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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By
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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 :

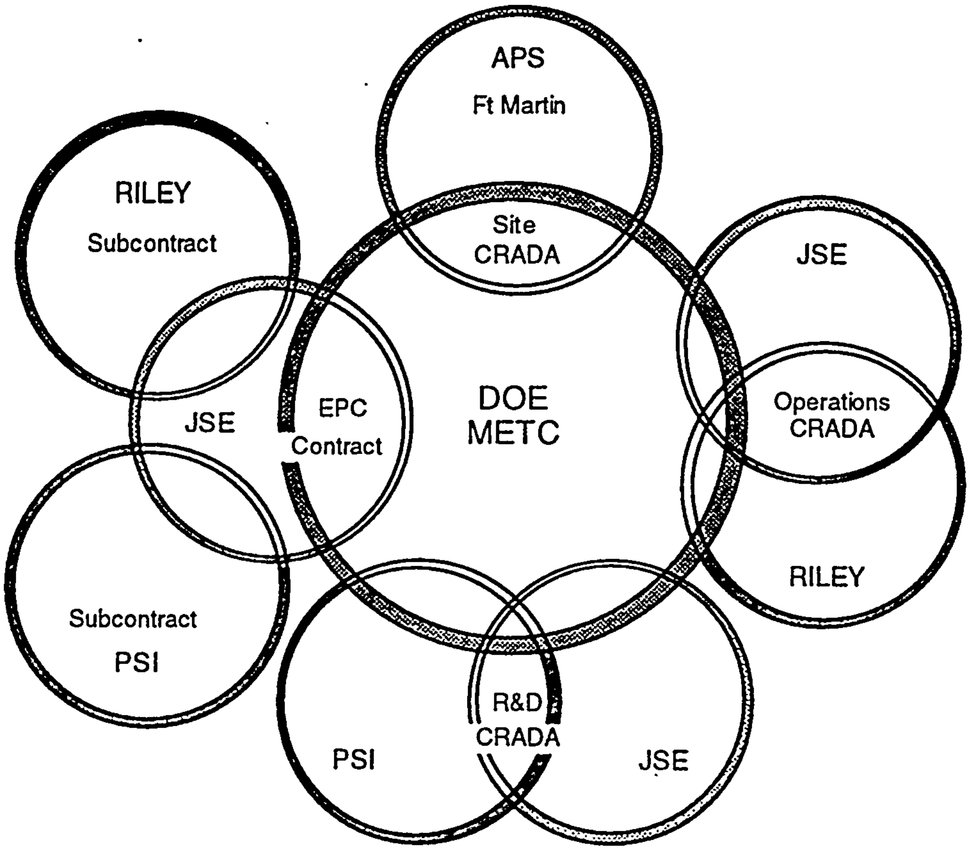


Figure 1 GPIF - A Government, Utility, and Industry Partnership

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 :

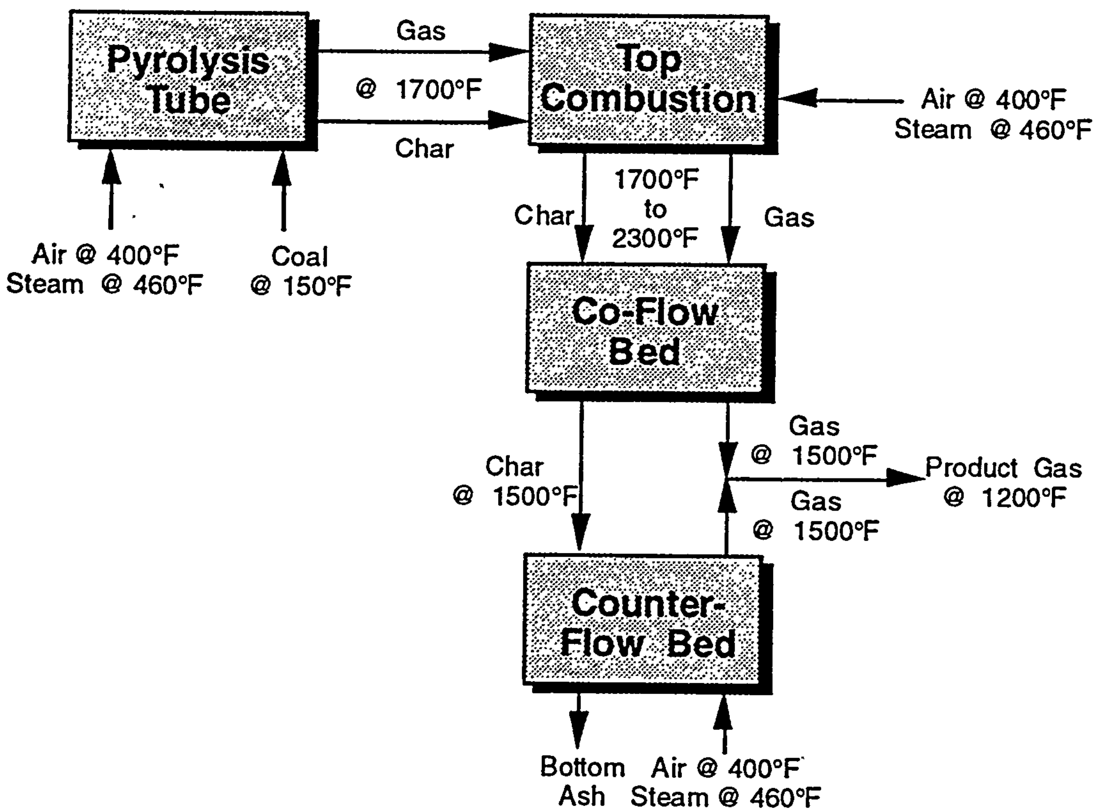


Figure 2 PyGas™ Process Schematic

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.

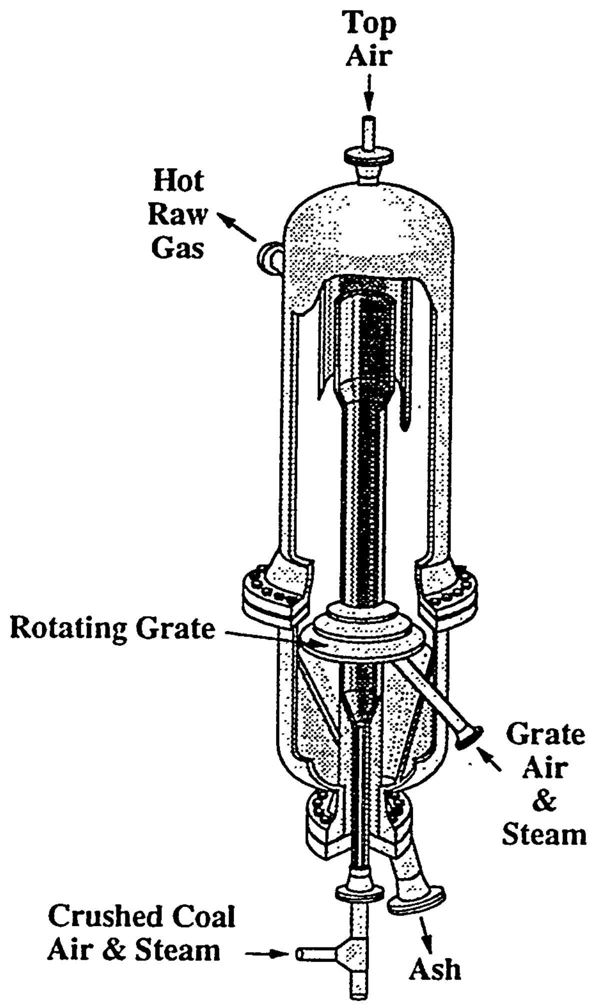


Figure 3 General PyGas™ Gasifier Arrangement

## 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.

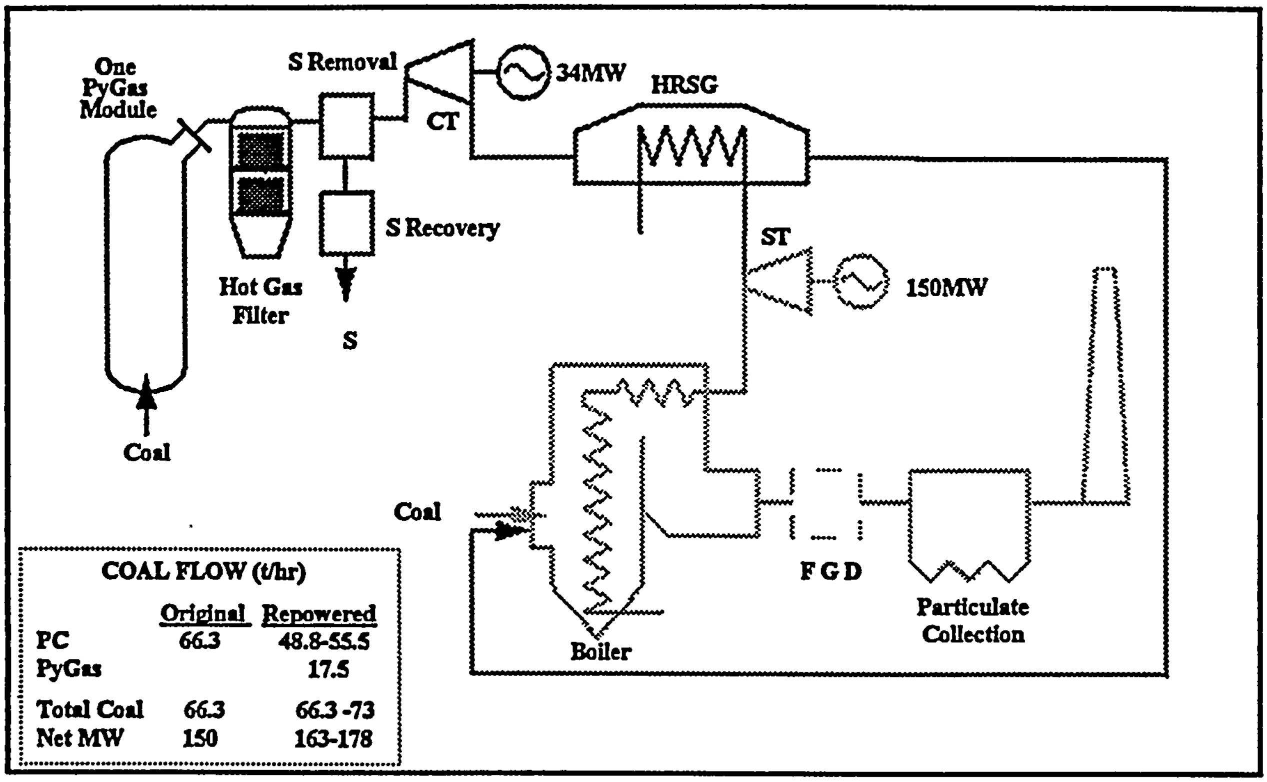


Figure 3 Partial IGCC Repowering With PyGas™

### 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.

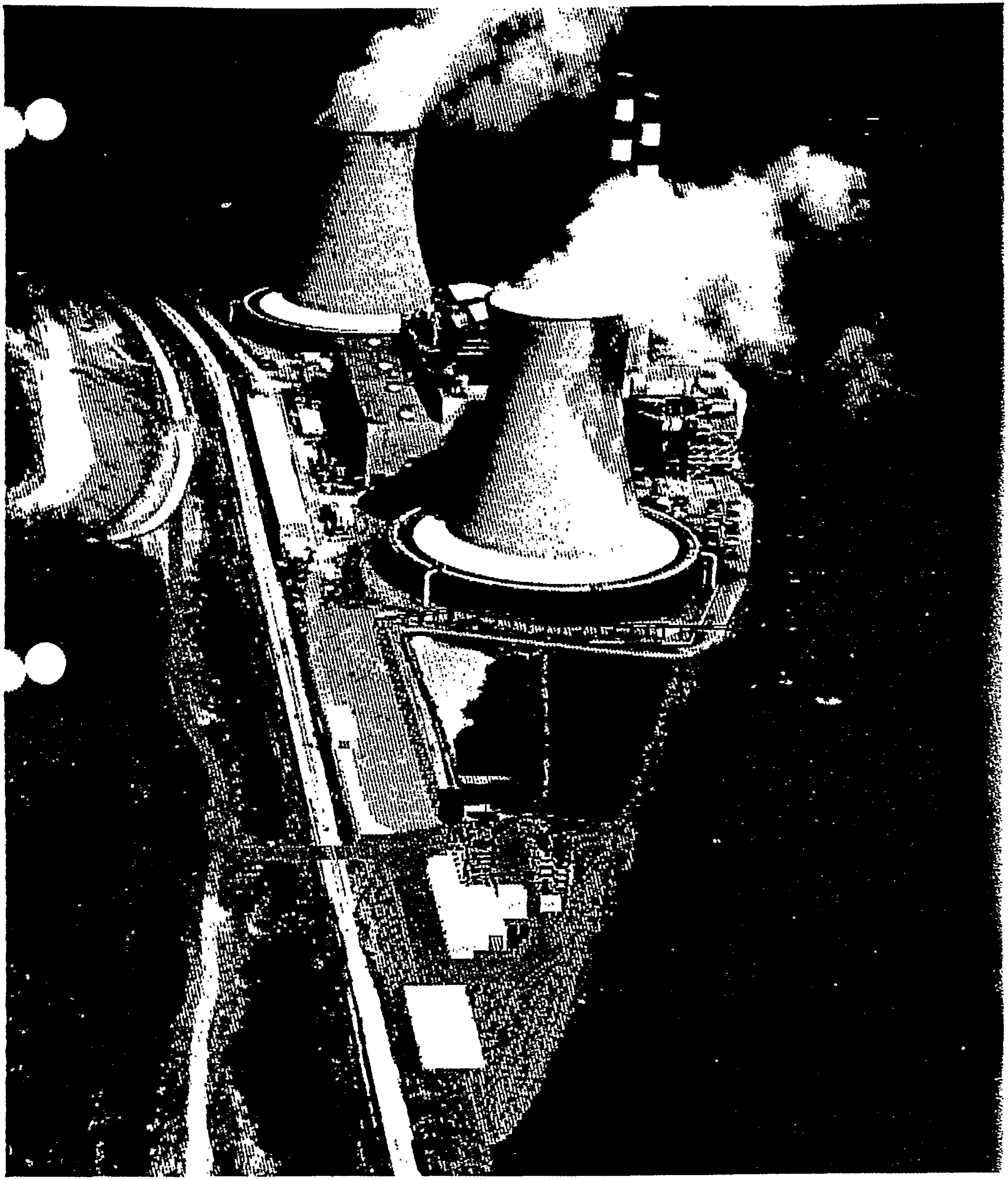

Figure 4 The GPIF Facility as it Would Look at the Fort Martin Generating Station

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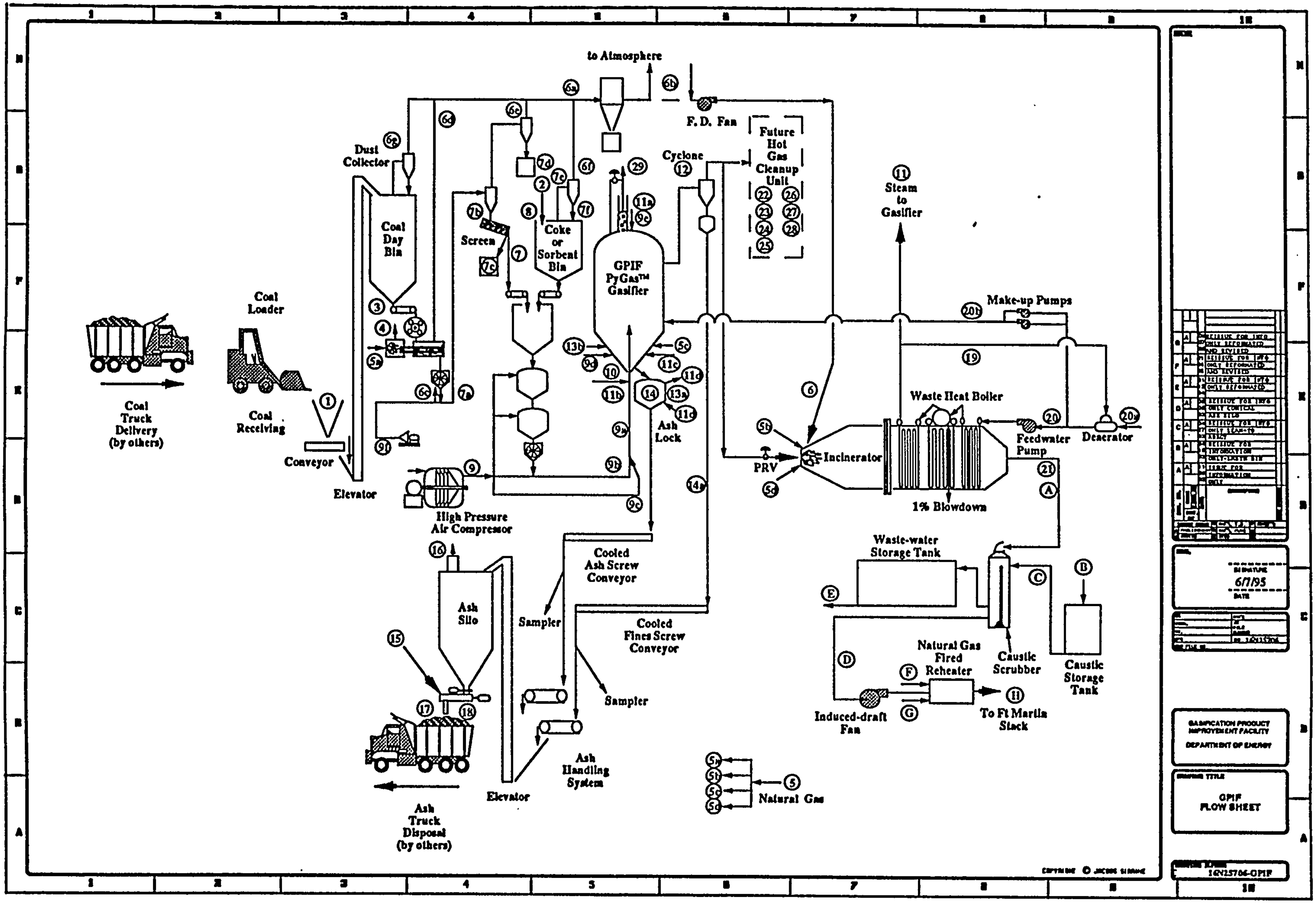
to Atmosphere
F. D. Fan
Future Hot Gas Cleanup Unit
Dust Collector
Cyclone
Coal Day Bin
Screen
Coke or Sorbent Bin
GPIF PyGas™ Gasifier
Steam to Gasifier
Make-up Pumps
Coal Loader
Coal Truck Delivery (by others)
Coal Receiving
Conveyor
Elevator
Ash Lock
Waste Heat Boiler
Incinerator
PRV
Feedwater Pump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

# 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 Balanced Temperature, Carbon Remaining & Mass | | |
|---|---|---|---|---|---|
| *AIR/COAL | 1.720 | 4.54fps @ 1773°F | | | |
| *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% | | | | |

$CO + H_2O \rightleftharpoons CO_2 + H_2$

| 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 | | |

| Inlet | | Outlet | |
|---|---|---|---|
| 19.86% CO | Start With | 19.24% | CO |
| 19.87% H2 | 0.031 | 20.49% | H2 |
| 6.09% CO2 | Conversion = | 6.71% | CO2 |
| 8.87% H20 | 0.031 | 8.24% | H20 |
| 1.37% CH4 | of CO | 1.37% | CH4 |
| 0.42% H2S | | 0.42% | H2S |
| 43.53% N2 | | 43.53% | N2 |

7.96

CP(AVE)= 7.19
T = 1657

*Iterative Formula

T (Ht. Bal) = 1585.46 CP (AVE) = 7.96
T (Equil.) = 1585.51 CP(EST)= 7.96
1585.51

| # | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | DOE - GPIF - PyGas™ (Base Case 2 TPH) | | | | | 325 psi Operation - Specified Design | | | Reference Coal - RFP Specification - MGAS Kinetics | | | | | | 10/19/95 14:40 |
| 3 | Design Support Document, Mass Balance | | | *Using Thermomodel (Assume 50% Devolatilization) | | | Page 1 | | 5 ft Dia Test Size | | | JBE Predicted Output (58% Bed Voidage) | | | |
| 4 | | | | | | | | | | | | | | | |
| 5 | Stream No. | | 1 | | Sorb/Coal | 2 | 3 | 4 | 4a | 5a | 5b | 5c | 5d | | 5 |
| 6 | Identification | | Raw Coal | | 8.000 | Limestone | Coal | Coal Dryer Combustion Air | Coal Dryer Combustion Gas | Natural Gas | Natural Gas | Natural Gas | Natural Gas | | Natural Gas |
| 7 | From | | Ft. Martin Pile | | | Sorbent Pile | Storage Bin | Ambient | Coal Dryer | Pipeline | Pipeline | Pipeline | Pipeline | | Pipeline |
| 8 | To | | GPIF Receiving Hopper | wt % | | Limestone/Coke Bin | Crusher/Dryer | Coal Dryer | Vent System | Coal Dryer | Burner Support | PyGas™ Preheat | Start-up HRSG | | Total Usage @Start |
| 9 | Gas | Mol Wt | | | | 8.00 *Ca/S Mole Ratio | | lb/hr | | lb/hr | lb/hr | lb/hr | lb/hr | | lb/hr |
| 10 | | | | | | | | | | | | | | | |
| 11 | CO | 28.010 | | | | | | | | | | | | | |
| 12 | H2 | 2.016 | | | | | | | | 30 | 75 | 10 | 47 | | 162 |
| 13 | CO2 | 44.010 | | | | | | 1 | 332 | | | | | | |
| 14 | H2O | 18.015 | | | | | | 17 | 282 | | | | | | |
| 15 | CH4 | 16.042 | | | | | | | | 91 | 230 | 31 | 142 | | 494 |
| 16 | C2H6 | 30.068 | Proximate Analysis | | | | | | | | | | | | |
| 17 | H2S | 34.076 | | | | | | | | | | | | | |
| 18 | COS | 60.070 | Vol Matter | 30.00% | | | | | | | | | | | |
| 19 | N2 | 28.013 | Fixed Carbon | 52.00% | | | | 1963 | 1959 | 11 | 27 | 4 | 17 | | 58 |
| 20 | Ar | 39.948 | Moisture | 3.00% | | | | 52 | 52 | | | | | | |
| 21 | HCl | 36.461 | Ash | 15.00% | | | | | | | | | | | |
| 22 | HCN | 27.026 | | | | | | | | | | | | | |
| 23 | NH3 | 17.030 | | | | | | | | | | | | | |
| 24 | CS2 | 76.131 | | | | | | | | | | | | | |
| 25 | SO2 | 64.059 | | | | | | | | | | | | | |
| 26 | NO | 30.006 | | | | | | | | | | | | | |
| 27 | O2 | 31.999 | | | | | | 675 | 124 | | | | | | |
| 28 | NaCl | 58.497 | | | | | | | | | | | | | |
| 29 | KCl | 74.596 | | | | | | | | | | | | | |
| 30 | CaSO4 | 136.142 | | | | | | | | | | | | | |
| 31 | Ca(OH)2 | 74.095 | | | | | | | | | | | | | |
| 32 | Cl2 | 35.500 | | | | | | | | | | | | | |
| 33 | Total Gas (lb/hr) | | | | | | | 2618 | 2749 | 131 | 332 | 45 | 206 | | 714 |
| 34 | | | | | | | | | | | | | | | |
| 35 | Volumetric Flow Rates (STP 14.7 psia, 59F) | | | | | | | | | | | | | | |
| 36 | (acfm) | | | | | | | | | | | | | | |
| 37 | (scfm) | | | | | | | | | 50 | 126 | 17 | 78 | | 270 |
| 38 | | | | | | | | | | | | | | | |
| 39 | Heat (BTU/lb) | | | | | | | | | 22,711 | 22,711 | 22,711 | 22,711 | | 22,711 |
| 40 | Cp (BTU/lb F) | | | | | | | | | | | | | | |
| 41 | HHV (BTU/lb) | | | 12500 | | 1523 | 12500 | | | 22,711 | | | | | |
| 42 | LHV (BTU/lb) | | | 12036 | | 1429 | 12036 | | | 20,566 | | | | | |
| 43 | Sensible Heat above | | | | | | | | | | | | | | |
| 44 | 59 F Btu/lb steam | | | 21 | | #DIV/0! | 21 | | | | | | | | |
| 45 | Latent Heat of | | | | | | | | | | | | | | |
| 46 | Water Btu/lb steam | | | 482 | | #DIV/0! | 482 | | | | | | | | |
| 47 | | | | | | | | | | | | | | | |
| 48 | Chemical Heat | | | 60.60 | | 0.00 | 60.44 | | | | | | | | |
| 49 | (LHV) MBtu/hr | | | | | | | | | | | | | | |
| 50 | Sensible Heat | | | 0.11 | | 0.00 | 0.11 | | | | | | | | |
| 51 | above 59 F MBtu/hr | | | | | | | | | | | | | | |
| 52 | Latent Heat | | | 2.32 | | 0.00 | 2.32 | | | | | | | | |
| 53 | of Water MBtu/hr | | | | | | | | | | | | | | |
| 54 | Total Heat(MBtu/hr) | | | 63.03 | | 0.00 | 62.87 | | | 3.0 | 7.5 | 1.0 | 4.7 | | 16.2 |
| 55 | | | | | | | | | | | | | | | |
| 56 | | | Ultimate Analysis | | | | | | | | | | | | |
| 57 | C | 12.011 | 68.60% | 3453 | 9% | 0 | 3444 | | | 91 | 230 | 31 | 142 | 69.26% | 494 |
| 58 | H | 1.008 | 4.60% | 232 | Purity | | 231 | | | 30 | 75 | 10 | 47 | 22.68% | 162 |
| 59 | O | 16.000 | 4.70% | 237 | | 0 | 236 | | | | | | | | |
| 60 | N | 14.007 | 1.20% | 60 | | | 60 | | | 11 | 27 | 4 | 17 | 8.06% | 58 |
| 61 | S | 32.060 | 2.80% | 141 | | | 141 | | | 0 | 0 | 0 | 0 | 0.00% | 0 |
| 62 | CaO | 56.079 | 0.10% | 5 | | | 5 | | | | | | | | |
| 63 | H2O | 18.016 | 3.00% | 151 | 9% | 0 | 151 | | | | | | | | |
| 64 | NaCl | 58.497 | | | Moisture | | | | | | | | | | |
| 65 | KCl | 74.596 | | | | | | | | | | | | | |
| 66 | CaSO4 | 136.142 | | | | | | | | | | | | | |
| 67 | Ca | 40.080 | | | | 0 | | | | | | | | | |
| 68 | CaS | 72.140 | | | | | | | | | | | | | |
| 69 | ASH, Inerts (pph) | | 15.00% | 755 | | 0 | 753 | | | | | | | | |
| 70 | Total Solids (pph) | | | 5034 | | 0 | 5021 | | | | | | | | |
| 71 | Total Flow (pph) | | | 5034 | | 0 | 5021 | 2618 | 2749 | 131 | 332 | 45 | 206 | 100.0% | 714 |
| 72 | | | | | | | | | | | | | | | |
| 73 | Total Flow (pps) | | | 1.40 | | 0.00 | 1.40 | 0.73 | 0.76 | 0.04 | 0.09 | 0.01 | 0.06 | | 0.20 |
| 74 | Pressure (psig) | | | 0.0 | | 0.0 | 0.0 | 1 | 0 | 20 | 20 | 20 | 20 | | 20 |
| 75 | Temperature (F) | | | 80 | | 80 | 80 | 80 | 450 | 80 | 80 | 80 | 80 | | 80 |
| 76 | 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 9d to less than 1%. | | | | | | | | | | | | |

The Information on This Page is Confidential and Proprietary.

