of Greenville, SC to DB Riley, Inc. located in Worcester, MA. DB Riley, and its parent, Deutsche Babcock have experience in gasification, combustion, and boiler design and manufacture. The PyGas™ technology is complemented by a number of other key IGCC related components currently offered or being developed by Deutsche Babcock and DB Riley such as hot gas filters, gas coolers, and heat recovery steam generators (HRSG).

DB Riley will be responsible for the marketing, sales, and manufacture of the PyGas™ gasification system. Commercialization efforts will be lead by DB Riley. Under a teaming arrangement, Jacobs-Sirrine Engineers will assist DB Riley in its commercialization efforts, and will concentrate its efforts in the pulp and paper and refinery industries. Under the same teaming arrangement, Jacobs-Sirrine plans to provide design, engineering and construction services.

The main focus of the entire effort surrounds the gasifier itself which will be designed and supplied by DB Riley. The team's timing plans in conjunction with the case studies developed for several repowering strategies as well as new installation scenarios are as follows :

1996-1997

- Discuss with utility companies their plans for repowering/new additions.
- Introduce PyGas™ and pilot plant results for repowering their specific site.
- Identify potential sites for new PyGas™ modules in repowering or new utilities.

1998-2000

- Utilize pilot plant data to prepare initial offerings.
- Book initial repowering project.

There are a significant number of 30-, 40-, and 50-year old generating units in the U.S.

The Office of Technology Assessment has estimated that approximately 170,000 MWe of the U.S.'s steam generating units will be at least 30 years old by 1995. In a separate analysis, EPRI has stated that by the year 2000 - there will be 87,000 MWe over 45 years old. The average size plant is 150 MWe. Another source states that the majority of fossil fired units in the U.S. with a plant output under 300 MWe were built during the 1950's and are now approaching the end of their design life. In addition, many utilities report the need for additional generating facilities in the coming decade. According to the Association of Edison Illuminating Companies April, 1995 projections, there could be 30,000 to 85,000 MWe growth during the next 10 year period.

How will the utilities cope with the small inefficient units that may have already suffered some capacity and efficiency degradation over time?

New "greenfield" coal fired plants cost in excess of $1000/kW and new advanced clean coal technologies may be in the $1200 to $1500/kW range. Coupling low natural gas fired new combined cycle and repowered plant costs with current low natural gas prices, new coal based generating facilities cannot compete in the near future.

Repowering can extend the life of older coal based plants and lead to a resurgence of the U.S. power generating equipment market. Most of the existing facility equipment including coal receiving, handling, storage, preparation, and conveying systems, water treatment, condensing and cooling systems, boiler island steam generation systems, steam turbine and generator systems, power transforming and distribution systems as well as most of the related auxiliary systems can continue to be utilized.

Installed capital costs in the range of $500/kW have been reported for natural gas fired CTCC repowering projects. This compares to $600 to $800/kW for an equivalent but entirely new CTCC installation. These costs were typical from several of the references included even as recently as May, 1995 Power Engineering.

Coal costs less than natural gas although the differential of $1.00 to $1.50/milBtu is low and may continue to remain low for the near term. Consequently, for a coal fired repowering scenario to make sense, the plant would most likely have to be built at a capital cost consistent with the all inclusive cost of electricity equal to that of a natural gas fired repowered combined cycle. According to EPRI, this allows only a $600 to $800/kW capital expenditure. Therefore, only existing coal fired installations where the plant's equipment infrastructure is in place and in good condition can be considered coal repowering candidates in the near term.

Eventually, coal to gas price differential is expected to increase as the world-wide demand for natural gas continues to grow and the resource becomes depleted. In the interim, IGCC plant capital costs will decrease, and new PyGas™ "greenfield" installations will by built. This may not occur before the year 2010.

5.0 CONCLUSION

Repowering existing coal based electric power generating stations with PyGas™ is, by far, the least capital cost approach to the currently untapped IGCC market. In addition, potential operating efficiency gains from such repowering are greater than the efficiency differences of the entire range of existing coal fired facilities. This means that even the least efficient existing coal fired utility which currently gets virtually no dispatch operation would, if repowered, become the most efficient coal fired unit of the utility, with the highest percentage of dispatch. Therefore, there is currently a vast untapped market for PyGas™.

The majority of coal based repowering candidates in the near term will be under 300 MWe in size. This makes most of them too small for conventional IGCC consideration utilizing oxygen separation plants, high temperature gasification with associated fuel gas cooling requirements, and costly hot gas desulfurization. Such systems, while technically viable, are not cost effective.

Cost of electricity of less than 3 cents/kWh for partial repowering is more economical with PyGas™ than even partial repowering with natural gas.

However, unless and until a successfully operating PyGas™ pilot development facility is built, this promising technology cannot be commercialized.

5.1 PROJECT CANCELLATION BY DOE

The unfortunate reality of this project is that the DOE/METC has chosen to cancel this project for their convenience. We understand this decision stems from a general congressional mandate to reduce the overall fossil fuel program budget. We also understand this decision to be totally budget based and should not be construed as a negative reflection on the technology, and that the DOE/METC has not found anything that would prove the PyGas™ technology to not be viable.

5.2 OBJECTIVE NOT MET

Since the GPIF contract has been canceled, the original objective of the development of an advanced highly efficient fixed-bed gasification process at a cost of less than $1,000 per kilowatt has not been met.

5.3 HOPEFUL OF FUTURE CONTRACT FOR PyGas™ PILOT TEST UNIT

The entire project team is very disappointed at the unfortunate decision to discontinue this project at a time when the most essential prerequisite to commercialization, hardware design, fabrication, installation, and demonstration was so close to being achieved.

Figure 4 shows what the GPIF would have looked like at the Fort Martin station site.
While we appreciate the efforts to date of the DOE/METC in support of PyGas™, we can only hope for the resurrection of the PyGas™ technology at a new facility location at a future date.

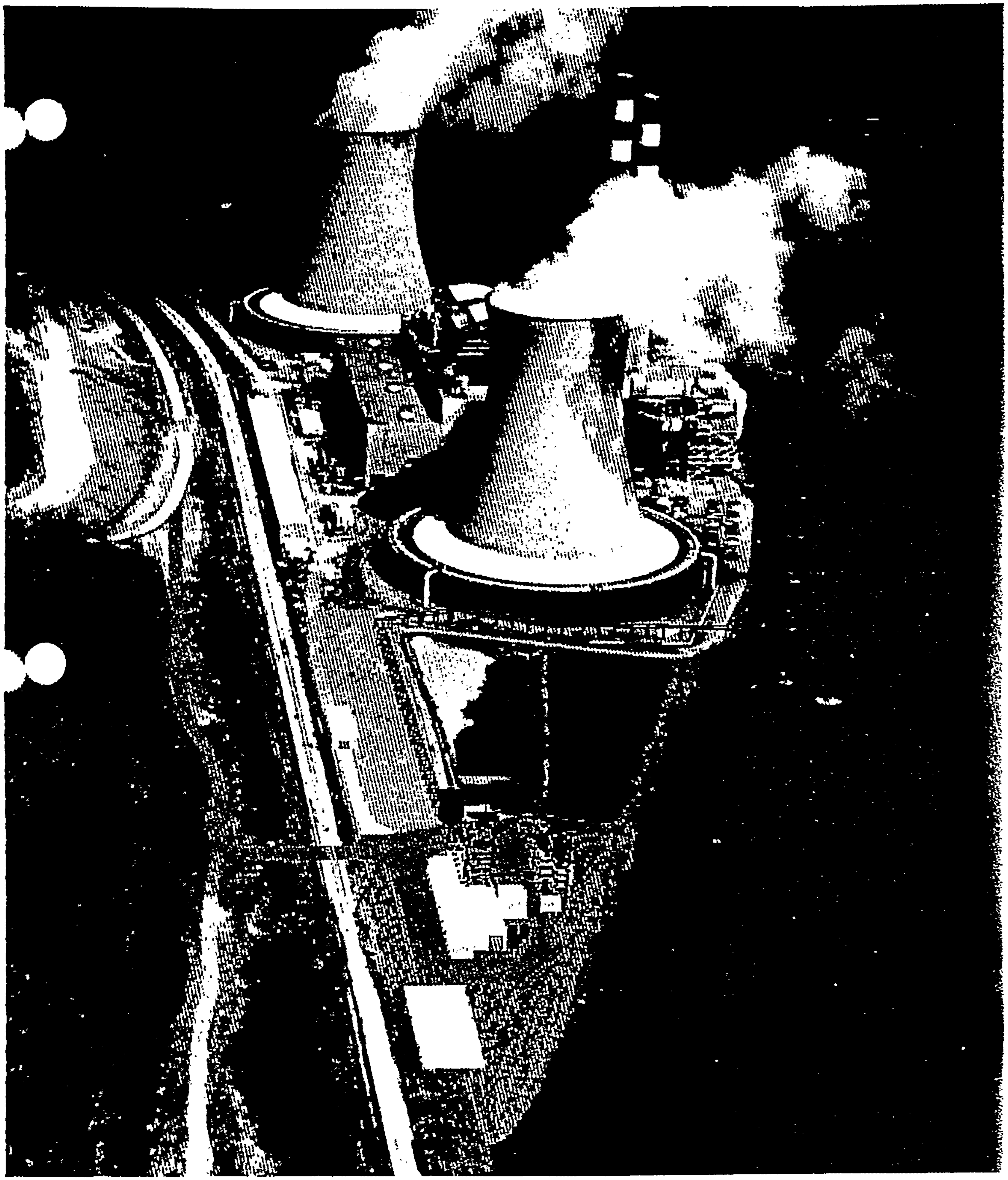


Figure 4 The GPIF Facility as it Would Look at the Fort Martin Generating Station

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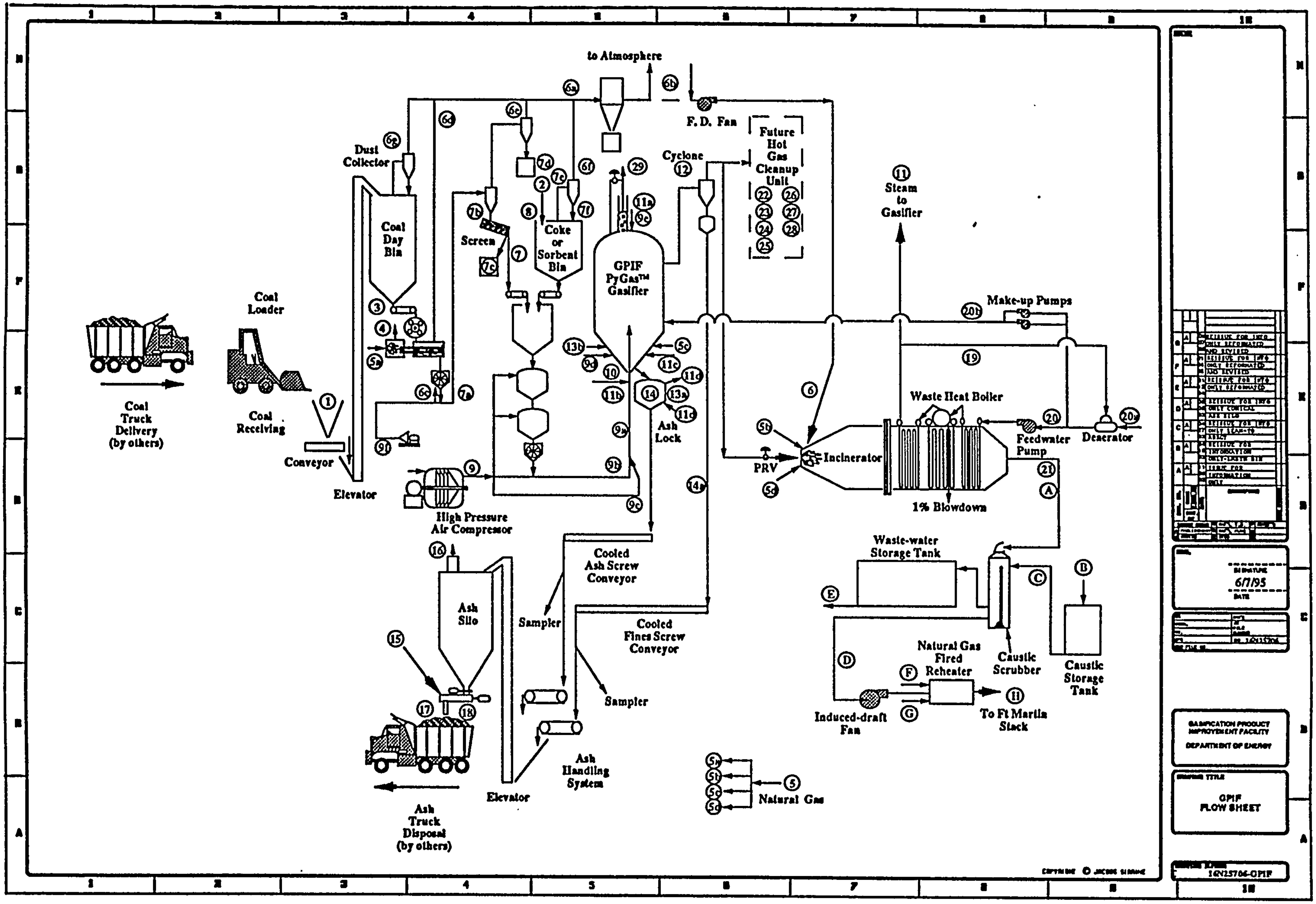

Coal Truck Delivery (by others)
Coal Loader
Coal Receiving
Conveyor
Elevator
Dust Collector
Coal Day Bin
Screen
Coke or Sorbent Bin
to Atmosphere
F. D. Fan
Cyclone
Future Hot Gas Cleanup Unit
GPIF PyGas™ Gasifier
Ash Lock
High Pressure Air Compressor
Steam to Gasifier
Make-up Pumps
Waste Heat Boiler
Feedwater Pump
Deaerator
PRV
Incinerator
1% Blowdown
Waste-water Storage Tank
Caustic Scrubber
Caustic Storage Tank
Natural Gas Fired Reheater
Induced-draft Fan
To Ft Martin Stack
Natural Gas
Cooled Ash Screw Conveyor
Cooled Fines Screw Conveyor
Sampler
Sampler
Ash Silo
Ash Handling System
Elevator
Ash Truck Disposal (by others)
GASIFICATION PRODUCT IMPROVEMENT FACILITY
DEPARTMENT OF ENERGY
GPIF FLOW SHEET
6/7/95
14V25706-GPIF

HEAT AND MATERIAL BALANCE CALCULATIONS FOR THE PYROLYZER

JSE THERMOMODEL - MASS BALANCE INPUTS

DESIGNATED INPUTS	Spec Coal THERMOMODEL INPUTS	W/WATER-GAS REACTION W.E. SKINNER	10/19/95 15:48 "Normal Operation" 325 psig Operating Press; Spec Coal		
*AIR/COAL	1.720	4.54fps @ 1773°F	Balanced Temperature, Carbon Remaining & Mass		
*STEAM/COAL	0.17	1.701	fps (Pyro SV)	863 °C	
*SORBENT/COAL	0.2404	37%	ofSV@1.72 A/C	1136 °K	
T FINAL DEG. F	1657	1585		1585 °F	Calc.
*% CARBON REMAINING	50%	50%		lb/hr	Wt %
% CO	19.86%	19.24%		2342	23.66%
% CO2	6.09%	6.71%		1284	12.98%
% H2	19.87%	20.49%		180	1.81%
% H20	8.87%	8.24%		646	6.52%
% CH4	1.37%	1.37%		95	0.96%
% N2	43.53%	43.53%		5300	53.54%
%H2S	0.42%	0.42%		51	0.52%
*COAL FEED RATE (LB/HR)	4000	50%		9899	Pyrolysis Gas
T DEG. F FOR CP (EST.)	1657		C 2852		
Kp (T)	0.77		H 279		
Kp (apparent)	0.69		O 3080		
*METHANE CONVERSION %	5%		N 5300		
*SULFUR CONVERSION %	48%		S 112		
DELTA MASS	0				
*CO/C02 =	3.26	3.26006069	*= Iterative Formula	Ht Form Based on LHV	
*O2	0.23	HT. FORM OF COAL BTU/LB		-0.05 X 1000	
*CO	0.77		HHV Analysis :	Btu/lb As Rec'd	(LHV)
% CONV BY O	9%		DuLong Formula =	12580	12114
% CONV BY H2O	41%		Foster Wheeler Tests =	12724	12258
BTU/DSCF 59 DEG F	155.9	154.9	METC Specs. =	12500	12034
BTU/WACF 59 DEG F	142.9	141.9	Used to Tie (LHV)=	12034	
HT. FORM OF COAL BTU/LB	-54		% OF COAL AS CH	73%	
PYRO HEAT LOSS - ASSUMED	14.55%	1.25E+06 BTU/HR	MW OF CH	6.70	
CALCULATED °F PYRO HT LOSS	282	**CHANGE CO/CO2 RATIO**			
PYRO HEAT LOSS (% OF TOTAL)	2.60%	**UNTIL DELTA MASS EQUALS 0**			
CLOSURE (OUT/IN) - FW TEST TR-2.5	11%				

HEAT AND MATERIAL BALANCE CALCULATIONS FOR THE PYROLYZER

$$CO + H_2O \rightleftarrows CO_2 + H_2$$

Gibbs Free Energy (kcal/mole) (25 deg C)	Enthalpy (kcal/mole) (25 deg C)	Entropy (cal/(mole deg.)) (25 deg C)
-6.816	-9.834	-10.13
		0.0%

Equilibrium Constant Reaction

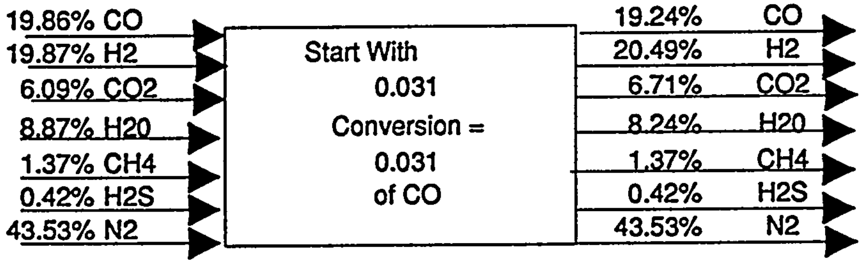
$$Kp(T) = Y(CO2)*Y(H2)/(Y(CO)*Y(H2O))$$

$\log(Kp) = a + b*T + c*T^2 + d*T^3 + e*T^4 + f*T^5$

coefficients	a	b	c	d	e	f
	18.74	-6.28E-02	8.79E-05	-6.35E-08	2.32E-11	-3.38E-15

T (DEG. F)	T (DEG.K)	Kp(T)	Kp(app.)	T deg. F (at Kp(app.))
1657	1176	0.77	0.69	1766.3624

Kp = 8.67E-01



7.96

CP(AVE)= 7.19
T = 1657

*Iterative Formula

T (Ht. Bal) = 1585.46
T (Equil.) = 1585.51
1585.51

CP (AVE) = 7.96
CP(EST)= 7.96

DOE - GPIF - PyGas™ (Base Case 2 TPH)
Design Support Document, Mass Balance

325 psi Operation - Specified Design
*Using Thermomodel (Assume 50% Devolatilization)
Page 1 5 ft Dia Test Size

Reference Coal - RFP Specification - MGAS Kinetics
JSE Predicted Output (58% Bed Voidage)

10/19/95 14:40

Stream No. Identification From To Gas	Mol Wt	1 Raw Coal Ft. Martin Pile GPIF Receiving Hopper	wt %	Sorb/Coal 8.000	2 Limestone Sorbent Pile Limestone/Coke Bin 8.00 *Ca/S Mole Ratio	3 Coal Storage Bin Crusher/Dryer	4 Coal Dryer Combustion Air Ambient Coal Dryer lb/hr	4a Coal Dryer Combustion Gas Coal Dryer Vent System	5a Natural Gas Pipeline Coal Dryer lb/hr	5b Natural Gas Pipeline Burner Support lb/hr	5c Natural Gas Pipeline PyGas™ Preheat lb/hr	5d Natural Gas Pipeline Start-up HRSG lb/hr		5 Natural Gas Pipeline Total Usage @Start lb/hr
CO	28.010													
H2	2.018								30	75	10	47		162
CO2	44.010						1	332						
H2O	18.015						17	282						
CH4	16.042								91	230	31	142		494
C2H6	30.068	Proximate Analysis												
H2S	34.076													
COS	60.070	Vol Matter	30.00%											
N2	28.013	Fixed Carbon	52.00%				1963	1959	11	27	4	17		58
Ar	39.948	Moisture	3.00%				52	52						
HCl	36.461	Ash	15.00%											
HCN	27.026													
NH3	17.030													
CS2	76.131													
SO2	64.059													
NO	30.006													
O2	31.999						675	124						
NaCl	58.497													
KCl	74.596													
CaSO4	136.142													
Ca(OH)2	74.095													
Cl2	35.500													
Total Gas (lb/hr)							2618	2749	131	332	45	206		714
Volumetric Flow Rates (STP 14.7 psia, 59F)														
(acfm)														
(scfm)									50	126	17	78		270
Heat (BTU/lb)									22,711	22,711	22,711	22,711		22,711
Cp (BTU/lb F)														
HHV (BTU/lb)			12500		1523	12500			22,711					
LHV (BTU/lb)			12038		1429	12038			20,588					
Sensible Heat above														
59 F Btu/lb steam			21		#DIV/0!	21								
Latent Heat of														
Water Btu/lb steam			482		#DIV/0!	482								
Chemical Heat			60.60		0.00	60.44								
(LHV) MBtu/hr														
Sensible Heat			8.11		0.00	8.11								
above 59 F MBtu/hr														
Latent Heat			2.32		0.00	2.32								
of Water MBtu/hr														
Total Heat(MBtu/hr)			83.03		0.00	62.87			3.0	7.5	1.0	4.7		16.2
		Ultimate Analysis												
C	12.011	68.60%	3453	9%	0	3444			91	230	31	142	69.26%	494
H	1.008	4.60%	232	Purity		231			30	75	10	47	22.68%	162
O	16.000	4.70%	237		0	236								
N	14.007	1.20%	60			60			11	27	4	17	8.06%	58
S	32.060	2.80%	141			141			0	0	0	0	0.00%	0
CaO	56.079	0.10%	5			5								
H2O	18.016	3.00%	151	9%	0	151								
NaCl	58.497			Moisture										
KCl	74.596													
CaSO4	136.142													
Ca	40.080				0									
CaS	72.140													
ASH, Inerts (pph)		15.00%	755		0	753								
Total Solids (pph)			5034		0	5021								
Total Flow (pph)			5034		0	5021	2618	2749	131	332	45	206	100.0%	714
Total Flow (pps)			1.40		0.00	1.40	0.73	0.76	0.04	0.09	0.01	0.06		0.20
Pressure (psig)			0.0		0.0	0.0	1	0	20	20	20	20		20
Temperature (F)			80		80	80	80	450	80	80	80	80		80
Changes in this issue :		Deleted Ca from pyrolyzer reactions (streams 10f & 14); Set Ar to Thermomodel calculations; Recovered lost Sulfur in CoFlow region (was fed to Ca as CaS); Reduced error in Stream 5d to less than 1%.												