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 58% 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 | 8 Combustion Air Total Incinerator Burner lb/hr | 8a Total Exhausts Baghouse Vents Airs or Incinerator Comb. | 8b Combustion Air Balance Less Baghouse Vents Incin. (If Vents Used) | 8c Rotary Valve Leakage Convey Blower Coal Dryer @ 1.25 lb/lb Coal | 8d Coal Dryer Air Coal Dryer Vent System | 8e Coal Prep Exhaust Coal Prep System Incinerator | Removed Limestone System | 8f (was 8g) 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) | | | | | | | 12036 | 12036 | 12036 |
| 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. / Identification / From / To / Gas | 7 Coal Sizing Screens Coal Surge Bin | 7a Crushed Coal Crusher Rolls Cyclone Separator | 7b Coal Cyclone Separator Screens | 7c Coal Rejects Tote Bin Ft. Martin Coal Pile @ 18.00% | 7d Coal Crusher Dust Classifier Dust Collector Tote Bin @ .01 lb/Mbtu | 7e Deleted | 7f Deleted | 7g Coal Feed Weigh Feeder Coal/Lm'stne Pressure Locks lb/hr | 7h Limestone/Coke Feed Weigh Feeder 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, 59F) | | | | | | | | | |
| (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) | 12036 | 12036 | 12036 | 12036 | 11944 | 11944 | 11944 | 12036 | 0 |
| Sensible Heat above | | | | | | | | | |
| 59 F Btu/lb steam | 50 | 50 | 59 | 50 | 50 | 50 | 50 | 50 | |
| Latent Heat of | | | | | | | | | |
| Water Btu/lb steam | 482 | 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 59 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 | | | 2805 | 0 |
| H | 188 | 231 | 225 | 42 | 6.0 | | | 188 | |
| O | 192 | 236 | 230 | 42 | 6.1 | | | 192 | 0 |
| N | 40 | 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 |
| | | | | | | | | 800 lb/hr Min | 200 lb/hr min |

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| 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. | | 8 | 9 | 9a | | | % Theo. Air | 9b | 9c |
| Identification | | Limestone/Delayed Coke | Compressed Air | Total Flow | 1.72 A/C | | 18.62% | Coke/Coal/Lm'stn Convey Air | Compressed Air |
| From | | Coal Feed System or Separate Bin | High Pressure Compressor | Air,Coal,Sorbent | | | | High Pressure Compressor | High Pressure Compressor |
| To | | Surge Bin | Total to Process | Pyrolyzer | | | | Pyrolyzer | Pyrolyzer |
| Gas | Mol Wt | lb/hr | lb/hr | lb/hr | mol wgt | wt % | mol% | lb/hr | |
| 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, 59F) | | | (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 | 11844 | | | | 11844 | 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 | | 5.60 | 0.00 | 47.77 | | | | 47.77 | |
| (LHV) MBtu/hr | | | | | | | | | |
| Sensible Heat | | 0.02 | 1.02 | 0.14 | | | | 0.06 | |
| above 50 F MBtu/hr | | | | | | | | | |
| Latent Heat | | 0.00 | 0.00 | 0.04 | | | | 0.02 | |
| of Water MBtu/hr | | | | | | | | | |
| Total Heat(MBtu/hr) | | 5.62 | 1.10 | 47.95 | | | | 47.85 | |
| C | 12.011 | 305 | | 2605 | | | | 2605 | |
| 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 | Normally During Start-up Only | | 0 | | | | 0 | |
| CaO | 56.079 | Not Added in this Mass Balance | | | | | | | |
| ASH, Inerts (pph) | | | | 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 |

DOE - GPIF - PyGas™ (Base Case 2 TPH) — 325 psi Operation - Specified Design — Page 5 — 10/19/95 14:40

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

9d: GrateAir/TotCoal 1.42; GrateSteam/TotAir 0.400; Air/Grate Carbon 4.27; Steam/Grate Carbon 1.71

9e: 0.00 A/C

| | Stream No. / Identification / From / To / Gas | 9d Compressed Air@ High Pressure Compressor Under Gasifier Grate lb/hr | 9d lb-mol/hr | 9d wt % | 9d mol% | 9e Compressed Air@ High Pressure Compressor At Gasifier Top lb/hr | 9e lb-mol/hr | 9e wt % | 9e mol% | 9f Coal Prep Delivery Air / Coal Prep Air Blower / Coal Preparation Conveying lb/hr |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 35 | Volumetric Flow Rates (STP 14.7 psia, 59F) | | | | | | | | | |
| 36 | (scfm) | 90 | | | | 0 | | | | 221.39 |
| 37 | (acfm) | 1262 | | | | 0 | | | | 2954 |
| 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 | 59 F Btu/lb steam | 84 | | | | 84 | | | | 84 |
| 45 | Latent Heat of | | | | | | | | | |
| 46 | Water Btu/lb steam | 6 | | | | 6 | | | | 6 |
| 48 | Chemical Heat | 0.00 | | | | 0.00 | | | | 0.00 |
| 49 | (LHV) MBtu/hr | | | | | | | | | |
| 50 | Sensible Heat | 0.48 | | | | 0.00 | | | | 1.13 |
| 51 | above 59 F MBtu/hr | | | | | | | | | |
| 52 | Latent Heat | 0.04 | | | | 0.00 | | | | 0.00 |
| 53 | of Water MBtu/hr | | | | | | | | | |
| 54 | Total Heat(MBtu/hr) | 0.51 | | | | 0.00 | | | | 1.22 |
| 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 |
| 73 | Total Flow (pps) | 1.58 | | | | 0.00 | | | | 3.75 |
| 74 | Pressure (psig) | 338 | | | | 338 | | | | 325 |
| 75 | Temperature (F) | 400 | | | | 400 | | | | 400 |

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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. / Identification / From / To / Gas | | 10 Feed to Pyrolyzer Coal, Sorb, Air, Steam Pyrolyzer Inlet lb/hr | 10a Products of Pyrolysis - Gases Pyrolyzer Section Upper Area of Gasifier lb/hr | lb-mol/hr | Assumed N in Coal to NH3 in Gas 90.00% Conversion wt % | mol% | 10b Pyrolysis - Solids Pyrolyzer Product Upper Area of Gasifier lb/hr | Assumed Pyritic Sulfur Capture 0% wt % | 10c Gases - Upper Portion of Gasifier Pyrolyzer Section Fixed Bed lb/hr | lb-mol/hr | wt % | mol% | 10d Solids - Upper portion of Gasifier Pyrolyzer Section Fixed Bed lb/hr | Bed Voidage 38.00% 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, 56F) | | | | | | | | | | | | | | |
| (acfm) | | 85 | 489 | | Exit Velocity (ft/sec)= 2.60 | | | | 489 | | Actual Density | | | |
| (scfm) (Gas Constant Used=1545) | | 1704 | 2748 | | | | | | 2748 | | 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 | 2460 | | | | 9751 | | 2459 | | | | 9750 | |
| LHV (BTU/lb) | | 11944 | 2253 | | | | 9751 | | 2279 | | | | 9750 | |
| Sensible Heat above | | | | | | | | | | | | | | |
| 56 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 | | 5.16 | | | | 1.08 | |
| above 56 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 | 1565 | | | | 1565 | | 1565 | | | | 1565 | |

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| 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 | | | | 10f | | 10g | Grate S/A 0.48 | |
| 6 Identification | | | Gases Evolved through Gasification | | | Ash & Carbon | Uncomb % 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 % |
| 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 | | | 9286 | 390.07 | 100.00 | 100.00 |
| 35 Volumetric Flow Rates (STP 14.7 psia, 59F) | | | | | | | | | | | |
| 36 (acfm) | | 489 | | | | | | 419 | 0.25 fps top of fixed bed | | |
| 37 (scfm) | | 2746 | | | | | | 2463 | | | |
| 39 Heat (BTU/lb) | | | | | | | | | | | |
| 40 Cp (BTU/lb F) | | 0.341 | | | | 0.341 | | 0.332 | | | |
| 41 HHV (BTU/lb) | | 2458 | | | | 9006 | | 1918.4 | | | |
| 42 LHV (BTU/lb) | | 2279 | | | | 9006 | | 1650.2 | | | |
| 43 Sensible Heat above | | | | | | | | | | | |
| 44 59 F Btu/lb steam | | 515 | | | | 520 | | 475 | | | |
| 45 Latent Heat of | | | | | | | | | | | |
| 46 Water Btu/lb steam | | 78 | | | | 0 | | 136 | | | |
| 48 Chemical Heat | | 22.73 | Low Btu Gas HHV | | | 18.14 | | 15.41 | Low-Btu Gas HHV | | |
| 49 (LHV) MBtu/hr | | | | 158 Btu/dscf | | | | | | 135 Btu/dscf | |
| 50 Sensible Heat | | 5.16 | | 142 Btu/wscf | | 1.03 | | 4.41 | | 108 Btu/wscf | |
| 51 above 59 F MBtu/hr | | | | | | | | | | | |
| 52 Latent Heat | | 0.77 | | | | 0.00 | | 1.26 | | | |
| 53 of Water MBtu/hr | | | | | | | | | | | |
| 54 TotalHeat(MBtu/hr) | | 28.65 | | | | 20.17 | | 21.08 | | | |
| 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 | | 9286 | | | |
| 73 Total Flow (pps) | | 2.78 | | | | 0.55 | | 2.58 | | | |
| 74 Pressure (psig) | | 325 | | | | 325 | | 325 | | | |
| 75 Temperature (F) | | 1565 | | | | 1565 | | 1491 | | | |

| DOE - GPIF - PyGas™ (Base Case 2 TPH) | | | | | | 325 psi Operation - Specified Design Page 8 | | | | | | 10/19/95 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Support Document, Mass Balance | | *Using Thermomodel (Assume 50% Devolatilization) | | | | | | | | | | | |
| Stream No. | | 18h | | | | 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 | GPIF |
| 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 | 2.016 | 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, 50F) | | | | | | | | | | | | | |
| (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 | | 0.00 | | | | | | | | | | | |
| 50 F Btu/lb steam | | | | | | 532 | | 531.8 | | 532 | | 532 | 532 |
| Latent Heat of | | | | | | | | | | | | | |
| Water Btu/lb steam | | 0.00 | | | | 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 | | | | 146 Btu/dscf | | | | | | | | | |
| Sensible Heat | | 6.08 | | 126 Btu/wscf | | 0.00 | | 0.35 | | 1.21 | | 0.03 | 1.59 |
| above 50 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** — 325 psi Operation - Specified Design — Page 9 — 10/19/95 14:40

Mass & Energy Balance

*Using Thermonedit (Assume 30% Devolatilization)

| Stream No. / Identification / From / To / Gas | Mol Wt | 13a Water Spray Cyclone Inlet Pipe Combustor/HGCU lb/hr | 13a wt % | 13b Steam Injection Cyclone Inlet Pipe Combustor/HGCU lb/hr | 13b wt % | 12 Raw Gas Outlet Hot Cyclone Outlet Pipe Incinerator Combustor lb/hr | 12 lb-mol/hr | 12 wt % | 12 mol% | 13 = 13a & 13b Nitrogen Inerting Nitrogen Tanks PyGas™ Gasifier & Locks lb/hr | 14 Ash & Carbon Gasifier Ash System lb/hr | Uncomb % of C 8.31% wt % | 14a Fines Hot Cyclone Fines Collection Cooler 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, 50F) | | | | | | | | | | | | | |
| (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 | | | | | | | | | | | | | |
| 50 F Btu/lb steam | | | | 524 | | | | | | | 160 | | |
| Latent Heat of | | | | | | | | | | | | | |
| Water Btu/lb steam | | | | 800 | | | | | | | 0 | | |
| Chemical Heat | | | | | | 34.11 | Low-Btu Gas HHV | | | | 0.13 | | |
| (LHV) MBtu/hr | | | | | | | | 148 Btu/dscf | | | | | |
| Sensible Heat | | | | | | 6.06 | | 128 Btu/wscf | | | 0.10 | | |
| above 50 F MBtu/hr | | | | | | | | | | | | | |
| Latent Heat | | | | | | 2.05 | | | | | 0.00 | | |
| of Water MBtu/hr | | | | | | | | | | | | | |
| Total Heat (MBtu/hr) | | 0.00 | | 0.00 | | 46.23 | | | | | 0.22 | | |
| C | 12.011 | | | | | 4.9 | | | | | 0 | | 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 | | 82 |
| Total Flow (pph) | | 0 | | 0 | | 19301 | | | | | 601 | | 82 |
| 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 Thermamodel (Assume 58% Devolatilization)

325 psi Operation - Specified Design
Page 10

10/19/95 14:40

| Stream No. | | 15 | 15a | 15b | 15c | 15d | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|
| Identification | | Make-up Water | | | Vent | | Vent | Dust Control Spray | Ash |
| From | | Service Water | | | Ash Removal Screw | | Ash Site | Service Water | Ash Site Conditioner |
| To | | Ash Conditioning | | | Incinerator Burner | | Atmosphere | Ash Site Conditioner | Ft Martin Land Fill |
| Gas | Mol Wt | lb/hr | lb/hr | lb/hr | lb/hr (Later) | lb/hr | lb/hr | lb/hr (Later) | 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, 59F) | | | | | | | | | |
| (scfm) | | | | | 0 | | 0 | 0 | |
| (acfm) | | | | | 0 | | 0 | 0 | |
| Heat (BTU/hr) | | | | | | | | | |
| Cp (BTU/lb F) | | | | | | | | | |
| HHV (BTU/lb) | | | | | | | | | |
| LHV (BTU/lb) | | | | | | | | | |
| Sensible Heat above | | | | | | | | | |
| 59 F Btu/lb steam | | | | | | | | | |
| Latent Heat of | | | | | | | | | |
| Water Btu/lb steam | | | | | | | | | |
| Chemical Heat | | | | | | | | | |
| (LHV) MBtu/hr | | | | | | | | | |
| Sensible Heat | | | | | | | | | |
| above 59 F MBtu/hr | | | Circulation Ratio | | | | Air Flow Multiplier | | Excess Water From Filtration |
| Latent Heat | | | 0 | | | | 0.00 | | 0% |
| of Water MBtu/hr | | | ############### | | | | | | |
| 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 Thermomodel (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 | 20 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, 59F) | | 0.31 | | | | | | | | | |
| (acfm) | | | 77 | | | | 73118 | | | | 676 |
| (scfm) | | | 1121 | | | | 17117 | | | | 5209 |
| Heat (BTU/lb) | | 1278 | 1062 | 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 | | | | 3036 |
| Sensible Heat above 59 F Btu/lb steam | | | | | | | 41.50 | | | | 0.0 |
| Latent Heat of Water Btu/lb steam | | | | | | | 41.50 | | | | 0.00 |
| Chemical Heat (LHV) MBtu/hr | | | | | | | 0.03 | | | | 38 |
| Sensible Heat above 59 F MBtu/hr | | 2 | 5 | 1 | 1 | 0.4 | 41.50 | | | | 6 |
| Latent Heat of Water MBtu/hr | | | | | | | 0.02 | | | | 2 |
| Total Heat(MBtu/hr) | | 2<br>Total Heat In Steam | 5<br>Heat Added to FW | 1 | 1 | 0.4 | 50.64 | | | | 46 |
| 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 | 24,840 | -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 — Page 12

| 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 | 0.0067 | 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 | 3.3518 | 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 | 4.68 | -1.088 | -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 |

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

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 | 0.0067 | 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 | 1.3620 | 0.0064 | 0.0090 | 0.000004 | 1.34906 | 0.00631 | -0.88 | -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 | 0.28800 | 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 | 1.39 | -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 | 331.79 | -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)



| Stream No. / Identification / From / To / Gas | | 22 Hot Raw Coal Gas / Hot Cyclone / HGCU Absorber / lb/hr | Hot Raw Coal Gas / Hot Cyclone / spec vol / acfm | 23 Zinc Titanate (ZN4) (or Zinc Ferrite) Makeup / HGCU / lb/hr | 24 Solid Waste / HGCU Cyclone / Disposal / lb/hr | 25 Steam / HRSG / HGCU / lb/hr | 26 Air / Compressor Dryers / HGCU Regenerator / lb/hr | 27 @ SO2vol = 5% Regeneration Gas / Regenerator / HRSG / lb/hr | spec vol / acfm | 28 Desulfurized Gas / HGCU Absorber / HRSG / lb/hr | lb-mol/hr | Desulfurized Gas / HGCU Absorber / spec vol / 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) | | | | | | | | | | | | | |
| (acfm) | | 676 | | | | 60 | 35 | 60 | | 916 | | | |
| (scfm) | | 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 | | 1677 | | | |
| LHV (BTU/lb) | | 1975 | | | | | 0 | 0 | | 1542 | | | |
| Sensible Heat above | | | | | | | | | | | | | |
| 50 F Btu/lb steam | | | | | | 560 | 60 | | | | | | |
| Latent Heat of | | | | | | | | | | | | | |
| Water Btu/lb steam | | | | | | 793 | 6 | | | | | | |
| Chemical Heat | | 36.11 | | | | 0.00 | 0.00 | 0.00 | | 35.12 | | Low Btu Gas HHV | |
| (LHV) MBtu/hr | | | | | | | | | | | | 141 Btu/scf | |
| Sensible Heat | | 6.06 | | | | 1.80 | 0.16 | 0.00 | | 7.10 | | 97 Btu/wscf | |
| above 50 F MBtu/hr | | | | | | | | | | | | | |
| Latent Heat | | 2.06 | | | | 2.86 | 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 | | | |



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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: AA
DESCRIPTION: GASIFER PROCESS

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1AA-COND-1 | ASH DUSTLESS UNLOADER | | By Contractor | | | | 95 06 28 | |
| 1AA-CONV-1 | BOTTOM ASH<br>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<br>WEIGH BELT FEEDER | | By Contractor | | | | 95 06 28 | |
| 1AA-FDR-2 | BOTTOM ASH<br>WEIGH BELT FEEDER | | By Contractor | | | | 95 06 28 | |

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Jacobs-Sirrine Engineers

**E Q U I P M E N T   L I S T**
FOR
Department of Energy
Gasification Product Improvemnet Facility
ISSUED AS Rev.1

SIRRINE PROJECT:16N25706
GPIF

SYSTEM CODE: AA
DESCRIPTION: GASIFER PROCESS

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br><br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1AA-HPR-1 | BOTTOM ASH<br>LOCK HOPPER | | By Contractor | | | | 94 12 15 | |
| 1AA-HPR-2 | BOTTOM ASH COOLING<br>CONVEYOR FEED HOPPER | | By Contractor | | | | 94 12 15 | |
| 1AA-HPR-3 | CYCLONE FINES<br>SURGE HOPPER | | By Contractor | | | | 94 10 16 | |
| 1AA-HPR-4 | CYCLONE<br>FINES LOCK HOPPER | | By Contractor | | | | 94 10 16 | |
| 1AA-HPR-5 | FINES COOLING CONVEYOR<br>FEED HOPPER | | By Contractor | | | | 94 12 7 | |
| 1AA-HX-1 | GASIFIER CONDENSING<br>HEAT EXCHANGER | | By Contractor | | | | 95 06 28 | |
| 1AA-MO-1 | GASIFIER COOLING WATER<br>PUMP NO.1 MOTOR | | By Contractor | 6.00 HP<br>1800 RPM<br>M | | | 94 12 6 | |
| 1AA-MO-2 | GASIFIER COOLING WATER<br>PUMP NO.2 MOTOR | | By Contractor | 6.00 HP<br>1800 RPM<br>M | | | 94 12 6 | |

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# E Q U I P M E N T   L I S T
FOR
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Gasification Product Improvemnet Facility
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SYSTEM CODE: AA
DESCRIPTION: GASIFER PROCESS

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1AA-MO-3 | MOTOR, BOTTOM ASH<br>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<br>FEEDER MOTOR | | By Contractor | M | | | | |
| 1AA-MO-6 | BOTTOM ASH WEIGHBELT<br>FEEDER MOTOR | | By Contractor | 5.00 HP<br>1800 RPM<br>M | | | 94 12 6 | |
| 1AA-MO-7 | GRATE DRIVE<br>NO.1 MOTOR | | By Contractor | 6.00 HP<br>1800 RPM<br>M | | | 94 12 6 | |
| 1AA-MO-8 | GRATE DRIVE<br>NO.2 MOTOR | | By Contractor | 6.00 HP<br>1800 RPM<br>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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# E Q U I P M E N T   L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
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SYSTEM CODE: AA
DESCRIPTION: GASIFER PROCESS

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1AA-MO-11 | BOTTOM ASH<br>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<br>WATER PUMP NO.1 | | By Contractor | M | | | 94 10 16 | |
| 1AA-P-2 | GASIFIER COOLING<br>WATER PUMP NO.2 | | By Contractor | M | | | 94 10 16 | |
| 1AA-RPV-1 | PyGas<br>REACTOR | | By Contractor | | | | 94 10 16 | |
| 1AA-SD-1 | GASIFER JACKET<br>STEAM DRUM | | By Contractor | | | | 94 12 18 | |
| 1AA-SILO-1 | ASH SILO | | By Contractor | | | | 95 06 28 | |

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# E Q U I P M E N T L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
ISSUED AS Rev.1

SYSTEM CODE: AA
DESCRIPTION: GASIFER PROCESS

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 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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Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
GPIF

# EQUIPMENT LIST
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SYSTEM CODE: DG
DESCRIPTION: FUEL GAS SUPPLY SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC<br>ISSUE<br>REV | REV<br>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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# E Q U I P M E N T   L I S T
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Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
GPIF

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

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1DH-CHT-1 | DISCHARGE<br>CHUTE | | By Contractor | | | | | |
| 1DH-CHT-2 | DISCHARGE<br>CHUTE | | By Contractor | | | | | |
| 1DH-CHT-3 | DISCHARGE<br>CHUTE | | By Contractor | | | | | |
| 1DH-CHT-4 | DISCHARGE<br>CHUTE | | By Contractor | | | | 94 06 17 | |
| 1DH-CHT-5 | DISCHARGE CHUTE | | By Contractor | | | | | |
| 1DH-CHT-6 | COAL BY-PASS<br>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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# EQUIPMENT LIST
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Gasification Product Improvemnet Facility
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Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
GPIF

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

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>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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Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
GPIF

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

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

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1DH-MO-1 | MOTOR, COAL<br>SCREW FEEDER | | By Contractor | 15.00 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1DH-MO-2 | MOTOR, COAL<br>BUCKET ELEVATOR | | By Contractor | 7.50 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1DH-MO-3 | MOTOR, COAL<br>SCREW CONVEYOR | | By Contractor | 3.00 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1DH-MO-4 | MOTOR,COAL STORAGE<br>BIN DISCHARGER | | By Contractor | 2.00 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1DH-MO-5 | MOTOR, COAL STORAGE<br>BIN DUST COLLECTOR FAN | | By Contractor | 7.50 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1DH-MO-6 | MOTOR, COAL<br>SCREW FEEDER | | By Contractor | 3.00 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1DH-PSX-1 | COAL STORAGE BIN<br>AIR CANNONS | | By Contractor | | | | 94 12 | 18 |
| 1DH-TARP-1 | COAL STORAGE PILE<br>TARPAULIN | | By Contractor | | | | | |

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

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

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

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SIRRINE PROJECT:16N25706
GPIF

# E Q U I P M E N T   L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
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SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC<br>ISSUE<br><br>REV | REV<br>FLAG |
|---|---|---|---|---|---|---|---|---|
| 1DJ-CHT-5 | ACCEPTS CHUTE | | By Contractor | | | | | |
| 1DJ-CHT-6 | DISCHARGE<br>CHUTE | | By Contractor | | | | | |
| 1DJ-CHT-7 | DISCHARGE<br>CHUTE | | By Contractor | | | | | |
| 1DJ-CHT-8 | SAMPLE CHUTE | | By Contractor | | | | | |
| 1DJ-CHT-9 | DISCHARGE<br>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<br>CLASSIFIER | | By Contractor | M | | | | |

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

SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

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

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SIRRINE PROJECT:16N25706
GPIF

# E Q U I P M E N T   L I S T
FOR
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Gasification Product Improvemnet Facility
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SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

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

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# E Q U I P M E N T   L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
ISSUED AS Rev.1



SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

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

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Jacobs-Sirrine Engineers

SIRRINE PROJECT:16N25706
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# EQUIPMENT LIST
FOR
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SYSTEM CODE: DJ
DESCRIPTION: COAL PREPARATION AND LIMESTONE SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC<br>ISSUE<br>REV | REV<br>FLAG |
|---|---|---|---|---|---|---|---|---|
| 1DJ-TK-2 | COAL SURGE BIN | | By Contractor | | | | | |
| 1DJ-TK-3 | COAL<br>SAMPLER<br>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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SIRRINE PROJECT:16N25706
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# E Q U I P M E N T   L I S T
FOR
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SYSTEM CODE: DP
DESCRIPTION: PYROLYZER FEED SYSTEM

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

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# E Q U I P M E N T   L I S T
FOR
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SYSTEM CODE: EA
DESCRIPTION: MEDIUM-VOLTAGE POWER SYSTEM (601V - 15KV)

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

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# E Q U I P M E N T  L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
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SYSTEM CODE: GA
DESCRIPTION: COMBUSTION GAS DESULFURIZATION SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1GA-BLO-1 | SCRUBBER WASTE WATER<br>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<br>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<br>PUMP MOTOR | | By Contractor | M | | | 95 04 | 3 |
| 1GA-MO-2 | CAUSTIC INJECTION<br>PUMP MOTOR | | By Contractor. | M | | | 95 04 | 3 |

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SIRRINE PROJECT:16N25706
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# E Q U I P M E N T   L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
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SYSTEM CODE: GA
DESCRIPTION: COMBUSTION GAS DESULFURIZATION SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1GA-MO-3 | CONDENSATE DRAIN PUMP MOTOR | | By Contractor | M | | | 95 04 | 3 |
| 1GA-MO-5 | FULE GAS REHEATER<br>COMBUSTION AIR FAN MOTOR | | By Contractor | M | | | 95 04 | 3 |
| 1GA-MO-6 | SCRUBBER WASTE WATER<br>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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# EQUIPMENT LIST
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SYSTEM CODE: GA
DESCRIPTION: COMBUSTION GAS DESULFURIZATION SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC<br>ISSUE<br>REV | REV<br>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 |

# EQUIPMENT LIST
FOR
Department of Energy
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SYSTEM CODE: GG
DESCRIPTION: PROCESS VENT SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>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<br>AIR RECEIVER | | By Contractor | | | | 95 06 28 | |

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EQUIPMENT LIST
FOR
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Gasification Product Improvemnet Facility
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SIRRINE PROJECT:16N25706
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SYSTEM CODE: GH
DESCRIPTION:

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

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# E Q U I P M E N T   L I S T
FOR
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Gasification Product Improvemnet Facility
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SYSTEM CODE: KD
DESCRIPTION: CONDENSATE AND FEEDWATER CHEMISTRY CONTROL SYSTEM

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

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# EQUIPMENT LIST
FOR
Department of Energy
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SYSTEM CODE: KK
DESCRIPTION: POTABLE WATER SYSTEM

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

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EQUIPMENT LIST
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SYSTEM CODE: KV
DESCRIPTION: AUXILIARY WATER SYSTEM

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

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# E Q U I P M E N T   L I S T
FOR
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Gasification Product Improvemnet Facility
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SYSTEM CODE: KW
DESCRIPTION: SERVICE WATER SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1KW-MO-1 | SERVICE WATER<br>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<br>STORAGE TANK | | By Contractor | | | | 94 12 7 | |

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# EQUIPMENT LIST
FOR
Department of Energy
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SYSTEM CODE: LD
DESCRIPTION: COMPRESSED AIR SYSTEM

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

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# E Q U I P M E N T   L I S T
FOR
Department of Energy
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SYSTEM CODE: LF
DESCRIPTION: SERVICE AIR SYSTEM

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

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# E Q U I P M E N T   L I S T
FOR
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Gasification Product Improvemnet Facility
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SYSTEM CODE: LF
DESCRIPTION: SERVICE AIR SYSTEM

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

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# E Q U I P M E N T   L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
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SYSTEM CODE: LK
DESCRIPTION: NITROGEN SYSTEM

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

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# E Q U I P M E N T  L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
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SYSTEM CODE: LK
DESCRIPTION: NITROGEN SYSTEM

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

# E Q U I P M E N T   L I S T
FOR
Department of Energy
Gasification Product Improvemnet Facility
ISSUED AS Rev.1

SYSTEM CODE: SB
DESCRIPTION: MAIN STEAM SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>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 | | | | | |

# EQUIPMENT LIST
FOR
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SYSTEM CODE: SJ
DESCRIPTION: FEEDWATER SYSTEM

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

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# EQUIPMENT LIST
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SYSTEM CODE: VE
DESCRIPTION: ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1VE-ACU-1 | A.C.UNIT<br>CONTROL/RACK ROOM | | By Contractor | | | | 94 12 | 6 |
| 1VE-ACU-2 | A.C.UNIT<br>OFFICE/ELECT.RM. | | By Contractor | | | | 94 12 | 6 |
| 1VE-ACU-3 | A.C.UNIT<br>COAL HANDL.MCC ROOM | | By Contractor | | | | 94 12 | 6 |
| 1VE-EHTR-1 | ELECT UNIT HEATER NO.1<br>FIRE PUMP HOUSE | | By Contractor | 10.00 KW | | | 94 12 | 6 |
| 1VE-EHTR-2 | ELEC UNIT HEATER NO.2<br>FIRE PUMP HOUSE | | By Contractor | 10.00 KW | | | 94 12 | 6 |
| 1VE-EHTR-3 | ELECT UNIT HEATER NO.1<br>COMPRESSOR ROOM | | By Contractor | | | | 94 12 | 18 |
| 1VE-EHTR-4 | ELECT UNIT HEATER NO.4<br>COMPRESSOR ROOM | | By Contractor | 10.00 KW | | | 94 12 | 6 |
| 1VE-EHTR-5 | ELECT UNIT HEATER NO.5<br>COMPRESSOR | | By Contractor | 2.00 KW | | | 94 12 | 6 |

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GPIF

# EQUIPMENT LIST
FOR
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ISSUED AS Rev.1

SYSTEM CODE: VE
DESCRIPTION: ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM

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

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SYSTEM CODE: VE
DESCRIPTION: ACCESS CORRIDORS ENVIRONMENTAL CONTROL SYSTEM

| EQUIPMENT NO. | EQUIPMENT NAME & DESCRIPTION | VENDOR<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC ISSUE<br>REV | REV FLAG |
|---|---|---|---|---|---|---|---|---|
| 1VE-FAN-1 | VENT FAN<br>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<br>UPS ROOM | | By Contractor | M | | | 94 12 18 | |
| 1VE-FAN-4 | VENT FAN<br>COMPRESSOR ROOM | | By Contractor | M | | | 94 12 18 | |
| 1VE-FAN-5 | VENT FAN<br>COMPRESSOR ROOM | | By Contractor | M | | | 94 12 18 | |
| 1VE-FAN-6 | EXHAUST FAN<br>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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# E Q U I P M E N T   L I S T
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<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC<br>ISSUE<br>REV | REV<br>FLAG |
|---|---|---|---|---|---|---|---|---|
| 1VE-FAN-8 | VENT FAN<br>FIRE PUMP HSE | | By Contractor | <br><br>M | | | 94 12 | 18 |
| 1VE-LH-1 | CHEMICAL LAB HOOD | | By Contractor | | | | 94 12 | 18 |
| 1VE-LV-1 | MOTORIZED O.A. LOUVER<br>MAINT.RM | | By Contractor | | | | 94 12 | 18 |
| 1VE-LV-2 | MOTORIZED O.A. LOUVER<br>COMPRESSOR RM | | By Contractor | | | | 94 12 | 18 |
| 1VE-LV-3 | MOTORIZED O.A.LOUVER<br>FIRE PUMP HOUSE | | By Contractor | | | | 94 12 | 18 |
| 1VE-MO-2 | FAN MOTOR | | By Contractor | 0.25 HP<br><br>M | | | 94 12 | 6 |
| 1VE-MO-2 | FAN MOTOR | | By Contractor | 0.25 HP<br><br>M | | | 94 12 | 6 |
| 1VE-MO-3 | FAN MOTOR | | By Contractor | 0.17 HP<br>1800 RPM<br>M | | | 94 12 | 6 |

# 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<br>PO NUMBER<br>BUDGET COST<br>CCN | CONSTRUCTION<br>RESPONSIBILITY | DESIGN PWR<br>OP SPEED<br>DRIVER | EQ WT (EMPTY)<br>MTL CONSTRN | APPROVAL STATUS<br>DESIGN STATUS<br>USE STATUS | SPEC<br>ISSUE<br>REV | REV<br>FLAG |
|---|---|---|---|---|---|---|---|---|
| 1VE-MO-4 | FAN MOTOR | | By Contractor | 1.00 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1VE-MO-5 | FAN MOTOR | | By Contractor | 0.05 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1VE-MO-6 | FAN MOTOR | | By Contractor | 0.33 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1VE-MO-8 | FAN MOTOR | | By Contractor | 0.33 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1VE-MO-9 | MOTORIZED LOUVER<br>MAINT RM | | By Contractor | 0.17 HP<br>1800 RPM<br>M | | | 94 12 | 6 |
| 1VE-MO-10 | MOTORIZED LOUVER<br>COMPRESSOR RM | | By Contractor | M | | | 95 07 | 17 |
| 1VE-MO-11 | MOTORIZED LOUVER<br>FIRE PUMP HOUSE | | By Contractor | M | | | 95 07 | 17 |

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SYSTEM CODE: WS
DESCRIPTION: WASTE TREATMENT SYSTEM

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

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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

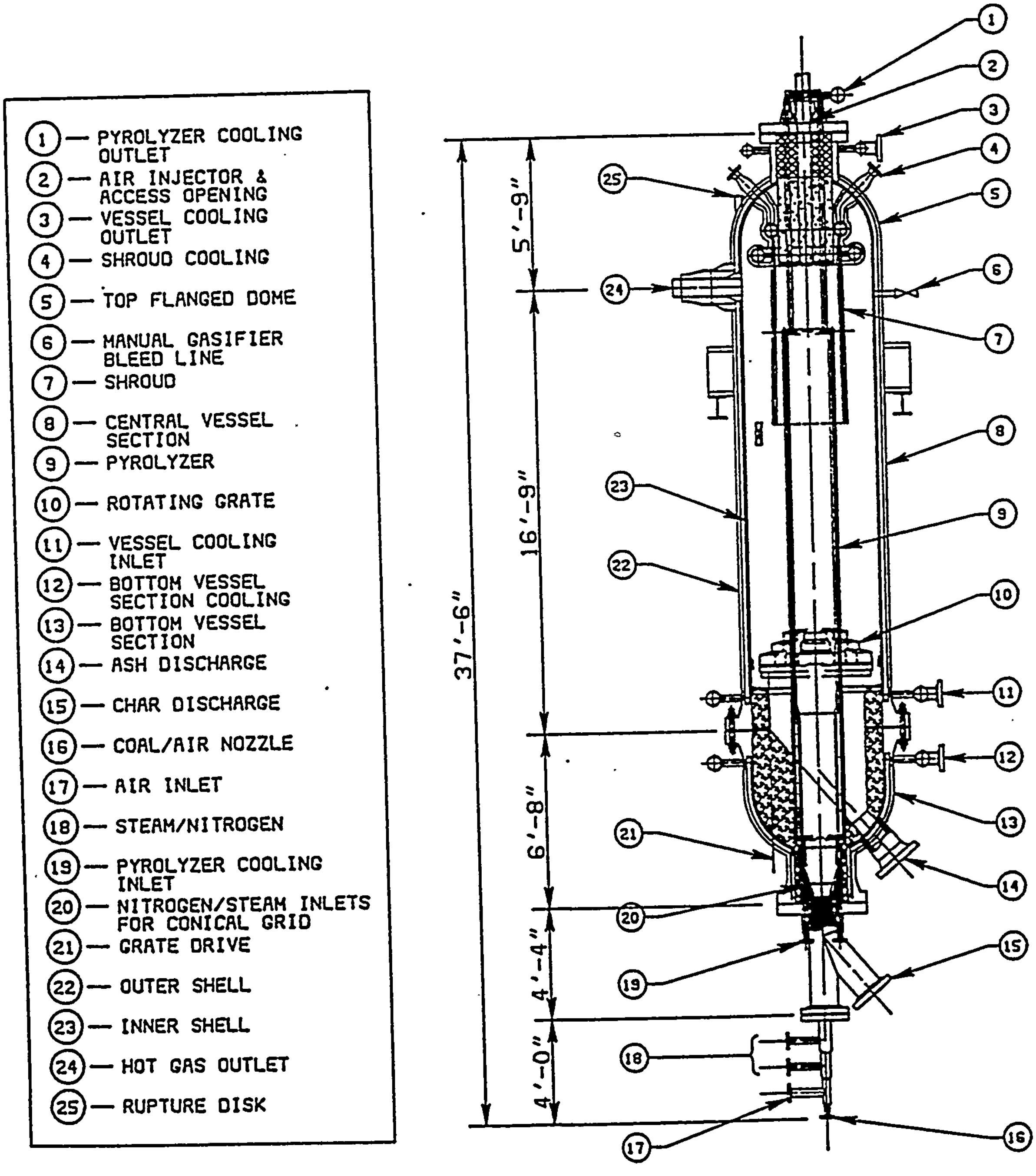


Figure 1. General Gasifier Arrangement.

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

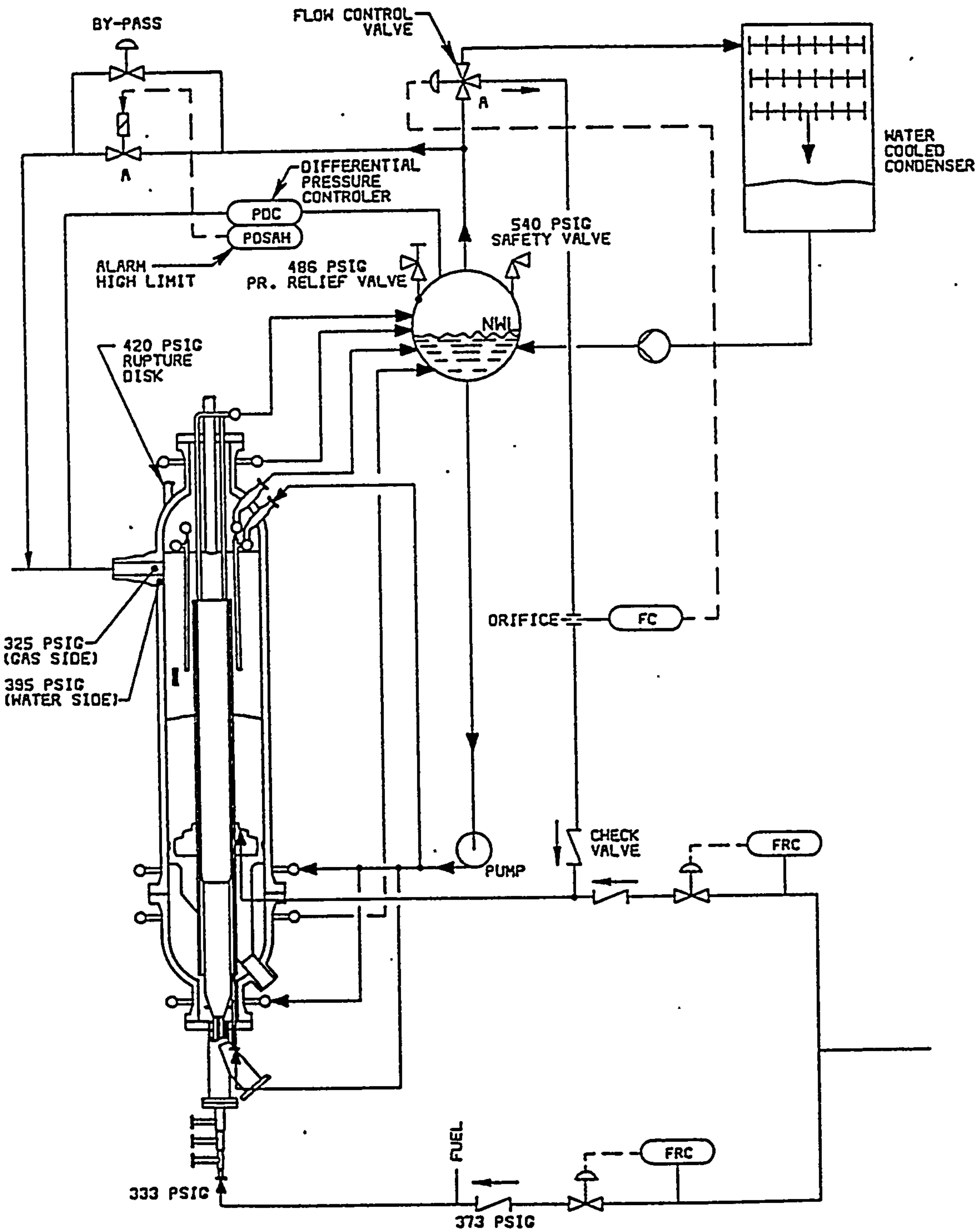


Figure 2. Gasifier Safety and Pressure Relief.

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) | $(373 + 70) \times 1.2 = 532 \cong 540$ 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 |

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
Flow Sheet No: 16N25706-40-F-1AA-3

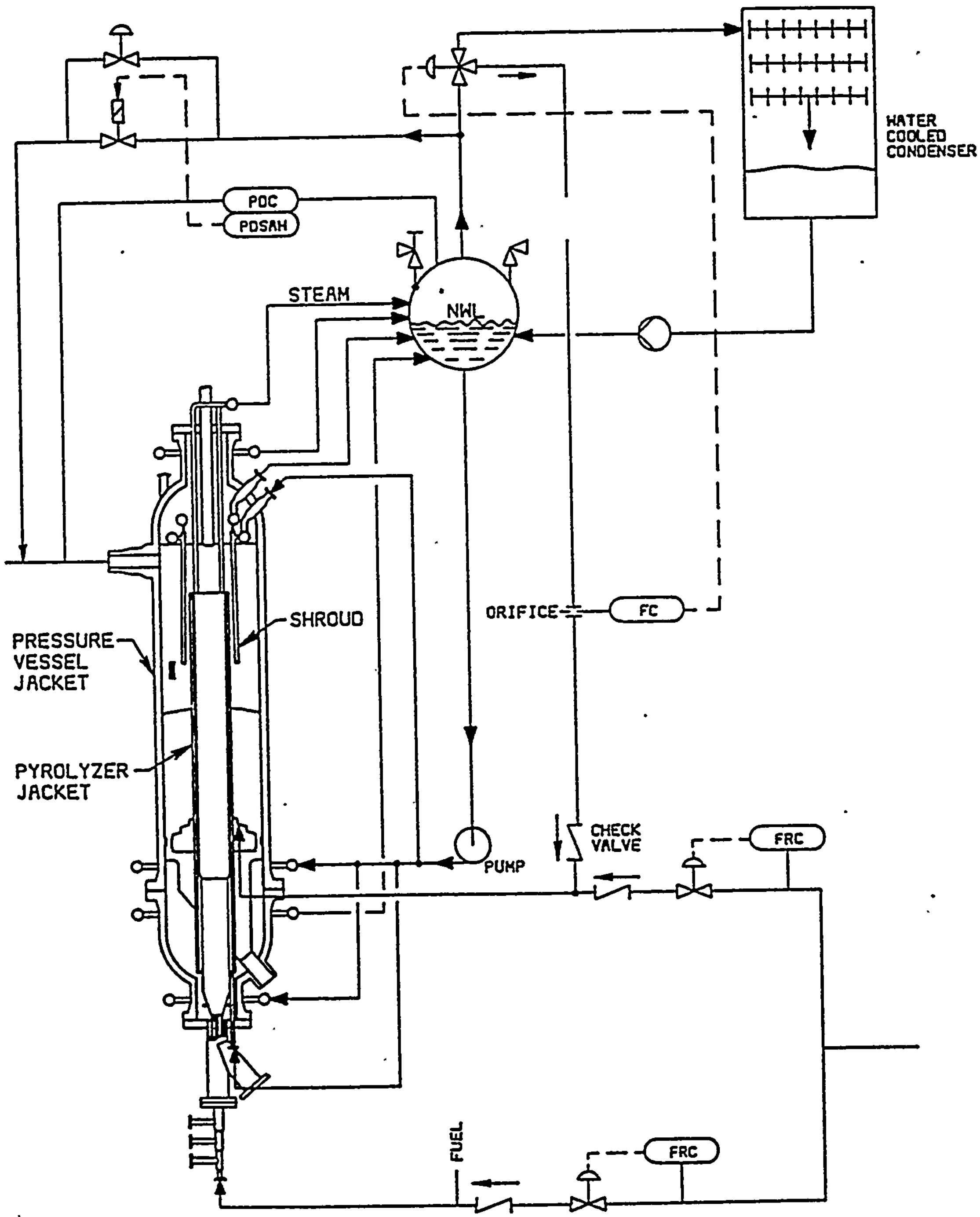


Figure 3. Gasifier Cooling Circuits.

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 Coefft. 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 | |
| | Total Pyrolizer Jacket | 210.13 | | | | 3.43 | 4304 | 32.35 |
| | 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 | |
| | Total Shroud Tube | 100.17 | | | | 3.35 | 4198 | 31.55 |
| | 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 | |
| | Total Vessel Jacket | 258.83 | | | | 3.76 | 4715 | 35.44 |
| 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

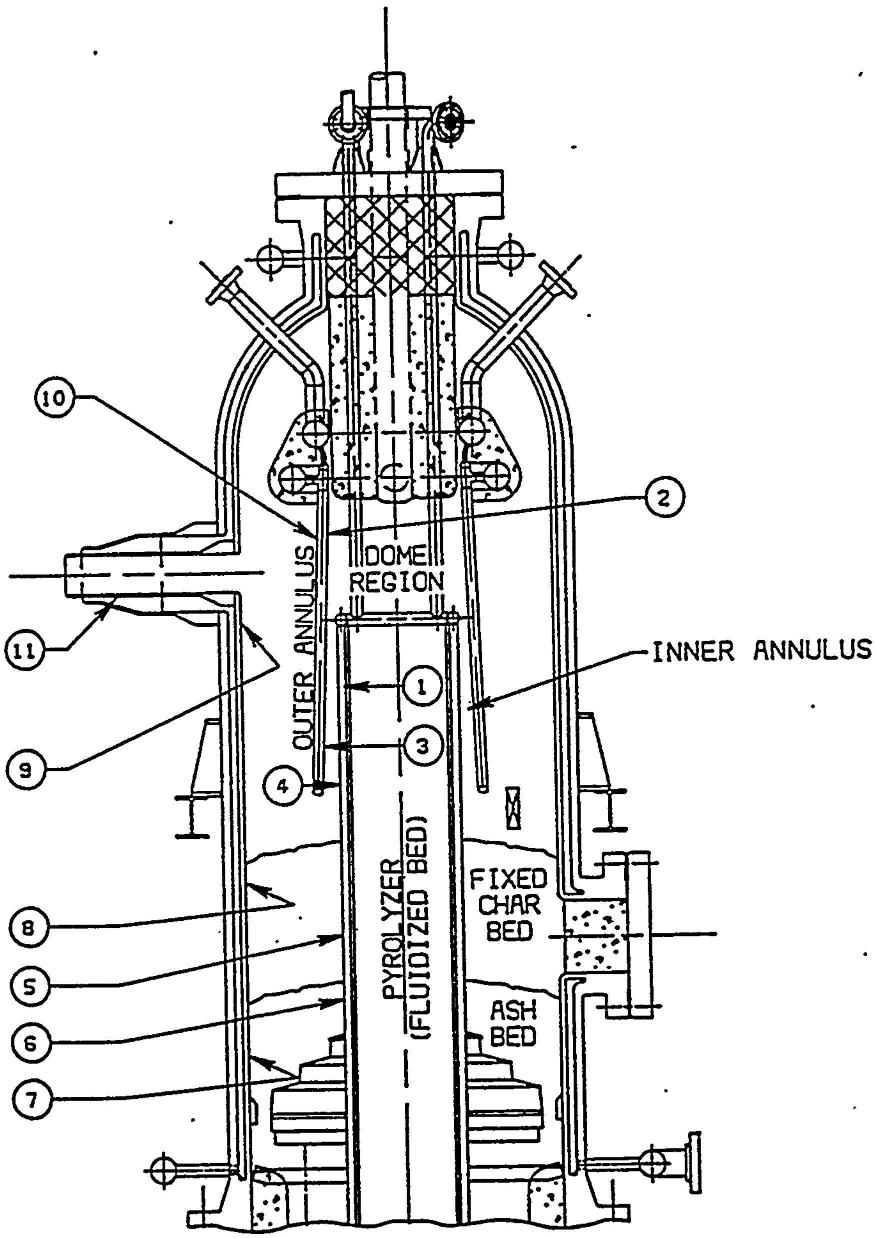


Figure 4. Cooling Section Identification.

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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 pre-determined 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.

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).

PyGas™ COAL GASIFIER
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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.

PyGas™ COAL GASIFIER
**PDB No. 40-1AA-1**

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.