DOE - GPIF - PyGas™ (Base Case 2 TPH) 325 psi Operation - Specified Design Gasifier Efficiency (Gas Out/(Coal In+Air In+Steam In)) = 77.26% 10/19/95 14:40

Design Support Document, Mass Balance *Using Thermoset (Assume 50% Devolatilization) CONTRACT NO. DE-AC21-92MC28202 Cold Gas Efficiency (Gas Out/Coal In) = 84.04% Page 2

Stream No. Identification From To Gas	Mol Wt	6 Combustion Air Total Incinerator Burner lb/hr	6a Total Exhausts Baghouse Vents Atm or Incinerator Comb.	6b Combustion Air Balance Less Baghouse Vents Incin. (If Vents Used)	6c Rotary Valve Leakage Convey Blower Coal Dryer @ 1.25 lb/lb Coal	6d Coal Dryer Air Coal Dryer Vent System	6e Coal Prep Exhaust Coal Prep System Incinerator	Removed Limestone System	6f (was 6g) Bucket Elevator Exhaust Coal Bin Vent System
CO	28.010	0	0	0	0	0	0	0	0
H2	2.016	0	0	0	0	0	0	0	0
CO2	44.010	21	343	21	1	1	6	2	2
H2O	18.015	278	428	278	9	9	77	29	31
CH4	16.042	0	0	0	0	0	0	0	0
C2H6	30.068	0	0	0	0	0	0	0	0
H2S	34.076	0	0	0	0	0	0	0	0
COS	60.070	0	0	0	0	0	0	0	0
N2	28.013	32809	19188	13621	1013	1013	9116	3386	3714
Ar	39.948	863	353	510	18	18	160	59	65
HCl	36.461	0	0	0	0	0	0	0	0
HCN	27.026	0	0	0	0	0	0	0	0
NH3	17.030	0	0	0	0	0	0	0	0
CS2	76.131	0	0	0	0	0	0	0	0
SO2	64.059	0	0	0	0	0	0	0	0
NO	30.006	0	0	0	0	0	0	0	0
O2	31.999	11276	5400	5875	310	310	2792	1037	1137
NaCl	58.497	0	0	0	0	0	0	0	0
KCl	74.596	0	0	0	0	0	0	0	0
CaSO4	136.142	0	0	0	0	0	0	0	0
Ca(OH)2	74.095	0	0	0	0	0	0	0	0
Cl2	35.500	0	0	0	0	0	0	0	0
Total Gas (lb/hr)		43758	22964	20795	1350	1350	12150	4514	4950
Volumetric Flow Rates (STP 14.7 psia, 59F)									
(acfm)		10148	5325	4822	307	461	3125	1028	1127
(scfm)		9575	5025	4550	295	295	2658	988	1083
Heat (BTU/lb)									
Cp (BTU/lb F)									
HHV (BTU/lb)							12500	12500	12500
LHV (BTU/lb)							12038	12038	12038
Sensible Heat above									
59 F Btu/lb steam							0	0	0
Latent Heat of									
Water Btu/lb steam									
Chemical Heat									
(LHV) MBtu/hr									
Sensible Heat									
above 59 F MBtu/hr									
Latent Heat									
of Water MBtu/hr									
TotalHeat(MBtu/hr)									
C	12.011						1.19		8.92
H	1.008						0.08		0.60
O	16.000						0.08		0.61
N	14.007						0.02		0.16
S	32.060						0.05		0.36
CaO	56.079								0.01
H2O	18.016						0.05	0.16	0.39
NaCl	58.497								
KCl	74.596								
CaCO3	100.089							0.16	
Ca	40.080						0.00		
CaS	72.140								
ASH, Inerts (pph)							0.26	1.40	1.96
Total Solids (pph)						104	1.74	1.71	3.2
Total Flow (pph)		43758	22964	20795	1350	1454	12152	4515	4953
Total Flow (pps)		12	6	6	4.20	0	3	1	1
Pressure (psig)		0	0	0	0.0	0.0	0.0	0.0	0.0
Temperature (F)		90	90	90	80	350	150	80	80

DOE - GPIF - PyGas™ (Base Case 2 TPH) 325 psi Operation - Specified Design 10/19/95 14:40

Design Support Document, Mass Balance *Using Thermomodel (Assume 50% Devolatilization) Page 3

Stream No.	7	7a	7b	7c	7d	7e	7f	7g	7h
Identification	Coal	Crushed Coal	Coal	Coal	Coal Crusher Dust	Deleted	Deleted	Coal Feed	Limestone/Coke Feed
From	Sizing Screens	Crusher Rolls	Cyclone Separator	Rejects Tote Bin	Classifier Dust Collector			Weigh Feeder	Weigh Feeder
To	Coal Surge Bin	Cyclone Separator	Screens	Ft. Martin Coal Pile @	Tote Bin			Coal/Lmstne Pressure Locks	
Gas				18.00%	@ .01 lb/MBtu			lb/hr	lb/hr
CO		0							
H2		0							
CO2		1							
H2O		9							
CH4		0							
C2H6		0							
H2S		0							
COS		0							
N2		1013							
Ar		18							
HCl		0							
HCN		0							
NH3		0							
CS2		0							
SO2		0							
NO		0							
O2		310							
NaCl		0							
KCl		0							
CaSO4		0							
Ca(OH)2		0							
Cl2		0							
Total Gas (lb/hr)		1350							
Volumetric Flow Rates (STP 14.7 psia, 58F)									
(acfm)		347							
(scfm)		295							
Heat (BTU/lb)									
Cp (BTU/lb F)	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341
HHV (BTU/lb)	12500	12500	12500	12500	12500	12500	12500	12500	0
LHV (BTU/lb)	12038	12038	12038	12038	11944	11944	11944	12038	0
Sensible Heat above									
58 F Btu/lb steam	50	50	59	50	50	50	50	50	
Latent Heat of									
Water Btu/lb steam	442	586	586	586	556	556	554	442	
Chemical Heat	48.15	76.70	75	10.84	1.55	1.43	1.41	48.15	
(LHV) MBtu/hr			0						
Sensible Heat	0.24	0.30	0	0.00	0.01	0.01	0.01	0.24	
above 58 F MBtu/hr			0						
Latent Heat	1.85	2.94	3	0.42	0.07	0.07	0.07	1.85	
of Water MBtu/hr			0						
Total Heat(MBtu/hr)	50.23	79.93	78	11.30	1.63	1.51	1.49	50.23	
C	2805	3444	3355	620	89.2			2806	0
H	188	231	225	42	6.0			188	
O	192	236	230	42	6.1			192	0
N	49	60	59	11	1.6			49	
S	114	141	137	25	3.6			114	
CaO		5	5	1	0.1				
H2O	40	151	147	27	3.9	10.9	10.75	40	0
NaCl									
KCl									
CaCO3						10.9	10.75		
Ca									0
CaS									
ASH, Inerts (pph)	611	753	734	136	19.5	98.2	96.78	611	0
Total Solids (pph)	4000	5021	4891	904	130	120	118	4000	0
Total Flow (pph)	4000	6371	6241	904	130	120	118	4000	0
Total Flow (pps)	1.1	2	1.7	0.3	0.04	0.03	0.033	1.11	0.00
Pressure (psig)	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Temperature (F)	150	150	150	150	80	80	80	125	125
								600 lb/hr Min	200 lb/hr min

DOE - GPIF - PyGas™ (Base Case 2 TPH) Reference Coal - RFP Specification - MGAS Kinetics **325 psi Operation - Specified Design** 10/19/95 14:40

Mass & Energy Balance 5 ft Dia Test Size *Using Thermomodel (Assume 50% Devolatilization) Page 4 CONTRACT NO. DE-AC21-92MC28202

Stream No. Identification From To Gas	Mol Wt	8 Limestone/Delayed Coke Coal Feed System or Separate Bin Surge Bin lb/hr	9 Compressed Air High Pressure Compressor Total to Process lb/hr	9a Total Flow Air,Coal,Sorbent Pyrolyzer lb/hr	1.72 A/C mol wgt	wt %	% Theo. Air 18.62% mol%	9b Coke/Coal/Lm'stn Convey Air High Pressure Compressor Pyrolyzer lb/hr	9c Compressed Air High Pressure Compressor Pyrolyzer
CO	28.010		0	0	0.00	0.00	0.00	0	0
H2	2.016		0	0	0.00	0.00	0.00	0	0
CO2	44.010		6	3	0.01	0.05	0.03	2	2
H2O	18.015		81	44	0.18	0.64	1.02	20	23
CH4	16.042		0	0	0.00	0.00	0.00	0	0
C2H6	30.068		0	0	0.00	0.00	0.00	0	0
H2S	34.076		0	0	0.00	0.00	0.00	0	0
COS	60.070		0	0	0.00	0.00	0.00	0	0
N2	28.013		9524	5164	21.65	75.03	77.28	2401	2764
Ar	39.948		250	136	0.38	1.31	0.95	42	94
HCl	36.461		0	0	0.00	0.00	0.00	0	0
HCN	27.026		0	0	0.00	0.00	0.00	0	0
NH3	17.030		0	0	0.00	0.00	0.00	0	0
CS2	76.131		0	0	0.00	0.00	0.00	0	0
SO2	64.059		0	0	0.00	0.00	0.00	0	0
NO	30.006		0	0	0.00	0.00	0.00	0	0
O2	31.999		3273	1775	6.63	22.96	20.72	735	1040
NaCl	58.497		0	0	0.00	0.00	0.00	0	0
KCl	74.596		0	0	0.00	0.00	0.00	0	0
CaSO4	136.142		0	0	0.00	0.00	0.00	0	0
Ca(OH)2	74.095		0	0	0.00	0.00	0.00	0	0
CaO	56.079		0	0	0.00	0.00	0.00	0	0
Total Gas (lb/hr)			12702	7122	28.86	100.00	100.00	3200	3922
Volumetric Flow Rates (STP 14.7 psia, 50F)			(Does Not Include Phase II & Wet Oxidation Air)					Dense Phase Air/Solids Approx 8.8	
(acfm)			208	77				30	64
(scfm)			2823	1531				711	872
Heat (BTU/lb)									
Cp (BTU/lb F)		0.341	0.235	0.294				0.294	0.235
HHV (BTU/lb)		14000	0	12500				12500	0
LHV (BTU/lb)		13995	0	11944				11944	0
Sensible Heat above 50 F Btu/lb steam		50	80	20				18	
Latent Heat of Water Btu/lb steam		0	0	6				5	
.									
Chemical Heat (LHV) MBtu/hr		5.60	0.00	47.77				47.77	
Sensible Heat above 50 F MBtu/hr		0.02	1.02	0.14				0.06	
Latent Heat of Water MBtu/hr		0.00	0.00	0.04				0.02	
Total Heat(MBtu/hr)		5.62	1.10	47.95				47.85	
C	12.011	305		2805				2805	
H	1.008	27		188				188	
O	16.000	27		192				192	
N	14.007	7		49				49	
S	32.060	16		114				114	
CL2	35.500								
H2O	18.016	17		40				40	
NaCl	58.497								
KCl	74.596								
CaSO4	136.142								
Ca	40.080			0				0	
CaO	56.079	Normally During Start-up Only							
ASH, Inerts (pph)		Not Added in this Mass Balance		611				611	
Total Solids (pph)		400	0	4000				4000	
Total Flow (pph)		400	12702	11122				7200	3922
Total Flow (pps)		0.111	3	3.09				2	1
Pressure (psig)		0	325	325				365	325
Temperature (F)		80	400	125				125	400

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2	DOE - GPIF - PyGas™ (Base Case 2 TPH)		325 psi Operation - Specified Design				Page 5			10/19/95 14:40
3	Design Support Document, Mass Balance		*Using Thermostat (Assume 50% Devolatilization)							
4										
5	Stream No.	9d		GrateAir/TotCoal	1.42		9e			9f
6	Identification	Compressed Air@		GrateSteam/TotAir	0.400	Compressed Air@	0.00 A/C			Coal Prep Delivery Air
7	From	High Pressure Compressor		Air/Grate Carbon	4.27		High Pressure Compressor			Coal Prep Air Blower
8	To	Under Gasifier Grate		Steam/Grate Carbon	1.71		At Gasifier Top			Coal Preparation Conveying
9	Gas	lb/hr	lb-mol/hr	wt %	mol%	lb/hr	lb-mol/hr	wt %	mol%	lb/hr
10										
11	CO	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
12	H2	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
13	CO2	3	0.01	0.05	0.03	0	0.01	0.05	0.03	6
14	H2O	36	0.18	0.64	1.02	0	0.18	0.64	1.02	86
15	CH4	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
16	C2H6	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
17	H2S	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
18	COS	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
19	N2	4261	21.65	75.03	77.28	0	21.65	75.03	77.28	10128
20	Ar	75	0.38	1.31	0.95	0	0.38	1.31	0.95	177
21	HCl	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
22	HCN	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
23	NH3	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
24	CS2	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
25	SO2	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
26	NO	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
27	O2	1305	6.63	22.98	20.72	0	6.63	22.98	20.72	3102
28	NaCl	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
29	KCl	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
30	CaSO4	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
31	Ca(OH)2	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
32	Cl2	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0
33	Total Gas (lb/hr)	5814	28.86	100.00	100.00	0	28.86	100.00	100.00	13500
34										
35	Volumetric Flow Rates (STP 14.7 psia, 60F)									
36	(acfm)	90				0				221.39
37	(scfm)	1262				0				2954
38										
39	Heat (BTU/lb)									
40	Cp (BTU/lb F)	0.246				0.246				0.246
41	HHV (BTU/lb)	0.0				0.0				0.0
42	LHV (BTU/lb)	0				0				0
43	Sensible Heat above									
44	60 F Btu/lb steam	84				84				84
45	Latent Heat of									
46	Water Btu/lb steam	6				6				6
47										
48	Chemical Heat	0.00				0.00				0.00
49	(LHV) MBtu/hr									
50	Sensible Heat	0.48				0.00				1.13
51	above 60 F MBtu/hr									
52	Latent Heat	0.04				0.00				0.09
53	of Water MBtu/hr									
54	Total Heat(MBtu/hr)	0.51				0.00				1.22
55										
56										
57	C									
58	H									
59	O									
60	N									
61	S									
62	CaO									
63	H2O									
64	NaCl									
65	KCl									
66	CaSO4									
67	Ca									
68	CaS									
69	ASH, Inerts (pph)									
70	Total Solids (pph)					0				0
71	Total Flow (pph)	5814				0				13500
72										
73	Total Flow (pps)	1.58				0.00				3.75
74	Pressure (psig)	338				338				325
75	Temperature (F)	400				400				400
76										

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DOE - GPIF - PyGas™ (Base Case 2 TPH)

Design Support Document, Mass Balance

*Using Thermomodel (Assume 50% Devolatilization)

325 psi Operation - Specified Design
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Stream No.		10	10a				10b		10c				10d	
Identification		Feed to Pyrolyzer	Products of Pyrolysis - Gases		Assumed		Pyrolysis - Solids	AssumedPyritic	Gases - Upper Portion of Gasifier				Solids - Upper portion of Gasifier	
From		Coal, Sorb, Air, Steam	Pyrolyzer Section		N in Coal to NH3 in Gas		Pyrolyzer Product	SulfurCapture	Pyrolyzer Section				Pyrolyzer Section	Bed Voidage
To		Pyrolyzer Inlet	Upper Area of Gasifier		90.00% Conversion		Upper Area of Gasifier	0%	Fixed Bed				Fixed Bed	38.00%
Gas		lb/hr	lb/hr	lb-mol/hr	wt %	mol%	lb/hr	wt %	lb/hr	lb-mol/hr	wt %	mol%	lb/hr	wt %
CO	28.010	0	2342	83.61	23.62	19.22			2609	93.13	26.30	21.41		
H2	2.016	0	180	89.29	1.81	20.53			161	79.77	1.62	18.34		
CO2	44.010	3	1284	29.18	12.95	6.71			865	19.66	8.72	4.52		
H2O	18.015	711	646	35.86	6.51	8.24			818	45.38	8.24	10.43		
CH4	16.042	0	95	5.92	0.96	1.36			95	5.92	0.96	1.36		
C2H6	30.068	0	0	0.00	0.00	0.00				0.00	0.00	0.00		
H2S	34.076	0	61	1.79	0.61	0.41			61	1.79	0.61	0.41		
COS	60.070	0		0.00	0.00	0.00				0.00	0.00	0.00		
N2	28.013	5164	5120	182.77	51.63	42.02			5120	182.77	51.63	42.02		
Ar	39.948	136	136	3.40	1.37	0.78			136	3.40	1.37	0.78		
HCl	36.461	0		0.00	0.00	0.00				0.00	0.00	0.00		
HCN	27.026	0		0.00	0.00	0.00				0.00	0.00	0.00		
NH3	17.030	0	54	3.15	0.54	0.72			54	3.15	0.54	0.72		
CS2	76.131	0		0.00	0.00	0.00				0.00	0.00	0.00		
SO2	64.059	0		0.00	0.00	0.00				0.00	0.00	0.00		
NO	30.006	0		0.00	0.00	0.00				0.00	0.00	0.00		
O2	31.999	1775		0.00	0.00	0.00				0.00	0.00	0.00		
NaCl	58.497	0		0.00	0.00	0.00				0.00	0.00	0.00		
KCl	74.596	0		0.00	0.00	0.00				0.00	0.00	0.00		
CaSO4	136.142	0		0.00	0.00	0.00				0.00	0.00	0.00		
Ca(OH)2	74.095	0		0.00	0.00	0.00				0.00	0.00	0.00		
Cl2	56.079	0		0.00	0.00	0.00				0.00	0.00	0.00		
Total Gas (lb/hr)		7789	9917	434.97	100.00	100.00			9917	434.97	100.00	100.00		
Volumetric Flow Rates (STP 14.7 psia, 59F)														
(scfm)		85	489	Exit Velocity (ft/sec)= 2.60					489		Actual Density			
(scfm) (Gas Constant Used=1545)		1704	2746						2746		0.338 lbm/acf			
Heat (BTU/lb)														
Cp (BTU/lb F)		0.294	0.343				0.341		0.341				0.341	
HHV (BTU/lb)		12500	2466				9751		2459				9750	
LHV (BTU/lb)		11944	2253				9751		2279				9750	
Sensible Heat above														
59 F Btu/lb steam														
Latent Heat of			ASSUMED DEVOL		50.00%									
Water Btu/lb steam														
Chemical Heat		47.77	22.34		Pyrolysis Gas HHV		20.19		22.51				20.19	
(LHV) MBtu/hr					155 Btu/dscf									
Sensible Heat		0.39	5.19		142 Btu/wscf		1.08		5.18				1.08	
above 59 F MBtu/hr														
Latent Heat		0.72	0.61				0.00		0.77				0.00	
of Water MBtu/hr														
TotalHeat(MBtu/hr)		48.88	28.15				21.27		28.43				21.26	
C		2805					1402						1402	68%
H		188												
O		192					0						0	0%
N		49												
S		114					57						57	3%
CaO		0												
H2O		40												
NaCl														
KCl														
CaSO4														
Ca		0					0						0	0%
CaS							0						0	0%
ASH, Inerts (pph)		611					611						611	30%
Total Solids (pph)		4000					2071						2071	100%
Total Flow (pph)		11786	9917				2071		9918				2071	
Total Flow (pps)		3.27	2.75				0.58		2.75				0.58	
Pressure (psig)		333	325				325		325				325	
Temperature (F)		125	1585				1585		1585				1585	

DOE - GPIF - PyGas™ (Base Case 2 TPH) 325 psi Operation - Specified Design 10/19/95 14:40
Design Support Document, Mass Balance *Using Thermomodel (Assume 50% Devolatilization) Page 7

5 Stream No.			10e			1f	Uncomb		10g	Grate S/A 8.48	
6 Identification			Gases Evolved through Gasification			Ash & Carbon	% of C	Hot Coal Gas@	Assumed Organic	Air/Grate Carbon= 4.27	
7 From			Down Through Fixed Char Bed			Gasifier	48.43%	Lower Bed	Sulfur Removal	Steam/Grate Carbon= 1.71	
8 To			Slowed Endothermic Reaction Point			Above Grate		Exit	0%	N2 in coal NH3 Conv. 0.0%	
9 Gas	Mol Wt	lb/hr	lb-mol/hr	wt %	mol%	lb/hr	wt %	lb/hr	lb-mol/hr	wt %	mol %
10											
11 CO	28.010	2609	93.13	26.30	21.41			2226	79.47	23.97	20.37
12 H2	2.016	161	79.77	1.62	18.34			103	51.25	1.11	13.14
13 CO2	44.010	865	19.66	8.72	4.52			1176	26.72	12.66	6.85
14 H2O	18.015	818	45.38	8.24	10.43			1385	76.86	14.91	19.70
15 CH4	16.042	95	5.92	0.96	1.36			0	0.00	0.00	0.00
16 C2H6	30.068	0	0.00	0.00	0.00			0	0.00	0.00	0.00
17 H2S	34.076	61	1.79	0.61	0.41			61	1.79	0.66	0.46
18 COS	60.070	0	0.00	0.00	0.00			0	0.00	0.00	0.00
19 N2	28.013	5120	182.77	51.63	42.02			4261	152.12	45.89	39.00
20 Ar	39.948	136	3.40	1.37	0.78			75	1.87	0.80	0.48
21 HCl	36.461	0	0.00	0.00	0.00			0	0.00	0.00	0.00
22 HCN	27.026	0	0.00	0.00	0.00			0	0.00	0.00	0.00
23 NH3	17.030	54	3.15	0.54	0.72			0	0.00	0.00	0.00
24 CS2	76.131	0	0.00	0.00	0.00			0	0.00	0.00	0.00
25 SO2	64.059	0	0.00	0.00	0.00			0	0.00	0.00	0.00
26 NO	30.006	0	0.00	0.00	0.00			0	0.00	0.00	0.00
27 O2	31.999	0	0.00	0.00	0.00			0	0.00	0.00	0.00
28 NaCl	58.497	0	0.00	0.00	0.00			0	0.00	0.00	0.00
29 KCl	74.596	0	0.00	0.00	0.00			0	0.00	0.00	0.00
30 CaSO4	136.142	0	0.00	0.00	0.00			0	0.00	0.00	0.00
31 Ca(OH)2	74.095	0	0.00	0.00	0.00			0	0.00	0.00	0.00
32 CaO	56.079	0	0.00	0.00	0.00			0	0.00	0.00	0.00
33 Total Gas (lb/hr)		9917	434.97	100.00	100.00			9266	390.07	100.00	100.00
34											
35 Volumetric Flow Rates (STP 14.7 psia, 50F)											
36 (acfm)		489						419	0.25 fps top of fixed bed		
37 (scfm)		2748						2463			
38											
39 Heat (BTU/lb)											
40 Cp (BTU/lb F)		0.341				0.341		0.332			
41 HHV (BTU/lb)		2458				9096		1918.4			
42 LHV (BTU/lb)		2279				9096		1650.2			
43 Sensible Heat above											
44 50 F Btu/lb steam		515				520		475			
45 Latent Heat of											
46 Water Btu/lb steam		76				0		136			
47											
48 Chemical Heat		22.73	Low Btu Gas HHV			19.14		15.41	Low-Btu Gas HHV		
49 (LHV) MBtu/hr				156 Btu/dscf					135 Btu/dscf		
50 Sensible Heat		5.16		142 Btu/wscf		1.03		4.41	106 Btu/wscf		
51 above 50 F MBtu/hr											
52 Latent Heat		0.77				0.00		1.28			
53 of Water MBtu/hr											
54 TotalHeat(MBtu/hr)		28.65				20.17		21.08			
55											
56											
57 C	12.011					1358	69%				
58 H	1.008										
59 O	16.000					23	1%				
60 N	14.007										
61 S	32.060										
62 CaO	56.079										
63 H2O	18.016										
64 NaCl	58.497										
65 KCl	74.596										
66 CaSO4	136.142										
67 Ca	40.080					0	0%				
68 CaS	72.140					0	0%				
69 ASH						593	30%				
70 Total Solids						1974	100%				
71 Total Flow (pph)		10016				1974		9266			
72											
73 Total Flow (pps)		2.78				0.55		2.58			
74 Pressure (psig)		325				325		325			
75 Temperature (F)		1565				1565		1491			
76											