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):<br>(5/31/95 Mass Balance - 325 psig) | 18,900 |
| 1.2 | Operating Gasifier Outlet Coal Gas Pressure (psig):<br>(Pyrolyzer Inlet Pressure 333 psig, Anticipated Gasifier Delta P=8 psi) | 325 |
| 1.3 | Phase I Operating Gasifier Outlet Coal Gas Temperature (°F):<br>(347-Stainless Steel Piping Design Limit Less 15 °F Operating Margin) | 1085 |
| | Phase II Operating Gasifier Outlet Coal Gas Temperature (°F):<br>(includes water cooled outlet nozzle, refractory lined cyclone & piping to HGCU flange) | N/A |
| 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):<br>(per Site Access Agreement) | 170 |
| 3.0 | MAXIMUM GASIFIER OPERATING TEMPERATURE (°F):<br>(Peak Anticipated Top dome air/steam injector and Fixed-bed Temperatures) | 2300 |
| 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):<br>(Mass Balance - 325 psig, Column 12) | 1995 |
| 4.1.3 | Coal Gas Temperature (°F):<br>(Mass Balance - 325 psig, Column 12) | 1023 F |
| 4.1.4 | Coal Gas Flow (lb/hr):<br>(Mass Balance - 325 psig, Column 12) | 18,900 |
| 4.1.5 | Coal Gas Specific Volume:<br>(Mass Balance - 325 psig, Column 10h) | 54 to 86 scf/lb |
| 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):<br>(from Ft. Martin Certified Topographical Drawings) | 820 |

PyGas™ GASIFIER DESIGN CRITERIA (continued)

| | | Operating Pressure (psig) | Operating Temperature (°F) | Design Pressure (psig) | Design Temperature (°F) |
|---|---|---|---|---|---|
| 4.4.4 | Utilities: | | | | |
| | 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
PDB No. 40-1AA-1

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 |

| PyGas™ GASIFIER DESIGN CRITERIA (continued) | | MINIMUM | MAXIMUM |
|---|---|---|---|
| 4.1.2 | Coal Gas Heating Value (Btu/# HHV):<br>(Mass Balance - 5/31/95 & 325 psig, Column 12) | 1335 | 2014 |
| 4.1.3 | Coal Gas Heating Value (Btu/dscf):<br>(Mass Balance - 5/31/95 & 325 psig, Column 10h) | 103 | 146 |
| 4.1.4 | Future Phase II HGCU Input Coal Gas Temperature (°F):<br>(Mass Balance - 325 psig, Column 12) | 1000 | 1087 |
| 4.1.5 | Coal Gas Specific Volume (scf/lb):<br>(Mass Balance - 325 psig, Column 12) | 54 | 86 |
| 4.2 | Coal Throughput | | |
| 4.2.1 | The Gasifier Coal Feed Rate (short tons per hour)<br>(per METC contract specifications) | 1 | 2 |
| 4.3 | Dolomite/Limestone Throughput | | |
| 4.3.1 | The Gasifier Dolomite/Limestone Feed Rate (short tons per hour)<br>(based on coal with a max. of 4% sulfur content,<br>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)<br>(per Mass Balance - 325 psig, Appendix A-9 Column 9b/2)<br>(adjustments to these figures are anticipated<br>depending upon each sub-system vendor's requirements) | 1,200 | 4,000 |
| 4.4.2 | Pyrolyzer Fluidizing Air Feed Rate (lb/hr)<br>(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)<br>(per Project Team Agreement) | 0 | 0 |
| 4.5 | Pyrolyzer Steam Feed | | |
| 4.5.1 | Pyrolyzer Conveying Air Feed System Steam Rate (lb/hr)<br>(per Mass Balance - 325 psig, Appendix A-9 Column 9b) | 0 | 0 |
| 4.5.2 | Pyrolyzer Fluidizing Air Feed System Steam Rate (lb/hr)<br>(per Riley Research) | 0 | 750 |
| 4.5.3 | Pyrolyzer Sweeping Steam Feed Rate (lb/hr)<br>(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)<br>(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)<br>(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)<br>(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)<br>(per Mass Balance - Appendix A-3&9 Column 11c/2) | 550 | 2,700 |

End of Attachment B

PyGas™ COAL GASIFIER
PDB No. 40-1AA-1

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<br>______ AWCFM<br>______ pounds/hour |
| 12.15 | Quantity of Flue Gas Leaving the Pyrolyzer Cone - No. 2 Oil: | ______ DSCFM<br>______ AWCFM<br>______ pounds/hour |
| 12.16 | Quantity of Air Entering Pre-heat Burner - Natural Gas: | ______ CFM<br>______ pounds/hour |
| 12.17 | Quantity of Air Entering Pre-heat Burner- No. 2 Oil: | ______ CFM<br>______ 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<br>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

# PyGas™ GASIFIER

# PRESSURE VESSEL

# STRUCTURAL DESIGN CRITERIA

Prepared by ______________________________ Date __________

Approved by ______________________________ Date __________

Approved by ______________________________ Date __________

January, 1995

PyGas$^{tm}$ GASIFIER VESSEL
STRUCTURAL INTEGRITY

MECHANICAL DESIGN

PROCESS DESIGN

FABRICATION & INSTALLATION

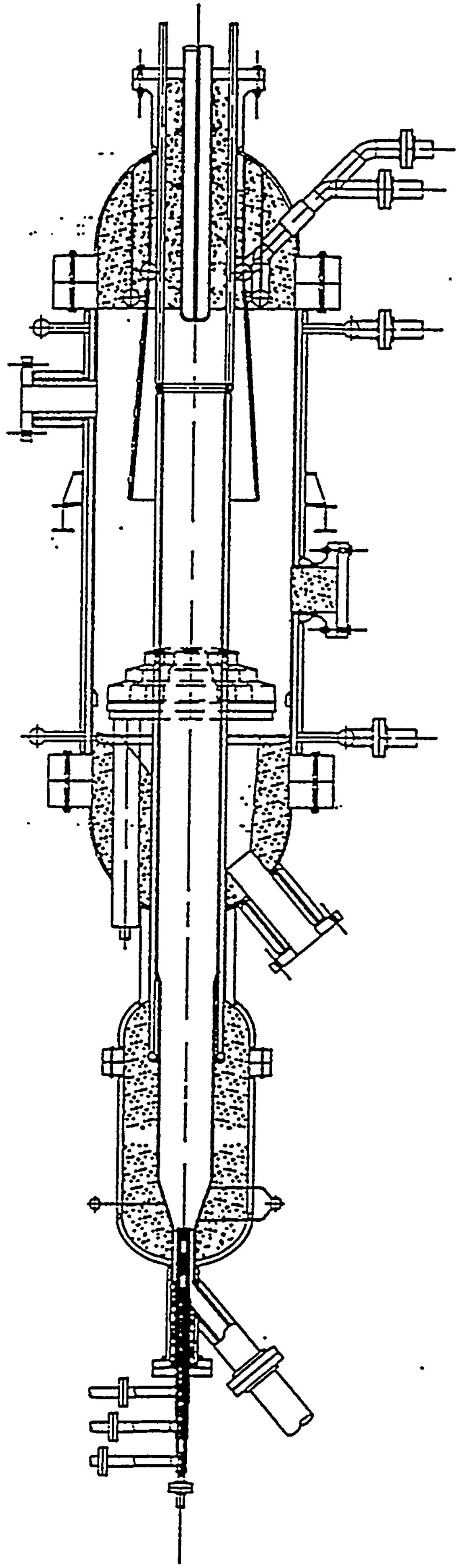
INSPECTION

HYDROTEST

INSTRUMENTATION & CONTROL

OPERATION & MAINTENANCE

PRESSURE RELIEF



GPIF

TABLE OF CONTENTS

## GPIF PROJECT PyGas[tm] GASIFIER VESSEL APPLICABLE ASME BOILER CODE SECTION

### SECTION I VS. SECTION VIII, DIV. 1

- SECTION I APPLIES TO POWER BOILERS; PyGas[tm] VESSEL IS PRIMARILY A PROCESS VESSEL
- SECTION VIII INCLUDES PROVISIONS FOR UNFIRED STEAM BOILERS
- SECTION VIII, DIV. 1 USED AS DESIGN BASIS FOR PROCESS REACTOR VESSELS; SOME ARE USED TO CONTAIN COMBUSTION
    - PFB SYSTEM
- BOLTED CLOSURE RULES INCLUDED IN SECTION VIII, DIV. 1
- OTHER GASIFIER VESSELS CONSTRUCTED IN ACCORDANCE WITH SECTION VIII, DIV. 1
    - GREAT PLAINS GASIFICATION PROJECT
    - PIÑON PINES
- FOR PRESSURE RELIEF, SECTION I IS APPLICABLE TO BOILERS
- MORE STRINGENT HYDROSTATIC TEST REQUIREMENTS PER SECTION VIII, DIV. 1
- FULL RADIOGRAPHY REQUIRED FOR BUTT WELDS PER SECTION VIII, DIV. 1 FOR VESSELS CONTAINING LETHAL GAS

SECTION 2

## 2.0 SCOPE

Structural design of the PyGas™ vessel includes the following items.

### 2.1 PRESSURE BOUNDARY COMPONENTS

- Intermediate water-cooled outer shell
- Upper head and air inlet
- Lower head
- Coal inlet shell assembly
- Bolted closures
- Removable coal/air nozzles
- Gas product outlet
- Access penetration
- Other nozzles and penetrations including reinforcement
- Vessel shell support attachments

### 2.2 INTERNALS REQUIRING STRUCTURAL DESIGN

- Pyrolyzer tube including cooling system
- Water-cooled upper shroud
- Shell cooling system inner wall
- Shell cooling system headers
- Shroud cooling system headers
- Pyrolyzer cooling system headers
- Support of grate
- Grate drive shaft penetration

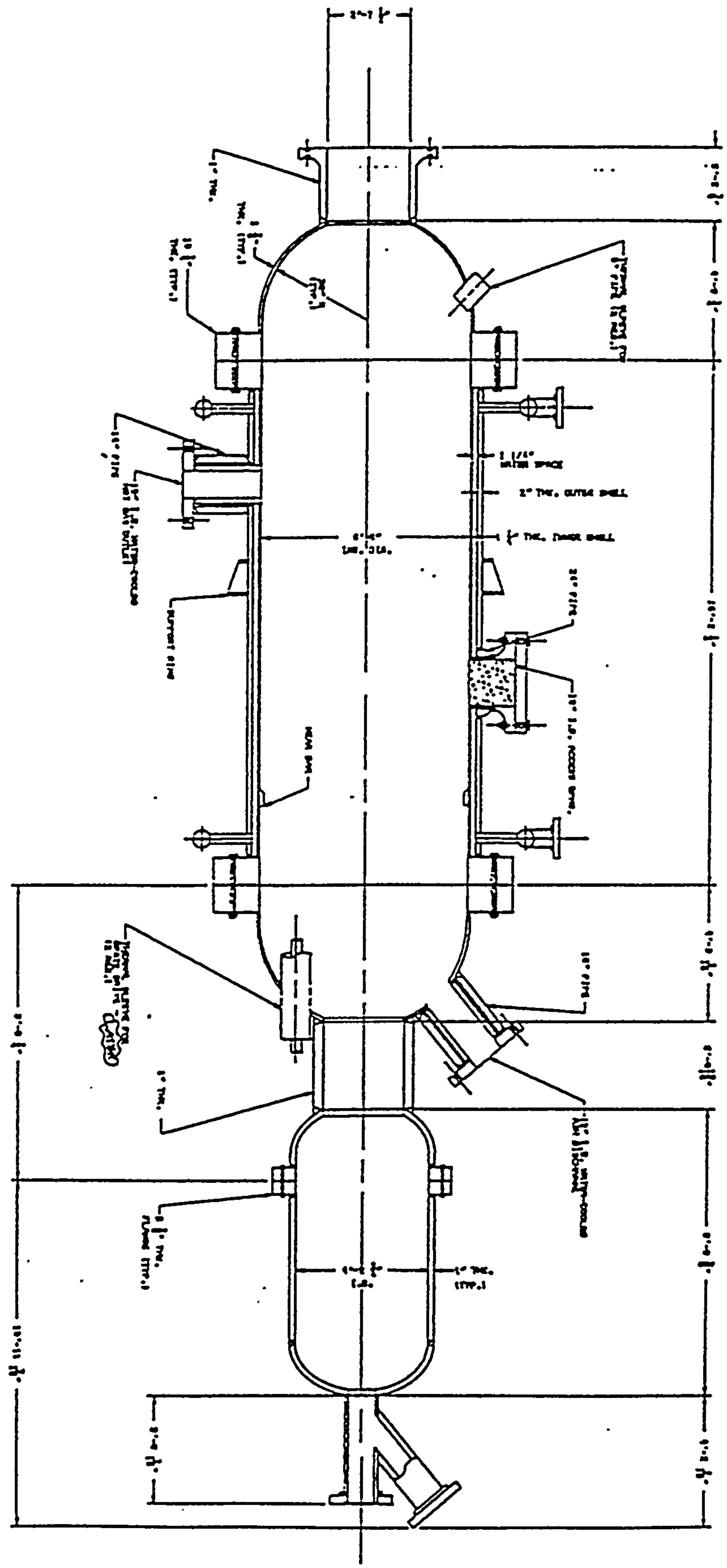
## DESIGN INPUTS REQUIRED FOR

## STRUCTURAL DESIGN

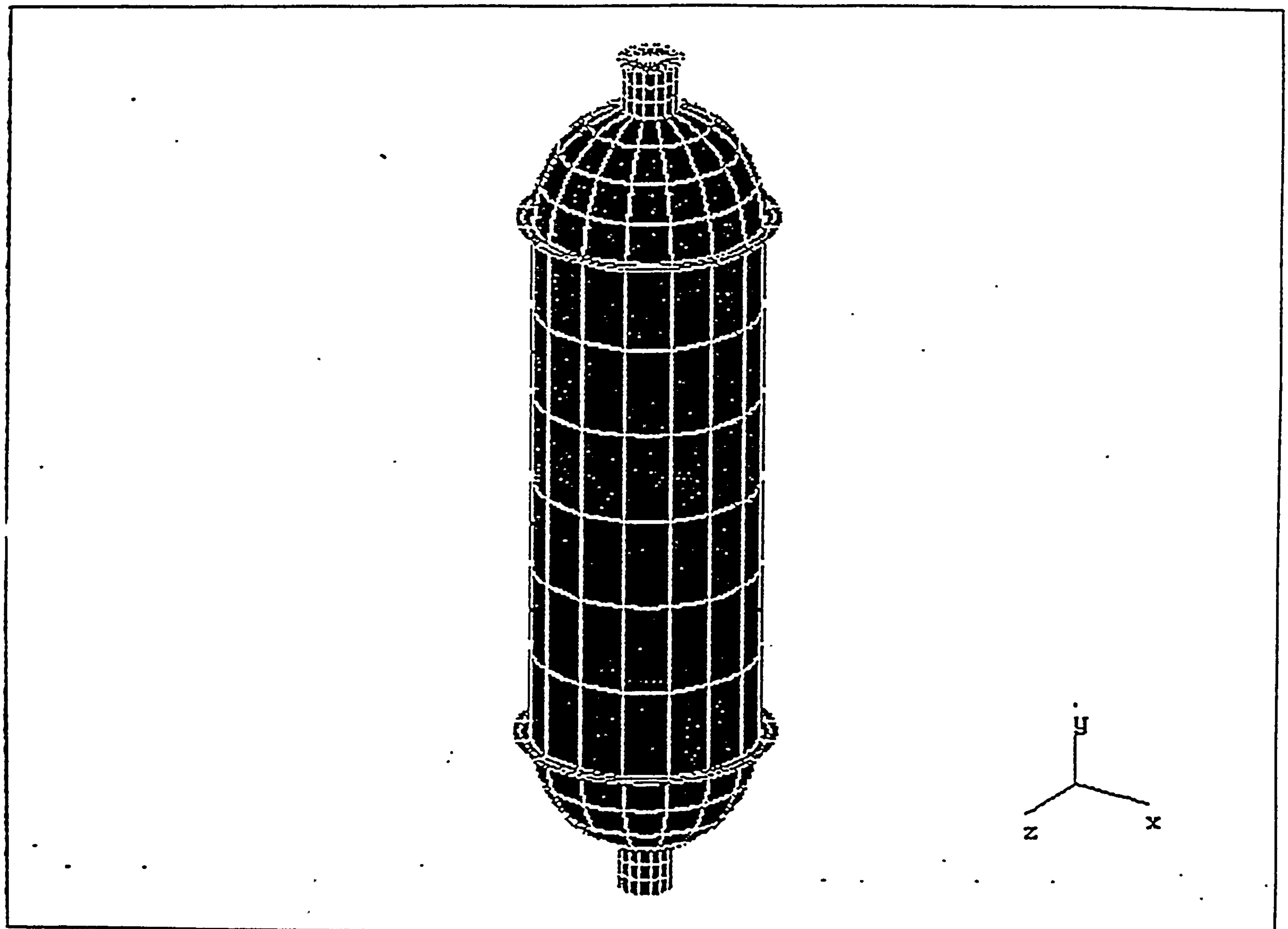
- DESIGN PRESSURE
  - MAXIMUM ALLOWABLE WORKING PRESSURE
  - MARGIN
  - DIFFERENTIAL PRESSURE
- DESIGN TEMPERATURE
  - METAL TEMPERATURE
- OPERATIONAL CYCLES
  - PRESSURE TIME HISTORY
  - TEMPERATURE TIME HISTORY
- ABNORMAL PROCESS REACTIONS
  - EXPLOSIONS
- SEISMIC LOADING
  - BOCA 1990

PRESSURE BOUNDARY DESIGN CONDITIONS

- PROCESS CHAMBER
  - 510 PSIG
- COOLING JACKET OUTER SHELL
  - 660 PSIG
- COOLING JACKET INNER SHELL
  - 150 PSID
- DESIGN TEMPERATURE
  - 700°F (METAL TEMP)



1 1/4" WATER SPACE
2" THK. OUTER SHELL
1/2" THK. INNER SHELL




| | | |
|---|---|---|
| HEAD | Tue Jan 10 08:42:06 1995 | FE/PIPE Version 2.7 |

PRESSURE RELIEF DEVICES

- REQUIRED BY CODE

- LIMITS MAX PRESSURE IN VESSEL OR CHAMBER
    - 110% $P_{DES}$ - SINGLE DEVICE
    - 116% $P_{DES}$ - MULTIPLE DEVICES

- HOW DO WE MEET CODE?
    - SELECT DEVICE SIZE
    - SELECT LOCATION
    - ANALYZE PROCESS TO SHOW PRESSURE LIMITS ARE NOT EXCEEDED
        - INCLUDE EFFECTS OF RELIEF DEVICE, VESSEL CONFIGURATION AND VENT PIPING (LOSSES)

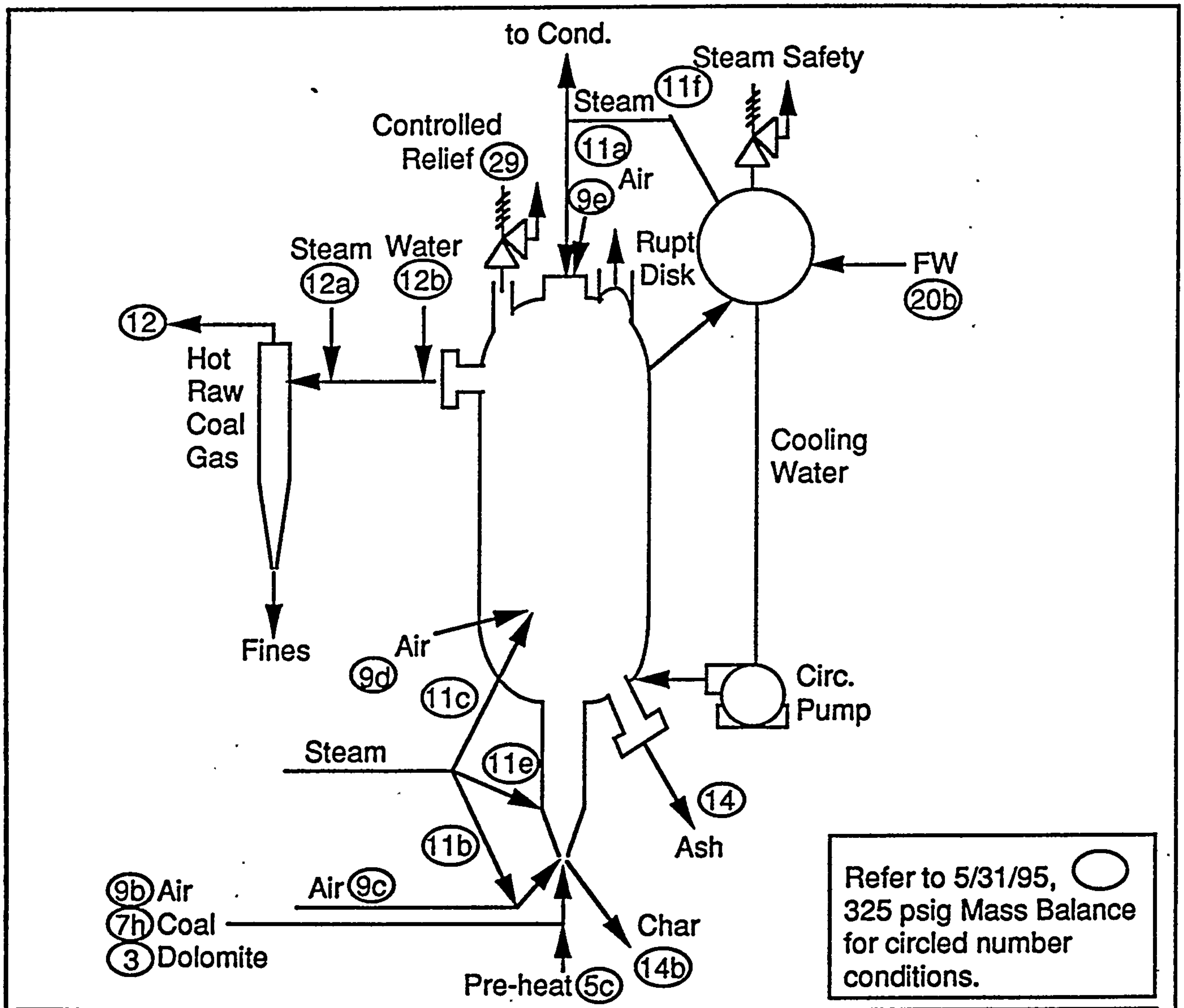
- SET PRESSURE LIMITED TO $P_{DES}$ IN GENERAL

- CERTIFICATION AND STAMPING REQUIRED

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 40-1AA-1**

Equipment Name: PyGas™ Coal Gasifier
Equipment No. 1AA-RPV-1
System Name: Coal Gasifier Island
Flowsheet No. 16N25706-40-F-1AA-001




Refer to 5/31/95, ◯ 325 psig Mass Balance for circled number conditions.

### SYSTEM EQUIPMENT SPECIFICS

1. Gasifier & system to be designed per U.S. Patents 5,133,780, & 5,145,490.
2. Provisions for coal, air & steam injection per mass balances columns 7, 9 & 11.
3. Gasifier to operate at 325 psig at pyrolyzer inlet nozzle.
4. Pyrolyzer operating temperature range is 1300°F to 2000°F.
5. Top gas & fixed-bed operating range 1500°F to 2200°F (peak 2300°F).

REV. 1

## Gasifier Load Sheet
## Gasifier Flows, Pressures, & Temperatures

10/19/95 15:39

| | C. System Dry | D. Ready For Ignition | E. Pyrolyzer In Service (Start-up) | F. Fixed-bed Ignited (Start-up) | G. DualBeds In Service 30 psig | H. Steady State 325 psig | H. Steady State Hot Hold (Min Flows) | H. Steady State Future Top Air/Steam |
|---|---|---|---|---|---|---|---|---|
| **Pyrolyzer Nozzle:** | | | | | | | | |
| **Coal Convey Line:** | | | | | | | | |
| Air Flow (lb/hr) (9b): | - | 397 | 3,175 | 3,175 | 3,175 | 3,969 | 3,175 | 3,969 |
| Air Viscosity (Cp): | - | 0.04 | 0.002 | 0.002 | 0.024 | 0.024 | 0.024 | 0.024 |
| Kinematic Visc., (cs) | - | 13.21 | 2.45 | 2.45 | 1.72 | 0.84 | 0.84 | 0.84 |
| Coke Flow (lb/hr) (8): | - | - | 3,969 | 3,969 | - | - | - | - |
| Coal Flow (lb/hr) (7g): | - | - | - | - | 400 | 4,000 | 1,774 | 4,000 |
| Limestone Flow (lb/hr) (7h): | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| Air Pressure (psig) (10): | - | 30 | 30 | 30 | 30 | 325 | 325 | 325 |
| Air/Coke/Coal Temp. (°F) (10): | - | - | 125 | 125 | 125 | 125 | 125 | 125 |
| **Fluidization Annulus:** | | | | | | | | |
| Air Flow (lb/hr) (9c): | - | 292 | 441 | 441 | 573 | 2,919 | 1,264 | 2,919 |
| Air Pressure (psig) (9c): | - | - | 30 | 30 | 30 | 325 | 325 | 325 |
| Air Temp. (°F) (9c): | - | - | 400 | 400 | 400 | 400 | 400 | 400 |
| Steam Flow (lb/hr): | - | - | - | - | - | - | - | - |
| Steam Pressure (psig): | - | - | 353 | 353 | 353 | 353 | 353 | 353 |
| Steam Temperature (°F): | - | - | 530 | 530 | 530 | 530 | 530 | 530 |
| **Outer Char Sampling Annulus:** | | | | | | | | |
| Air Flow (lb/hr): | - | 750 | - | - | - | - | - | - |
| Air Pressure (psig): | - | 30 | - | - | - | - | - | - |
| Air Temp. (°F): | - | 400 | - | - | - | - | - | - |
| Steam Flow (lb/hr) (11b): | - | 62 | 62 | 100 | 33 | 417 | 46 | 417 |
| Steam Pressure (psig) (11b): | - | - | 353 | 353 | 353 | 353 | 353 | 353 |
| Steam Temperature (°F) (11b): | - | - | 530 | 530 | 530 | 530 | 530 | 530 |
| **Cone Sweep Steam:** | | | | | | | | |
| Steam Flow (lb/hr) (11b): | - | 62 | 62 | 100 | 100 | 250 | 250 | 250 |
| Steam Pressure (psig) (11b): | - | - | 353 | 353 | 353 | 353 | 353 | 353 |
| Steam Temperature (°F) (11b): | - | - | 530 | 530 | 530 | 530 | 530 | 530 |
| Pyroyzer Superficial Velocity (fps) (10a): | - | 5.44 | 14.90 | 8.27 | 4.55 | 4.54 | 2.00 | 4.54 |
| **Top Air/Steam Nozzle:** | | | | | | | | |
| Air Flow (lb/hr) (9e): | - | - | - | - | - | - | - | 2,200 |
| Air Pressure (psig) (9e): | - | - | - | - | - | - | - | 332 |
| Air Temp. (°F) (9e): | - | - | - | - | - | - | - | 400 |
| Steam Flow (lb/hr) (11a): | - | - | - | - | - | - | - | 778 |
| Steam Pressure (psig) (11a): | - | - | - | - | - | - | - | 332 |
| Steam Temperature (°F) (11a): | - | - | - | - | - | - | - | 530 |
| **Undergrate Blast:** | | | | | | | | |
| Air Flow (lb/hr) (9d): | 5,193 | 415 | 415 | 1,072 | 763 | 5,238 | 1,596 | 1,721 |
| Air Pressure (psig) (9d): | 30 | 30 | 30 | 30 | 30 | 328 | 328 | 328 |
| Air Temp. (°F) (9d): | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| Steam Flow (lb/hr) (11c): | - | 1,662 | 1,662 | 482 | 298 | 2,032 | 603 | 640 |
| Steam Pressure (psig) (11c): | - | 31 | 31 | 31 | 31 | 332 | 332 | 332 |
| Steam Temperature (°F) (11c): | - | 530 | 530 | 530 | 530 | 530 | 530 | 530 |
| **Jacket Heat-up WHB Steam:** | | | | | | | | |
| Steam Flow (lb/hr): | 5,640 | 5,640 | 5,076 | 4,568 | - | - | - | - |
| Steam Pressure (psig): | 353 | 353 | 353 | 353 | - | - | - | - |
| Steam Temperature (°F): | 353 (Tsat=435) | 530 | 530 | 530 | - | - | - | - |
| **Excess Jacket Steam Condensed:** | | | | | | | | |
| Steam Flow (lb/hr): | - | - | - | - | 932 | 2,330 | 2,330 | 2,330 |
| Steam Pressure (psig): | - | - | - | - | 353 | 353 | 353 | 353 |
| Steam Temperature (°F): | - | - | - | - | 274 | 274 | 274 | 274 |
| **Raw Coal Gas Output:** | | | | | | | | |
| Coal Gas Flow (lb/hr) (10h): | - | - | - | 5,371 | 6,274 | 21,155 | 11,037 | 19,224 |
| Coal Gas Pressure (psig) (10h): | - | - | - | 28 | 25 | 319 | 319 | 319 |
| Coal Gas Temp. (°F) (10h): | - | - | - | 1083 | 1083 | 1083 | 975 | 1083 |
| Coal Gas HHV (Btu/dscf) (10h): | - | - | - | 113 | 150 | 149 | 150 | 140 |
| **Gas Cooling Water Spray:** | | | | | | | | |
| Steam & Water Flow (lb/hr) (12a,12b): | - | - | - | 0 | 0 | 0 | 0 | 0 |
| Water Pressure (psig) (12a,12b): | - | - | - | 35 | 35 | 334 | 334 | 334 |
| Water Temp. (°F) (12a,12b): | - | - | - | 170 | 170 | 170 | 227 | 227 |
| **Cooled Coal Gas Output:** | | | | | | | | |
| Coal Gas Flow (lb/hr) (12): | - | - | - | 5,371 | 6,274 | 21,155 | 11,037 | 19,224 |
| Coal Gas Pressure (psig) (12): | - | - | - | 27 | 27 | 319 | 319 | 319 |
| Coal Gas Temp. (°F) (12): | - | - | - | 1083 | 1083 | 1083 | 1083 | 1083 |
| Coal Gas HHV (Btu/dscf) (12): | - | - | 80 | 91 | 150 | 149 | 150 | 140 |