DOE - GPIF - PyGas™ (Base Case 2 TPH)

325 psi Operation - Specified Design
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Design Support Document, Mass Balance

*Using Thermomodel (Assume 50% Devolatilization)

Stream No.		11h				11a		11b		11c		11d	11
Identification		Mixture of Gases from Upper Bed and Lower Bed				Steam	@ H2O/coal	Steam @ H2O/coal		Steam @ H2O/coal		Steam	Total Steam
From		Gasifier Outlet Flange		78 scfm of coal		HRSG	0.00000	HRSG	0.17	HRSG	0.57	HRSG	HRSG
To		External Hot Cyclone				Gasifier Top	S/C	Pyrolyzer	S/C	Under Grate	S/C	Ash Lock	GPF
Gas		lb/hr	lb-mol/hr	wt %	mol%	lb/hr		lb/hr		lb/hr		lb/hr	lb/hr
CO	28.010	4835	173	25.18	20.92								
H2	2.018	264	131	1.38	15.88								
CO2	44.010	2041	46	10.63	5.62								
H2O	18.015	2202	122	11.47	14.82	0.00		667		2272		60	2999
CH4	16.042	95	6	0.49	0.72								
C2H6	30.068	0	0	0.00	0.00								
H2S	34.076	122	4	0.63	0.43								
COS	60.070	0	0	0.00	0.00								
N2	28.013	9381	335	48.85	40.59								
Ar	39.948	210	5	1.10	0.64								
HCl	36.461	0	0	0.00	0.00								
HCN	27.026	0	0	0.00	0.00								
NH3	17.030	54	3	0.28	0.38								
CS2	76.131	0	0	0.00	0.00								
SO2	64.059	0	0	0.00	0.00								
NO	30.006	0	0	0.00	0.00								
O2	31.999	0	0	0.00	0.00								
NaCl	58.497	0	0	0.00	0.00								
KCl	74.596	0	0	0.00	0.00								
CaSO4	136.142	0	0	0.00	0.00								
Ca(OH)2	74.095	0	0	0.00	0.00								
Cl2	56.079	0	0	0.00	0.00								
Total Gas (lb/hr)		19204	825	100.00	100.00	0.00		667		2272		60	2999
Volumetric Flow Rates (STP 14.7 psia, 59F)													
(acfm)		653	OuterAnnulusSup.Vel.(ft/sec)= 0.38			0		12		41		1	54
(scfm)		5209				0		528		1800		45	2235
Heat (BTU/lb)						1351.80 Btu/lbm		1351.80 Btu/lbm		1351.80 Btu/lbm		1351.80	1351.80
Cp (BTU/lb F)		0.327				0.483		0.483		0.483		0.483	
HHV (BTU/lb)		2125											
LHV (BTU/lb)		1975											
Sensible Heat above		6.06											
59 F Btu/lb steam						532		531.8		532		532	532
Latent Heat of													
Water Btu/lb steam		6.06				793		793.0		793		793	793
Chemical Heat		38.61		Low-Btu Gas HHV		0.00		0.00		0.00		0.00	0.00
(LHV) MBtu/hr					148 Btu/dscf								
Sensible Heat		6.06			138 Btu/wscf	0.00		0.35		1.21		0.03	1.59
above 59 F MBtu/hr													
Latent Heat		2.05				0.00		0.53		1.80		0.05	2.38
of Water MBtu/hr													
Total Heat(MBtu/hr)		46.74				0.00		0.88		3.01		0.08	3.97
C	12.011	49											
H	1.008												
O	16.000												
N	14.007												
S	32.060												
CaO	35.500	0											
H2O	18.016												
NaCl													
KCl				Steam/Coal= 0.73									
CaSO4				Steam/Carbon= 1.05									
Ca				Carbon in Ash= 1.45%									
CaS		0		Air/Coal= 3.14									
ASH, Inerts (pph)		21		Grate Air/Carbon= 4.18									
Total Solids (pph)		60		Grate Steam/Carbon= 1.67									
Total Flow (pph)		19370				0		667		2272		60	2999
Total Flow (pps)		5				0.00		0.19		0.63		0.02	0.83
Pressure (psig)		324				353		353		353		332	332
Temperature (F)		1023				530		530		530		530	530

The Information on This Page is Confidential and Proprietary.

DOE - GPIF - CRSS Coal Gasification Process

Mass & Energy Balance

*Using Thermomodel (Assume 50% Devolatilization)

325 psi Operation - Specified Design
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Stream No.		13a		13b				12		13 = 13a & 13b	14	Uncomb	14a
Identification		Water Spray		Steam Injection				Raw Gas Outlet		Nitrogen Inerting	Ash & Carbon	% of C	Fines
From		Cyclone Inlet Pipe		Cyclone Inlet Pipe				Hot Cyclone Outlet Pipe		Nitrogen Tanks	Gasifier	8.31%	Hot Cyclone
To		Combustor/HGCU		Combustor/HGCU				Incinerator Combustor		PyGas™ Gasifier & Locks	Ash System		Fines Collection Cooler
Gas	Mol Wt	lb/hr	wt %	lb/hr	wt %	lb/hr	lb-mol/hr	wt %	mol%	lb/hr	lb/hr	wt %	lb/hr
CO	28.010					4835	172.60	25.18	20.92				
H2	2.016					264	131.02	1.38	15.88				
CO2	44.010					2041	46.37	10.63	5.62				
H2O	18.015	0	100	0	100.00	2202	122.26	11.47	14.82				
CH4	16.042					95	5.92	0.49	0.72				
C2H6	30.068					0	0.00	0.00	0.00				
H2S	34.076					122	3.57	0.63	0.43				
COS	60.070					0	0.00	0.00	0.00				
N2	28.013					9381	334.89	48.85	40.59				
Ar	39.948					210	5.27	1.10	0.64				
HCl	36.461					0	0.00	0.00	0.00				
HCN	27.026					0	0.00	0.00	0.00				
NH3	17.030					54	3.15	0.28	0.38				
CS2	76.131					0	0.00	0.00	0.00				
SO2	64.059					0	0.00	0.00	0.00				
NO	30.006					0	0.00	0.00	0.00				
O2	31.999					0	0.00	0.00	0.00				
NaCl	58.497					0	0.00	0.00	0.00				
KCl	74.596					0	0.00	0.00	0.00				
CaSO4	136.142					0	0.00	0.00	0.00				
Ca(OH)2	74.095					0	0.00	0.00	0.00				
CaO	56.079					0	0.00	0.00	0.00				
Total Gas (lb/hr)		0	100	0	100.00	19204	825	100	100				
Volumetric Flow Rates (STP 14.7 psia, 60F)													
(acfm)		0		0		676							
(scfm)		0		0		5209				100			
Heat (BTU/lb)		48.00		1352									
Cp (BTU/lb F)		1.000		0.463		0.327					0.341		
HHV (BTU/lb)				0.0		2125					206		
LHV (BTU/lb)				0		1975					206		
Sensible Heat above													
60 F Btu/lb steam				524							160		
Latent Heat of													
Water Btu/lb steam				828							0		
Chemical Heat						38.11	Low-Btu Gas HHV				0.13		
(LHV) MBtu/hr								148 Btu/dscf					
Sensible Heat						6.06		126 Btu/wscf			0.10		
above 60 F MBtu/hr													
Latent Heat						2.05					0.00		
of Water MBtu/hr													
TotalHeat(MBtu/hr)		0.00		0.00		46.23					0.22		
C	12.011					4.9					9		44
H	1.008												
O	16.000												
N	14.007												
S	32.060												
CaO	56.079					0.0					0		0
H2O	18.016												
NaCl	58.497												
KCl	74.596												
CaSO4	136.142										0		
Ca	40.080												
CaS	72.140					0.0					0		0
ASH, Inerts (pph)						2.1					593		19
Total Solids (pph)						7					601		62
Total Flow (pph)		0		0		19301					601		62
Total Flow (pps)		0.00		0.00		5.36					0.17		0.02
Pressure (psig)		328		328		324					325		323.7
Temperature (F)		80		530		1023					530		1023

Assume All Fines Under 100 Micron Carry Out
Design Cooled Shroud to Perform as a Flow Baffle.
Minimize Carryover With Cooled Shroud (Winnowing Effect).
Internal Winnowing Effect Efficiency = 80%
This Balance Reflects Calculated Carbon Consumption on Grate.
This Balance Reflects Calculated Air Flow to Grate.
Two External Hot Cyclones Now Included.
Net Cyclone Efficiencies= 90%
Fines Rem. Syst. Design Cap. (lb/hr)= 500
Calculated Fines to Cyclone (lb/hr)= 69
Fines to Cyclone (lb/hr) (bal chk)= 80

DOE - GPIF - CRSS Coal Gasification Process
Mass & Energy Balance
*Using Thermomodel (Assume 58% Devolatilization)

325 psi Operation - Specified Design
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Stream No. Identification From To Gas	Mol Wt	15 Make-up Water Service Water Ash Conditioning lb/hr	15a lb/hr	15b lb/hr	15c Vent Ash Removal Screws Incinerator Burner lb/hr (Later)	15d lb/hr	16 Vent Ash Silo Atmosphere lb/hr	17 Dust Control Spray Service Water Ash Silo Conditioner lb/hr (Later)	18 Ash Ash Silo Conditioner Ft Martin Land Fill lb/hr
CO	28.01								
H2	2.016								
CO2	44.01				0.00		0.00	0.0	
H2O	18.015				0	0	0	0	
CH4	16.042								
C2H6	30.068								
H2S	34.076								
COS	60.07								
N2	28.013				0		0	0	
Ar	39.948				0		0	0	
HCl	36.461								
HCN	27.026								
NH3	17.03								
CS2	76.131								
SO2	64.059								
NO	30.006								
O2	31.999				0		0	0	
NaCl	58.497								
KCl	74.596								
CaSO4	136.1416								
Ca(OH)2	74.09474								
Cl2	35.5								
Total Gas (lb/hr)					0	0	0	0	
Volumetric Flow Rates (STP 14.7 psia, 50F)									
(scfm)					0		0	0	
(acfm)					0		0	0	
Heat (BTU/lb)									
Cp (BTU/lb F)									
HHV (BTU/lb)									
LHV (BTU/lb)									
Sensible Heat above									
50 F Btu/lb steam									
Latent Heat of									
Water Btu/lb steam									
Chemical Heat									
(LHV) MBtu/hr									
Sensible Heat									
above 50 F MBtu/hr			Circulation				Air Flow		Excess Water
Latent Heat			Ratio				Multiplier		From Filtration
of Water MBtu/hr			0				0.00		0%
TotalHeat(MBtu/hr)			#################						
C	12.0105		0	0					52
H	1.008								
O	15.9995								
N	14.0065								
S	32.06								
Ca(OH)2	74.095		0	0					0
H2O	18.0155	35	0	0				35	35
NaCl	58.497								
KCl	74.596								
CaSO4	136.1416		0	0					0
Ca	40.08								
CaS	72.14								
ASH, Inerts (pph)			0	0					611
Total Solids (pph)		35	0	0			(Later)	35	699
Total Flow (pph)		35	0	0	0	0	0	35	699
Total Flow (pps)		0.01	0	0.00	0.000	0.00	0.00	0.010	0.19
Pressure (psig)		0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
Temperature (F)		80	150	150	150	530	150	80	150

DOE - GPIF - PyGas™ (Base Case 2 TPH) — 325 psi Operation - Specified Design — Page 11 — 10/19/95 14:40

*Using Thermamodel (Assume 50% Devolatilization) — Design Support Document, Mass Balance

Stream No. Identification From To Gas	Mol Wt	19a Excess Steam Waste Heat Boiler Vent lb/hr	19 Total Steam Gen. Waste Heat Boiler Process & Vents lb/hr	30 Feedwater Deaerator GPIF FW Pump lb/hr	20a Make-up Water Service Water Chem. Treatment Tank lb/hr	20b Make-up GPIF Feedwater Pump Gasifier Jacket lb/hr	21 Flue Gas (Phase I) Waste Heat Boiler Caustic Scrubber lb/hr	lb-mol/hr	wt %	mol%	29 Emergency Flare Gasifier Atmosphere lb/hr
CO	28.010						7	0.2	0.01	0.01	4835
H2	2.016							0.0	0.00	0.00	264
CO2	44.010						10502	238.6	15.0	9.5	2041
H2O	18.015	1319	4318				8903	494.2	12.69	19.75	2202
CH4	16.042							0.0	0.00	0.00	95
C2H6	30.068							0.0	0.00	0.00	
H2S	34.076							0.0	0.00	0.00	122
COS	60.070							0.0	0.00	0.00	
N2	28.013						43661	1558.6	62.25	62.29	9381
Ar	39.948						1112	27.8	1.59	1.11	210
HCl	36.461							0.0	0.00	0.00	
HCN	27.026							0.0	0.00	0.00	
NH3	17.030							0.0	0.00	0.00	54
CS2	76.131							0.0	0.00	0.00	
SO2	64.059						229	3.6	0.33	0.14	
NO	30.006						13	0.4	0.02	0.02	
O2	31.999						5715	178.6	8.15	7.14	
NaCl	58.497							0.0	0.00	0.00	
KCl	74.596							0.0	0.00	0.00	
CaSO4	136.142							0.0	0.00	0.00	
Ca(OH)2	74.095							0.0	0.00	0.00	
Cl2	35.500							0.0	0.00	0.00	
Total Gas (lb/hr)		1319	4318				70134	2502	100	100	1920
Volumetric Flow Rates (STP 14.7 psia, 50F)		0.31									
(acfm)			77				73118				676
(scfm)			1121				17117				5209
Heat (BTU/lb)		1278	1082	196	196	196					
Cp (BTU/lb F)		Total Heat in Steam	Heat Added to FW				0.341				0.33
HHV (BTU/lb)							0.4				3186
LHV (BTU/lb)							0.4				3038
Sensible Heat above							41.59				0.0
50 F Btu/lb steam											
Latent Heat of											
Water Btu/lb steam							41.59				0.00
Chemical Heat							0.03				38
(LHV) MBtu/hr											
Sensible Heat		2	5	1	1	0.4	41.59				6
above 50 F MBtu/hr											
Latent Heat							9.02				2
of Water MBtu/hr											
Total Heat(MBtu/hr)		2	5	1	1	0.4	50.64				46
		Total Heat in Steam	Heat Added to FW								
C	12.011			Column 19a Plus 1% For Blowdown	Column 20a 95% Of Col. 20 &20b						4.9
H	1.008										
O	16.000										
N	14.007										
S	32.060										
CaO	56.079										
H2O	18.016			4361	6043	2000					
NaCl	58.497										
KCl	74.596										
CaSO4	136.142										
Ca	40.080										
CaS	72.140										
ASH, Inerts (pph)											2.1
Total Solids (pph)							7				6.9
Total Flow (pph)		1319	4318	4361	6043	2000	70141				1927
Total Flow (pps)		0	1	1	2	1	19				5
Pressure (psig)		415	415	5	200	346	0				385
Temperature (F)		850	850	227	170	170	1800				1023

	Criteria Pollutants Ft. Martin Station Stack (Normal) lb/hr	Criteria Pollutants Ft. Martin Station Stack (GPIF Operating) lb/hr	Criteria Pollutants Ft. Martin Station Change Due To GPIF %
SO2	24,880	24,640	-0.96%
NOx	5,443	5,442	-0.0002%
Particulates	471	465	-1.28%
		CoalGasFired HRSG to Exist. ESP	
SO2		4.6 lb/Mil Btu	
NOx		0.40 lb/Mil Btu	
Particulates		0.2 lb/Mil Btu	

	Criteria Pollutants Ft. Martin Station Stack (Normal) lb/hr	Criteria Pollutants Ft. Martin Station Stack (GPIF Operating) lb/hr	Criteria Pollutants Ft. Martin Station Change Due To GPIF %
SO2	24,976	24,735	-0.96%
NOx	9,366	9,366	-0.0002%
Particulates	473	468	-1.28%

Mass & Energy Balance DOE - GPIF - CRSS Coal Gasification Process 325 psi Operation - Specified Design 10/19/95 14:40

Estimated Trace Metals Emissions for NEPA Report

Typical Expected Case

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NOTE : THE VALUES ON THIS PAGE HAVE BEEN CARRIED OUT TO SUFFICENT SIGNIFICANT FIGURES TO ARITHMETICALLY COMPUTE. THEY ARE NOT REFLECTIVE OF EXACTING MEASUREMENTS, BUT DO REPRESENT "TYPICAL" VALUES BASED ON RELEVENT PUBLICATIONS IN THE LITERATURE.

Identification From To	Trace Elements Normal Ft. Martin Ash Ft. Martin Ash Landfill lb/hr	Trace Elements Normal Ft. Martin Flue Gas Ft. Martin Stack lb/hr	Trace Elements GPIF Ash Ft. Martin Ash Landfill lb/hr	Trace Elements GPIF Flue Gas Ft. Martin Stack lb/hr	Trace Elements Combined Ash Ft. Martin Ash Landfill lb/hr	Trace Elements Combined Flue Gas Ft. Martin Stack lb/hr	Trace Elements Change Due To GPIF Ft. Martin Ash Landfill %	Trace Elements Change Due To GPIF Ft. Martin Stack %
Antimony	0.7421	0.0042	0.0087	0.000014	0.73645	0.00413	-0.761	-0.600
Arsenic	14.6723	0.2557	0.0967	0.000407	14.48589	0.25117	-1.270	-0.668
Barium	105.3615	0.3785	0.6800	0.00017	104.00876	0.37137	-1.284	-0.712
Beryllium	1.362	0.0064	0.0090	0.000004	1.34472	0.00628	-1.260	-0.705
Boron	27.2296	3.0518	0.2073	0.00272	26.91150	2.99564	-1.168	-0.695
Cadmium	0.2905	0.0019	0.0021	0.0000027	0.28697	0.00187	-1.216	-0.675
Chromium	9.2404	0.0896	0.0603	0.000068	9.12246	0.08794	-1.276	-0.070
Cobalt	3.7805	0.0136	0.0247	0.000007	3.73223	0.01334	-1.277	-0.071
Copper	9.894	0.0581	0.0643	0.000038	9.77545	0.05702	-1.198	-0.704
Lead	6.759	0.0830	0.0447	0.000079	6.67327	0.08148	-1.268	-0.693
Manganese	26.625	0.1210	0.1843	0.000059	26.29566	0.11872	-1.237	-0.710
Mercury	0.0125	0.1863	0.0004	0.000300	0.01263	0.18301	1.004	-0.668
Molybdenum	2.0337	0.0190	0.0150	0.000012	2.00946	0.01865	-1.192	-0.704
Nickel	8.6515	0.0565	0.0560	0.000043	8.54059	0.05545	-1.282	-0.700
Selenium	1.5642	0.3472	0.0112	0.000260	1.54649	0.34076	-1.132	-0.700
Vanadium	13.5963	0.0877	0.0910	0.000055	13.42499	0.08606	-1.260	-0.705
Uranium	1.3015	0.0047	0.0091	0.0000017	1.28549	0.00461	-1.230	-0.715
Thorium	1.9833	0.0071	0.0130	0.000003	1.95804	0.00697	-1.274	-0.711
TOTAL TRACE METALS	235.10	4.77	1.58	0.004	232.15	4.66	-1.086	-0.678
Normal Criteria Particulates (Ash, Limestone, Carbon Loss)	92729	331	697	0.446	92560	325		
TOTALS (Particulates & Trace Metals)	92964	336	699	0.45	92792.48	329.97	-1.00	-0.678

Estimated Trace Metals Emissions for NEPA Report

Worst Expected Case

Stream No. Identification From To	Trace Elements Normal Ft. Martin Ash Ft. Martin Ash Landfill lb/hr	Trace Elements Normal Ft. Martin Flue Gas Ft. Martin Stack lb/hr	Trace Elements GPIF Ash Ft. Martin Ash Landfill lb/hr	Trace Elements GPIF Flue Gas Ft. Martin Stack lb/hr	Trace Elements Combined Ash Ft. Martin Ash Landfill lb/hr	Trace Elements Combined Flue Gas Ft. Martin Stack lb/hr	Trace Elements Change Due To GPIF Ft. Martin Ash Landfill %	Trace Elements Change Due To GPIF Ft. Martin Stack %
Antimony	0.7421	0.0042	0.0087	0.000014	0.73031	0.00415	-0.34	-0.45
Arsenic	14.6723	0.2557	0.0967	0.000407	14.54251	0.25216	-0.88	-0.52
Barium	105.3615	0.3785	0.6800	0.000170	104.41530	0.37263	-0.90	-0.57
Beryllium	1.3420	0.0064	0.0090	0.000004	1.34906	0.00631	-0.84	-0.54
Boron	27.2296	3.0518	0.2073	0.002717	27.01666	3.00741	-0.78	-0.55
Cadmium	0.2905	0.0019	0.0021	0.0000027	0.28809	0.00187	-0.83	-0.53
Chromium	9.2404	0.0896	0.0603	0.000068	9.15811	0.08829	-0.89	-0.55
Cobalt	3.7805	0.0136	0.0247	0.000007	3.74682	0.01340	-0.89	-0.56
Copper	9.8940	0.0581	0.0643	0.000038	9.80562	0.05724	-0.89	-0.56
Lead	6.7500	0.0830	0.0447	0.000079	6.69935	0.08180	-0.88	-0.55
Manganese	26.6250	0.1210	0.1843	0.000059	26.39830	0.11919	-0.85	-0.56
Mercury	0.0125	0.1863	0.0004	0.000300	0.01267	0.18372	1.30	-0.52
Molybdenum	2.0337	0.0190	0.0150	0.000012	2.01731	0.01872	-0.81	-0.56
Nickel	8.6515	0.0565	0.0560	0.000043	8.57397	0.05567	-0.90	-0.55
Selenium	1.5642	0.3472	0.0112	0.000260	1.55122	0.34210	-0.83	-0.55
Vanadium	13.5963	0.0877	0.0910	0.000055	13.47745	0.08640	-0.87	-0.56
Uranium	1.3015	0.0047	0.0091	0.0000017	1.29051	0.00463	-0.84	-0.57
Thorium	1.9833	0.0071	0.0130	0.000003	1.96569	0.00699	-0.89	-0.57
TOTAL TRACE METALS	235.10	4.77	1.58	0.004	233.05	4.70	1.23	-0.53
Normal Criteria Particulates (Ash, Limestone, Carbon Loss)	92729	331	697	0.446	93870	327		
TOTALS (Particulates & Trace Metals)	92964	336	699	0.45	94103.19	331.70	-0.71	-0.53

DOE - GPIF - CRSS Coal Gasification Process, Phase II, Hot Gas Cleanup Unit (HGCU) 325 psi Operation - Specified Design 10/19/95 14:40

Design Support Document, Mass Balance *Using Thermomodel (Assume 50% Devolatilization) Page 13

Stream No.		22		23	24	25	26	27 @ SO2vol = 5%		28			
Identification		Hot Raw Coal Gas	Hot Raw Coal Gas	Zinc Titanate (ZnT) (or Zinc Ferrite) Makeup	Solid Waste	Steam	Air	Regeneration Gas		Desulfurized Gas		Desulfurized Gas	
From		Hot Cyclone	Hot Cyclone		HGCU Cyclone	HRSG	Compressor Dryers	Regenerator		HGCU Absorber		HGCU Absorber	
To		HGCU Absorber	spec vol	HGCU	Disposal	HGCU	HGCU Regenerator	HRSG	spec vol	HRSG		spec vol	
Gas		lb/hr	acfm	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	acfm	lb/hr	lb-mol/hr	scfm	mol%
CO	28.010	4835	1088						0	4842	172.88	1000	17.17
H2	2.016	264	826						0	264	131.02	826	13.01
CO2	44.010	2041	291				1	1	0	2041	46.37	291	4.61
H2O	18.015	2202	984			3377	12	12	0.6	5579	309.69	2492	30.76
CH4	16.042	95	37						0		0.00	0	0.00
C2H6	30.068	0	0						0		0.00	0	0.00
H2S	34.076	122	22						0	1	0.04	0	0.00
COS	60.070		0						0		0.00	0	0.00
N2	28.013	9381	2102				1470	1470	329	9381	334.89	2102	33.26
Ar	39.948	210	134				39	39	25	210	5.27	134	0.52
HCl	36.461		0						0		0.00	0	0.00
HCN	27.026		0						0		0.00	0	0.00
NH3	17.030	54	0						0	54	3.15	0	0.31
CS2	76.131		0						0		0.00	0	0.00
SO2	64.059		0					229	22		0.00	0	0.00
NO	30.006		0						0		0.00	0	0.00
O2	31.999		0				505	391	77	114	3.58	23	0.36
NaCl	58.497		0						0		0.00	0	0.00
KCl	74.596		0						0		0.00	0	0.00
CaSO4	136.142		0						0		0.00	0	0.00
Ca(OH)2	74.095		0						0		0.00	0	0.00
Cl2	35.500		0						0		0.00	0	0.00
Total Gas (lb/hr)		19204	5485			3377	1961	2142	454	22487	1007	6958	100
Volumetric Flow Rates (STP 14.7 psia, 60F)													
(scfm)		676				60	35	60		916			
(acfm)		5485				3209	459	454		6958			
Heat (BTU/lb)						1351.80							
Cp (BTU/lb F)		0.327					0.235			0.327			
HHV (BTU/lb)		2125					0	0		1877			
LHV (BTU/lb)		1975					0	0		1542			
Sensible Heat above													
60 F Btu/lb steam						560	60						
Latent Heat of													
Water Btu/lb steam						793	6						
Chemical Heat		38.11				0.00	0.00	0.00		35.12		Low Btu Gas HHV	
(LHV) MBtu/hr												141 Btu/dscf	
Sensible Heat		6.06				1.90	0.16	0.00		7.10		97 Btu/wscf	
above 60 F MBtu/hr													
Latent Heat		2.06				2.66	0.01	0.00		0.00			
of Water MBtu/hr													
Total Heat (MBtu/hr)		46.23				4.56	0.17	0.00		42.22			
C	12.011												
H	1.008												
O	16.000												
N	14.007												
S	32.060												
CaO	56.079												
H2O	18.016												
Zinc Titanate or Zinc Ferrite				20	18								
KCl	74.596												
CaSO4	136.142												
Ca	40.080												
CaS	72.140												
ASH, Inerts (pph)		2											
Total Solids (pph)		7		20	18								
Total Flow (pph)		19301		20	18	3377	1961	2142		22487			
Total Flow (pps)		5		0.01	0.01	0.94	0.54	0.59		6.25			
Pressure (psig)		323		0.0	0.0	418	318	319		319			
Temperature (F)		1023		80	1023	550	400	1023		1023			

Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
GPIF

SYSTEM CODE: AA
DESCRIPTION: GASIFER PROCESS

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Gasification Product Improvemnet Facility
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EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1AA-COND-1	ASH DUSTLESS UNLOADER		By Contractor				95 06 28	
1AA-CONV-1	BOTTOM ASH COOLING CONVEYOR		By Contractor	M			95 02 7	
1AA-CONV-2	FINES COOLING CONVEYOR		By Contractor				95 06 28	
1AA-CYCL-1	NO.1 GAS CYCLONE		By Contractor				94 12 18	
1AA-DCOL-1	ASH SILO DUST COLLECTOR		By Contractor				95 08 4	
1AA-ELEV-1	ASH BUCKET ELEVATOR		By Contractor				95 06 28	
1AA-FDR-1	CYCLONE FINES WEIGH BELT FEEDER		By Contractor				95 06 28	
1AA-FDR-2	BOTTOM ASH WEIGH BELT FEEDER		By Contractor				95 06 28	

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1AA-HPR-1	BOTTOM ASH LOCK HOPPER		By Contractor				94 12 15	
1AA-HPR-2	BOTTOM ASH COOLING CONVEYOR FEED HOPPER		By Contractor				94 12 15	
1AA-HPR-3	CYCLONE FINES SURGE HOPPER		By Contractor				94 10 16	
1AA-HPR-4	CYCLONE FINES LOCK HOPPER		By Contractor				94 10 16	
1AA-HPR-5	FINES COOLING CONVEYOR FEED HOPPER		By Contractor				94 12 7	
1AA-HX-1	GASIFIER CONDENSING HEAT EXCHANGER		By Contractor				95 06 28	
1AA-MO-1	GASIFIER COOLING WATER PUMP NO.1 MOTOR		By Contractor	6.00 HP 1800 RPM M			94 12 6	
1AA-MO-2	GASIFIER COOLING WATER PUMP NO.2 MOTOR		By Contractor	6.00 HP 1800 RPM M			94 12 6	

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1AA-MO-3	MOTOR, BOTTOM ASH COOLING CONVEYOR		By Contractor	M			95 07 17	
1AA-MO-4	FINES COOLING CONVEYOR MOTOR		By Contractor	M			95 07 17	
1AA-MO-5	CYCLONE FINES WEIGHBELT FEEDER MOTOR		By Contractor	M				
1AA-MO-6	BOTTOM ASH WEIGHBELT FEEDER MOTOR		By Contractor	5.00 HP 1800 RPM M			94 12 6	
1AA-MO-7	GRATE DRIVE NO.1 MOTOR		By Contractor	6.00 HP 1800 RPM M			94 12 6	
1AA-MO-8	GRATE DRIVE NO.2 MOTOR		By Contractor	6.00 HP 1800 RPM M			94 12 6	
1AA-MO-9	ASH BUCKET ELEVATOR MOTOR		By Contractor	M			95 02 6	
1AA-MO-10	FINE SAMPLER MOTOR		By Contractor	M			95 06 28	

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1AA-MO-11	BOTTOM ASH SAMPLER MOTOR		By Contractor	M			95 06 28	
1AA-MO-12	MOTOR, ASH SILO DUST COLLECTOR		By Contractor	M			95 08 4	
1AA-MO-13	ASH DUSTLESS UNLOADER MOTOR		By Contractor	M				
1AA-P-1	GASIFIER COOLING WATER PUMP NO.1		By Contractor	M			94 10 16	
1AA-P-2	GASIFIER COOLING WATER PUMP NO.2		By Contractor	M			94 10 16	
1AA-RPV-1	PyGas REACTOR		By Contractor				94 10 16	
1AA-SD-1	GASIFER JACKET STEAM DRUM		By Contractor				94 12 18	
1AA-SILO-1	ASH SILO		By Contractor				95 06 28	

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1AA-SMX-1	FINES SAMPLER		By Contractor				95 06 28	
1AA-SMX-2	BOTTOM ASH SAMPLER		By Contractor				95 06 28	
1AA-STK-1	RUPTURE DISK STACK		By Contractor				95 06 28	

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SYSTEM CODE: DG
DESCRIPTION: FUEL GAS SUPPLY SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DG-STR-1	NATURAL GAS STRAINER NO.1		By Contractor				95 08	4
1DG-STR-2	NATURAL GAS STRAINER NO.2		By Contractor				95 08	4

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SYSTEM CODE: DH
DESCRIPTION: COAL RECEIVING, STORAGE AND RECLAIM SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DH-CHT-1	DISCHARGE CHUTE		By Contractor					
1DH-CHT-2	DISCHARGE CHUTE		By Contractor					
1DH-CHT-3	DISCHARGE CHUTE		By Contractor					
1DH-CHT-4	DISCHARGE CHUTE		By Contractor				94 06 17	
1DH-CHT-5	DISCHARGE CHUTE		By Contractor					
1DH-CHT-6	COAL BY-PASS CHUTE		By Contractor					
1DH-CHT-7	DISCHARGE CHUTE		By Contractor				95 02 7	
1DH-CONV-1	COAL SCREW CONVEYOR		By Contractor	M			94 09 29	

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SYSTEM CODE: DH
DESCRIPTION: COAL RECEIVING, STORAGE AND RECLAIM SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DH-CONV-2	COAL BIN DISCHARGER		By Contractor	M			94 06 20	
1DH-DCOL-1	COAL STORAGE BIN DUST COLLECTOR		By Contractor					
1DH-DVTV-1	COAL BY-PASS DIVERTER VALVE		By Contractor					
1DH-ELEV-1	COAL BUCKET ELEVATOR		By Contractor					
1DH-FAN-1	COAL STORAGE BIN DUST COLLECTOR FAN		By Contractor	M				
1DH-FDR-1	COAL SCREW FEEDER		By Contractor	M				
1DH-FDR-2	COAL SCREW FEEDER		By Contractor	M				
1DH-HPR-1	COAL CHARGE HOPPER		By Contractor				94 07 5	

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1DH-MO-1	MOTOR, COAL SCREW FEEDER		By Contractor	15.00 HP 1800 RPM M			94 12	6
1DH-MO-2	MOTOR, COAL BUCKET ELEVATOR		By Contractor	7.50 HP 1800 RPM M			94 12	6
1DH-MO-3	MOTOR, COAL SCREW CONVEYOR		By Contractor	3.00 HP 1800 RPM M			94 12	6
1DH-MO-4	MOTOR,COAL STORAGE BIN DISCHARGER		By Contractor	2.00 HP 1800 RPM M			94 12	6
1DH-MO-5	MOTOR, COAL STORAGE BIN DUST COLLECTOR FAN		By Contractor	7.50 HP 1800 RPM M			94 12	6
1DH-MO-6	MOTOR, COAL SCREW FEEDER		By Contractor	3.00 HP 1800 RPM M			94 12	6
1DH-PSX-1	COAL STORAGE BIN AIR CANNONS		By Contractor				94 12	18
1DH-TARP-1	COAL STORAGE PILE TARPAULIN		By Contractor					

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EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DH-TARP-2	COKE STORAGE PILE TARPAULIN		By Contractor				95 02 14	
1DH-TK-1	COAL STORAGE BIN		By Contractor					

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SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DJ-AL-1	ROTARY VALVE CRUSHED COAL NO.1		By Contractor					
1DJ-AL-2	ROTARY VALVE CRUSHED COAL NO.2		By Contractor					
1DJ-AL-3	COAL PREP. ROTARY VALVE		By Contractor					
1DJ-BLO-1	BLOWER, CRUSHED COAL TRANSFER		By Contractor	M				
1DJ-CHT-1	DISCHARGE CHUTE		By Contractor					
1DJ-CHT-2	DISCHARGE CHUTE		By Contractor					
1DJ-CHT-3	DISCHARGE CHUTE		By Contractor					
1DJ-CHT-4	FINES CHUTE		By Contractor					

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DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

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1DJ-CHT-5	ACCEPTS CHUTE		By Contractor					
1DJ-CHT-6	DISCHARGE CHUTE		By Contractor					
1DJ-CHT-7	DISCHARGE CHUTE		By Contractor					
1DJ-CHT-8	SAMPLE CHUTE		By Contractor					
1DJ-CHT-9	DISCHARGE CHUTE		By Contractor					
1DJ-CHT-13	DISCHARGE CHUTE		By Contractor				95 02	7
1DJ-CHT-14	DISCHARGE CHUTE		By Contractor				95 02	8
1DJ-CLF-1	COAL CLASSIFIER		By Contractor	M				

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EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DJ-CRSH-1	COAL CRUSHER		By Contractor	M				
1DJ-CYCL-1	CYCLONE RECEIVER CRUSHED COAL		By Contractor					
1DJ-DCOL-1	COAL PREP. DUST COLLECTOR		By Contractor					
1DJ-DRY-1	COAL SCREW/ DRYER		By Contractor	M				
1DJ-FAN-1	OIL HEATER FAN		By Contractor	M				
1DJ-FAN-2	COAL PREP. DUST COLLECTOR FAN		By Contractor	M				
1DJ-FDR-1	COAL WEIGHBELT FEEDER		By Contractor	M				
1DJ-HPR-1	ROTARY VALVE VENT HOPPER		By Contractor					

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DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DJ-HX-1	OIL HEATER		By Contractor					
1DJ-MO-1	MOTOR, COAL CRUSHER		By Contractor	20.00 HP 1800 RPM M			94 12	6
1DJ-MO-2	MOTOR, COAL SCREW/DRIER		By Contractor	15.00 HP 1800 RPM M			94 12	6
1DJ-MO-3	MOTOR, OIL HEATER FAN		By Contractor	20.00 HP 1800 RPM M			94 12	6
1DJ-MO-4	MOTOR, OIL HEATER PUMP		By Contractor	15.00 HP 1800 RPM M			94 12	6
1DJ-MO-5	MOTOR, BLOWER, CRUSHED COAL TRANSFER		By Contractor	20.00 HP 1800 RPM M			94 12	6
1DJ-MO-6	MOTOR, ROTARY VALVE, CRUSHED COAL NO.1		By Contractor	1.00 HP 1800 RPM M			94 12	6
1DJ-MO-7	MOTOR, ROTARY VALVE, CRUSHED COAL NO.2		By Contractor	1.00 HP 1800 RPM M			94 12	6

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SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DJ-MO-8	MOTOR, COAL CLASSIFIER		By Contractor	1.50 HP 1800 RPM M			94 12	6
1DJ-MO-9	MOTOR,COAL WEIGHTBELT FEEDER		By Contractor	1.00 HP 1800 RPM M			94 12	6
1DJ-MO-10	MOTOR, COAL SAMPLER		By Contractor	0.50 HP 1800 RPM M			94 12	6
1DJ-MO-11	MOTOR, COAL PREP. DUST COLLECTOR FAN		By Contractor	25.00 HP 1800 RPM M			94 12	6
1DJ-MO-12	MOTOR, COAL PREP. ROTARY VALVE		By Contractor	1.00 HP 1800 RPM M			94 12	6
1DJ-P-1	OIL HEATER PUMP		By Contractor	M				
1DJ-SMX-1	COAL SAMPLER		By Contractor					
1DJ-TK-1	FINES TOTE BIN		By Contractor					

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DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DJ-TK-2	COAL SURGE BIN		By Contractor					
1DJ-TK-3	COAL SAMPLER CONTAINER		By Contractor					
1DJ-TK-4	TOTE BIN		By Contractor					
1DJ-TK-5	COKE/LIMESTONE BIN		By Contractor				95 06 28	

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SYSTEM CODE: DP
DESCRIPTION: PYROLYZER FEED SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1DP-FDR-1	ROTORY FEEDER		By Contractor					
1DP-HPR-1	CHARGE HOPPER		By Contractor					
1DP-HPR-2	TRANSFER HOPPER		By Contractor					
1DP-MO-1	MOTOR, ROTARY FEEDER		By Contractor	3.00 HP 1800 RPM M			94 12	6
1DP-TK-1	SURGE BIN		By Contractor					

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SYSTEM CODE: EA
DESCRIPTION: MEDIUM-VOLTAGE POWER SYSTEM (601V - 15KV)

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1EA-HVSW-1	4.16KV, 250MVA, MED. VOLTAGE SWITCH GEAR & MOTOR CONTROL WITH METERERING SECTION.		By Contractor				94 12 18	
1EA-XFRM-1	MASTER UNIT SUB STATION TRANSFORMER (11.5 KV - 4160 VOLTS)		By Contractor					
1EA-XFRM-2	LOW VOLTAGE LOAD CENTER TRANSFOMER (11.5 KV-480 VOLTS)		By Contractor				94 12 20	

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SYSTEM CODE: EC
DESCRIPTION: LOW-VOLTAGE POWER SYSTEM (600V AND LESS)

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1EC-CAB-1	(5) PANEL CABINET FOR FIREALAR PAGING SYSTEM PANEL, SECURITY PANEL, AND CO2 PANEL.		By Contractor				94 12 18	
1EC-MCC-1	480V, 3 WIRE, NEMA 12 MOTOR CONTROL CENTER		By Contractor					
1EC-MCC-2	480V, 3 WIRE, NEMA 3R MOTOR CONTROL CENTER		By Contractor					
1EC-MCC-3	480V, 3 WIRE FUEL HANDLING MOTOR CONTROL CENTER		By Contractor				94 12 20	
1EC-MCC-4	480V, 3 WIRE ESSENTIAL POWER MOTOR CONTROL CENTER		By Contractor				94 12 20	
1EC-UPS-1	480V, 30KVA UNUNTERRUPTABLE POWER SUPPLY WITH (2)200A, 3 PHASE, 4 WIRE PANELS CONSISTING OF 42 CIRCUIT BREAK		By Contractor					
1EC-XFRM-4	575V, 4 WIRE, 112.5 KVA TRANSFORMER		By Contractor					
1EC-XFRM-5	575-208/120 4 WIRE, 75 KVA TRASFORMER		By Contractor					

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SYSTEM CODE: GA
DESCRIPTION: COMBUSTION GAS DESULFURIZATION SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1GA-BLO-1	SCRUBBER WASTE WATER OXIDATION BLOWER		By Contractor	M			95 04	3
1GA-CHTR-1	FLUE GAS REHEATER		By Contractor				95 04	3
1GA-DMP-1	FLUE GAS DAMPER		By Contractor				95 04	3
1GA-FAN-1	FLUE GAS REHEATER COMBUSTION AIR FAN		By Contractor	M			95 04	3
1GA-FAN-2	ID FAN		By Contractor	M			95 08	29
1GA-HX-1	QUENCH CHAMBER		By Contractor				95 06	28
1GA-MO-1	SCRUBBER RECYCLE PUMP MOTOR		By Contractor	M			95 04	3
1GA-MO-2	CAUSTIC INJECTION PUMP MOTOR		By Contractor	M			95 04	3

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SIRRINE PROJECT:16N25706
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SYSTEM CODE: GA
DESCRIPTION: COMBUSTION GAS DESULFURIZATION SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1GA-MO-3	CONDENSATE DRAIN PUMP MOTOR		By Contractor	M			95 04	3
1GA-MO-5	FULE GAS REHEATER COMBUSTION AIR FAN MOTOR		By Contractor	M			95 04	3
1GA-MO-6	SCRUBBER WASTE WATER OXIDATION BLOWER MOTOR		By Contractor	M			95 04	3
1GA-MO-7	FLUE GAS DAMPER MOTOR		By Contractor	M			95 08	2
1GA-MO-8	ID FAN MOTOR		By Contractor	M			95 08	29
1GA-P-1	SCRUBBER RECYCLE PUMP		By Contractor	M			95 04	3
1GA-P-2	CAUSTIC INJECTION PUMP		By Contractor	M			95 04	3
1GA-P-3	CONDENSATE DRAIN PUMP		By Contractor	M			95 04	3

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SYSTEM CODE: GA
DESCRIPTION: COMBUSTION GAS DESULFURIZATION SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1GA-SCG-1	CAUSTIC SCRUBBER		By Contractor				95 04	3
1GA-TK-1	CAUSTIC STORAGE TANK		By Contractor				95 04	3
1GA-TK-2	CONDENSATE DRAIN TANK		By Contractor				95 07	10

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SYSTEM CODE: GG
DESCRIPTION: PROCESS VENT SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1GG-CYCL-1	VENT CYCLONE		By Contractor				94 10 16	
1GG-HPR-1	VENT CYCLONE HOPPER		By Contractor				94 10 16	
1GG-STK-1	FLARE STACK		By Contractor				94 12 7	
1GG-TK-1	FLARE INSTRUMENT AIR RECEIVER		By Contractor				95 06 28	

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SYSTEM CODE: GH
DESCRIPTION:

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN.	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1GH-FAN-1	FD FAN		By Contractor	M			95 07 12	
1GH-INCN-1	INCINERATOR		By Contractor				95 08 29	
1GH-MO-1	FD FAN MOTOR		By Contractor	M			95 07 12	

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SYSTEM CODE: KD
DESCRIPTION: CONDENSATE AND FEEDWATER CHEMISTRY CONTROL SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1KD-MO-1	PHOSPHATE METERING PUMP MOTOR		By Contractor	0.25 HP 1800 RPM M			94 12 6	
1KD-MO-2	NEUTALIZING AMINE METERING PUMP MOTOR		By Contractor	0.25 HP 1800 RPM M			94 12 6	
1KD-MO-3	OXYGEN SCAVENGER METERING PUMP MOTOR		By Contractor	0.25 HP 1800 RPM M			94 12 6	
1KD-P-1	PHOSPHATE METERING PUMP		By Contractor	M			94 10 16	
1KD-P-2	NEUTALIZING AMINE METERING PUMP		By Contractor	M			94 10 16	
1KD-P-3	OXYGEN SCAVENGER METERING PUMP		By Contractor	M			94 10 16	