400 Psig DESIGN

| PYROLIZER DESIGN SUMMARY | | | | A/C = 1.72 | |
|---|---|---|---|---|---|
| Low Load vs Pressure Relation | Design | W = kP | | W = kP^n | |
| Load, % | 100 | 76 | 52 | 87 | 72 |
| DESIGN PARAMETERS | | | | | |
| Coal flow rate, lb/hr | 8000 | 6071 | 4142 | 6969 | 5756 |
| Limestone flow rate, lb/hr | 1884 | 1430 | 975 | 1641 | 1356 |
| Total Solids Flow, lb/hr | 9884 | 7501 | 5117 | 8610 | 7112 |
| Pressure Scale Down Index, n | – | 1.0 | 1.0 | 0.5 | 0.5 |
| Pyrolizer Bed Pressure, psig (linear W/ % load) | 400 | 300 | 200 | 300 | 200 |
| Pyrolizer Bed Pressure, psia (linear W/ % load) | 415 | 315 | 215 | 315 | 215 |
| Pyrolizer Bed Temperature, °F | 1600 | 1600 | 1600 | 1600 | 1600 |
| Total Pyrolizer Air/ Coal Ratio (From Mass Bal. Sheets) | 1.72 | 1.72 | 1.72 | 1.72 | 1.72 |
| Total Pyrolizer Air/ Coal Ratio (Calc. For Heat Reqd.) | 1.71 | 1.82 | 2.14 | 1.78 | 1.90 |
| Total Pyrolizer Air/Solids Ratio | 1.39 | 1.39 | 1.39 | 1.39 | 1.39 |
| Transport Air/Solids Flow Ratio | 0.8000 | 0.8000 | 0.8000 | 0.6969 | 0.5764 |

| SOLID PARTICLE SIZE | | | | | |
|---|---|---|---|---|---|
| Solid Particle Diameter For Design, mm | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Solid Particle Maximum Diameter, mm | 6.35 | 6.35 | 6.35 | 6.35 | 6.35 |
| Solid Particle Minimum Diameter, mm | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Sphericity for Bituminous Coal | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 |
| Sphericity* Coal Particle Design Diameter, mm | 2.58 | 2.58 | 2.58 | 2.58 | 2.58 |
| Sphericity* Coal Particle Maximum Diameter, mm | 5.46 | 5.46 | 5.46 | 5.46 | 5.46 |
| Sphericity* Coal Particle Minimum Diameter, mm | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 |

| FLUIDIZATION VELOCITIES | | | | | |
|---|---|---|---|---|---|
| Char Density(Assumed), lbm/ft^3 | 60 | 60 | 60 | 60 | 60 |
| Voidage @ Minimum Fludization Condition | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| Minimum Fluid'n Vel. For Design Particle Dia., ft/sec | 1.06 | 1.20 | 1.40 | 1.20 | 1.40 |
| Minimum Fluid'n Vel. For Max. Particle Dia., ft/sec | 3.56 | 4.07 | 4.88 | 4.07 | 4.88 |
| Minimum Fluid'n Vel. For Min. Particle Dia., ft/sec | 0.37 | 0.39 | 0.42 | 0.39 | 0.42 |
| Terminal Velocity For Design Particle Dia., ft/sec | 8.89 | 10.07 | 11.94 | 10.07 | 11.94 |
| Terminal Velocity For Max. Particle Dia., ft/sec | 14.14 | 16.12 | 19.29 | 16.12 | 19.29 |
| Terminal Velocity For Min. Particle Dia., ft/sec | 3.95 | 4.40 | 5.07 | 4.40 | 5.07 |
| Jetting Region Bed Voidage(Rihardson & Zaki) | 0.68 | 0.65 | 0.61 | 0.68 | 0.69 |
| Jetting Region Bed Voidage(Linear Fn(Umf, Ucf & Emf) | 0.60 | 0.57 | 0.54 | 0.60 | 0.61 |
| Fluidiz'n Vel. @ Jet Rgion Flows & Linear fn. Void, ft/sec | 3.24 | 3.24 | 3.25 | 3.72 | 4.52 |
| Bubbling Region Bed Voidage(Richardson & Zaki) | 0.73 | 0.70 | 0.66 | 0.74 | 0.75 |
| Bubbling Region Bed Voidage(Linear Fn(Umf, Ucf & Emf | 0.65 | 0.62 | 0.58 | 0.65 | 0.66 |
| Fluidiz'n Vel. @ Linear fn. void & Py. Flows, ft/sec | 3.96 | 3.98 | 4.01 | 4.56 | 5.58 |
| Bubbling Region Bed Voidage(Jovanavic–Fast Bubble) | 0.68 | 0.68 | 0.68 | 0.71 | 0.74 |
| Fluidiz'n Vel. @ Jovanavic Void & Py. Flows, ft/sec | 4.48 | 5.06 | 5.98 | 5.40 | 6.97 |

GPIF

400 Psig Design Pr.

| PYROLIZER DESIGN SUMMARY | | | | | A/C = 1.72 |
|---|---|---|---|---|---|
| Low Load vs Pressure Relation | Design | W = kP | | W = kP^n | |
| Load, % | 100 | 76 | 52 | 87 | 72 |
| **INNER JET** | | | | | |
| Solids Transport Air (Inner Jet) Flow, lb/hr | 7907 | 6000 | 4094 | 6000 | 4099 |
| Solids Transport Air Pr. @ Injection pt., psig | 400 | 300 | 200 | 300 | 200 |
| Solids Transport Air Temp. @ Injection pt., °F | 125 | 125 | 125 | 125 | 125 |
| Solids Transport Air (Inner Jet) Flow, ft^3/sec | 1.152 | 1.152 | 1.152 | 1.152 | 1.154 |
| Solids Transport Pipe(2-1/2"Sch.160) ID, in. | 2.125 | 2.125 | 2.125 | 2.125 | 2.125 |
| Air Vel. @ Solids Transport Pipe Exit (Vi), ft/sec | 46.8 | 46.8 | 46.8 | 46.8 | 46.8 |
| **OUTER JET** | | | | | |
| Total Outer Jet Air Flow, lb/hr | 5868 | 4453 | 3038 | 6000 | 5812 |
| Air Temperature @ Injection pt., °F | 400 | 400 | 400 | 400 | 400 |
| Total Outer Jet Air flow, ft^3/sec | 1.257 | 1.257 | 1.257 | 1.693 | 2.405 |
| Outer Jet Air Annulus Gap, in. | 0.4755 | 0.4755 | 0.4755 | 0.475 | 0.475 |
| Outer Jet Air Pipe (4" Sch.80) ID, in. | 3.826 | 3.826 | 3.826 | 3.826 | 3.826 |
| Outer Jet Air Superficial Vel. in Annulus, ft/sec(Vo) | 36.2 | 36.2 | 36.2 | 48.7 | 69.2 |
| **CHAR REMOVAL ANNULUS** | | | | | |
| Total Fluidizing Steam Flow, lb/hr | 1334 | 1012 | 691 | 1162 | 960 |
| Steam Pressure @ Injection pt. °F | 400 | 300 | 200 | 300 | 200 |
| Steam Temperature @ Injection pt., °F | 610 | 610 | 610 | 610 | 610 |
| Total Fluidizing Steam flow, ft^3/sec | 0.57 | 0.57 | 0.57 | 0.66 | 0.79 |
| % Of Total Fluidizing Steam Through Annulus | 70 | 70 | 70 | 70 | 70 |
| Steam Flow Through The Char Removal Annulus, lb/hr | 934 | 709 | 483 | 813 | 672 |
| Char Removal Annulus Gap, in. | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Char Removal Annulus Outer Pipe ID, in. | 8.063 | 8.063 | 8.063 | 8.063 | 8.063 |
| Superficial Velocity in Char Removal Annulus, ft/sec(Va) | 1.64 | 1.64 | 1.64 | 1.88 | 2.27 |
| Multiplying factor of Umf for Va | 1.54 | 1.37 | 1.16 | 1.57 | 1.62 |
| **SPARGER # 1** | | | | | |
| Design Steam Flow For Each Sparger 1 & 2, lb/hr | 560 | 425 | 290 | 488 | 403 |
| Design Steam Flow For Each Sparger 1 & 2, ft^3/sec | 0.240 | 0.240 | 0.240 | 0.275 | 0.333 |
| Sparger annulus 1 outer pipe(5"sch80) ID, in. | 4.813 | 4.813 | 4.813 | 4.813 | 4.813 |
| Sparger annulus 1 gap, in. | 0.1565 | 0.1565 | 0.1565 | 0.156 | 0.156 |
| Velocity in the Sparger Annulus 1, ft/sec | 15.1 | 15.1 | 15.1 | 17.3 | 21.0 |
| Number Of Orifices In Sparger 1 | 12 | 12 | 12 | 12 | 12 |
| Diameter Of Each Orifice Of Sparger 1, in. | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| Steam Velocity @ Each Orifice Of Sparger 1, ft/sec | 73.7 | 73.7 | 73.7 | 84.6 | 102.4 |
| **SPARGER # 2** | | | | | |
| Sparger Annulus 2 (6"sch80) ID, in. | 5.761 | 5.761 | 5.761 | 5.761 | 5.761 |
| Sparger Annulus 2 gap, in | 0.099 | 0.099 | 0.099 | 0.099 | 0.099 |
| Velocity in the Sparger Annulus 2, ft/sec | 19.6 | 19.6 | 19.6 | 22.5 | 27.2 |
| Number of Orifices In Sparger 2 | 12 | 12 | 12 | 12 | 12 |
| Diameter Of Each Orifice Of Sparger 2, in. | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Steam Velocity @ Each Orifice Of Sparger 2, ft/sec | 58.6 | 58.6 | 58.6 | 67.3 | 81.4 |

GPIF

400 Psig Design Pr Coke

# PYROLIZER DESIGN SUMMARY

A/C = 1.72

| Low Load vs Pressure Relation | Design | W = kP | | W = kP^n | |
|---|---|---|---|---|---|
| Load, % | 100 | 76 | 52 | 87 | 72 |
| **CONICAL GRID** | | | | | |
| Steam Flow For Conical Grid, lb/hr | 400 | 304 | 207 | 349 | 288 |
| Steam Flow For Conical Grid, ft^3/sec | 0.17 | 0.17 | 0.17 | 0.20 | 0.24 |
| Total Number Of Tubes In The Cone | 12 | 12 | 12 | 12 | 12 |
| ID of Each Tube, in. | 0.213 | 0.213 | 0.213 | 0.213 | 0.213 |
| Velocity @ The Exit Of Each Tube, ft/sec | 57.4 | 57.4 | 57.4 | 57.4 | 57.4 |
| **JET HEIGHT CALCULATION(YANG'S CORRELATION)** | | | | | |
| ID of support air annulus outer pipe*7.65, ft | 2.439 | 2.439 | 2.439 | 2.439 | 2.439 |
| Area corresponding to ID of air annulus out. pipe, ft^2 | 0.0798 | 0.0798 | 0.0798 | 0.0798 | 0.0798 |
| (Ucf)atmospheric/(Ucf)pressurized Ratio | 3.88 | 3.39 | 2.82 | 3.43 | 2.91 |
| 1/(particle density−gas density), ft^3/lb | 0.0111 | 0.0111 | 0.0111 | 0.0111 | 0.0111 |
| 1/(gravity(32.174)*ID of air annul out. pipe),(sec/ft)^2 | 0.0975 | 0.0975 | 0.0975 | 0.0975 | 0.0975 |
| Flow area of transport Noz. & air annulus, ft^2 | 0.0594 | 0.0594 | 0.0594 | 0.0594 | 0.0594 |
| Equivalent Diameter for flow area, ft | 0.2750 | 0.2750 | 0.2750 | 0.2750 | 0.2750 |
| Jet Momentum based on ID of Annulus, lb/ft−sec^2 | | | | | |
| Jet Momentum Due To Transport Air, lb/ft−sec^2 | 1287 | 977 | 666 | 976 | 668 |
| Jet Momentum Due To Solids, lb/ft−sec^2 | 1303 | 958 | 620 | 1100 | 863 |
| Jet Momentum Due to Support Air, lb/ft−sec^2 | 738 | 560 | 382 | 1017 | 1399 |
| Total Jet Momentum, lb/ft−sec^2 | 3328 | 2495 | 1669 | 3093 | 2931 |
| Overall Jet Ht. based on ID of Air Annulus, ft. | 8.5 | 6.9 | 5.3 | 7.7 | 7.0 |
| Overall Jet Ht. based on equiv. ID of flow area, ft. | 8.4 | 6.9 | 5.2 | 7.7 | 6.9 |
| **JET BUBBLE SIZE & JET HALF ANGLE** | | | | | |
| Total air through jet nozzle, lb/hr | 13775 | 10453 | 7132 | 12000 | 9912 |
| Pyrolizer Bed Pressure, psig | 400 | 300 | 200 | 300 | 200 |
| Pyrolizer Bed Temperature, °F | 1600 | 1600 | 1600 | 1600 | 1600 |
| Air Density @ Bed Pr. & Temp., lb/ft^3 | 0.5433 | 0.4123 | 0.2813 | 0.412 | 0.281 |
| Total Jet Air Volumetric flow, ft^3/sec | 7.042 | 7.042 | 7.042 | 8.084 | 9.787 |
| Bubble Dia. based on Bosev et al(1969), in. | 17 | 17 | 17 | 18 | 19 |
| Bubble Dia. based on Davidson & Harrison, in. | 17 | 17 | 17 | 18 | 19 |
| Max. Bubble Dia. based on volume of Jet air & Umf , in | 25 | 23 | 21 | 25 | 25 |
| Bubble Vol. based on Bosev et al(1969), in. | 1.54 | 1.54 | 1.54 | 1.80 | 2.24 |
| Bubble Vol. based on Davidson & Harrison, in. | 1.49 | 1.49 | 1.49 | 1.76 | 2.21 |
| Max. Bubble Vol. based on Max. bubble Dia., in | 4.55 | 3.80 | 2.99 | 4.68 | 4.89 |
| Jet half Angle based on Bosev et al., deg | 3.6 | 4.4 | 5.7 | 4.2 | 5.1 |
| Jet Half Angle based on Davidson & Harrison, in. | 3.5 | 4.3 | 5.7 | 4.2 | 5.1 |
| Jet half Angle based on Max. bubble Dia., deg | 5.7 | 6.4 | 7.6 | 6.3 | 7.1 |
| Bubble Rise Vel., ub, ft/sec (Eqn 12.6−Davidson) | 4.80 | 4.80 | 4.80 | 4.94 | 5.13 |

400 Psig Design Pr. Case.

| PYROLIZER DESIGN SUMMARY | | | | | A/C = 1.72 |
|---|---|---|---|---|---|
| Low Load vs Pressure Relation | Design | W = kP | | W = kP^n | |
| Load, % | 100 | 76 | 52 | 87 | 72 |
| CHECK ON SOLIDS RESIDENCE TIME ABOVE THE JET TOP FOR 100% DEVOLATALIZATION | | | | | |
| Avg. Solids Residence Time Above the Jet, min. | 7.75 | 12.02 | 20.86 | 9.10 | 11.13 |
| Time Reqd. For 100% Devolatalization (Pillai, 1981) | Coal Analysis Used | | Ft.Martin | Ft.Martin | Ft.Martin |
| Coal Type | In Mass Bal. A-8 | | Mapco#2 | Meltiki#2 | Consol#2 |
| Free Swelling Index(FSI) of the Coal | Assume <6 | Assume >6 | 3.5 | 9 | 7.5 |
| Coal Volatiles, % (dry ash free) | 36.4 | 36.4 | 41.0 | 21.6 | 40.0 |
| Average Bed Temperature, °F | 1600 | 1600 | 1600 | 1600 | 1600 |
| Design Particle Size With Sphericity, mm | 2.58 | 2.58 | 2.58 | 2.58 | 2.58 |
| Time for 100% Devolatilization, tv–press.., min. | 0.23 | 0.62 | 0.22 | 0.54 | 0.59 |
| Maximum Particle Size With Sphericity, mm | 5.46 | 5.46 | 5.46 | 5.46 | 5.46 |
| Time for 100% Devolatilization, tv–press.., min. | 0.44 | 1.18 | 0.39 | 0.91 | 1.09 |
| Minimum Particle Size With Sphericity, mm | 0.86 | 0.86 | 0.86 | 0.86 | 0.86 |
| Time for 100% Devolatilization, tv–press.., min. | 0.09 | 0.24 | 0.09 | 0.25 | 0.25 |
| Conclusion: There is enough Residence Time Above The Jet Top For 100% Devolatalization | | | | | |

| FLOW VELOCITY ALONG THE JET AXIS | | | | | |
|---|---|---|---|---|---|
| Distance Downstream of Jet Entry, x, ft | 25 | 25 | 25 | 25 | 25 |
| Average Jet Inj. Vel @ Noz. Exit, ft/sec | 44.1 | 44.1 | 44.1 | 47.3 | 54.5 |
| Overall Bed Density, lb/ft^3 | 21.5 | 23.3 | 25.4 | 21.1 | 20.5 |
| Flow Velocity @ x along the Jet Axis(Slip Vel.) | 1.10 | 0.92 | 0.73 | 1.07 | 1.06 |
| Terminal Velocity For Min. Particle Dia., ft/sec | 3.95 | 4.40 | 5.07 | 4.40 | 5.07 |
| Terminal Velocity For Design Particle Dia., ft/sec | 8.89 | 10.07 | 11.94 | 10.07 | 11.94 |
| (Jet Flow Vel. + Comp. Fluid Vel.), ft/sec | 4.33 | 4.16 | 3.98 | 4.79 | 5.58 |
| CHAR TO COAL CONCENTRATION ALONG THE JET HEIGHT | | | | | |
| Coal Concentration @ x, lb/ft^3 | 0.22 | 0.20 | 0.17 | 0.20 | 0.17 |
| Diff. bet. Char Conc. in Bed & Jet Axis, lb/ft^3 | 12.24 | 15.96 | 22.16 | 14.19 | 16.93 |
| Char Concentration @ x, lb/ft^3 | 8.94 | 7.12 | 3.11 | 6.66 | 3.35 |
| Distance from jet nozzle on Jet Axis @ 0.5 sec, ft | 5.2 | 4.8 | 4.3 | 5.2 | 5.1 |
| Char./Coal Conc. @ time = 0.5 sec | –35 | –57 | –102 | –50 | –77 |
| Distance from jet nozzle on Jet Axis @ 1 sec, ft | 7.4 | 6.8 | 6.0 | 7.3 | 7.3 |
| Char./Coal Conc. @ time = 1 sec | –27 | –48 | –92 | –41 | –66 |
| Time To Reach Top of Jet Height, sec | 1.3 | 1.1 | 0.8 | 1.1 | 0.9 |
| Char./Coal Conc. @ Top of jet | 32 | 32 | 30 | 32 | 34 |
| Time To Reach Top of Pyrolizer, sec | 14 | 17 | 21 | 14 | 14 |
| Char./Coal Conc. @ Top of Pyrolizer | 37 | 28 | 2 | 27 | 7 |
| Along the Jet Axis, Residence Time Above Jet Top, sec | 12.64 | 15.63 | 20.32 | 13.01 | 13.35 |

| SUPERFICIAL GAS VELOCITY PROFILE | | | | | |
|---|---|---|---|---|---|
| Gas Flow @ Pyrolizer Bottom, lb/hr | 15109 | 11466 | 7822 | 13162 | 10871 |
| Gas Temperature @ Pyrolizer Bottom, °F | 1600 | 1600 | 1600 | 1600 | 1600 |
| Gas Velocity in Pyrolizer(21"Dia) ft/sec | 3.24 | 3.24 | 3.25 | 3.72 | 4.52 |
| Pyrolizer Product Gas Flow, lb/hr | 19496 | 14795 | 10094 | 16984 | 14028 |
| Pyrolizer Product Gas Temperature @ Its Outlet, °F | 1637 | 1637 | 1637 | 1637 | 1637 |
| Gas Velocity in Pyrolizer(24"Dia) ft/sec | 3.96 | 3.98 | 4.01 | 4.56 | 5.58 |
| Gas Superficial Vel., Inlet to the inner annulus, ft/sec | 5.51 | 5.33 | 5.01 | 6.12 | 6.96 |
| (Gas+Fines) Velocity, inlet to the inner annulus, ft/sec | 7.32 | 7.08 | 6.66 | 8.13 | 9.25 |
| Gas Superficial Vel., Outlet of the inner annulus, ft/sec | 3.11 | 3.01 | 2.83 | 3.45 | 3.93 |
| (Gas+Fines) Vel., Outlet of the inner annulus, ft/sec | 4.12 | 3.98 | 3.74 | 4.57 | 5.20 |
| Gas Velocity, Fixed Bed Exit, ft/sec | 0.44 | 0.45 | 0.45 | 0.51 | 0.63 |
| Gas Vel. – Outer Annulus @ Shroud Bot., ft/sec | 1.07 | 1.06 | 1.08 | 1.22 | 1.50 |

PyGas™ COAL GASIFIER
**PDB No. 40-1AA-1**

# MAJOR PHILOSOPHY FOR SAFE OPERATION (HAZOPS CREDO)

1. The incinerator/WHB is the primary disposal method of the coal gas.
2. The most environmentally friendly way of consuming coal gas is in the incinerator/WHB.
3. Coal gas produced from the gasifier will normally flow to the incinerator/WHB.
4. Only in an emergency will coal gas be diverted to the flare.
5. The gasifier outlet rupture disk is the code compliant gas pressure relief safety.
6. Venting to the flare is an emergency shut-down operation for equipment & personnel protection.
7. Gasifier testing should only proceed if the incinerator/WHB is in service.
8. The coal preparation system shall be operated as a direct fired system per NFPA.
9. The oxygen concentration leaving the pyrolyzer tube should not be allowed to exceed 1% vol when either the pyrolyzer or the fixed-bed are generating coal gas.
10. The oxygen concentration leaving the fixed-bed should not be allowed to exceed 4% vol whenever either the pyrolyzer or the fixed-bed are generating coal gas.

# NORMAL START-UP, NORMAL SHUT-DOWN, EMERGENCY SHUT-DOWN TO INCINERATOR/WHB, EMERGENCY SHUT-DOWN TO FLARE, UNCONTROLLED EMERGENCY SHUTDOWN

The following reflects the conceptualized normal start-up procedure assuming "cold" start-up conditions. It should be anticipated that all safety related interlocks and permissives to include all fail-safe equipment design considerations will be integrated into this plan as the detailed design process continues.

## NORMAL START-UP

(Verify all cooling water systems are filled and in operation)

1. START INCINERATOR/WHB AND BRING TO OPERATING CONDITION

2. PROVE GASIFIER WATER JACKET COOLING CIRCULATION

3. NITROGEN PURGE THE GASIFIER INTO THE INCINERATOR/WHB

4. PRE-HEAT GASIFIER JACKET COOLING SYSTEM WITH STEAM
   (flow and rate of temperature rise per mechanical design requirements)
   WHEN GASIFIER DRUM TEMPERATURE EXCEEDS SATURATION, STEAM WILL VENT THROUGH THE GRATE PREVENTING PREMATURE IGNITION OF FIXED-BED. MAINTAIN MINIMUM STEAM FLOW.

5. START AIR COMPRESSOR AND BUILD PRESSURE (within mechanical stress limit constraints) TO START-UP PRESSURE
   (approximately 30 psi gas side pressure)
   (air flows into INCINERATOR/WHB);
   PROVE INCINERATOR/WHB COAL GAS FLAME SCANNER SEES STABILIZATION FLAME, AND EMERGENCY FLARE READY PERMISSIVE IS MET

6. PREHEAT PYROLYZER CONE WITH NATURAL GAS (Direct Combustion in Fluidized Cone) (flow and rate of temperature rise per mechanical design requirements) UNTIL TEMPERATURE REACHES 1000°F (anticipate several hours)

7. ADJUST PYROLYZER AIR AND STEAM FLOW TO MINIMUM FLUIDIZATION FLOW RATE (at proper ratio for startup; air flow to reach set point pyrolyzer operating temperature and steam flow will be required in both the coal conveying and pyrolyzer fluidization streams)
   BYPASS BALANCE OF COMPRESSOR AIR TO ATMOSPHERE (if necessary)

8. ADD COKE, CHAR OR LOW VOLATILE NON-CAKING COAL TO PYROLYZER AT MINIMUM FLOW RATE
   (approximately one tenth of maximum rotary feeder speed)

9. RAISE PYROLYZER TEMPERATURE TO SET POINT (approx. 1600°F), THEN SHUT DOWN DIRECT PRE-HEATING (will likely take several minutes), AND BUILD SOLIDS BED IN PYROLYZER.