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SYSTEM CODE: KK
DESCRIPTION: POTABLE WATER SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1KK-MO-1	POTABLE WATER BOOSTER PUMP NO.1 MOTOR		By Contractor	3.00 HP 1800 RPM M			94 12	6
1KK-MO-2	POTABLE WATER BOOSTER PUMP NO.2 MOTOR		By Contractor	3.00 HP 1800 RPM M			94 12	6
1KK-P-1	POTABLE WATER BOOSTER PUMP NO.1		By Contractor	M				
1KK-P-2	POTABLE WATER BOOSTER PUMP NO.2		By Contractor	M				
1KK-TK-1	POTABLE WATER STORAGE TANK		By Contractor					

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SYSTEM CODE: KV
DESCRIPTION: AUXILIARY WATER SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1KV-MO-1	COOLING WATER TRANSFER PUMP NO.1 MOTOR		By Contractor	80.00 HP 1800 RPM M			94 12	15
1KV-MO-2	COOLING WATER TRANSFER PUMP NO.2 MOTOR		By Contractor	80.00 HP 1800 RPM M			94 12	15
1KV-P-1	COOLING WATER TRANSFER PUMP NO.1		By Contractor	M			94 12	7
1KV-P-2	COOLING WATER TRANSFER PUMP NO.2		By Contractor	M			94 12	7

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SYSTEM CODE: KW
DESCRIPTION: SERVICE WATER SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1KW-MO-1	SERVICE WATER PUMP MOTOR		By Contractor	M			95 06 28	
1KW-P-1	SERVICE WATER PUMP		By Contractor	M			95 06 28	
1KW-TK-1	FIRE & SERVICE WATER STORAGE TANK		By Contractor				94 12 7	

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SYSTEM CODE: LD
DESCRIPTION: COMPRESSED AIR SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1LD-DRY-1	INSTRUMENT AIR DRYER		By Contractor				94 12	7
1LD-FLT-1	DRYER PREFILTER		By Contractor				94 12	7
1LD-FLT-2	DRYER AFTERFILTER		By Contractor				94 12	7
1LD-TK-1	INSTRUMENT AIR RECEIVER		By Contractor				94 12	7
1LD-TK-2	FUEL FEED SYSTEM INSTRUMENT AIR RECEIVER		By Contractor				95 07	10

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SYSTEM CODE: LF
DESCRIPTION: SERVICE AIR SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1LF-CMP-1	PROCESS AIR COMPRESSOR		By Contractor	M				
1LF-CMP-2	PROCESS BOOSTER COMPRESSOR		By Contractor				95 06 28	
1LF-CMP-3	PLANT AIR COMPRESSOR AND RECEIVER PACKAGE		By Contractor				95 06 28	
1LF-DRY-1	FUEL FEED AIR DRYER		By Contractor					
1LF-FLT-1	INLET FILTER SILENCER		By Contractor					
1LF-FLT-2	DRYER PREFILTER		By Contractor					
1LF-FLT-3	DRYER AFTERFILTER		By Contractor					
1LF-HX-1	1st STAGE INTERCOOLER		By Contractor				94 12 7	

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SYSTEM CODE: LF
DESCRIPTION: SERVICE AIR SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1LF-HX-2	2nd STAGE INTERCOOLER		By Contractor				94 12	7
1LF-HX-3	3rd STAGE INTERCOOLER		By Contractor				94 12	7
1LF-HX-4	4th STAGE INTERCOOLER		By Contractor				94 12	7
1LF-HX-5	RECYCLE COOLER		By Contractor				95 02	6
1LF-HX-6	LUBE OIL COOLER		By Contractor				95 06	28
1LF-HX-7	FUEL FEED AIR COOLER		By Contractor				94 12	7
1LF-MO-1	PROCESS AIR COMPRESSOR MOTOR		By Contractor	3000.00 HP 1800 RPM M			95 02	7
1LF-MO-2	PROCESS BOOSTER COMPRESSOR MOTOR		By Contractor				95 06	28

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SYSTEM CODE: LF
DESCRIPTION: SERVICE AIR SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1LF-SIL-1	BLOWOFF SILENCER		By Contractor					
1LF-TK-1	PROCESS AIR RECEIVER		By Contractor					
1LF-TK-2	FUEL FEED AIR RECEIVER		By Contractor				95 06 28	

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SYSTEM CODE: LK
DESCRIPTION: NITROGEN SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1LK-HX-1	HITROGEN HEATER		By Contractor				95 02	6
1LK-MO-1	NITROGEN PUMP NO.1		By Contractor	40.00 HP 1800 RPM M			94 12	6
1LK-MO-2	NITROGEN PUMP NO.2		By Contractor	40.00 HP 1800 RPM M			94 12	6
1LK-P-1	NITROGEN PUMP NO.1		By Contractor	 M			94 12	7
1LK-P-2	NITROGEN PUMP NO.2		By Contractor	 M			94 12	7
1LK-TK-1	NITROGEN STORAGE TANK NO.1		By Contractor				94 12	7
1LK-TK-2	NITROGEN STORAGE TANK NO.2		By Contractor				94 12	7
1LK-TK-3	HIGH PRESSURE NITROGEN SURGE TANK		By Contractor				94 12	7

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SYSTEM CODE: LK
DESCRIPTION: NITROGEN SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1LK-VAP-1	L.P.NITROGEN VAPORIZER		By Contractor					
1LK-VAP-2	H.P.NITROGEN VAPORIZER		By Contractor				95 02	6

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SYSTEM CODE: SB
DESCRIPTION: MAIN STEAM SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1SB-BLR-1	PACKAGE BOILER		By Contractor				94 12 18	
1SB-FAN-1	FD FAN		By Contractor	M			95 07 17	
1SB-MO-1	FD FAN MOTOR		By Contractor	M			95 07 17	
1SB-SIL-1	S.H. VENT SILENCER		By Contractor				94 12 18	
1SB-SIL-2	DRUM VENT SILENCER NO.1		By Contractor				94 12 18	
1SB-SIL-3	DRUM VENT SILENCER NO.2		By Contractor				94 12 18	
1SB-STK-1	STACK		By Contractor				95 07 12	
1SB-TK-1	CBD TANK		By Contractor					

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SYSTEM CODE: SJ
DESCRIPTION: FEEDWATER SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1SJ-DEA-1	DEAERATOR		By Contractor					
1SJ-MO-1	BOILER FEEDWATER PUMP MOTOR		By Contractor	25.00 HP 1800 RPM M			94 12	6
1SJ-MO-2	GASIFIER CW MAKEUP PUMP NO.1 MOTOR		By Contractor	300.00 HP 1800 RPM M			94 12	15
1SJ-MO-3	GASIFIER CW MAKEUP PUMP NO.2 MOTOR		By Contractor	300.00 HP 1800 RPM M			94 12	6
1SJ-P-1	BOILER FEEDWATER PUMP		By Contractor	M				
1SJ-P-2	GASIFIER CW MAKEUP NO.1		By Contractor	M			94 12	7
1SJ-P-3	GASIFIER CW MAKEUP PUMP NO.2		By Contractor	M				

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SYSTEM CODE: VE
DESCRIPTION: ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM

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1VE-ACU-1	A.C.UNIT CONTROL/RACK ROOM		By Contractor				94 12	6
1VE-ACU-2	A.C.UNIT OFFICE/ELECT.RM.		By Contractor				94 12	6
1VE-ACU-3	A.C.UNIT COAL HANDL.MCC ROOM		By Contractor				94 12	6
1VE-EHTR-1	ELECT UNIT HEATER NO.1 FIRE PUMP HOUSE		By Contractor	10.00 KW			94 12	6
1VE-EHTR-2	ELEC UNIT HEATER NO.2 FIRE PUMP HOUSE		By Contractor	10.00 KW			94 12	6
1VE-EHTR-3	ELECT UNIT HEATER NO.1 COMPRESSOR ROOM		By Contractor				94 12	18
1VE-EHTR-4	ELECT UNIT HEATER NO.4 COMPRESSOR ROOM		By Contractor	10.00 KW			94 12	6
1VE-EHTR-5	ELECT UNIT HEATER NO.5 COMPRESSOR		By Contractor	2.00 KW			94 12	6

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SYSTEM CODE: VE
DESCRIPTION: ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1VE-EHTR-6	ELECT UNIT HEATER NO.1 MAINT. RM		By Contractor	3.00 KW			94 12	6
1VE-EHTR-7	ECECT UNIT HEATER NO.2 MAINT. RM		By Contractor	2.00 KW			94 12	6
1VE-EHTR-8	WALL HEATER F.P.VALVE HOUSE		By Contractor	3.00 KW			94 12	6
1VE-EHTR-9	ELCT RH NO.1 TOILET		By Contractor	2.00 KW			94 12	6
1VE-EHTR-10	ELECT RH NO.2 TOILET		By Contractor	3.00 KW			94 12	6
1VE-EHTR-11	ELECT. DUCT HEATER CONTROL/I.O.ROOM/LAB		By Contractor	5.00 KW			94 12	6
1VE-EHTR-12	ELECT. DUCT HEATER ELECT. RM.		By Contractor				94 12	18
1VE-EHTR-13	ELECT. DUCT HEATER COAL HANDL. MCC ROOM		By Contractor				95 07	17

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SYSTEM CODE: VE
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EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1VE-FAN-1	VENT FAN MAINT.ROOM		By Contractor	M			94 12 18	
1VE-FAN-2	TOILET EXHAUST FAN		By Contractor	M			94 12 18	
1VE-FAN-3	EXHAUST FAN UPS ROOM		By Contractor	M			94 12 18	
1VE-FAN-4	VENT FAN COMPRESSOR ROOM		By Contractor	M			94 12 18	
1VE-FAN-5	VENT FAN COMPRESSOR ROOM		By Contractor	M			94 12 18	
1VE-FAN-6	EXHAUST FAN F.P.VALVE HOUSE		By Contractor	M			94 12 18	
1VE-FAN-7	LAB HOOD S.A.FAN		By Contractor	M			94 12 18	
1VE-FAN-7	FAN MOTOR		By Contractor	M			94 12 18	

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EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1VE-FAN-8	VENT FAN FIRE PUMP HSE		By Contractor	M			94 12	18
1VE-LH-1	CHEMICAL LAB HOOD		By Contractor				94 12	18
1VE-LV-1	MOTORIZED O.A. LOUVER MAINT.RM		By Contractor				94 12	18
1VE-LV-2	MOTORIZED O.A. LOUVER COMPRESSOR RM		By Contractor				94 12	18
1VE-LV-3	MOTORIZED O.A.LOUVER FIRE PUMP HOUSE		By Contractor				94 12	18
1VE-MO-2	FAN MOTOR		By Contractor	0.25 HP M			94 12	6
1VE-MO-2	FAN MOTOR		By Contractor	0.25 HP M			94 12	6
1VE-MO-3	FAN MOTOR		By Contractor	0.17 HP 1800 RPM M			94 12	6

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EQUIPMENT LIST
FOR
Department of Energy
Gasification Product Improvemnet Facility
ISSUED AS Rev.1

SYSTEM CODE: VE
DESCRIPTION: ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1VE-MO-4	FAN MOTOR		By Contractor	1.00 HP 1800 RPM M			94 12	6
1VE-MO-5	FAN MOTOR		By Contractor	0.05 HP 1800 RPM M			94 12	6
1VE-MO-6	FAN MOTOR		By Contractor	0.33 HP 1800 RPM M			94 12	6
1VE-MO-8	FAN MOTOR		By Contractor	0.33 HP 1800 RPM M			94 12	6
1VE-MO-9	MOTORIZED LOUVER MAINT RM		By Contractor	0.17 HP 1800 RPM M			94 12	6
1VE-MO-10	MOTORIZED LOUVER COMPRESSOR RM		By Contractor	M			95 07	17
1VE-MO-11	MOTORIZED LOUVER FIRE PUMP HOUSE		By Contractor	M			95 07	17

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Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
GPIF

EQUIPMENT LIST
FOR
Department of Energy
Gasification Product Improvemnet Facility
ISSUED AS Rev.1

SYSTEM CODE: WS
DESCRIPTION: WASTE TREATMENT SYSTEM

EQUIPMENT NO.	EQUIPMENT NAME & DESCRIPTION	VENDOR PO NUMBER BUDGET COST CCN	CONSTRUCTION RESPONSIBILITY	DESIGN PWR OP SPEED DRIVER	EQ WT (EMPTY) MTL CONSTRN	APPROVAL STATUS DESIGN STATUS USE STATUS	SPEC ISSUE REV	REV FLAG
1WS-MO-1	STORM/PROCESS WASTE SUMP PUMP NO.1 MOTOR		By Contractor	5.00 HP 1800 RPM M			94 12	6
1WS-MO-2	STORM/PROCESS WASTE SUMP PUMP NO.2 MOTOR		By Contractor	5.00 HP 1800 RPM M			94 12	15
1WS-MO-3	SANITARY WASTE DOSING PUMP NO.1		By Contractor	15.00 HP 1800 RPM M			94 12	6
1WS-MO-4	SANITARY WASTE DOSING PUMP NO.2 MOTOR		By Contractor	2.00 HP 1800 RPM M			94 12	15
1WS-P-1	STORM/PROCESS WASTE SUMP PUMP NO.1		By Contractor	M			95 06	28
1WS-P-2	STORM/PROCESS WASTE SUMP PUMP NO.2		By Contractor	M			95 06	28
1WS-P-3	SANITARY WASTE DOSING PUMP NO.1		By Contractor	M			95 07	10
1WS-P-4	SANITARY WASTE DOSING PUMP NO.2		By Contractor	M			95 07	10

GPIF PROJECT
JACOBS-SIRRINE PROJECT NO. 16N25706

PROCESS DESIGN BASIS INDEX

August 28, 1995

DOCUMENT NUMBER	DOCUMENT TITLE
DBR-1AA-1	GASIFIER DESIGN PRESSURE
DBR-1AA-2	GASIFIER COOLING
40-1AA-1	GASIFIER
40-1AA-2	GAS CLEAN-UP SYSTEM
40-1AA-3	GASIFIER ASH HANDLING
40- 1AA-4	SOLID WASTE DISPOSAL
40-1DG-1	NATURAL GAS DISTRIBUTION
40-1GA-1	FLUE GAS DESULFURIZATION SYSTEM
40-1GG-1	LOCK HOPPER VENT SYSTEM
40-1GG-2	FLARE SYSTEM
40-1GH-1	INCINERATOR SYSTEM
40-1KK-1	POTABLE WATER SYSTEM
40-1KV-1	AUXILIARY WATER DISTRIBUTION
40-1KW-1	SERVICE WATER SYSTEM
40-1LD-1	PLANT & INSTRUMENT AIR SYSTEMS
40-1LF-1	PROCESS AIR SYSTEM
40-1LK-1	NITROGEN STORAGE DISTRIBUTION
40-1SB-1	PACKAGE BOILER
40-1SJ-1	CONDENSATE/DEAERATOR/FEEDWATER
40-1WS-1	PROCESS WASTE WATER DISTRIBUTION
82-1DH-1	COAL STORAGE BIN
82-1DH-2	COAL STORAGE BIN DISCHARGER
82-1DH-3	COAL SCREW CONVEYORS & FEEDERS
82-1DH-4	COAL BUCKET ELEVATOR
82-1DH-5	COAL STORAGE BIN VENT DUST COLLECTOR & EXHAUST FAN
82-1DJ-1	COAL SCREW DRYER
82-1DJ-2	COAL CRUSHER
82-1DJ-3	COAL CLASSIFIER
82-1DJ-4	COAL WEIGH BELT FEEDER/SAMPLER
82-1DJ-5	COAL SURGE BIN
82-1DJ-6	COKE WEIGHBELT FEEDER
82-1DJ-7	COKE SURGE BIN
82-1DJ-8	TRUCK UNLOADING PIPE & TARGET BOX
82-1DJ-9	COAL PREPARATION DUST COLLECTOR w/ EXHAUSTER FAN
82-1DJ-10	COAL TRANSFER SYSTEM
82-1DP-1	CHARGE HOPPER, TRANSFER HOPPER, SURGE BIN

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-1

System Name: Gasifier Design Pressure
Flow Sheet No: 16N25706-40-F-1AA-1

I. DESIGN PHILOSOPHY

GASIFIER CONFIGURATION

1. The PyGas™ gasifier is an air blown dry bottom gasifier designed for an operating pressure of 325 psig.
2. The gasifier is shown in Figure 1. The internal diameter of the vessel is 5 feet. The vessel houses a rotating grate, which supports the gasifier fixed bed, a central pyrolyzer tube, and an upper shroud attached to the top of the vessel. The vessel consists of a dome with a top flanged connection, a central section, and a bottom flanged section. The vessel is double-walled and designed for evaporative water cooling. The vessel heads are refractory lined.
3. The lower portion of the pyrolyzer tube extends through the bottom of the vessel.
4. The gasifier has openings for process inlet and outlet flows including air, steam, nitrogen, coal and limestone inlet flows, product gas outlet flow, and ash and solids discharge. Openings are also included for the vessel access, the rotating grate drive shaft and pressure relief. In addition, there are openings for inlet water and outlet steam/water lines for the vessel cooling jacket as well as cooling circuits for internal gasifier components. The vessel contains a number of instrument connections.
5. The pressure vessel, as shown in Figure 1, will be designed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. This code shall also be used to establish allowable stresses for certain nonpressure boundary parts such as vessel support attachments. It is noted that Section VIII, Division 1 provides all safety attributes of Section I of the code but Section VIII, Division 1 goes beyond Section I to provide additional assurance of safety. Because the gasification process temperatures range from 1100°F to 2500°F, the cooling system and refractory lined surface will be designed to limit material temperatures of the pressure boundary and internals to levels that maintain stress limits in accordance with code requirements. The outer vessel will be constructed of carbon steel with a design temperature of 700°F. Metals selected for the internal components will follow the latest code requirements.
6. Refractory and insulating materials are considered to be maintenance materials and their replacement is a function of unit operation, availability, and performance.

DESIGN PRESSURE

1. The design pressure for the vessel outer shell is 540 psig. This pressure is calculated based on the vessel inner shell maximum pressure of 420 psig and the pressure differential between the vessel cooling jacket and the gas side.
2. The inner vessel wall will be designed for 140 psi differential pressure.
3. The design pressure of the steam drum is 540 psig.
4. The start-up pressure is 150 psig. The vessel design pressure of 540 psig is higher than explosion pressures predicted for 150 psig start-up conditions.

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-1

System Name: Gasifier Design Pressure
Flow Sheet No: 16N25706-40-F-1AA-1

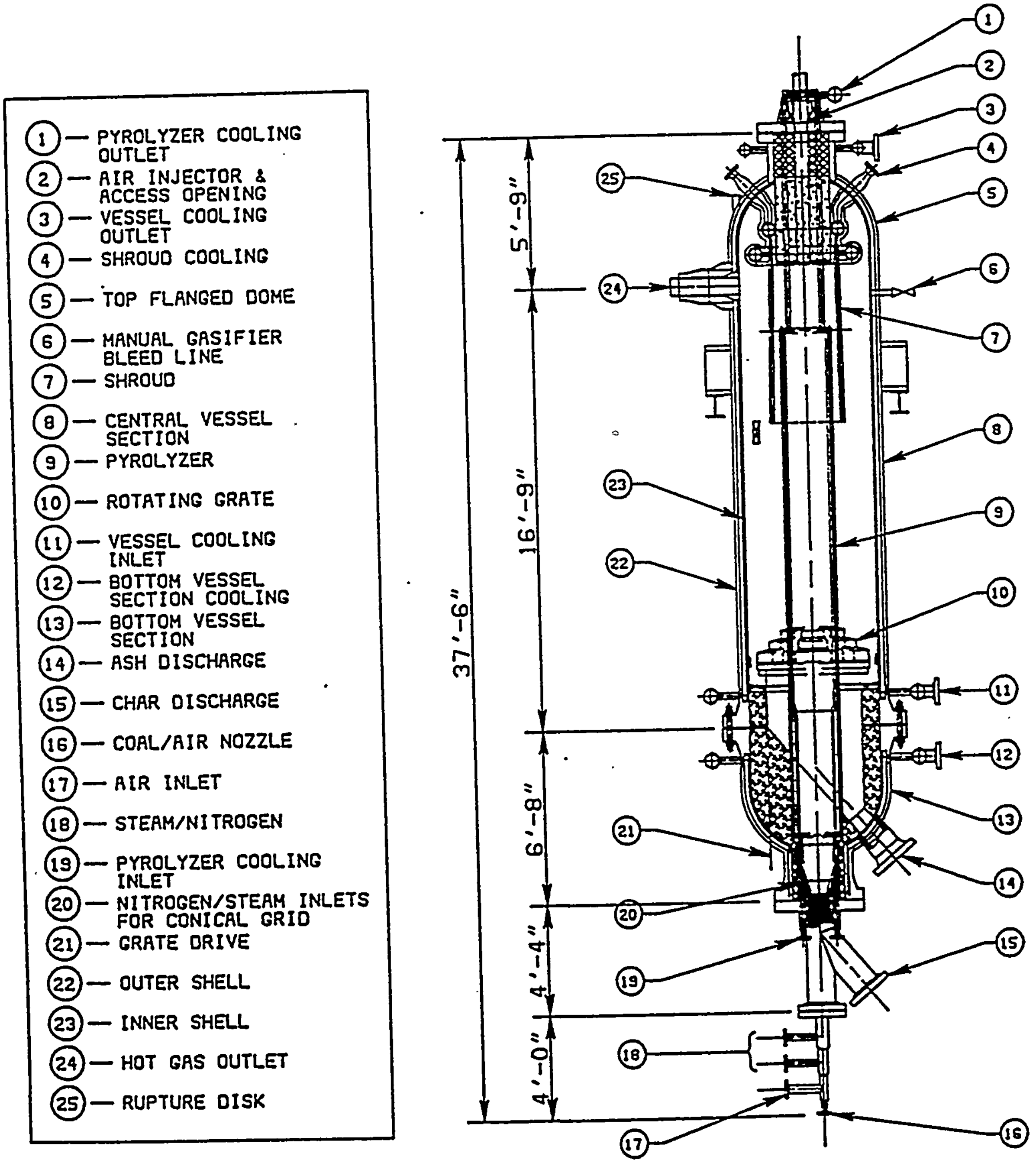

Figure 1. General Gasifier Arrangement.

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-1

System Name: Gasifier Design Pressure
Flow Sheet No: 16N25706-40-F-1AA-1

PRESSURE RELIEF

1. The ASME Code requires that pressure safety relief devices be installed on the process gas side as well as on the water/steam cooling circuits. In addition, pressure relief devices will be required to limit the inlet pressure of process flow streams (air, steam, nitrogen). A system schematic listing operating pressures and pressure relief set points is shown in Figure 2.

2. Pressure relief valves on the steam drum will be reclosing type. Because of the dirty environment in the gasifier, a reclosing type of pressure relief device can not be used for relieving the gasifier overpressure. A rupture disk will be used as the gas side pressure relief device.

3. The pressure relief devices will be designed for overpressure only and not for explosion at the 325 psig gasification operating condition. The GPIF control system will be designed to prevent this abnormal condition.

4. The steam drum reclosing type pressure relief valve will be set at 486 psig and the non-reclosing type safety valve at 540 psig. The safety valve will be designed to relieve the full capacity of the steam circuit. Steam line from the drum to the gasifier will be equipped with a check valve to prevent contamination from the dirty gases. This is described in the gasifier cooling system process design.

5. The GPIF gasifier vessel will be designed for a maximum gas side pressure equal to the convey system inlet pressure of 373 psig (Ref. JSE Letter No 475 dated 5/31/95 on System Design Pressures). The GPIF will have upstream air, steam and nitrogen pressure reliefs to insure this gas side pressure is not exceeded.

6. The vessel contains a rupture disk designed for 420 psig with a design margin of -10%. The rupture disk will be exposed to high temperatures and will need a protective heat shield which may be cooled by nitrogen.

7. A manually operated valve will also be installed on the gasifier to bring down the pressure in the vessel as part of normal shut down procedure. This line will not be designed for emergency pressure relief.

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-1

System Name: Gasifier Design Pressure
Flow Sheet No: 16N25706-40-F-1AA-1

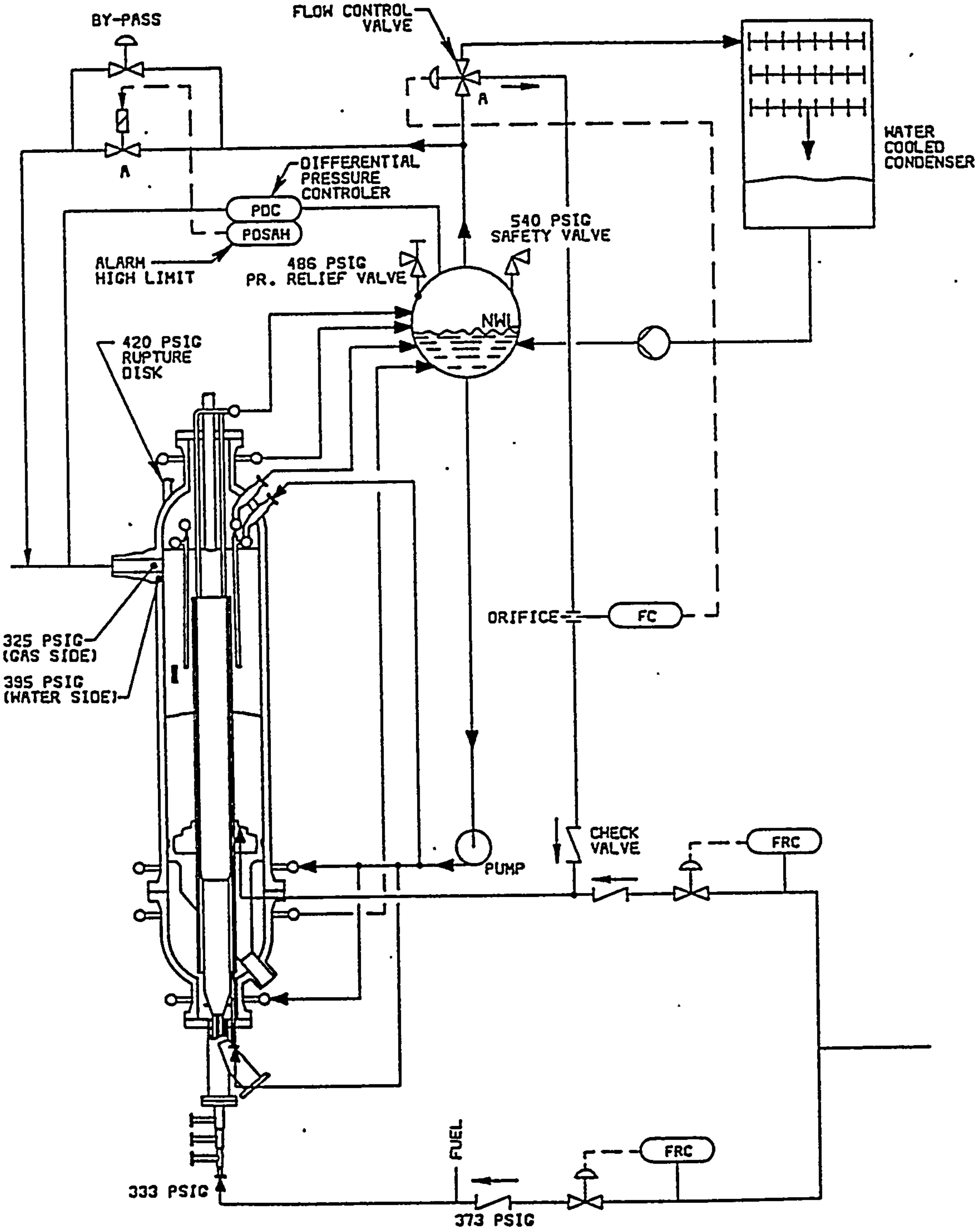

Figure 2. Gasifier Safety and Pressure Relief.

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-1

System Name: Gasifier Design Pressure
Flow Sheet No: 16N25706-40-F-1AA-1

II. DESIGN NOTES

1. The Rev. 1 design is based on the Jacobs-Sirrine Letter No. 475 on system design pressures, dated 5/31/95 for the 5' ID vessel and the 325 psig, 4000 lb/hr coal operation.

2. Vessel Outer Shell Design Pressure:

Maximum gasifier pressure at the hot gas outlet	373 psig
Differential pressure across the cooling jacket inner wall	70 psi
Design margin for the vessel pressure	20%
Vessel outer shell design pressure (to nearest 10 psi)	(373 + 70) × 1.2 = 532 ≅ 540 psig

3. Drum Design Pressure and Pressure Relief:

Steam drum design pressure	540 psig
Non-reclosing drum safety valve set point	540 psig
Margin for the reclosing drum pressure relief valve	10%
Reclosing drum pressure relief valve set point	540 - (0.1) (540) = 486 psig

Gasification Product Improvement Facility
Fort Martin Station, West Virginia
Sirrine Job No. 16N25706
Riley Contract No. 93856

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Date: 8/28/95
Rev.: 1

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

I. DESIGN PHILOSOPHY

1. The primary function of the cooling system is to cool the gasifier vessel, pyrolyzer, and the shroud to maintain these sections under their metal temperature limits. Figure 3 shows the gasifier cooling circuits and major components.
2. The cooling medium is water. The cooling is performed by evaporation.
3. The cooling circuits operate under forced circulation with a circulation rate sufficient to avoid overheating of the metal.
4. The cooling circuits are designed to operate at a higher pressure than the gasification process.
5. The four cooling circuits are connected into one common steam drum.
6. The steam drum has one reclosing type pressure relief valve and one non-reclosing type safety valve.
7. The make-up water is supplied to the steam drum.
8. During normal operation, the generated steam in the system is used in the gasification process and/or condensed back into the steam drum.
9. As shown in Figure 3, the cooling system is connected to (i) the gasifier outlet pipe, (ii) the gasifier grate/air/steam feed line, and (iii) steam drum through a water cooled condenser.

   Loop (i) contains a control valve with a differential pressure between the gasifier and steam drum controller. In a situation of gas side breakdown where a rapid reduction of gasifier pressure occurs compared to the steam drum pressure, the differential pressure between the gasifier and steam drum will increase to the high alarm limit. At this point, the differential pressure controller will send signals to open the control valve in this loop and release steam to bring the differential pressure within the limit, thus preventing rupturing of the gasifier inner wall.

   Loops (ii) and (iii) branch off of a three way flow control valve. Through loop (ii) the cooling side is open to the gasifier, and the pressure in the cooling circuits follow the gas side pressure and is maintained at higher pressure. Loop (ii) contains an orifice and a check valve. The excess steam not required for the gasifier process will be condensed and returned to the steam drum through loop (iii).

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
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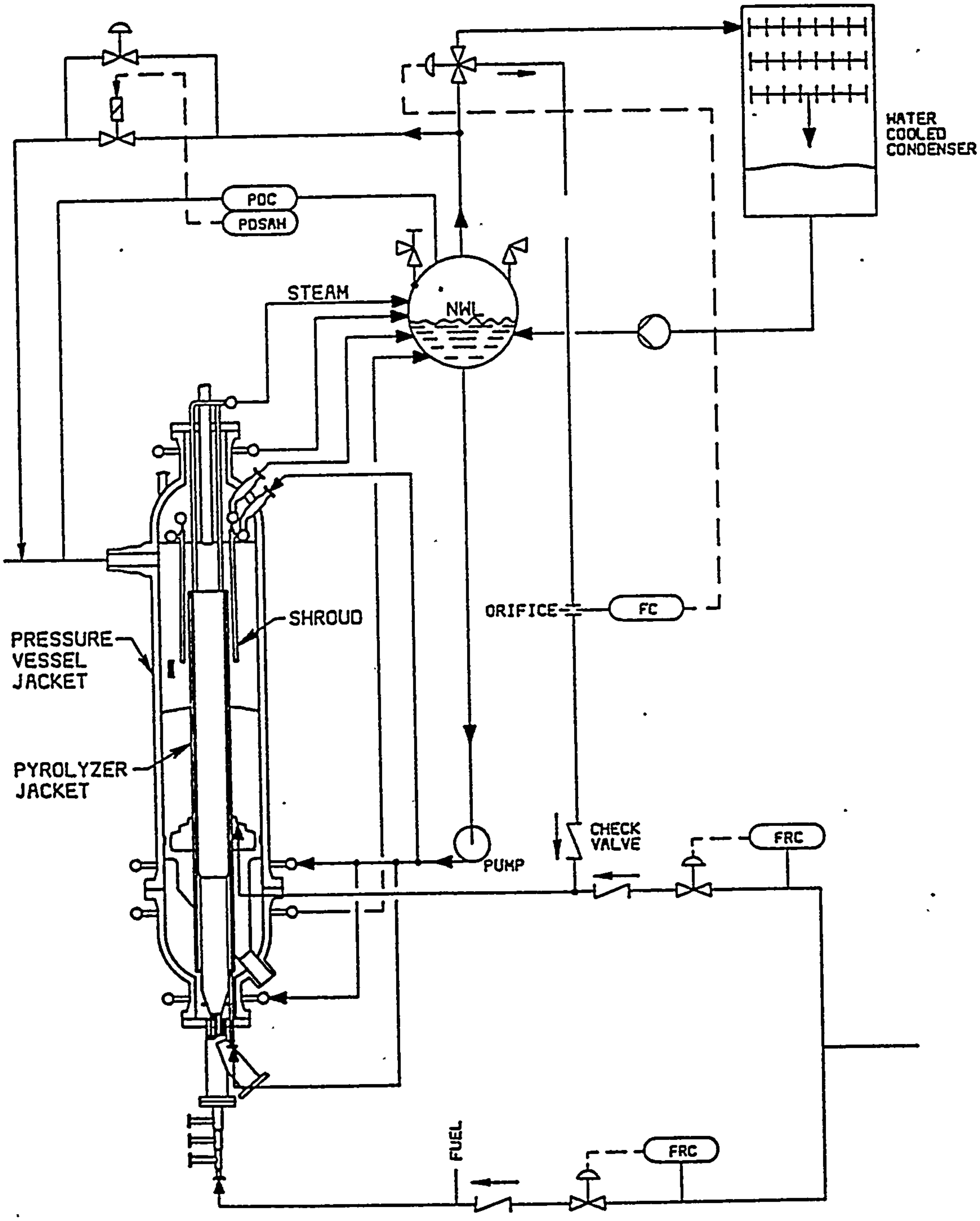

Figure 3. Gasifier Cooling Circuits.

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

II. DESIGN NOTES

1. Table 1 summarizes the pressure, flow and predicted temperature at various zones for the design, high, and low operating temperature cases.

2. For design and high temperature cases, the gasifier gas side operating pressure is 325 psig at the gasifier hot gas outlet and the water circuit pressure is 395 psig. For the low temperature case, the gas side operating pressure is 200 psig at the gasifier hot gas outlet and the water circuit pressure is 270 psig.

3. Pyrolyzer jacket fluid bed side is refractory lined. All other cooling surfaces are bare wall.

4. For gasifier cooling component dimensions, refer to Riley drawing No. 93856-8-2641-10-05 (enclosed).

5. The Design, High and Low operating temperature case parameters are shown in Tables 2 through 4 respectively. Data for High and Low Temperature Cases for Rev-1 was linearly extrapolated from Rev-1 Design Case.

   Ref. i) JSE Material Balance for Design Case dated 5/31/95 contained in JSE Letter No 477 dated 6/1/95, and
   ii) JSE Letter No 384 dated 3/15/95 for Rev-0 Process Design Basis.

   Surface areas, estimated mean temperature differences, overall heat transfer coefficients, heat flux, heat flows and steam generated are given for 11 heat transfer sections. The heat transfer sections are shown in Figure 4. The total predicted heat transfer to the cooling system for the design, high and low temperature cases are about 7, 11, and 5 million Btu/hr respectively. The total steam generated for the design, high and low temperature cases is 8,900, 13,300 and 5,300 lb/hr respectively.

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

Table 1 – Predicted Temperature at Key Locations

Description	Design Case	High Temp. Case	Low Temp. Case
Pressure, psig	325	325	150
Pyrolyzer Air/Coal Ratio	1.72	2.5	1.13
Flows, lb/hr:			
– Coal Input	4000	4000	2000
– Product Gas From Pyrolyzer	10225	14950	6090
– Product Gas From Fixed Bed	9535	9535	1525
– Fines @ Gasifier Exit	1000	1000	500
– Total Out @ Gasifier Exit	20760	25485	8115
Temperature, °F:			
– Pyrolyzer Exit	1690	1856	1500
– Dome	1690	2300*	1500
– Inner Annulus Entry	1548	2063	1256
– Inner Annulus Exit	1202	1625	780
– Fixed Bed Exit	1450	1700	1400
– Outer Annulus Entry	1186	1485	725
– Gasifier Outlet Nozzle	1023	1277	575

* Includes Top Air Injector Flow

93856/Tham
08/31/95

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

Table 2 – Heat Transfer Analysis – Design Case (325 psig & 2 t/hr coal)

Location No.	Cooling System Component/ Heat Source	Surface Area ft^2	Mean T * °F	Heat Transfer Coeff. U Btu/hr-ft^2-°F	Heat Flux Density Btu/hr-ft^2	Heat Flow X10^6 Btu/hr	Steam Generated lb/hr	Heat/ Steam Flow %
	Pyrolizer Jacket:							
1	Fluidized Bed **	103.31	1248	8	9679	1.00	1255	
4	Shroud Inner Annulus	21.99	917	28	25682	0.56	709	
5	Fixed Bed – Char	42.41	1440	13	18856	0.80	1003	
6	Fixed Bed – Ash	42.41	225	14	3096	0.13	165	
	Total Pyrolizer Jacket	210.13				2.50	3131	35.08
	Shroud Tube:							
2	Dome Region	19.48	1183	25	29584	0.58	723	
3	Inner Annulus	27.72	917	28	25682	0.71	893	
10	Outer Annulus	52.97	657	12	7885	0.42	524	
	Total Shroud Tube	100.17				1.71	2140	23.97
	Vessel Jacket:							
9	Outer Annulus/Freeboard	141.02	694	12	8330	1.17	1474	
8	Fixed Bed – Char	58.90	1440	16	22634	1.33	1673	
7	Fixed Bed – Ash	58.90	225	27	6173	0.36	456	
	Total Vessel Jacket	258.83				2.87	3603	40.36
11	Gas Outlet Nozzle	5.59	578	13	7520	0.04	53	
	Total	574.71				7.12	8926	100.00

* = Cooling Media: Water at saturated temperature of 447 °F
** = Refractory Lined

GPIF/ 93856
THAM 08/31/95

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

Table 3 – Heat Transfer Analysis – High Temperature Case (325 psig & 2 t/hr coa

Location No.	Cooling System Component/ Heat Source	Surface Area ft^2	Mean T * °F	Heat Transfer Coefft. U Btu/hr–ft^2–°F	Heat Flux Density Btu/hr–ft^2	Heat Flow X 10^6 Btu/hr	Steam Generated lb/hr	Heat/ Steam Flow %
	Pyrolizer Jacket:							
1	Fluidized Bed**	103.31	1400	8	10831	1.12	1404	
4	Shroud Inner Annulus	21.99	1385	35	48488	1.07	1338	
5	Fixed Bed – Char	42.41	1615	16	26276	1.11	1398	
6	Fixed Bed – Ash	42.41	225	14	3095	0.13	165	
						3.43	4304	32.35
	Total Pyrolizer Jacket	210.13						
	Shroud Tube:							
2	Dome Region	19.48	1745	40	69782	1.36	1705	
3	Inner Annulus	27.72	1385	35	48488	1.34	1686	
10	Outer Annulus	52.97	934	13	12142	0.64	807	
						3.35	4198	31.55
	Total Shroud Tube	100.17						
	Vessel Jacket:							
9	Outer Annulus/Freeboard	141.02	981	13	12749	1.80	2256	
8	Fixed Bed – Char	58.90	1615	17	27111	1.60	2003	
7	Fixed Bed – Ash	58.90	225	27	6171	0.36	456	
						3.76	4715	35.44
	Total Vessel Jacket	258.83						
11	Gas Outlet Nozzle	5.59	834	15	12505	0.07	88	
	Total	574.71				10.61	13305	100.00

* = Cooling Media: Water at saturated temperature of 447 °F
** = Refractory Lined

GPIF/ 93856
THAM 08/31/95

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

Table 4 – Heat Transfer Analysis – Low Temperature Case (150 psig & 1 t/hr coal

Location No.	Cooling System Component/ Heat Source	Surface Area ft^2	Mean T * °F	Heat Transfer Coefft, U Btu/hr–ft^2–°F	Heat Flux Density Btu/hr–ft^2	Heat Flow X 10^6 Btu/hr	Steam Generated lb/hr	Heat/ Steam Flow %
	Pyrolizer Jacket:							
1	Fluidized Bed	103.31	1118	8	8653	0.89	1043	
4	Shroud Inner Annulus	21.99	622	24	14932	0.33	383	
5	Fixed Bed – Char	42.41	1446	7	10683	0.45	529	
6	Fixed Bed – Ash	42.41	295	12	3578	0.15	177	
	Total Pyrolizer Jacket	210.13				1.83	2132	40.62
	Shroud Tube:							
2	Dome Region	19.48	1019	22	22418	0.44	509	
3	Inner Annulus	27.72	622	24	14932	0.41	483	
10	Outer Annulus	52.97	280	10	2801	0.15	173	
	Total Shroud Tube	100.17				1.00	1166	22.21
	Vessel Jacket:							
9	Outer Annulus/Freeboard	141.02	317	10	3168	0.45	521	
8	Fixed Bed – Char	58.90	1446	10	15147	0.89	1041	
7	Fixed Bed – Ash	58.90	295	18	5429	0.32	373	
	Total Vessel Jacket	258.83				1.66	1936	36.88
11	Gas Outlet Nozzle	5.59	212	11	2327	0.01	15	
	Total	574.71				4.50	5248	100.00

* = Cooling Media: Water at saturated temperature of 366 °F
** = Refractory Lined

GPIF/ 93856
THAM 08/31/95

SYSTEM PROCESS DESIGN BASIS
PDB No. DBR-1AA-2

System Name: Gasifier Cooling
Flow Sheet No: 16N25706-40-F-1AA-3

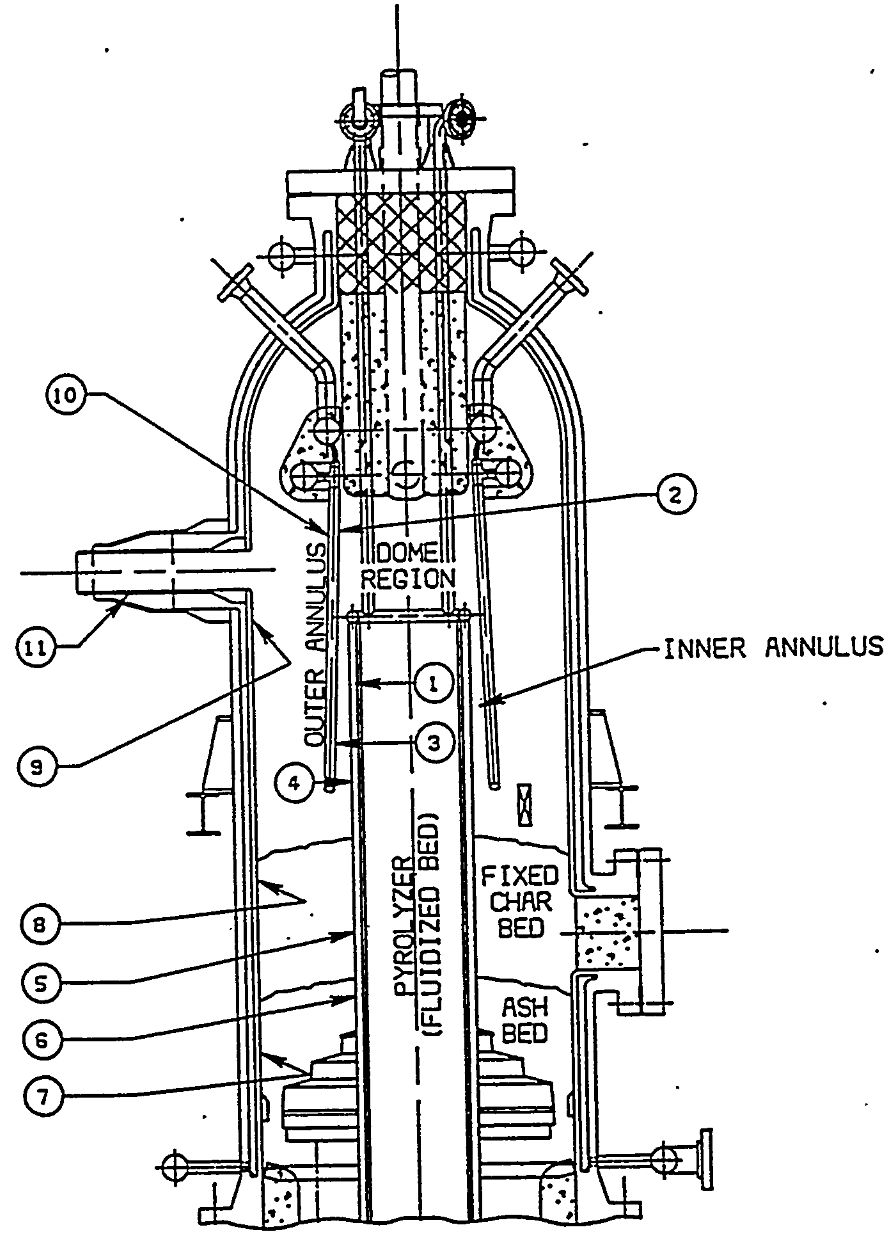

Figure 4. Cooling Section Identification.