10. SWITCH TO TEST COAL WHEN PYROLYZER LEVEL INDICATOR/MONITOR INDICATES PYROLYZER SOLIDS OVERFLOW (prevents caking before bed can accept increased coal flow)

11. AS COAL RATE IS INCREASED, ADJUST PYROLYZER AIR FLOW TO MAINTAIN SET POINT TEMPERATURE, AND DECREASE STEAM FLOW WHILE MAINTAINING ABOVE MINIMUM FLUIDIZATION FLOW (may be automatically controlled)

12. WHEN INDICATOR/MONITOR INDICATES PROPER FIXED-BED SOLIDS LEVEL, TURN ON GRATE AIR AND INCREASE GRATE STEAM TO MAINTAIN SET POINT PEAK BED TEMPERATURE (approximately 2300°F; may be automatically or manually controlled)

13. GRATE ROTATION IS INITIATED WHEN INDICATOR/MONITOR INDICATES HIGH SOLIDS LEVEL

14 GRATE SPEED IS PROPORTIONED BY COAL FEED RATE AND TRIMMED BY ABOVE GRATE TEMPERATURE SET POINT (decreases speed as temperature increases, and the reverse)

15. HIGH INNER ANNULUS DELTA PRESSURE OVERRIDES TEMPERATURE CONTROL OF GRATE SPEED AND INCREASES GRATE SPEED UNTIL INDICATOR/MONITOR INDICATES LOSS OF BED LEVEL. HIGH ABOVE GRATE TEMPERATURE INCREASES GRATE STEAM FLOW.

## NORMAL SHUT-DOWN

1. RAMP OPERATING PRESSURE TO 30 PSI.
(rate of temperature decline per mechanical design requirements)

2. REDUCE COAL FEED TO MINUMUM FEED RATE (Approximately 10%).

3. STOP COAL FEED.

4. PURGE PYROLYZER INVENTORY; CONTROL PYROLYZER OPERATING TO 1500°F TO PREVENT AGGLOMERATION

5. START DIRECT PRE-HEAT NATURAL GAS BURNER TO CONTROL RATE OF PYROLYZER CONE TEMPERATURE DECLINE IF NECESSARY
(rate of temperature decline per mechanical design requirements)

6. STOP AIR FLOW TO PYROLYZER. AS PYROLYZER TEMPERATURE DECREASES, REDUCE STEAM FLOW (may be automatic)

7. ALLOW FIXED-BED TO BURN-OUT CONTROLLING PEAK BED TEMPERATURE AT SETPOINT

8. STOP ALL AIR FLOW & INDIRECT HEATER & CONTINUE REDUCING STEAM FLOW THROUGH PYROLYZER & GRATE UNTIL ITS TEMPERATURE IS CLOSE TO WATER JACKET (rate of temperature decline per mechanical design requirements); THEN STOP STEAM FLOW & PURGE WITH NITROGEN.

9. REMOVE REMAINING SOLIDS FROM FIXED-BED VIA THE GRATE AND PRESSURE LOCKS

10. CONTINUE NITROGEN FLOW THROUGH GRATE UNTIL ITS TEMPERATURE IS CLOSE TO WATER JACKET; THEN STOP NITROGEN FLOW

11. INERT WITH NITROGEN, AND ISOLATE WITH A NITROGEN BLANKET TO PROTECT AGAINST FIRES AND CORROSION
(important note: bypass this step if personnel expect to enter system within 2 days)

12. SHUT DOWN THE INCINERATOR/WHB

13. CLOSE FLUE GAS ISOLATION DAMPER TO FT MARTIN

14. SHUT DOWN ALL WATER COOLING CIRCUITS

15. NITROGEN BLANKET ALL WATER CIRCUITS TO PROTECT AGAINST CORROSION
(important note: bypass this step if personnel expect to enter system within 2 days)

16. WHEN COOL, AIR PURGE SYSTEM THROUGH THE INCINERATOR/WHB PRIOR TO ALLOWING ANY PERSONNEL ENTRY INTO THE SYSTEM.

## CONTROLLED EMERGENCY SHUTDOWN TO INCINERATOR/WHB

INITIATED AUTOMATICALLY OR BY OPERATOR

COVERS THE FOLLOWING CASES:

1. LOSS OF COAL FEED
2. WATER LEAK INTO SHELL
3. HIGH TEMPERATURE ALARM ON GASIFIER OUTLET

PROCEDURE:

1. STOP COAL AND AIR COMPRESSOR
2. DEPRESSURIZE SYSTEM TO INCINERATOR/WHB AT A CONTROLLED RATE USING STEAM
   (rate of pressure decline per mechanical design requirements)
3. REDUCE STEAM TO PYROLYZER & GASIFIER TO MINIMUM
4. CLOSE FLUE GAS ISOLATION DAMPER TO FT MARTIN
5. DRAIN PYROLYZER CHAR THROUGH ASH LOCK SYSTEM
6. INERT WITH NITROGEN
   (important note: bypass this step if personnel expect to enter system within 2 days)
7. EITHER CONTINUE SHUT-DOWN FOLLOWING NORMAL SHUT-DOWN PROCEDURES, OR LEAVE SYSTEM BLANKETED UNTIL READY FOR RESTART (OPERATOR DECISION)

# CONTROLLED EMERGENCY SHUTDOWN TO FLARE (OR INCINERATOR/WHB STUB STACK)

INITIATED AUTOMATICALLY OR BY OPERATOR

COVERS THE FOLLOWING CASES:

1. LOSS OF ELECTRIC POWER
2. INCINERATOR/WHB GOES DOWN
3. FORT MARTIN GOES DOWN

ITEMS IN THE PROCEDURE ARE LISTED SEQUENTIALLY, HOWEVER, EVENTS 1 THRU 4 ARE SIMULTANEOUS (by control system)

PROCEDURE:

1. TRIP AIR COMPRESSOR
2. STOP COAL AND AIR TO GASIFIER
3. OPEN FLARE (OR INCINERATOR/WHB STUB STACK) CONTROL VALVE AND DEPRESSURIZE SYSTEM AT A CONTROLLED RATE
   (rate of pressure decline per mechanical design requirements)
4. DEPRESSURIZE SYSTEM TO INCINERATOR/WHB AT A CONTROLLED RATE USING STEAM (rate of pressure decline per mechanical design requirements)
5. REDUCE STEAM TO PYROLYZER & GASIFIER TO MINIMUM
6. TRIP VENT SYSTEM
7. CLOSE FLUE GAS ISOLATION DAMPER TO FT MARTIN
8. DRAIN PYROLYZER CHAR THROUGH ASH LOCK SYSTEM
9. INERT WITH NITROGEN
   (important note: bypass this step if personnel expect to enter system within 2 days)
10. CLOSE FLARE (OR INCINERATOR/WHB) CONTROL VALVE AND LEAVE SYSTEM UNDER NITROGEN BLANKET
    (important note: bypass this step if personnel expect to enter system within 2 days)
11. EITHER CONTINUE SHUT-DOWN FOLLOWING NORMAL SHUT-DOWN PROCEDURES, OR LEAVE SYSTEM BLANKETED UNTIL READY FOR RESTART (OPERATOR DECISION)

## UNCONTROLLED EMERGENCY SHUTDOWN

INITIATED AUTOMATICALLY

COVERS THE FOLLOWING CASES:

1. PRESSURE RELIEF THROUGH RUPTURE DISK

ITEMS IN THE PROCEDURE ARE LISTED SEQUENTIALLY, HOWEVER, EVENTS 1 THROUGH 6 ARE SIMULTANEOUS (by control system)

PROCEDURE:

1. TRIP AIR COMPRESSOR
2. STOP COAL AND AIR TO GASIFIER
3. TRIP INCINERATOR/WHB
4. CLOSE FLUE GAS ISOLATION DAMPER TO FT MARTIN
5. INERT GASIFIER WITH STEAM
6. INERT WITH NITROGEN
7. CONTINUE SHUT-DOWN FOLLOWING NORMAL SHUT-DOWN PROCEDURES

| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| Locked Out **(Inerted/Idle)** | All systems locked out. | Warning alarm permissive. |
| **A Ready for Start-up** | All systems ready. | All permissives met. |
| System Purged **(Idle/Purge)** | Incinerator/WHB then gasifier are air purged using induced draft fan. | Prerequisite to personnel entry. O2 test must prove air present. Flue gas isolation damper to Ft. Martin then closed. ID fan then tripped & proven shut down. |
| Precharged **(Purge/Pre-Charge)** | Fixed-bed is manually loaded with startup materials. | Breathing air introduced into gasifier. Other gasifier systems locked-out. |
| Nitrogen Purged **(Pre-Charge/Inerted)** | Nitrogen system on with continuous flow through gasifier out flare stack until $O_2 < 5\%$. | This step not necessary if startup is imminent (within one day). |
| Water Filled **(Inerted/Water Filled)** | WHB water drum level proven. Gasifier water drum level proven. | Condensate water (110°F max) used to fill both WHB circuits & gasifier jacket prior to start-up. |
| Water Circulating **(Water Full/Circ.)** | WHB circulating water pump on. Gasifier circulating water pump on. | Proven water circulation is a WHB & gasifier start-up permissive. |
| **B WHB in Service** | Generating Steam at 353 psig/530°F | WHB prerequisite to Gasifier opn. |
| Incinerator Spt Fuel Burn **(Idle/WHB In Service)** | Incinerator firing on support fuel. | Boiler drum water temperature rise rate during start-up of 100°F/hour. |
| Start-up System : Cold Stand-by **(Circ./Ready)** | Air compressor on and receiver at minimum pressure (in venting mode). | Gasifier purging and drying-out with compressed air decompressing through system to Incinerator/WHB. |
| Steam Pre-heat Method **(Ready/Pre-heat)** | Jacket water heater and pump is in service. Steam the cooling circuit to pre-heat water. | Water jacket and gasifier water cooled internals always at slightly higher pressure than gasifier gas side (well within maximum full load differential pressure). Rate of gasifier drum water temperature rise limit is 100°F per hour. |

| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| Alternate Start-up System Gas Pre-heat Method **(Ready/Pre-heat)** | Unheated jacket water (approx. 110°F). Indirect natural gas pre-heat burner in service. 1200°F heated compressed air entering pyrolyzer. | WHB must be in service. Heat water until rate of gasifier drum temperature rise becomes less than 100°F per hour. Then add "shot of solid fuel" to pyrolyzer. When pyrolyzer temperature starts to rise, set solid fuel feed rate to minimum. Raise gasifier cooling water temperature at 100°F per hour until steam pressure exceeds air pressure. |
| **C System Dry** | Pre-heat in Service. | 530°F Superheated Steam available. |
| Cone Air Pre-heat **(Ready/Cone Pre-heat)** | Introduce pre-heated air into pyrolyzer and steam & nitrogen into fixed-bed. Use jacket.auxiliary indirect air pre-heater & sand to heat pyrolyzer refractory. | Pressure balance maintained between jacket & gasifier. Also between nitrogen and air flows. Flow and pressure dependent upon pressure letdown system. Steam/nitrogen maintained below minimum fluidization velocity in fixed-bed. Preheater output. Materials thermal stress constraints. Maintain steam/nitrogen purge in the fixed-bed to prevent premature ignition and moisture condensation. Pressure ramp limited by gasifier steam condensation temperature. Gasifier train through WHB must be above condensation temperature. |
| **D Ready for Ignition** | Pre-heat system in operation. | 1000°F cone temperature reached by burning natural gas in fluidized cone. |
| Coke Pre-heat **(Cone PH/Coke PH)** | Conveying coke with hot air and sustain substoichiometric air to heat the pyrolyzer. | Maintain velocities below the point of solid fuel feed carryover during building of pyrolyzer solids inventory. Maintain maximum combustion temperatures below ash fusion temperatures by introducing annular steam flow when necessary. Maintain minimum fluidization of solids. |

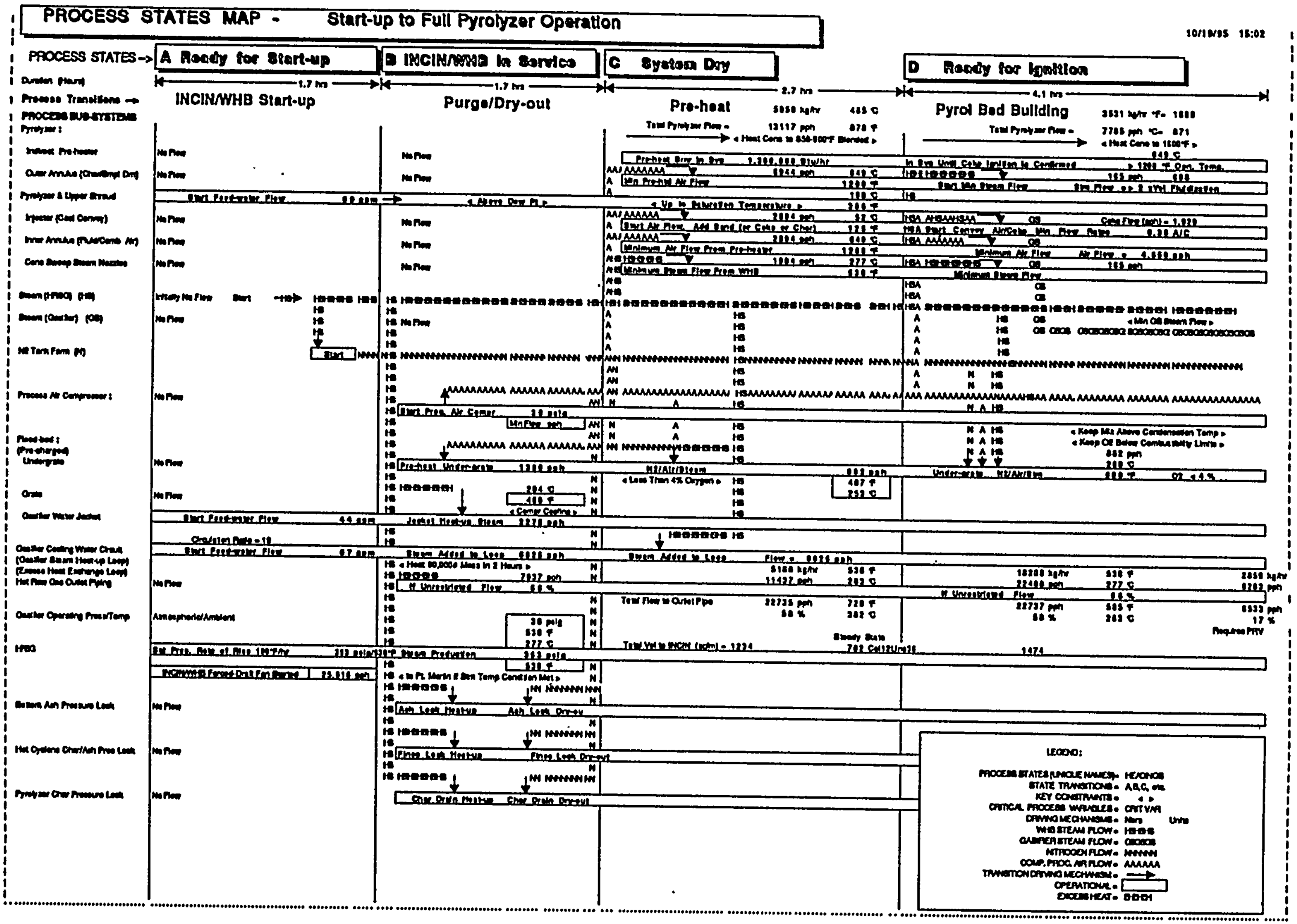
| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| Bed-building **(Coke PH/Bed Bldg)** | Build coke bed in pyrolyzer sufficient to obtain coke ignition while continuing to pre-heat the pyrolyzer.Continue conveying coal/coke to completely fill the pyrolyzer. Shut down pyrolyzer cone pre-heater. | Coke feed rate. Solids entrainment velocity. Minimum fluidization velocity. Coke bed level below the water walls to minimize heat losses until ignition is achieved. Maintain sufficient oxygen to offset increased heat losses due to water walls. Maintain velocities below the point of jet penetration through the bed to prevent hot char carryover. Maintain temperatures above dew-point of sulfur when feeding coal. |
| **E Pyrolyzer in Service** | Char/Air/Steam feed to pyrolyzer. | Char inventory built. |
| Direct Grate Heating Hot Char **(Bed-Bldg/Grate Ign)** | Allow hot pyrolyzer char to overflow the pyrolyzer and fall onto the grate below. Operate grate for at least one revolution. | Pyrolyzer temperature >1200°F. Grate Oxygen concentration <4%. Assure hot char distribution. |
| **F Fixed-bed Ignited** | Char/Air/Steam feed to fixed-bed. | Several feet of hot char (at 1600°F) inventory built on fixed-bed. |
| Fixed-bed Building **(Grate Ign/Bed Bldg)** | Ignite fixed-bed. Start flow of air and steam under the grate. Pyrolyzer char overflowing. | Adjust air flow to retain the combustion zone within the bed (ie no oxygen breakthrough). Adjust steam to keep peak temperature below ash fusion temperature. Maintain grate rotation to ensure uniform solids bed temperature profile. |

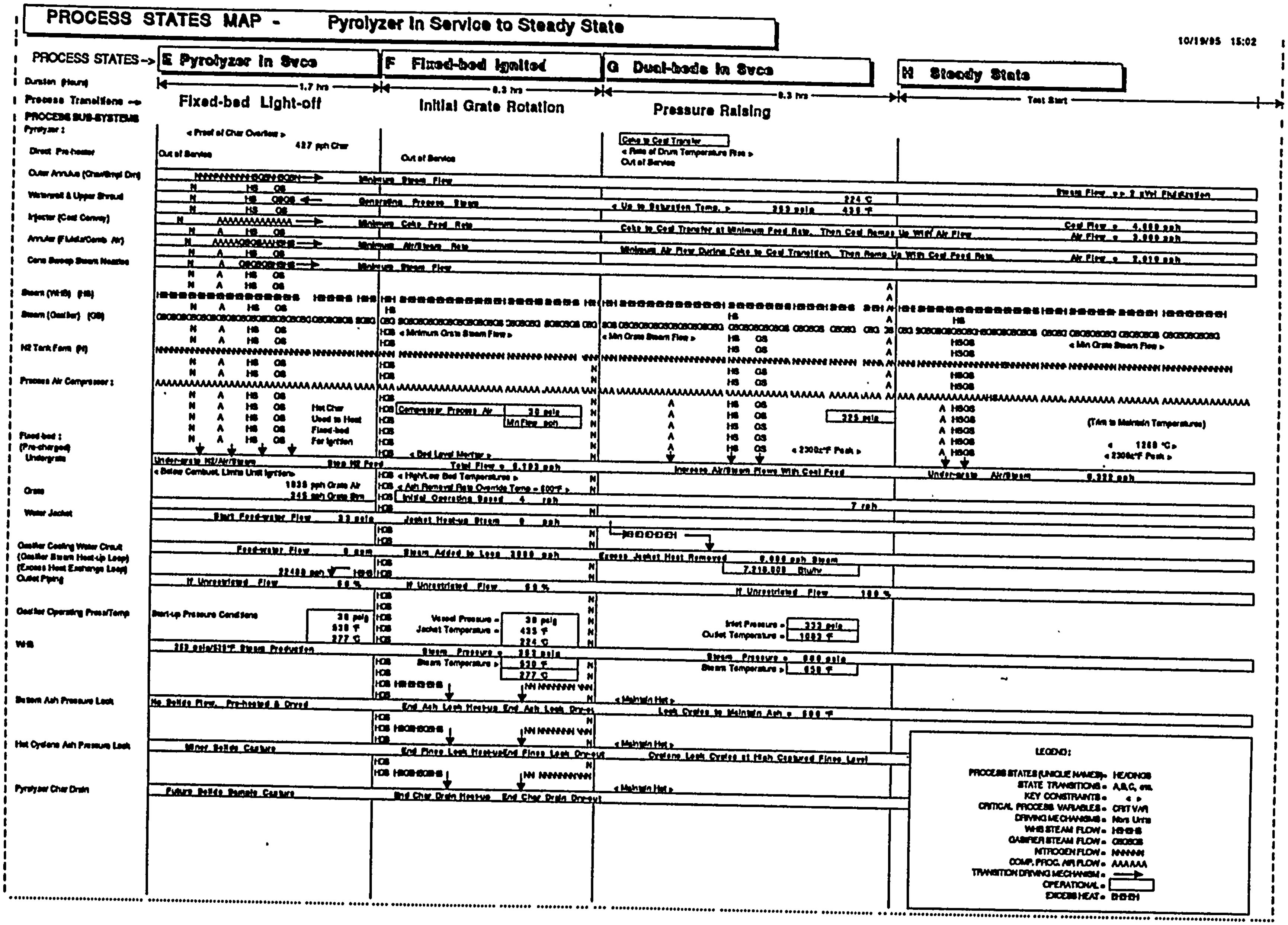
| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| **G Dual-beds in Service** | Char/Air/Steam feed to pyrolyzer and fixed-bed. | Oxygen at outlet < 4% vol. |
| Pressure Ramp **(Bed Bldg/Pres Ramp)** | Incrementally increase the pressure by increasing throughput. | Fluidization air flow in fluid-bed. Stay below fines entrainment velocity. Avoid channeling in fixed-bed by maintaining sufficient grate steam flow to maintain peak fixed-bed temperatures below ash fusion temperature. Maintain water jacket and gasifier pressure balance. Adjust air flows in fixed-bed and air/coke ratio in pyrolyzer to compensate for higher wall temperatures and lower heat losses at lower pressures by maintaining set-point temperatures. coke feed ramp. Balance input flows in fixed-bed to prevent gases from penetrating the fixed-bed. |
| Coal Feed **(Pres Ramp/Coal Feed)** | Switching from coke to coal feed. | Adjust the coal/coke, air and steam flows in the nozzle to maintain desired reaction temperature. Maintain fluidization and sub-entrainment velocity in the pyrolyzer. Maintain desired pyrolyzer jet penetration momentum by operating at appropriate coal/air/steam flows. |
| **H Steady State** | All test load required systems in service. | No transients. |
| Gasification **(Coal Feed/Gasification)** | Low sulfur bituminous coal. | Adjust the grate speed to keep the bed level from raising above the shroud (high bed level) during tests which do not call for inner annulus solids inventory (initial tests). Adjust the grate air flow to consume carbon laden ash. Adjust grate steam flow to control peak fixed-bed temperature below the ash fusion temperature. Increase low solids bed-level by reducing grate speed. Raise peak fixed-bed temperature elevation by increasing grate air/steam flow. Lower peak fixed-bed temperature elevation by reducing grate air/steam flow (within ash carbon loss limitations). |

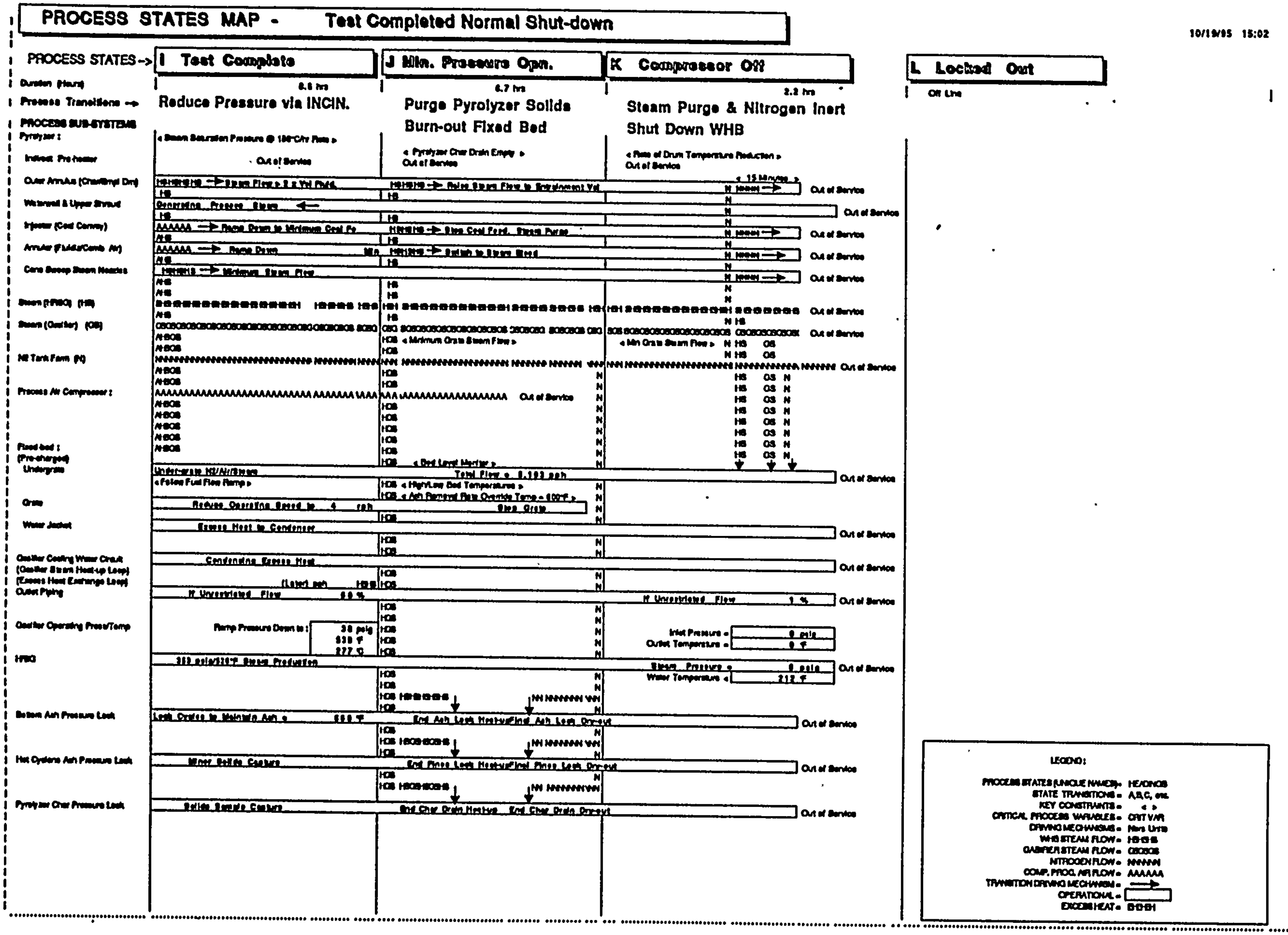
| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| Hot Hold **(Stdy State/Min Opn)** | Minimum pyrolyzer coal feed & fluidization. Pyrolyzer air flow at minimum operating temperature. Minimized fixed-bed air, steam, & bottom ash (grate speed) flows. | Coal caking characteristics will affect minimum pyrolyzer velocities and operating temperature. When fixed-bed combustion zone moves up-ward to top of bed and temperature cannnot be maintained, stop under-grate air & steam flows. When fixed-bed temperature becomes reduced to below 800°F, abort test and stut-down. |
| Co-flow Bed Building **(Gasif/CF Bed Bldg)** | Adjust the grate speed to raise the fixed-bed level above the shroud. | Avoid high pressure drop in the inner annulus. Avoid filling outer annulus with solids to gasifier outlet gas nozzle. |
| Sub-bituminous Coal Gasification **(CF Bed Bldg/Sub-bit Gasif)** | Switching from coke to sub-bituminous coal. | Adjust the coal/coke, air and steam flows in the nozzle to maintain desired reaction temperature. Maintain fluidization and sub-entrainment velocity in the pyrolyzer. Maintain desired pyrolyzer jet penetration momentum by operating at appropriate coal/air/steam flows. |
| High Sulfur Bituminous Gasification **(CF Bed Bldg/Bit Coal Gasif)** | Switching from coke to high sulfur bituminous coal | Not an option unless previous testing with limestone proves sufficient sulfur capture, or previous testing with Phase II HGCU provided sufficient sulfur capture. Adjust the coal/coke, air and steam Coal flows in the nozzle to maintain desired reaction temperature. Maintain fluidization and sub-entrainment velocity in the pyrolyzer. Maintain desired pyrolyzer jet penetration momentum by operating at appropriate coal/air/steam flows. |
| Coal Plus Limestone Gasification **(Coal Gasif/Sorb Feed)** | Co-feeding of pressure lock with coke and limestone. | Wall temperatures above lime hydration temperature. Do not feed limestone at flow rates which produce low temperature eutectics when combined with coal ash (prior ash analysis information required). |
| Top Injection **(Sorb Feed/Top Air Injection)** | Introduce Air and/or steam into top injector. | Max. temperature below ash fusion temperature. Materials temperature constraint. Insure top air/steam injector has been added to system. |

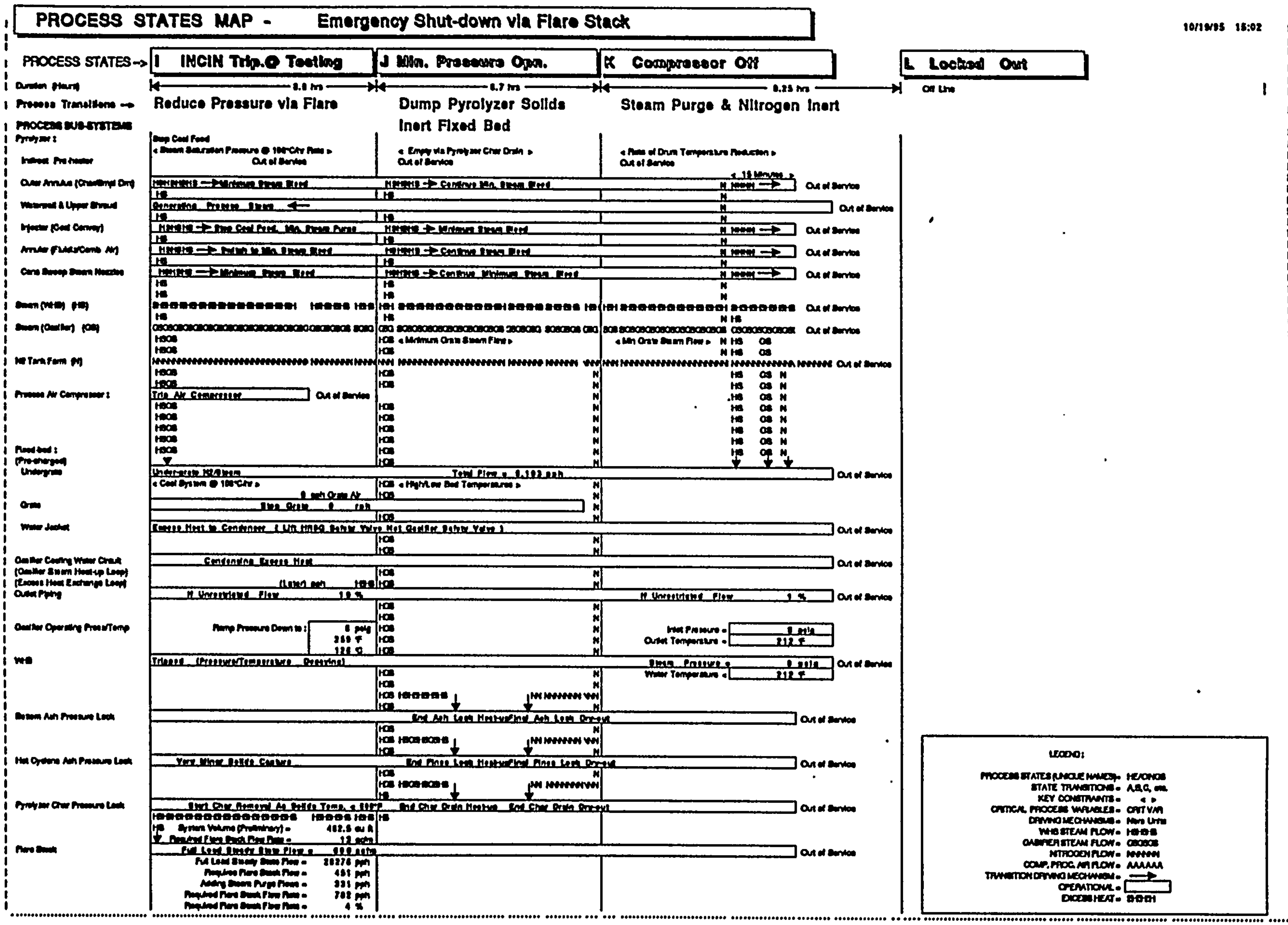
| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| **I Test Complete** | All test load required systems in service. | No transients. |
| **J Minimum Pressure Opn** | Ramp down complete. | 30 psig pressure. |
| Bed Burnout **(TA Inject/Bed Burn)** | Purge fluid-bed & burn-out fixed-bed. Produce a benign ash. | Low pressure operation similar to start-up sequence. Preclude mixing of reducing and oxidizing gases. Avoid entrainment of solids. |
| Controlled Shut-down General | Gradually reduce pressure and temperature by decreasing throughput. | Steam from gasifier drum used to balance pressure. Follow bed-burnout. |
| **K Compresor Off** | Coal feed also off. | Use superheated steam to gasifier outlet to maintain system pressure under controlled pressure ramp-down. |
| **L Locked Out** | All systems off. | Nitrogen inerted unless personnel entry is anticipated. System cooled to 150°F. |
| Controlled Emergency Shut-down via WHB **(Opn/Cntr Shut-dn WHB)** | Loss of Coal Feed | Follow NORMAL SHUT-DOWN procedure. Extend the process while attempting to reestablish coal feed.If cause is found and corrected, follow NORMAL START-UP procedure from appropriate STATUS STATE. |
| | Water Leak Into Gasifier Vessel | Follow NORMAL SHUT-DOWN procedure with HRSG incineration. |
| | High Gasifier Exit Gas Temperature Increasing steam flow has failed. | Follow NORMAL SHUT-DOWN procedure. Accelerate the process to reduce operating pressure to a safe level. If cause is found and corrected, follow NORMAL START-UP procedure from point of pressure raising. |
| | Loss of Gasifier Water Cooling | Follow NORMAL SHUT-DOWM procedure. Accelerate the process. If cause is found and corrected, follow NORMAL START-UP procedure from appropriate STATUS STATE. |

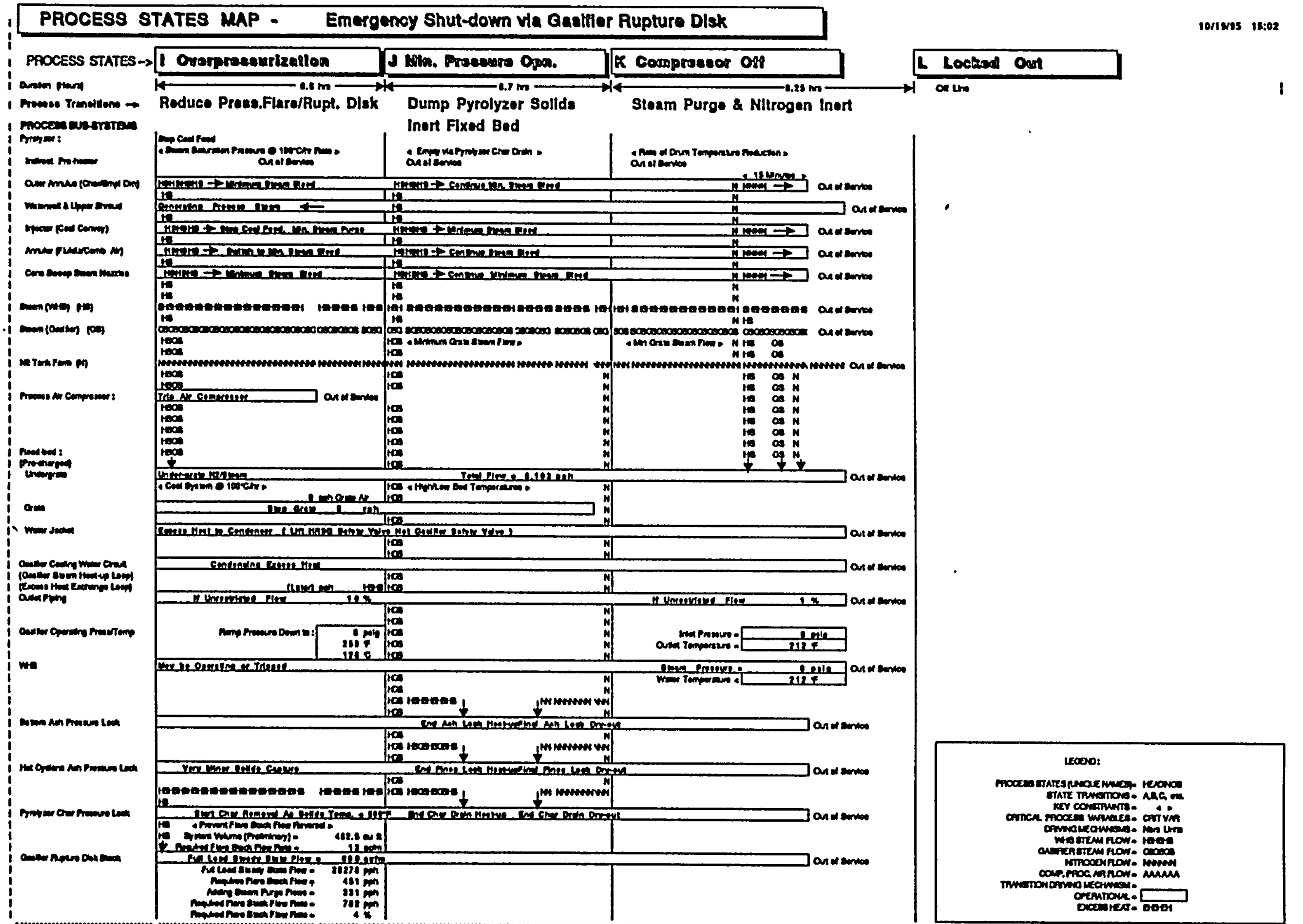
| STATES /Sub-states (TRANSITIONS) | SUBSYSTEM STATUS | CONSTRAINTS |
|---|---|---|
| **I WHB Trip** | Could be anywhere in start-up. | Controlled emergency shutdown required. No further testing allowed. |
| Controlled Emergency Shut-down to Flare or Incinerator Dump Stack **(Opn/Cntr Shut-dn Flare)** | Ft. Martin Trip | Trip WHB. Trip air compressor. Follow NORMAL SHUT-DOWN procedure. Accelerate the process. If cause is found and corrected, follow NORMAL START-UP procedure from appropriate STATUS STATE. |
| | Loss of Ft. Martin Condensate | Trip Incin. Trip air compressor. Follow NORMAL SHUT-DOWN procedure. Accelerate the process. If cause is found and corrected, follow NORMAL START-UP procedure from appropriate STATUS STATE. |
| | Incinerator/WHB - Trip | Incinerator/WHB has tripped. Trip air compressor. Follow NORMAL SHUT-DOWN procedure. Accelerate the process. If cause is found and corrected, follow NORMAL START-UP procedure from appropriate STATUS STATE. |
| | Loss of Electric Power | Incinerator/WHB has tripped. Uninterruptable power source (UPS) backup system employed. Accelerate the process. If cause is found and corrected, follow NORMAL START-UP procedure from appropriate STATUS STATE. |
| **I Overpressurization** | Gasifier rupture disk has relieved. Flare stack control valve (or Incinerator stub stack) has opened, and flare stack (or incinerator stub stack) is in service. | Vent steam to gasifier to control pressure let-down ramp to 180°F per hour. Isolate and trip air compressor. Stop coal feed. Inert with nitrogen. |


PROCESS STATES MAP - Start-up to Full Pyrolyzer Operation
PROCESS STATES->
A Ready for Start-up
B INCIN/WHB In Service
C System Dry
D Ready for Ignition
Duration (Hours)
Process Transitions ->
PROCESS SUB-SYSTEMS
INCIN/WHB Start-up
Purge/Dry-out
Pre-heat
Pyrol Bed Building
1.7 hrs
1.7 hrs
2.7 hrs
4.1 hrs
LEGEND:
PROCESS STATES (UNIQUE NAMES) = HEADINGS
STATE TRANSITIONS = A,B,C, etc.
CRITICAL PROCESS VARIABLES = CRIT VAR
OPERATIONAL =


PROCESS STATES MAP - Pyrolyzer In Service to Steady State
10/19/95 15:02
PROCESS STATES->
E Pyrolyzer In Svce
F Fixed-bed Ignited
G Dual-beds In Svce
H Steady State
Duration (Hours)
Process Transitions ->
Fixed-bed Light-off
Initial Grate Rotation
Pressure Raising
Test Start
PROCESS SUB-SYSTEMS
Pyrolyzer :
Direct Pre-heater
Outer Annulus (Char/Empty Ctr)
Waterwall & Upper Shroud
Injector (Coal Convey)
Annular (Fluidiz/Comb Air)
Cone Sweep Steam Nozzles
Steam (WHB) (HS)
Steam (Gasifier) (GS)
N2 Tank Farm (N)
Process Air Compressor :
Fixed-bed : (Pre-charged) Undergrate
Grate
Water Jacket
Gasifier Cooling Water Circuit (Gasifier Steam Heat-Up Loop) (Excess Heat Exchange Loop) Outlet Piping
Gasifier Operating Press/Temp
WHB
Bottom Ash Pressure Lock
Hot Cyclone Ash Pressure Lock
Pyrolyzer Char Drain
Out of Service
Hot Char
Used to Heat
Fixed-bed
For Ignition
Start-up Pressure Conditions
Vessel Pressure =
Jacket Temperature =
Inlet Pressure =
Outlet Temperature =
Steam Pressure =
Steam Temperature =
LEGEND:
PROCESS STATES (UNIQUE NAMES) = HEADINGS
STATE TRANSITIONS = A,B,C, etc.
KEY CONSTRAINTS = < >
CRITICAL PROCESS VARIABLES = CRIT VAR
DRIVING MECHANISMS = Non Units
WHB STEAM FLOW = HSHSHS
GASIFIER STEAM FLOW = GSGSGS
NITROGEN FLOW = NNNNNN
COMP. PROC. AIR FLOW = AAAAAA
TRANSITION DRIVING MECHANISM =
OPERATIONAL =
EXCESS HEAT =

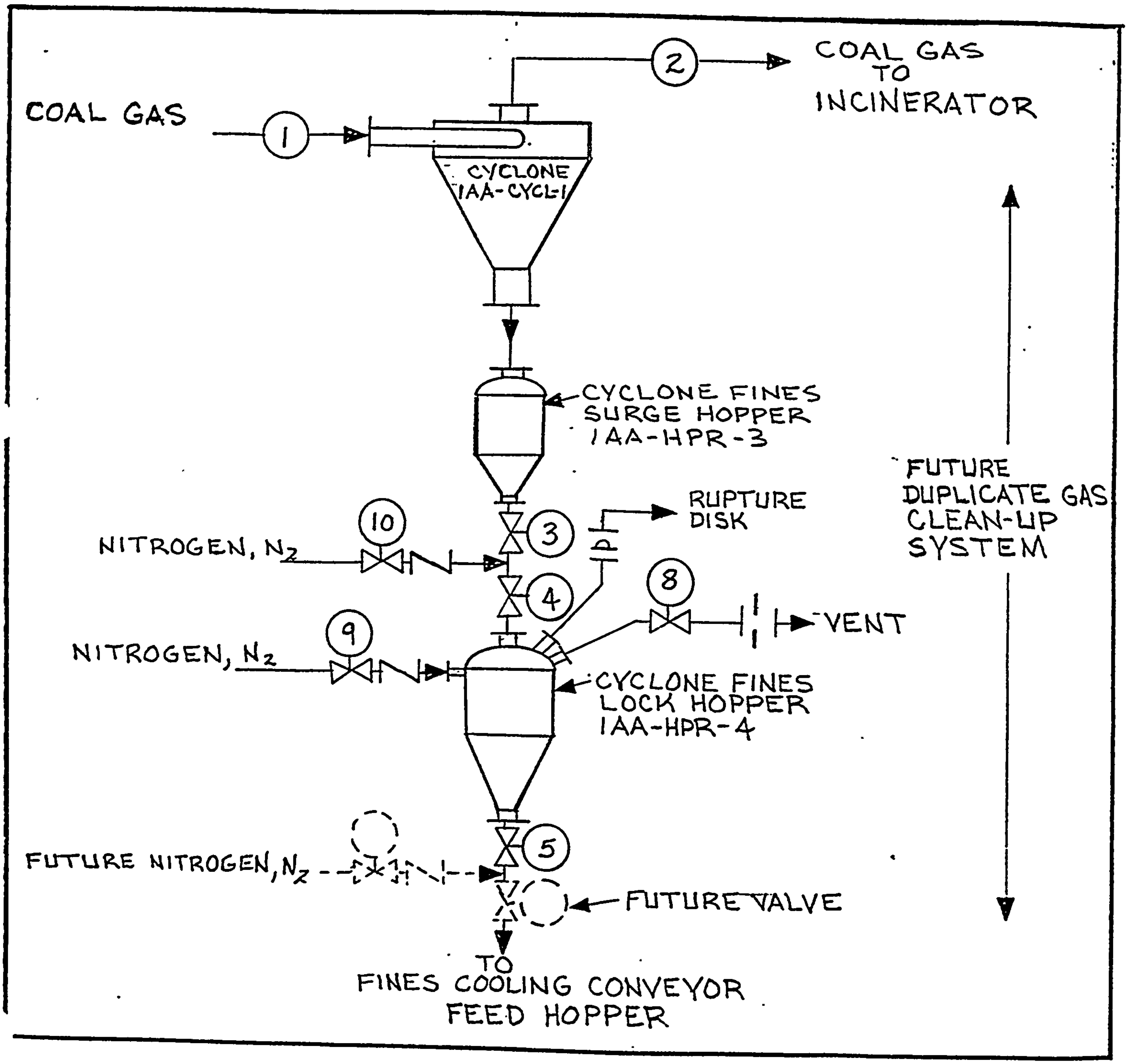

PROCESS STATES MAP - Test Completed Normal Shut-down
10/19/95 15:02
PROCESS STATES ->
I Test Complete
J Min. Pressure Opn.
K Compressor Off
L Locked Out
Duration (Hours)
6.8 hrs
6.7 hrs
2.2 hrs
Off Line
Process Transitions ->
Reduce Pressure via INCIN.
Purge Pyrolyzer Solids
Burn-out Fixed Bed
Steam Purge & Nitrogen Inert
Shut Down WHB
PROCESS SUB-SYSTEMS
Pyrolyzer :
Indirect Pre-heater
Outer Annulus (Char/Smpl Drn)
Waterwall & Upper Shroud
Injector (Coal Convey)
Annular (Fluidiz/Comb Air)
Core Sweep Steam Nozzles
Steam (HRSG) (HS)
Steam (Gasifier) (GS)
N2 Tank Farm (N)
Process Air Compressor :
Fixed-bed : (Pre-charged) Undergrate
Grate
Water Jacket
Gasifier Cooling Water Circuit (Gasifier Steam Heat-up Loop) (Excess Heat Exchange Loop) Outlet Piping
Gasifier Operating Press/Temp
HRSG
Bottom Ash Pressure Lock
Hot Cyclone Ash Pressure Lock
Pyrolyzer Char Pressure Lock
< Steam Saturation Pressure @ 150°C/hr Rate >
Out of Service
< Pyrolyzer Char Drain Empty >
< Rate of Drum Temperature Reduction >
< 15 Minutes >
Steam Flow
Purge Steam Flow to Entrainment Vsl
Generating Process Steam
Ramp Down to Minimum Coal Fe
Stop Coal Feed, Steam Purge
Ramp Down
Min
Switch to Steam Bleed
Minimum Steam Flow
< Minimum Grate Steam Flow >
< Min Grate Steam Flow >
< Bed Level Monitor >
Under-grate N2/Air/Steam
Total Flow = 8,193 pph
< Follow Fuel Flow Ramp >
< High/Low Bed Temperatures >
< Ash Removal Rate Override Temp = 600°F >
Reduce Operating Speed to 4 rph
Stop Grate
Excess Heat to Condenser
Condensing Excess Heat
(Latent) pph
N Unrestricted Flow
60 %
1 %
Ramp Pressure Down to :
30 psig
530 °F
277 °C
Inlet Pressure = 0 psig
Outlet Temperature = 0 °F
350 psig/520°F Steam Production
Steam Pressure = 0 psig
Water Temperature = 212 °F
Lock Cycles to Maintain Ash
End Ash Lock Heatup/Final Ash Lock Dry-out
Minor Solids Capture
End Fines Lock Heatup/Final Fines Lock Dry-out
Solids Sample Capture
End Char Drain Heatup
End Char Drain Dry-out
Out of Service
LEGEND:
PROCESS STATES (UNIQUE NAMES) = HEADINGS
STATE TRANSITIONS = A,B,C, etc.
KEY CONSTRAINTS = < >
CRITICAL PROCESS VARIABLES = CRIT VAR
DRIVING MECHANISMS = Nars Units
WHB STEAM FLOW = HSHSHS
GASIFIER STEAM FLOW = GSGSGS
NITROGEN FLOW = NNNNNN
COMP. PROC. AIR FLOW = AAAAAA
TRANSITION DRIVING MECHANISM =
OPERATIONAL =
EXCESS HEAT = EHEHEH


PROCESS STATES MAP - Emergency Shut-down via Flare Stack
10/19/95 15:02
PROCESS STATES -->
I INCIN Trip.@ Testing
J Min. Pressure Opn.
K Compressor Off
L Locked Out
Duration (Hours)
Off Line
Process Transitions -->
Reduce Pressure via Flare
Dump Pyrolyzer Solids
Inert Fixed Bed
Steam Purge & Nitrogen Inert
PROCESS SUB-SYSTEMS
Pyrolyzer :
Indirect Pre-heater
Outer Annulus (Char/Bmyl Dm)
Waterwall & Upper Shroud
Injector (Coal Convey)
Annular (Fluidiz/Comb. Air)
Cone Sweep Steam Nozzles
Steam (WHB) (HS)
Steam (Gasifier) (GS)
N2 Tank Farm (N)
Process Air Compressor :
Fixed bed :
(Pre-charged)
Undergrate
Grate
Water Jacket
Gasifier Cooling Water Circuit
(Gasifier Steam Heat-up Loop)
(Excess Heat Exchange Loop)
Outlet Piping
Gasifier Operating Press/Temp
WHB
Bottom Ash Pressure Lock
Hot Cyclone Ash Pressure Lock
Pyrolyzer Char Pressure Lock
Flare Stack
Out of Service
Generating Process Steam
Trip Air Compressor
Total Flow
Excess Heat to Condenser
Condensing Excess Heat
Ramp Pressure Down to :
Inlet Pressure =
Outlet Temperature =
Steam Pressure =
Water Temperature =
End Ash Lock Heatup/Final Ash Lock Dry-out
Very Minor Solids Capture
End Fines Lock Heatup/Final Fines Lock Dry-out
End Char Drain Heatup
End Char Drain Dry-out
System Volume (Preliminary) =
Full Load Steady State Flow =
Full Load Steady State Flow =
Required Flare Stack Flow =
Adding Steam Purge Flow =
Required Flare Stack Flow Rate =
LEGEND :
PROCESS STATES (UNIQUE NAMES) = HEADINGS
STATE TRANSITIONS = A,B,C, etc.
KEY CONSTRAINTS = < >
CRITICAL PROCESS VARIABLES = CRIT VAR
DRIVING MECHANISMS = Hors Units
WHB STEAM FLOW = HSHS
GASIFIER STEAM FLOW = GSGSGS
NITROGEN FLOW = NNNNN
COMP. PROC. AIR FLOW = AAAAAA
TRANSITION DRIVING MECHANISM =
OPERATIONAL =
EXCESS HEAT =