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PyGas™ COAL GASIFIER
PDB No. 40-1AA-1

PARAGRAPH

ATTACHMENTS

PyGas™ COAL GASIFIER
PDB No. 40-1AA-1

(325 psi OPERATING PRESSURE & 2300°F PEAK OPERATING TEMPERATURE)

1. GENERAL

1.1 This specification covers the furnishing of one (1) complete natural gas preheated coal gasifier (PyGas™) conforming to United States Patent Numbers 5,133,780, and 5,145,490, complete with all required accessories.

1.2 The PyGas™ gasifier shall be designed to generate low BTU, high pressure, high temperature coal gas produced at the Gasification Product Improvement Facility at Fort Martin Generating Station near Morgantown, West Virginia. Coal gas flow will be controlled by air flow from an air compressor designed to produce 325 psi operating pressure at the pyrolyzer outlet to the PyGas™ gasifier.

1.3 The intended function of this PyGas™ gasifier is to combine a variety of air and steam with coal feed flows to continuously generate low Btu gas (80 Btu/dscf to 180 Btu/ dscf) of suitable heating value and sensible heat to fire either a gas turbine or a boiler downstream.

1.4 The quantity of coal gas to be generated is based on the coal, air, and steam feed flow rates, as well as the efficiency of coal conversion within the PyGas™ coal gasifier. The anticipated coal throughput shall be from 1 ton per hour to 2 tons per hour.

1.5 The PyGas™ coal gasifier shall be shop assembled to the extent shipping limits will permit.

PyGas™ COAL GASIFIER
PDB No. 40-1AA-1

2. ITEMS FURNISHED BY DB-RILEY

2.1 The following is a list of items to be supplied by the Riley. This list is not intended to be all inclusive, it is only a general list. Riley is to include all items required to constitute a complete unit and system. The system shall include the following as a minimum:

2.1.1 High pressure PyGas™ gasifier steam generating vessel cooling walls (5 ft inside diameter) with external steam drum, steam separating drum internals, and (optional cooled) upper shroud and (optional cooled) pyrolyzer tube. The upper shroud shall be designed to minimize fines carryover and system pressure drop to acceptable levels for continuous efficient system operation.

(NOTE: If the cooled option is selected, each cooled section must be integrated into the gasifier gas or steam generation circuit. Since this unit is intended to confirm commercial design-ability, separate cooled circuits shall not be utilized).

2.1.2 Natural gas fueled preheat burner, gasifier system safety vent and rupture disk (set to relieve at 420 psi), field instruments and control devices, trap and vent valves, flame detectors, and a PLC based logic control system. Capacity of pre-heat burner to be sufficient to pre-heat the pyrolyzer tube to 1000°F within three hours. Location of pre-heat burner to insure fluidization during the transition from pre-heat to coal ignition (both to proceed simultaneously until coal ignition is established), all at sub-stoichiometric conditions.

2.1.3 A crushed coal (1/4" x 0") and limestone (50 mesh mean diameter) pressurization lock designed for 325 psi operating pressure, and capable of pneumatically feeding coal and limestone into the PyGas™ gasifier inlet. Jacobs-Sirrine will develop and specify this lock for DB Riley to purchase and furnish.

2.1.4 An ash (up to 5" x 0" lumps) depressurization lock designed for 325 psi operating pressure, and capable of removing hot fused ash as well as ash fines from the PyGas™ gasifier grate dump outlet. Jacobs-Sirrine will develop and specify this lock for DB Riley to purchase and furnish.

2.1.5 A rotating and reversible grate, complete with planetary hydraulic type drive for producing a fixed-gasification bed, crushing ash clinkers, and for removing ash from the fixed-bed. The grate shall be partitioned to admit externally controlled air/steam blast flows via three discrete sealed annuli beneath the grate. Grate speed turndown to be a minimum of ten to one. Grate support bearings to be arranged such that the grate rotates in a continuous centered position (include thrust bearings) to assure a proper seal between the rotating grate and the fixed pyrolyzer outside diameter.

2.1.6 A pyrolyzer tube (water cooled at DB Riley option), to include an externally accessible flanged cone assembly which permits complete removal of pyrolyzer internals. Tube to have an inside diameter at the cone-cylinder interface consistent with a superficial velocity of 3 ft/sec, and a 20% larger inside diameter at the pyrolyzer exit. This pyrolyzer tube shall be cooled (if DB Riley selects a water cooled design) using a shell within shell arrangement. The pyrolyzer exit shall be completely unrestrictive to char overflow. An arrangement using under-grate steam for cooling is preferred.

(NOTE: If the water cooled option is selected, each water cooled section must be integrated into the gasifier steam generation circuit. Since this unit is intended to confirm commercial design-ability, separate water cooled circuits shall not be utilized).

2.1.7 A vertically oriented coal/coke/limestone pneumatic injection nozzle sized for sufficient momentum to produce a 10 foot pyrolyzer jet penetration under specification coal operation.

2. ITEMS FURNISHED BY RILEY - Continued

2.1.8 A pyrolyzer fluidizing air outer annulus around the feed nozzle sized to maintain at least minimum fluidization velocities. This outer annulus shall also be designed for future acceptance of returned hot cyclone solids to the pyrolyzer.

2.1.9 An emergency pyrolyzer solids removal drain pipe located in the fluidizing air outer annulus sized for a minimum of 1 1/2 inch clear space shall be provided.

2.1.10 A top air/steam injection nozzle located at the centerline of the upper vessel dome designed to admit air and steam at up to 0.8 air/coal and 0.4 steam/coal ratios respectively. A flanged connection shall be included at the top dome for removal of this top dome nozzle. Initially, this flange will be blanked-off.

2.1.11 A tempering air feed control system designed to monitor and feed-back a signal to maintain a predetermined set point feed temperature (from 125°F to 150°F) to the PyGas™ coal gasifier inlet. Jacobs-Sirrine will develop and specify this item for DB Riley to purchase and furnish.

2.1.12 Provisions for fifteen pyrolyzer tube temperature control thermocouple locations to be fabricated in the pyrolyzer tube for field-mounting of thermocouples.

2.1.13 Provisions for nine upper shroud PyGas™ gasifier temperature control thermocouple locations to be fabricated in the inner annulus shroud walls for field-mounting of thermocouples.

2.1.14 Provisions for two upper shroud PyGas™ gasifier PSIT furnished GASTEMP™ temperature control monitor locations to be fabricated in the upper dome vessel walls for field-mounting of the GASTEMP™ temperature monitor and feedback control device.

2.1.15 Provisions for one upper shroud PyGas™ gasifier PSIT furnished Alpha-NH3™ ammonia monitor location to be fabricated in the upper dome vessel walls for field-mounting of the Alpha-NH3™ ammonia monitor and feedback control device.

2.1.16 Provisions for twenty PyGas™ gasifier vessel temperature control thermocouple locations to be fabricated in the vessel walls for field-mounting of thermocouples.

2.1.17 A man-way access port through the water-cooled PyGas™ vessel walls for access to the gasifier internals (located above fixed-bed solids operating level).

2.1.18 A lower vessel flange for access to the gasifier grate and under-grate internals.

2.1.19 Steel support legs designed for supporting the PyGas™ gasifier vessel at the grate drive pinion and sprocket elevation to minimize thermal expansion impact on alignment.

2.1.20 Four pyrolyzer cone air sweeping nozzle connections and internal piping for solids flow promotion to be located at the pyrolyzer cone-tube transition connection.

2.1.21 Either a pressurized rotary feeder or a fluidized proportioning vessel for transitioning from batch to continuous feed to the PyGas™ gasifier to be located at the coal/limestone lock outlet. Feeder or proportioner turndown to be a minimum of ten to one. Jacobs-Sirrine will develop design basis and specifications for this item for DB Riley to purchase and furnish.

2. ITEMS FURNISHED BY RILEY - Continued

2.1.22 All pneumatic coal/coke/limestone interconnecting piping between the pressure lock rotary feeder or fluidized proportioner outlet flange and the gasifier. This pipe shall be designed for 373 psi operation, minimization of abrasion and solids saltation, insulated and lagged.

2.1.23 The Pyrolyzer shall be refractory lined in the vicinity of the cone to facilitate pre-heat to 1000°F.

2.1.24 Valved connections for feedwater controls shall be included.

2.1.25 Vent, drain, blowdown, chemical feed, instrument air, and fill piping, to within 12" of PyGas™ gasifier base. The gasifier shall be designed to be completely drainable and nitrogen inerted on both the water cooling and coal gas generation sides between tests.

2.1.26 All integral piping and valves associated with the PyGas™ gasifier unit island. Jacobs-Sirrine will develop design basis and specifications for this item for DB Riley to purchase and furnish.

2.1.27 PyGas™ gasifier insulation, casing, and lagging.

2.1.28 SAMA drawing of recommended control strategy.

2.1.29 Technical supervision of installation and start-up.

2.1.30 Any special tools required for maintenance and operation including tools required for tube preparation.

2.1.31 All labor for unloading and transporting the equipment furnished by DB Riley from point of delivery to site of installation and placing same on foundations.

2.1.32 All labor to completely install the equipment and materials specified, including the field assembly of such boiler appurtenances that could not be included on the shop assembled unit.

2.1.33 Installation of local control panel, tubing, wiring, etc.

2.1.34 Pressure tap provisions shall be designed and fabricated at the pyrolyzer coal/coke/limestone feed nozzle inlet, fluidizing air outer annulus inlet, emergency solids removal pipe inlet, future recycled hot cyclone return inlet to the inner annulus; three located equispaced circumferentially at the top of gasifier at the dome away from top dome air/steam injector influence; three equispaced circumferentially through the pressure vessel at the grate elevation, three equispaced circumferentially at the outer annulus mid-point, one in the hot raw gas exit, one at the top dome air/steam injection nozzle, and one for each of the three undergrate air injection annuli.

2.1.35 Air sampling ports shall be designed and fabricated in the conveying air line, fluidizing air line, top air injection nozzle, and the undergrate air feed streams.

2.1.36 A raw gas sampling port shall be designed and fabricated at the PyGas™ gasifier outlet nozzle.

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2. ITEMS FURNISHED BY RILEY - Continued

2.1.37 An upper gasifier (cooled at DB RILEY option) outer annulus shroud sealed between the gasifier dome and the hot raw gas exit nozzle, and open ended at the bottom to allow products of pyrolysis to continuously evacuate during operation. This shroud shall be tapered to increase its diameter as the products of pyrolysis proceed down-ward and around it at the open bottom end. This shroud shall be cooled (if DB RILEY selects a cooled design) using a tube within tube lances arrangement with welded fins. Fines carryover and pressure drop shall be minimized by design to produce continuous efficient operation. A future internal cyclone design shall be developed in anticipation of the potential need to restrict fines carry-over. A decision whether and when to apply this internal cyclones design will be made at some later date. The upper shroud shall be designed to facilitate the simple addition of the internal cyclone design if needed.

(NOTE: If the cooled option is selected, each cooled section must be integrated into the gasifier gas or steam generation circuit. Since this unit is intended to confirm commercial design-ability, separate cooled circuits shall not be utilized).

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3. ANCILLARY ITEMS SPECIFIED BY JACOBS-SIRRINE

3.1 The following is a list of items to be specified by Jacobs-Sirrine and purchased by DB Riley.

3.1.1 Foundations and anchor bolts.

3.1.2 Air piping to and gasifier flow control valves.

3.1.3 Steam piping to and gasifier flow control valves.

3.1.4 Feedwater piping to gasifier inlet stop-check valve.

3.1.5 Instrument air.

3.1.6 Blowdown piping from specified terminal points, 12" above PyGas™ gasifier base.

3.1.7 Chemical feed and fill piping to specified terminal points 12" above PyGas™ gasifier base.

3.1.8 Drain and rupture disk vent piping from specified terminal points 12" above PyGas™ gasifier..

3.1.9 All steam and feedwater piping insulation external from PyGas™ gasifier casing.

3.1.10 PyGas™ gasifier boilout including required chemicals and disposal thereof.

3.1.11 Coal/coke/limestone feeds to the pressure lock inlet flange.

3.1.12 Electric power to all drives and final elements at required conditions.

3.1.13 Hydrostatic test of DB Riley's steam generation system between control valves and gasifier steam drum outlet non-return valve.

3.1.14 Freeze protection.

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4. CODES AND STANDARDS

4.1 The equipment furnished by DB Riley shall be designed in accordance with the latest edition, latest addenda of the following codes and standards (as applicable).

4.1.1 ASME - American Society of Mechanical Engineers.

4.1.2 ABMA - American Boiler Manufacturers Association.

4.1.3 ASTM - American Society for Testing and Materials.

4.1.4 AISC - American Institute of Steel Construction.

4.1.5 HEI - Heat Exchanger Institute.

4.1.6 OSHA - Occupational Safety and Health Act.

4.1.7 NEC - National Electrical Code.

4.1.8 NEMA - National Electrical Manufacturers Association

4.1.9 TEMA - Tubular Exchanger Manufacturers Association.

4.1.10 CAGI - Compressed Air and Gas Institute.

4.1.11 ISA - Instrument Society of America.

4.1.12 ICEA - Insulated Cable Engineers of America.

4.1.13 IEEE - Institute of Electrical and Electronics Engineers.

4.1.14 AFBMA - American Gear Manufacturer's Association.

4.1.15 AGMA - American Gear Manufacturer's Association.

4.1.16 ANSI - American National Standards Institute.

4.1.17 NFPA - National Fire Protection Association.

4.1.18 All applicable state and local laws, ordinances or regulations.

4.1.19 The steam generating unit shall be inspected and stamped by a National Board of Boiler and Pressure Vessel Inspectors and registered with the National Boards.

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5. TERMINAL POINTS

5.1 The following terminal points shall apply to PURCHASER furnished equipment and systems:

5.1.1 Air/Gas

5.1.1.1 Coal conveying air at rotary feeder or fluidized proportioner inlet flange.

5.1.1.2 Coal/coke/limestone pressure lock air intake flange.

5.1.1.3 Pyrolyzer outer annulus fluidizing air inlet nozzle flange.

5.1.1.4 Top dome inlet air/steam nozzle flange.

5.1.1.5 Undergrate inlet air nozzle inlet flange.

5.1.1.6 PyGas™ gasifier hot raw gas outlet water cooled nozzle outlet flange.

5.1.2 Fuel Piping

5.1.2.1 Coal gas supply to Waste Heat Boiler (WHB)

5.1.2.2 Natural Gas supply.

5.1.2.3 Gasifier system vent flow inlet at gasifier top rupture disk outlet flange.

5.1.3 Steam/Water.

5.1.3.1 Pyrolyzer fluidizing outer annulus line at gasifier nozzle inlet flange.

5.1.3.2 Top dome injection air/steam nozzle inlet flange.

5.1.3.3 Under-grate feed at inlet nozzle flange.

5.1.3.4 Hot raw gas gasifier outlet water spray injection point.

5.1.3.5 Bottom ash depressurization lock vessel inlet flange.

5.1.3.6 Gasifier fire fighting deluge ring.

5.1.3.7 Instrument wiring connections, as required.

5.1.4 Feedwater.

5.1.4.1 Inlet to feed stop and check valves at the PyGas™ gasifier inlet.

5.1.4.2 Inlet to chemical feed stop valves.

5.1.4.3 Outlet of second valve for each gasifier vent and drain.

5. TERMINAL POINTS - Continued

5.1.5 Gasifier Cooling Water.

5.1.5.1 Outlet of second valve for each waterwall drain.

5.1.5.2 Outlet of intermittent blowdown valves.

5.1.5.3 Outlet of second valve on water level instrumentation connections.

5.1.5.4 Outlet of second valve on continuous blowdown connection.

5.1.5.5 Out of drum water gauge drain valves.

5.1.6 Instrument wiring connections, as required.

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6. CONSTRUCTION AND DESIGN REQUIREMENTS

6.1 Casing

6.1.1 The PyGas™ gasifier setting shall be designed and constructed gas tight. Riley shall furnish all insulation of proper material and thickness for insulating the space under the casing, including items necessary to support the insulation. The maximum possible welded wall shell construction shall be used to prevent gas leakage from within the gasifier to the outer casing and into the operating area.

6.1.2 All necessary access doors shall be furnished by the DB Riley.

6.1.3 The gasifier vessel shall be completely water cooled above the grate elevation to the upper flange. The water wall shells shall be designed to withstand the maximum rupture disk relief pressure capability.

6.1.5 The casing shall be constructed of ribbed aluminum for the entire height of the setting. The casing shall be properly reinforced and stiffened with structural members to provide rigidity and prevent buckling.

6.2 Gasifier Drum

6.2.1 The gasifier drum shall be fitted with proper drum internals such that when the gasifier is operating at maximum pounds steam per hour, carryover shall be less than 0.1 micro mho as cation-free conductivity and sodium levels of less than 3 ppm when leaving steam drum if steam must meet Ft Martin quality. If not connected to Ft. Martin, steam quality shall be per ABMA standards for the operating pressure and temperature level specified.

6.3 Nozzles

6.3.1 All nozzles on drums and headers shall be forged steel, weld end type.

6.4 Steam Temperature

6.4.1 Permanent thermocouples shall be provided to monitor steam temperature during start-up and shutdown. The number and location of the thermocouples shall be as recommended by DB Riley for successful start-up and shutdown of the unit.

6.5 Stress Relief

6.5.1 All pyrolyzer and inner annulus shroud elements shall be stress relieved with all welded attachments for supporting, etc., in place at the factory.

6.6 Gasifier Accessories

6.6.1 The following accessories shall be furnished with the gasifier, including all brackets, supports, etc., for attaching accessories to gasifier:

6.6.1.1 One inlet for feeding water to the unit shall be provided. Furnish stop valve and check valve or ASME Code approved combination stop-check valve for the inlet. Valves to be weld end, ANSI 600 pound rating.

6.6.1.2 Drum safety valves - Consolidated, or equal.

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6. CONSTRUCTION AND DESIGN REQUIREMENTS - Continued

6.6.1.3 Steam outlet header safety valves - Consolidated, or equal.

6.6.1.4 One bi-color, multi-port water gauge complete with illuminator, reflector hood, mirror, and floor stand. Gauge shall be as manufactured by Yarway or Diamond and shall be approved by the manufacturer for this service. Provide isolating valves in accordance with ASME Code. Provide one (1) Hydrastep drum level indication system for indication and tripping functions. The hydrastep unit shall be supplied with indication at the feedwater control valve and remote indication in the control room operators panel. Provide one set of double valved connections for the feedwater control level transmitter.

6.6.1.5 Lower drum tandem weld end type blow-off valves - Yarway or Edwards.

6.6.1.6 Provide connection on steam drum with internal collecting pipe for continuous blow-down. Provide two welded bonnet, weld end stop valves - Hancock, Yarway or Edwards.

6.6.1.7 Provide connection on steam drum with Type 304 stainless steel internal distribution pipe for chemical feed. Provide two Type 304 stainless steel welded bonnet, weld end stop valves - Hancock, Yarway or Edwards.

6.6.1.8 Provide steam sample connections in saturated steam header. Each connection to be doubled valved with welded bonnet, weld end stop valves - Hancock, Yarway or Edwards.

6.6.1.9 Provide steam drum vent connection double valved with welded bonnet, weld end stop valves - Hancock, Yarway, or Edwards.

6.6.1.10 Two shut-off valves shall be furnished by Riley for each miscellaneous high pressure connection on the boiler. Each valve shall be weld end, welded bonnet, Hancock, Yarway, or Edwards, and the boiler proposal shall list the number, size, manufacture, figure number and use for each set of valves being furnished.

6.7.3 Couplings

6.7.3.1 DB Riley shall furnish gear type couplings as manufactured by Falk or equal. Coupling halves shall be correctly bored and keyed for the fan and motor shafts. The fan half coupling and motor half coupling shall be mounted. Riley shall also furnish the coupling guard.

6.8 Fuel Burning Equipment

6.8.1 Fuel

6.8.1.1 Natural Gas: Natural gas shall be the primary fuel for pre-heat if available.

6.8.1.2 No. 2 Oil: No. 2 Oil shall be the alternate fuel for pre-heat only if natural gas is not available.

6.8.2 Burners

6.8.2.1 DB Riley shall furnish burner assemblies for the efficient burning of the fuels specified herein.

6.8.2.2 The pre-heater assembly shall include a natural gas burner suitable for the pre-heating function. The pre-heat burner shall be capable of 2 to 1 turndown under modulating control with stable fires and no indication of instability or poor combustion.

6.11.2.3 The pre-heater assembly shall include a Natural Gas electric ignitor and traveling flame front.

6. CONSTRUCTION AND DESIGN REQUIREMENTS - Continued

6.11.2.4 DB Riley shall determine the proper location in the pyrolyzer feed tube annuli to inject air and steam into the pyrolyzer to assure fluidization during start-up.

6.11.2.6 The pre-heater assembly shall include a natural gas and air pre-mixing device designed for automatic or remote manual operation. It shall be designed to be capable of directly pre-heating the pyrolyzer.

6.11.3 Pre-heater piping, valves and in-line instruments shall be by DB Riley. Jacobs-Sirrine will develop design basis and specifications for this item for DB Riley to purchase and furnish.

6.11.4 Flame Failure Safety Controls

6.11.4.1 DB Riley shall furnish a complete Burner Management System for control of the natural gas fired pyrolyzer cone pre-heater, including pre-heat to combustion. The system shall consist of the field instruments and control devices, the safety shutoff and vent valves, and an Allen-Bradley PLC-5 logic control system. All logic design and devices shall be FM approved and in compliance with NFPA.

6.11.4.2 DB Riley supplied logic systems shall interface to a DCS system through an Allen-Bradley Data Highway Plus communications network. The PLC system supplied shall connect through its Data Highway Plus port of this network. The logic shall be programmed such that the operator control, monitoring and alarming will be through this interface. DB Riley shall build a data transfer table within the PLC. The ladders and the DCS shall read and write data in this table for the monitoring, alarm and control functions. Operator initiated actions from the control room will be writes to this data table and shall be used in the ladders to initiate the desired control function. Status and alarm conditions will be read from this table by the DCS. The logic shall be built such that the DCS can read the cause of a trip (first out function). Coordination of the data table will be required during the design stage.

6.11.4.3 DB Riley shall furnish flame detectors for each fuel input point at the pre-heater. Loss of flame shall cause an immediate and safe trip of the pre-heat fuel at any time during the pre-heat cycle.

6.11.4.4 The Burner Management System PLC and electronics shall be supplied in a free standing cabinet with prewired terminal strips for connection of the field wiring. Complete documentation and wiring diagrams shall be supplied. The PLC programming and documentation shall be supplied on Allen-Bradley 6200 software. The cabinet will be installed in the DCS I/O room.

6.11.4.5 DB Riley shall provide a complete description of the Pre-heat Burner Management System hardware and control. Jacobs-Sirrine will develop design basis and specifications for this item for DB Riley to purchase and furnish.

6.11.4.6 DB Riley shall provide a complete description of the top dome air/steam nozzle GASTEMP temperature monitoring and feedback system hardware and control.

6.12 Motors

Grate Drives:
Each grate drive requires a motor driven hydraulic pump. These motors shall be TEFC.
Consult the Jacobs-Sirrine furnished electrical equipment specifications for further details.

Cooling Water Spray:
The coal gas cooling water spray shall include a motor driven pump. This motor shall be TEFC.
Consult the Jacobs-Sirrine furnished electrical equipment specifications for further details.

6.12.1 All motors will be furnished by DB Riley (unless otherwise specified herein).

PyGas™ COAL GASIFIER
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ATTACHMENT A

DESIGN CRITERIA

1.0 COAL GAS CONDITIONS AT GASIFIER OUTLET:

1.1 Maximum Continuous Rating Coal Gas Flow Rate (lbs/hr): 18,900
(5/31/95 Mass Balance - 325 psig)

1.2 Operating Gasifier Outlet Coal Gas Pressure (psig): 325
(Pyrolyzer Inlet Pressure 333 psig, Anticipated Gasifier Delta P=8 psi)

1.3 Phase I Operating Gasifier Outlet Coal Gas Temperature (°F): 1085
(347-Stainless Steel Piping Design Limit Less 15 °F Operating Margin)

Phase II Operating Gasifier Outlet Coal Gas Temperature (°F): N/A
(includes water cooled outlet nozzle, refractory lined cyclone & piping to HGCU flange)

1.4 Design Gasifier Outlet Coal Gas Pressure (psig): By DB Riley

1.5 Design Gasifier Outlet Coal Gas Temperature (°F): By DB Riley

2.0 FEEDWATER CONDITIONS AT GASIFIER INLET:

2.1 Temperature (°F): 170
(per Site Access Agreement)

3.0 MAXIMUM GASIFIER OPERATING TEMPERATURE (°F): 2300
(Peak Anticipated Top dome air/steam injector and Fixed-bed Temperatures)

4.0 FUELS:

4.1 Coal Gas Leaving gasifier (Page 9 Mass Balance 5/3/95 column 12) based on METC specification coal analysis.

4.1.1 Constituent Analysis (Percent by Wt.):

NH_3	0.28
CO	25.40
H_2	1.39
CO_2	10.48
CH_4	0.50
N_2	48.97
H_2S	0.64
H_20	11.23
Ar	1.10
Total	100.00

PyGas™ GASIFIER DESIGN CRITERIA (continued)

4.1.2 Coal Gas Heating Value (Btu/# HHV): 1995
(Mass Balance - 325 psig, Column 12)

4.1.3 Coal Gas Temperature (°F): 1023 F
(Mass Balance - 325 psig, Column 12)

4.1.4 Coal Gas Flow (lb/hr): 18,900
(Mass Balance - 325 psig, Column 12)

4.1.5 Coal Gas Specific Volume: 54 to 86 scf/lb
(Mass Balance - 325 psig, Column 10h)

4.2 Natural Gas

4.2.1 Elemental Analysis: 85% methane (minimum)

4.2.2 Heating Value: 1000 Btu/scf

4.3 Coal & Dolomite/Limestone Throughput

4.3.1 The gasifier coal feed rate shall be controlled to from 1 ton per hour to 2 tons per hour per METC ammended contract specifications.

4.3.2 The gasifier dolomite/limestone feed rate shall vary from zero to 0.6 tons per hour based on coal with a maximum of 4% sulfur content, and a calcium to coal molar ratio of 2.5. Feed shall be from the coke bin, and test durations using dolomite/limestone shall be limited by coke bin capacity.

4.3.3 The anticipated dolomite/limestone feed rate shall be from zero (Mass Balance Specification Coal Case - 325 psig) to 800 pounds per hour based on METC specification coal analysis, 2.8% sulfur coal on an as received basis, and a calcium to coal molar ratio of 2.5.

4.4 Ambient Conditions

4.4.1 Temperature:

4.4.1.1 Minimum Ambient Temperature (°F): -20

4.4.1.2 Maximum Ambient Temperature (°F): 120

4.4.2 Performance Ambient Conditions:

4.4.2.1 Temperature (°F): 80

4.4.2.2 Relative Humidity (%): 60

4.4.3 Elevation (feet above sea level): 820
(from Ft. Martin Certified Topographical Drawings)

PyGas™ GASIFIER DESIGN CRITERIA (continued)

4.4.4	Utilities:	Operating Pressure (psig)	Operating Temperature (°F)	Design Pressure (psig)	Design Temperature (°F)
	Compressed Air	373	400	by DB Riley	by DB Riley
	Cooling Water	375 (at grade)	105	by DB Riley	by DB Riley
	Process Steam to Gasifier	353	530	by DB Riley	by DB Riley

4.4.5	Electricity:	Later HP	Later HP	Controls
	Volts	4160	480	120
	Phase	3	3	1
	Hertz	60	60	60

4.4.6 Gasifier Cooling Criteria (at 50-million Btu/hr Coal Input):

Pyrolyzer Tube:	1.25-million Btu/hr Maximum, 1-million Btu/hr Preferred
Shroud:	2-million Btu/hr Maximum
Water Jacket:	4-million Btu/hr Maximum
Outlet Gas Nozzle:	2-million Btu/hr Maximum; If not water cooled, 0.25-million Btu/hr.

End of Attachment A

PyGas™ COAL GASIFIER
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ATTACHMENT B

ANTICIPATED RANGES OF OPERATION

PyGas™ GASIFIER

		MINIMUM (Appendix (A-9)/2)	MAXIMUM (400 psig)
1.0	COAL GAS CONDITIONS AT GASIFIER :		
1.1	Coal Gas Flow Rate (lbs/hr):	7,000	20,000
1.2	Operating Gasifier Inlet Coal Gas Pressure (psig): (Pyrolyzer Inlet Pressure 325 psig, Anticipated Gasifier Delta P=15 psi)	30	325
1.3	Operating Gasifier Coal Gas Product Temperature (°F): (Mass Balance, Column 10h)	800	1087
1.4	Operating Gasifier Outlet Coal Gas Temperature (°F): (High Alloy Steel Piping Design Limit Less 15°F Operating Margin)	1000	1085
1.5	Operating Gasifier Peak Top & Fixed-bed Temperature (°F): (Minimum Basis from Bill Early, Maximum Basis Riley Morgan Profile)	1800	2300

4.0 FUELS:

4.1 Coal Gas Leaving gasifier (Mass Balance column 12) based on METC specification coal analysis.

4.1.1 Constituent Analysis (Percent by Vol.):	MINIMUM (Apdx A-2&A-8)	MAXIMUM (Apdx A-4&A-8)
CO	17.75	20.06
H2	8.49	10.15
CO2	5.58	4.54
H2O	17.05	16.77
CH4	00.00	01.39
H2S	00.12	00.34
N2	44.82	50.03
Ar	00.66	00.93
NH3	00.27	00.35
TOTAL	Not Additive	Not Additive

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PyGas™ GASIFIER DESIGN CRITERIA (continued)		MINIMUM	MAXIMUM
4.1.2	Coal Gas Heating Value (Btu/# HHV): (Mass Balance - 5/31/95 & 325 psig, Column 12)	1335	2014
4.1.3	Coal Gas Heating Value (Btu/dscf): (Mass Balance - 5/31/95 & 325 psig, Column 10h)	103	146
4.1.4	Future Phase II HGCU Input Coal Gas Temperature (°F): (Mass Balance - 325 psig, Column 12)	1000	1087
4.1.5	Coal Gas Specific Volume (scf/lb): (Mass Balance - 325 psig, Column 12)	54	86
4.2	Coal Throughput		
4.2.1	The Gasifier Coal Feed Rate (short tons per hour) (per METC contract specifications)	1	2
4.3	Dolomite/Limestone Throughput		
4.3.1	The Gasifier Dolomite/Limestone Feed Rate (short tons per hour) (based on coal with a max. of 4% sulfur content, and a calcium to coal molar ratio of 2.5)	0	1
4.4	Pyrolyzer Air Feed		
4.4.1	Pyrolyzer Conveying Air Feed Rate (lb/hr) (per Mass Balance - 325 psig, Appendix A-9 Column 9b/2) (adjustments to these figures are anticipated depending upon each sub-system vendor's requirements)	1,200	4,000
4.4.2	Pyrolyzer Fluidizing Air Feed Rate (lb/hr) (per Mass Balance - 325 psig, Appendix A-9 Column 9c/2)	2,200	3,000
4.4.3	Pyrolyzer Sweeping Air Feed Rate (lb/hr) (per Project Team Agreement)	0	0
4.5	Pyrolyzer Steam Feed		
4.5.1	Pyrolyzer Conveying Air Feed System Steam Rate (lb/hr) (per Mass Balance - 325 psig, Appendix A-9 Column 9b)	0	0
4.5.2	Pyrolyzer Fluidizing Air Feed System Steam Rate (lb/hr) (per Riley Research)	0	750
4.5.3	Pyrolyzer Sweeping Steam Feed Rate (lb/hr) (per Riley Research)	0	250

PyGas™ GASIFIER DESIGN CRITERIA (continued)		MINIMUM	MAXIMUM
4.6	Gasifier Top Dome Air Feed		
4.6.1	Top Dome Air Feed Rate (lb/hr) (per Mass Balance - Appendix A-8&2 Column 9e/2)	0	3,200
4.7	Gasifier Top Dome Steam Feed		
4.7.1	Top Dome Steam Feed Rate (lb/hr) (per Mass Balance - Appendix A-8&9 Column 11a/2 & Jacobs-Sirrine)	0	750
4.8	Gasifier Under-grate Air Feed		
4.8.1	Gasifier Under-grate Air Feed Rate (lb/hr) (per Mass Balance - Appendix A-1&3 Column 9d/2)	750	4,900
4.9	Gasifier Under-grate Steam Feed		
4.9.1	Gasifier Under-grate Steam Feed Rate (lb/hr) (per Mass Balance - Appendix A-3&9 Column 11c/2)	550	2,700

End of Attachment B

PyGas™ COAL GASIFIER
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ATTACHMENT C

TABULATION SHEETS

THIS TABULATION SHEET FORMS A PART OF

PROJECT NO. ____________________

DATED: ____________________

NAME OF VENDOR: ____________________

DATE SUBMITTED: ____________________

NOTES:

(1) If space is insufficient, use Remarks Sheet at end of this specification.
(2) Items not applicable should be marked "NA".

1.0 GASIFIER

1.1 Type: Fluid-bed/Fixed-bed Hybrid

1.2 Number of Drums and Size:

1.2.1 Upper - inch diameter x feet long, number manholes: ____________________

1.2.2 Lower - inch diameter x feet long, number manholes: ____________________

1.3 Design Pressure of Drums: ____________________ psi

1.4 Pyrolyzer Cooling Surface: ____________________ sq.ft.

1.5 Shroud Cooling Surface: ____________________ sq.ft.

1.6 Water Jacket Cooling Surface: ____________________ sq.ft.

1.7 Outlet Nozzle Water Cooling Surface: ____________________ sq.ft.

1.8 Air Heater Heating Surface: ____________________ sq.ft.

1.9 Superheater Heating Surface: ____________________ sq.ft.

1.10 If fins are used, give percent of fin area taken as heating surface: ____________________ percent

1.11 Weight of Water in Gasifier at Normal Operating Level: ____________________ pounds

1.12 Weight of Water in Gasifier at Full Condition for Hydrostatic Test: ____________________ pounds

TABULATION SHEETS (continued)

1.13 Are All Water Jackets, Tubes and Drums Completely Drainable by Gravity? Yes ( ) No (X)

2.0 PYROLYZER

2.1 Cone Height: _____ feet-inch(es)

2.2 Cylinder Diameter: _____ feet-inch(es)

2.3 Cylinder Height: _____ feet-inch(es)

2.4 Pyrolyzer Volume: _____ cubic feet

2.5 Pyrolyzer Effective Project Radiant Surface Based on ABMA Standard: _____ sq.ft. "EPRS"

2.6 Centerline of Lower Drum Above Foundation: _____ feet-inch(es)

2.7 Centerline of Steam Drum Above Foundation: _____ feet-inch(es)

2.8 Overall Height of Gasifier Above Foundation (including safety rupture disk): _____ feet-inch(es)

2.9 Size and Spacing of Vessel Wall Jacket: _____ "/" _____ "/" centers

2.10 Thickness and Type of Outer Vessel Jacket Wall: _____ inch-gauge

2.11 Thickness and Type of Inner Vessel Jacket Wall: _____ inch-gauge

2.12 Insulation Thickness, Type: _____

2.12.1 Top and Sides: _____ inch(es)

2.12.2 Bottom: _____ inch(es)

2.12.3 Circumferential: _____ inch(es)

2.13 Gasifier Casing Material Thickness and Type: _____

2.13.1 Top and Sides: _____ inch(es)

2.13.2 Bottom: _____ inch(es)

2.13.3 Circumferential: _____ inch(es)

2.14 Number Observation Ports, Nitrogen Cooled? Yes ( ) No (X)

TABULATION SHEETS (continued)

3.0 GASIFIER ACCESSORIES

3.1 Feed Stop and Check Valves, Number: ____________

3.1.1 Figure Number: ____________

3.1.2 Make: ____________

3.1.3 Size: ____________

3.2 Safety Rupture Disk, Number: ____________

3.2.1 Figure Number: ____________

3.2.2 Make: ____________

3.2.3 Size: ____________

3.3 Water Column, Number: ____________

3.3.1 Figure Number: ____________

3.3.2 Make: ____________

3.3.3 Size: ____________

3.4 Drum Blow-Off Valves, Number: ____________

3.4.1 Figure Number: ____________

3.4.2 Make: ____________

3.4.3 Size: ____________

3.5 Water Jacket Header Blow-Off Valves, Number: ____________

3.5.1 Figure Number: ____________

3.5.2 Make: ____________

3.5.3 Size: ____________

3.6 Drum Pressure Gauge, Location: ____________

3.6.1 Figure Number: ____________

3.6.2 Make: ____________

TABULATION SHEETS (continued)

3.6.3 Size: ____________________

3.7 Superheater Pressure Gauge, Location: ____________________

3.7.1 Figure Number: ____________________

3.7.2 Make: ____________________

3.7.3 Size: ____________________

3.8 Remote Level Indicator, Location: ____________________

3.8.1 Figure Number: ____________________

3.8.2 Make: ____________________

3.8.3 Size: ____________________

3.8.4 Type: ____________________

3.8.5 Quantity: ____________________

4.0 COAL/LIMESTONE PRESSURE LOCK

4.1 Manufacturer: ____________________

4.2 Type: ____________________

4.3 Number: ____________________

4.4 Length: ____________________

4.5 Diameter: ____________________

4.6 Are Units Completely Installed and Piped When Gasifier is Shipped? Yes ( ) No ( )

4.7 Are controls included Yes (X) No ( )

4.8 Control Manufacturer and Type: ____________________

5.0 GASIFIER BOTTOM ASH PRESSURE LOCK

5.1 Manufacturer: ____________________

5.2 Type: ____________________

5.3 Number: ____________________

TABULATION SHEETS (continued)

5.4 Length: ____

5.5 Diameter: ____

5.6 Are Units Completely Installed and Piped When Gasifier is Shipped? Yes ( ) No ( )

5.7 Are controls included Yes (X) No ( )

5.8 Control Manufacturer and Type: ____

6.0 PIPING

6.1 Thickness of Air Nozzles: ____ inch(es)

6.2 Thickness of Gas Nozzles: ____ inch(es)

6.3 Quantity of Valves: ____

6.4 Location of Valves: ____

6.5 Type of Valves: ____

7.0 TOP DOME AIR/STEAM INJECTOR

7.1 Type: ____

7.2 Size: ____

7.3 Manufacturer: ____

7.4 Injection Nozzle Type and Manufacturer: ____

7.5 Injection Cone Angle : Yes ( ) No ( )

7.6 Injector Swirl Number: ____ CFM, F

7.7 Throughput Capacity at Test Block Conditions: ____ CFM, F

7.8 Static Pressure at Gasifier Continuous Rating: ____ iwg

7.9 Static Pressure at Test Block Conditions: ____ iwg

8.0 ROTATING/REVERSING GRATE

8.1 Type of Grate: ____

8.2 Manufacturer: ____

TABULATION SHEETS (continued)

8.3 Maximum Rotational Speed: ____________ rev/hr

8.4 Minimum Rotational Speed: ____________ rev/hr

8.5 Required Pressure of Air/Steam at Undergrate Header: ____________ psig

8.6 Grate Drive Type: Planetary Hydraulic

8.7 Location to Pressure Vessel: Inboard (X) Outboard ( )

8.8 Thrust Bearing Clearance to Pyrolyzer Seal: ____________ (mm)

9.0 PRE-HEAT BURNER - NATURAL GAS

9.1 Type of Pre-heater Burner: Fluidized-cone direct

9.2 Quantity of Burner Assemblies: one natural gas

9.3 Quantity of Gas Guns in Each Assembly: two, ignitor & direct

9.4 Maximum Fuel Burning Capacity of Each Natural Gas Burner: ____________ cubic feet/hour

9.5 Minimum Fuel Burning Capacity of Each Oil Burner: N/A gallons/hour

9.6 Required Pressure of Gas/Oil at Burner Piping Inlet: ____________ psig

9.7 Required Temperature of Gas/Oil at Burner Piping Inlet: ____________ F

9.8 Required Atomizing Steam or Air Pressure at Burner Piping Inlet: N/A psig

9.9 Atomizing Steam Required in Percent of Steam Generated, by Weight: N/A %

9.10 Quantity of Compressed Air Required at Maximum Fuel Burning Capacity: ____________ scfm

10.0 CONTROLS

10.1 Is the Down Level Monitoring System Supplied? Yes ( ) No ( )

10.2 Manufacturer and Model: ____________

10.3 Flame Sensor Quantity & Type: ____________

TABULATION SHEETS (continued)

10.4 Burner Management System Supplied? Yes ( ) No ( )

10.5 Manufacturer and Series: ____________________

10.6 Is the SAMA drawing included? Yes ( ) No ( )

10.7 Are damper actuators supplied? Yes ( ) No ( )

10.8 Quantity Manufacturer and Type: ____________________

10.9 Natural Gas Oil Control Valve, Number: ____________________

10.9.1 Figure Number: ____________________

10.9.2 Make: ____________________

10.9.3 Size: ____________________

10.10 No. 2 Fuel Oil Control Valve, Number: ____________________

10.10.1 Figure Number: ____________________

10.10.2 Make: ____________________

10.10.3 Size: ____________________

10.11 Is System Schematic Drawing Included? Yes ( ) No ( )

11.0 HEAT TRAP

11.1 Type: ____________________

11.2 Manufacturer: ____________________

11.3 Size: ____________________

11.4 Heating Surface: ____________________ sq.ft.

11.5 Sootblowers Number and Manufacturer: N/A

11.6 Steam Coil Air Heater Included: Yes ( ) No ( )

11.6.1 Tube Material: ____________________

11.6.2 Fin Material and Coating: ____________________

TABULATION SHEETS (continued)

12.0 PERFORMANCE - PREDICTED

12.1 Pounds of Gasifier Steam Produced Per Hour Continuous: ______ psig at FTT

12.2 Pre-heat Pyrolyzer Cone Heat Liberation - Gas: ______ BTU/hr-cu.ft.

12.3 Pre-heat Pyrolyzer Cone Heat Liberation - Oil: ______ BTU/hr-cu.ft.

12.4 Pre-heat Pyrolyzer Cone Net Heat Release - Gas: ______ BTU/hr-sq.ft. "EPRS"

12.5 Pre-heat Pyrolyzer Cone Net Heat Release - Oil: ______ BTU/hr-sq.ft. "EPRS"

12.6 CO_2 in Pre-heat Flue Gas at Gasifier Outlet: ______ percent

12.7 Quantity of Fuel Fired - Natural Gas: ______ cu.ft.

12.8 Quantity of Fuel Fired - No. 2 Oil: ______ gallon/hour

12.9 Gas Pressure Drop Through System to Pyrolyzer Cone: ______ psi

12.10 Temperature Gas Entering Pyrolyzer Cone - Natural Gas: ______ F

12.11 Temperature Gas Entering Pyrolyzer Cone - No. 2 Oil: ______ F

12.12 Temperature Gas Leaving Pyrolyzer Cone - Natural Gas: ______ F

12.13 Temperature Gas Leaving Pyrolyzer Cone - No. 2 Oil: ______ F

12.14 Quantity of Flue Gas Leaving the Pyrolyzer Cone - Natural Gas_ ______ DSCFM
______ AWCFM
______ pounds/hour

12.15 Quantity of Flue Gas Leaving the Pyrolyzer Cone - No. 2 Oil: ______ DSCFM
______ AWCFM
______ pounds/hour

12.16 Quantity of Air Entering Pre-heat Burner - Natural Gas: ______ CFM
______ pounds/hour

12.17 Quantity of Air Entering Pre-heat Burner- No. 2 Oil: ______ CFM
______ pounds/hour

12.18 Temperature of Feedwater to Gasifier: 170° F

12.19 Temperature of Air Entering the Pyrolyzer: 400° F

12.20 Temperature of Air Entering Fixed-bed Vessel: 400° F

TABULATION SHEETS (continued)

12.21 Draft Loss Through Pyrolyzer and Fixed-bed: ____________ psi

12.22 Maximum Steam Generating Capacity at Above Pressure and Temperature - 2-hour Period: ____________ (%/hr)

12.23 Maximum Allowable Gasifier Water Concentration: ____________ ppm

12.24 Solids in Steam Outlet: ____________ ppm

12.25 Maximum Percent Moisture in Steam at Outlet: ____________ percent

12.26 Combined Efficiency of Gasifier Steam Generation and Fuel Burning Equipment: Natural Gas ________ percent

No. 2 oil ________ percent

12.27 Opening Pressure Setting of Top Safety on Gasifier Steam Drum (per Site Access Agreement) : was 950 psig now 374 psig

12.28 Maximum Quantity of Feedwater Required When All Safety Valves are Blowing: ____________ pounds/hour

12.29 Gasifier Feedwater Pressure Required at Pump Side of Feed Stop and Check Valves When All Safety Valves are Blowing: ____________ psig

12.30 Gasifier Feedwater Pressure Required at Pump Side of Feed Stop and Check Valves at Rated Continuous Steam Generation: ____________ psig

12.31 Steam Pressure Drop Across Gasifier System: ____________ psi

13.0 PREDICTED PERFORMANCE OF GASIFIER COOLING STEAM GENERATION SYSTEM

13.1 Fuel: ____________

13.2 Process Steam Flow (Gasifier) with ______F Feedwater: ____________ pounds/hour

13.3 Pressure at Process Steam (Gasifier Cooling) Outlet: ____________ psig

13.4 Combined Efficiency: ____________ percent

13.5 Total Solids Content in Process Steam: ____________ ppm

13.6 Process Steam Outlet Temperature: ____________ °F

End of Attachment C