PROCESS STATES MAP - Emergency Shut-down via Gasifier Rupture Disk
10/19/95 15:02
PROCESS STATES ->
I Overpressurization
J Min. Pressure Opn.
K Compressor Off
L Locked Out
Duration (Hours)
Off Line
Process Transitions ->
Reduce Press.Flare/Rupt. Disk
Dump Pyrolyzer Solids
Inert Fixed Bed
Steam Purge & Nitrogen Inert
PROCESS SUB-SYSTEMS
Pyrolyzer :
Indirect Pre-heater
Outer Annulus (Char/Inyd Drn)
Waterwall & Upper Shroud
Injector (Coal Convey)
Annular (Fluidiz/Comb Air)
Cone Sweep Steam Nozzles
Steam (WHB) (HS)
Steam (Gasifier) (GS)
N2 Tank Farm (N)
Process Air Compressor :
Fixed bed :
(Pre-charged)
Undergrate
Grate
Water Jacket
Gasifier Cooling Water Circuit
(Gasifier Steam Heat-up Loop)
(Excess Heat Exchange Loop)
Outlet Piping
Gasifier Operating Press/Temp
WHB
Bottom Ash Pressure Lock
Hot Cyclone Ash Pressure Lock
Pyrolyzer Char Pressure Lock
Gasifier Rupture Disk Stack
Stop Coal Feed
Out of Service
Minimum Steam Bleed
Generating Process Steam
Stop Coal Feed, Min. Steam Purge
Switch to Min. Steam Bleed
Continue Min. Steam Bleed
Continue Steam Bleed
Continue Minimum Steam Bleed
< Empty via Pyrolyzer Char Drain >
< Rate of Drum Temperature Reduction >
< Minimum Gasifier Steam Flow >
< Min Gasifier Steam Flow >
Trip Air Compressor
Undergrate N2/Steam
Total Flow
< Cool System @ 100°C/hr >
< High/Low Bed Temperatures >
Stop Grate
Excess Heat to Condenser
Condensing Excess Heat
Ramp Pressure Down to :
Inlet Pressure =
Outlet Temperature =
May be Operating or Tripped
Steam Pressure =
Water Temperature <
End Ash Lock Heat-up/Final Ash Lock Dry-out
Very Minor Solids Capture
End Fines Lock Heat-up/Final Fines Lock Dry-out
Start Char Removal As Solids Temp. <
End Char Drain Heat-up
End Char Drain Dry-out
< Prevent Flare Stack Flow Reversal >
System Volume (Preliminary) =
Required Flare Stack Flow Rate =
Full Load Steady State Flow =
Full Load Steady State Flow =
Required Flare Stack Flow =
Adding Steam Purge Flows =
Required Flare Stack Flow Rate =
Required Flare Stack Flow Rate =
LEGEND:
PROCESS STATES (UNIQUE NAMES) = HEADINGS
STATE TRANSITIONS = A,B,C, etc.
KEY CONSTRAINTS = < >
CRITICAL PROCESS VARIABLES = CRIT VAR
DRIVING MECHANISMS = Hero Units
WHB STEAM FLOW = HSHSHS
GASIFIER STEAM FLOW = GSGSGS
NITROGEN FLOW = NNNNNN
COMP. PROC. AIR FLOW = AAAAAA
TRANSITION DRIVING MECHANISM =
OPERATIONAL =
EXCESS HEAT = EHEHEH

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1AA-2**

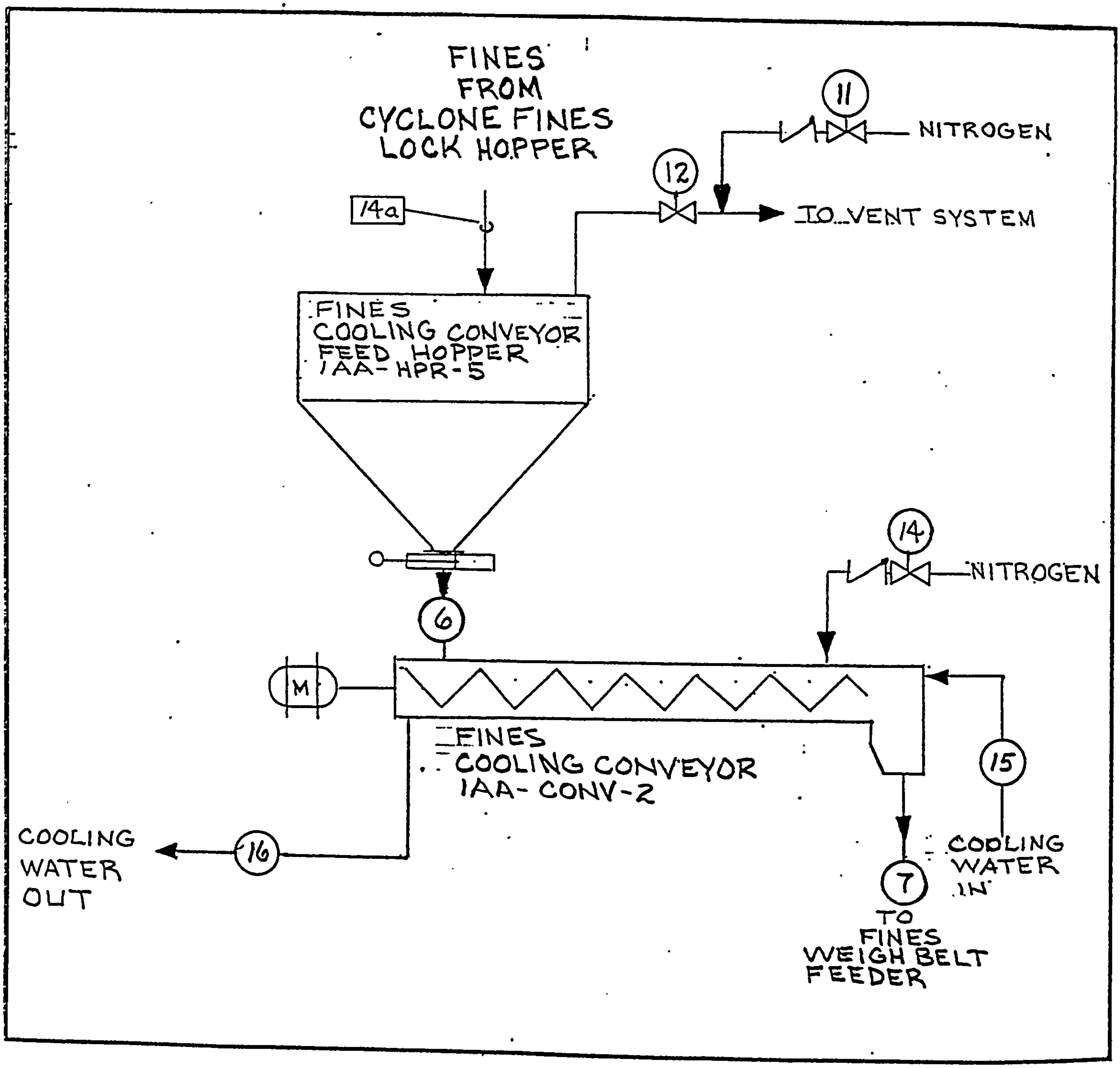
System Name Gas Clean Up System
Flowsheet No. 16N25706-40-F-1AA-002



SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1AA-2**

System Name Gas Clean Up System
Flowsheet No. 16N25706-40-F-1AA-002



SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

## I. DESIGN PHILOSOPHY

1. The purpose of the Gas Clean-Up System is to remove gasifier char fines from the coal gas stream. The fines are removed from the gas stream by a cyclone prior to the gas entering the incinerator.

2. Space for a future backup cyclone system has been saved in the building.

3. Each cyclone is designed to the following specifications:

| | | | | |
|---|---|---|---|---|
| a. | Coal Gas Flow Rate | = | 18,878 Lbs./Hr. | (19,822 Lbs./Hr. Maximum. See Note 9 Under Design Notes) |
| b. | Fines Flow Rate to Cyclone | = | 83 Lbs./Hr.<br>500 Lbs./Hr. | (Normal)<br>(Maximum) |
| c. | Total Gas and Fines | = | 18,961 Lbs./Hr.<br>20,322 Lbs./Hr. | (Normal)<br>(Maximum) |
| d. | Actual Cubic Feet Per Minute | = | 665 ACFM @ 18,878 lbs/hr | |
| e. | Temperatures: | | | |
| | Normal | = | 1023°F | |
| | Maximum | = | 1100°F | |
| f. | Pressure: To Cyclone | | | |
| | Normal | = | 324 PSIG | |
| | Maximum | = | 420 PSIG | |
| g. | Fines Removal Efficiency<br>(Actual will be Based on Vendor Selection) | = | 90% | |

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

h. Fines Particle Size Distribution

| Diameter MM | Microns | Weight % Less Than |
|---|---|---|
| 0.180 | 180 | 100 |
| 0.150 | 150 | 91 |
| 0.125 | 125 | 84 |
| 0.106 | 106 | 80 |
| 0.073 | 73 | 67 |
| 0.043 | 43 | 53 |
| 0.010 | 10 | 31 |

i. Solids Particle Density = 60 Lb./$Ft.^3$

j. Gas Composition

| | Inlet Gas Wt % |
|---|---|
| CO | 25.41 |
| $H_2$ | 1.39 |
| $CO_2$ | 10.48 |
| $H_2O$ | 11.23 |
| $CH_4$ | 0.50 |
| $H_2S$ | 0.64 |
| $N_2$ | 48.97 |
| AR | 1.10 |
| $NH_3$ | 0.28 |
| | 100.00 |

k. Gas Molecular Weight = 23.25

l. Materials of Construction:

Shell - Carbon Steel
Lining (Approximate) - 3" refractory layer for insulation and 3" refractory layer for abrasion (assuming a cyclone outside metal surface temperature of less than 270°F)

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

Outlet Tube - Stainless Steel
Inlet Nozzle - Refractory lined transition, round to rectangular

The exact material thicknesses will be determined by vendor.

m. Pressure drop across the cyclone will be determined by vendor at time of purchase.

4. Gasifier char fines that discharge from the bottom of the cyclone are collected in a Cyclone Fines Lock Hopper. Fines from the lock hopper fall into a Fines Cooling Conveyor Feed Hopper where they are fed to and cooled by the Fines Cooling Conveyor. Cooled fines discharge onto a Cyclone Fines Weigh Belt Feeder for weighing and conveying into the Ash Bucket Elevator. Samples of the fines are also taken from the weigh belt feeder.

   The Ash Bucket Elevator delivers a mixture of fines and bottom ash to an Ash Silo. The fines/ash mixture flows through a dustless rotary conditioner and falls into a truck for delivery to a landfill.

   This process design basis document ends at the outlet of the Fines Cooling Conveyor as shown on pages 1 and 2. (See Process Design Basis 40-1AA-4 for weight belt feeder, bucket elevator an aisle silo.)

5. The following is a description of the Gas Clean-Up System Operation.

   a. Cyclone Fines Collecting System

      1) Start fines cooling conveyor. Open cooling water supply valve(s) to conveyor (line 15 on sketch, page 2).

      2) The initial starting of the Cyclone Fines Lock Hopper requires a hopper warm-up sequence that brings the hopper's internal temperature to a temperature approaching that of the hot nitrogen. All valves surrounding the lock hopper are closed except the nitrogen fill Valve 9 and the lock hopper vent Valve 8. This allows hot nitrogen to pass through the lock hopper for vessel warming.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

3) After initial hopper warm-up the vent Valve 8 is closed while the nitrogen Valve 9 remains open to fill the hopper to its required internal pressure. This pressure will be 2 PSI to 10 PSI below the cyclone operating pressure to induce fines flow to the lock hopper and minimize fines re-entrainment when gas is displaced by solids. Once pressure is reached nitrogen Valve 9 is closed.

4) Positive pressure sealing inlet Valve 4 is opened then inlet Valve 3 is opened to allow cyclone fines to fall into the lock hopper.

5) When hopper level has reached its desired height of 70% full, inlet Valve 3 is closed followed by positive pressure sealing inlet Valve 4. Lock hopper filling time is based on percent of rated load of gasifier and lock hopper volume and will vary with cyclone particulate loading. (See Note 4).

6) After Valves 3 and 4 are closed and the lock hopper is going through its normal fines removal cycle, fines are collecting in the cyclone fines surge hopper located between the cyclone and lock hopper inlet Valve 3.

7) The cyclone fines surge hopper collects cyclone fines during the lock hopper's depressurizing and dumping cycle. The surge hopper will have the capacity to store as a minimum the quantity of fines that collect during one lock hopper dump cycle. Re-entrainment of fines by the cyclone's vortex action is also prevented by having the surge hopper located below the cyclone fines outlet. Fines re-entrainment is prevented due to the fact that a cyclone vortex is broken and unable to reach down into the surge hopper.

8) Open vent Valve 8 to vent remaining nitrogen/coal gas mixture to vent system. Vent Valve 8 remains open while the lock hopper's internal pressure is reduced to 2 psig or less.

9) After pressure constraint is met, open positive sealing dump Valve 5 allowing fines to drop into Fines Cooling Conveyor Feed Hopper. Space has been allocated for a future sealing valve located downstream of Valve 5 as shown on drawing on page 1.

10) When the lock hopper is indicated as empty, close dump Valve 5.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name Gas Clean-Up System
Flowsheet No. 16N25706-40-F-1AA-002

11) The lock hopper cycle time that is required to size the Cyclone Fines Surge Hopper will initially be established by approximation calculations on the lock hopper's vent line. An orifice in the vent line can be field modified based on actual operating tests to increase or decrease lock hopper venting time, therefore minimizing fines carryover to the vent system.

12) Open nitrogen fill Valve 9 allowing the lock hopper and vent line to purge for 5 to 10 seconds.

13) Close vent Valve 8 and allow the cyclone fines lock hopper to repressurize starting the cycle over.

14) The cyclone lock hopper and surge hopper will be designed for the same maximum pressure and temperature as the gasifier.

15) At this time fines have been deposited into the low pressure, Fines Cooling Conveyor Feed Hopper. This hopper will be sized to hold 1.5 times the volumetric capacity of the fines lock hopper. The equipment above the feed hopper is going through another cycle. The feed hopper is equipped with a vent Valve 12. If a plug occurs, nitrogen Valve 13 can be opened after Valve 12 is opened to facilitate unplugging hopper. If cracked open Valves 12 and 13 can also be used to cool the fines before they are delivered to the cooling conveyor. Care must be taken to prevent excessive nitrogen flow because of potential fines re-entrainment and carryover to the vent system.

16) Fines are removed from the feed hopper by a water cooled, screw type fines cooling conveyor. Fines will be removed at a maximum rate of 500 lbs./hr. and will be cooled from 1100°F maximum to 200°F before being discharged to a weigh belt feeder. Cooling water at a flow determined after equipment purchase will be used to cool the conveyor's screw and outer jacket. The fines cooling conveyor is driven by a variable speed drive.

b. Interlocks

Interlocks are provided to help prevent inadvertent sequencing of the cyclone fines lock hopper valves. The interlocks are as follows:

1) The lock hopper fines dump Valve 5 cannot open until pressure in lock hopper is less than 2 psig.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

2) Lock hopper fines dump Valve 5 cannot open if nitrogen fill Valve 9 is open.

3) Lock hopper fines dump Valve 5 cannot open unless vent Valve 8 is open.

4) Lock hopper fines dump Valve 5 and lock hopper fines inlet Valves 3 and 4 cannot be open at the same time.

5) Lock hopper fines inlet Valves 3 and 4 cannot open if nitrogen fill Valve 9 is open.

6) Lock hopper fines inlet Valves 3 and 4 and lock hopper vent Valve 8 cannot be opened at the same time.

7) The nitrogen fill Valve 9 cannot be opened if the lock hopper fines inlet Valve 4 or the lock hopper fines dump Valve 5 is open.

8) Lock hopper fines inlet Valve 3 cannot be opened until lock hopper fines positive sealing Valve 4 has been opened.

9) Dump Valve 5 cannot be opened if water (Line 15) is not proven to fines cooling conveyor screw and conveyor motor is not operating (screw is not turning).

10) Dump Valve 5 cannot be opened if low pressure nitrogen Valve 14 is closed.

11) The weigh belt feeder and bucket elevator motors will be interlocked to start when fines cooling conveyor motor starts.

12) Loss of electricity or instrument air pressure will cause the cyclone fines lock hopper to depressurize by opening vent Valve 8.

c. Miscellaneous

1) Nitrogen Valves 10 and 11 are used to purge or unplug fine lines or valves.

2) The operator should use caution when using these valves.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name Gas Clean-Up System
Flowsheet No. 16N25706-40-F-1AA-002

## II. DESIGN CRITERIA

| ITEM | GAS CLEAN-UP SYSTEM - NORMAL 400# GASIFIER OPERATION | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item No. | Process Stream | Maximum Flow | | Normal Flow | | Minimum Flow | | Maximum Temp °F | Normal Temp. °F | Maximum Pressure PSIG | Normal Pressure PSIG |
| | | Gas | Fines | Gas | Fines | Gas | Fines | | | | |
| 1 | Coal Gas to Cyclone | * 20.32 M Note 9 | 500 Lb/Hr | *18.878 M | 83 Lb/Hr | * M Note 3 | Note 3 | 1100 Note 1 | 1023 | 440 | 324 Note 10 |
| 2 | Coal Gas to Incinerator | * 20.32 M Note 9 | 150 Lb/Hr Note 8 | *18.878 M | 8 Lb/Hr Note 7 | Note 3 | Note 3 | 1100 Note 1 | 1023 | 440 | 321 Note 11 |
| 3 | Cycl. Fines L.H. Inlet | 500 Lb/Hr Note 4 | | 75 Lb/Hr | | ____ Lb/Hr | | 1100 Note 1 | 1023 | 440 | 321 |
| 4 | Cycl. Fines L.H. Inlet | 500 Lb/Hr Note 4 | | 75 Lb/Hr | | ____ Lb/Hr | | 1100 Note 1 | 1023 | 440 | 321 |
| 5 | Cycl. Fines L.H. Dump | 500 Lb/Hr Note 4 | | 75 Lb/Hr | | ____ Lb/Hr | | 1100 Note 1 | 1023 | Note 2 | 0 |
| 6 | Cycl. Fines to Cooling Conveyor | 500 Lb/Hr Note 4 | | 75 Lb/Hr | | ____ Lb/Hr | | 1100 Note 1 | 1023 | 10 | 0 |
| 7 | Cycl. Fines to Weigh Belt Feeder | 500 Lb/Hr Note 4 | | 75 Lb/Hr | | | | 220 | 200 | 10 | 0 |
| 8 | Cycl. Fines L.H. Vent | Note 5 | | Note 5 | | | | 1100 Note 1 | 1023 | 440 | 322 Note 13 |
| 9 | Cycl. Fines L.H. Nitrogen Fill | Note 6 | | Note 6 | | | | 465 | Hold | 374 | 324 |
| 10 | Nitrogen Purge - HP | Note 6 | | Note 6 | | | | 465 | Hold | 374 | 324 |
| 11 | Nitrogen Purge - LP | Note 6 | | Note 6 | | | | 100 | Hold | 10 | 2 |
| 12 | Fines Cooling Conv. F.H. Vent | Hold | | Hold | | Hold | | 1100 | 1023 | 10 | 2 |
| 13 | Nitrogen Purge - LP | Note 6 | | Note 6 | | | | 100 | Hold | 10 | 2 |
| 14 | Nitrogen Purge - LP | Note 6 | | Note 6 | | | | 100 | Hold | 10 | 2 |
| 15 | Cooling Water In | Note 12 | | Note 12 | | Note 12 | | Hold | Hold | 100 | Hold |
| 16 | Cooling Water Out | Note 12 | | Note 12 | | Note 12 | | Hold | Hold | 100 | Hold |

* M = 1000 Lb/hr

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name Gas Clean-Up System
Flowsheet No. 16N25706-40-F-1AA-002

II. DESIGN CRITERIA - Continued

The fines lock hopper system is designed to the following design criteria:

1. Fines Particles:

   Fines Particle Density = 60 $Lb/Ft^3$
   Fines Bed Density = 25 $Lb/Ft^3$

   Note: Particle and bed density is assumed. 25 $Lb/Ft^3$ is based on an assumed voidage of 0.58.

2. Lock hopper and surge hopper will be fabricated from refractory lined carbon steel or non-refractory lined stainless steel per most economical design. If refractory is used the lock hopper's skin temperature will not exceed 240°F. Interconnecting piping will be made of stainless steel.

3. The lock hopper and surge hopper outlet cones will have an angle of 70° from horizontal to help ash flow.

4. Ash Composition:

   "Later"

5. Expected composition at expected normal output.

| | |
|---|---|
| C | 52 Lb/Hr |
| CaO | 0 Lb/Hr |
| Inerts | 23 Lbs/Hr |
| Total Solids | 75 Lb/Hr |

   Composition at normal output taken from 325 psig mass balance dated 5-31-95, stream 14a.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

## III. DESIGN NOTES

1. 1100°F is based on maximum upset temperature from gasifier.

2. Cyclone fines lock hopper dump valve must hold against maximum pressure in cyclone which is 440 psig. The valve will open normally against 2 psig or less after lock hopper is vented.

3. From 200 psig mass balance. Note: This column does not show minimums at 200 psig operation.

4. 500 Lb./Hr. of fines is the anticipated maximum flow from the cyclone to the lock hopper. 75 Lb./Hr. is the anticipated normal flow to the lock hopper based on the May 31, 1995 mass balance. The lock hopper will be designed for three dump cycles per hour at the 500 Lb./Hr. flow rate. This equates to 167 Lb./Hr. per cycle, at a normal level of 70% full in the lock hopper. The calculated lock hopper size (based on 500 Lb./Hr.) will yield 2.2 hours between cycles at the normal flow rate of 75 Lb./Hr. Operating experience based on actual fines flow will show the optimum cycle time for the lock hopper. It is anticipated that one dump cycle per hour or 167 Lb./Hr. of fines would be optimum for fines removal and minimal valve cycle time.

5. The vent time for a dump cycle will be calculated based on a 1/4" orifice located in the vent pipe adjacent to the lock hopper. The orifice will set the depressurization time and the dump cycle time.

6. Nitrogen fill time of lock hopper will be based on 1/2" pipe and valve(s). Nitrogen purge will be accomplished with 1/2" pipe and valve(s). Pipe and valve size will be re-evaluated based on line loss due to routing.

7. 8 Lb./Hr. based on 90% efficiency from cyclone. Actual efficiency and mass carryover from cyclone will be determined during cyclone purchase.

8. 150 Lb./Hr. based on assumed derated cyclone efficiency of 70%.

9. 20,320 Lb./Hr. includes a 5% margin for equipment sizing on normal coal gas flow of 18,878 Lb./Hr. (stream 12 on mass balance dated June 1, 1995 plus 500 Lb./Hr. of fines in gas, i.e., 1.05 x 18,878 = 19,822 + 500 = 20,320.

10. 324 psig taken from mass balance dated May 31, 1995, Stream No. 10L.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-2

System Name: Gas Clean-Up System
Flowsheet No.: 16N25706-40-F-1AA-002

11. Assuming 3 psi pressure drop across the Cyclone (324 psig-3 psig = 321 psig).

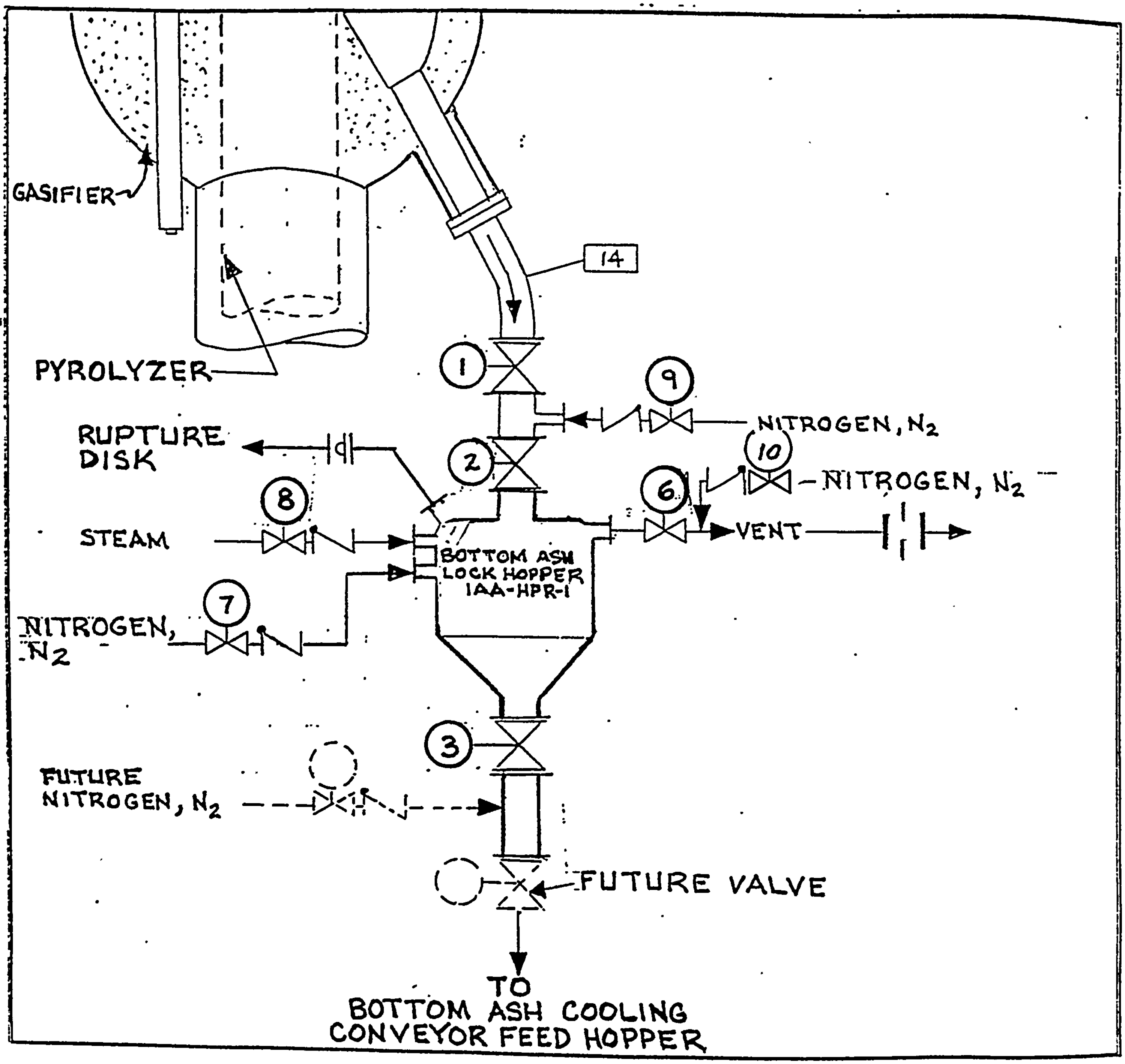
12. Flow requirements after equipment purchase.

13. Pressure in lock hopper is normally 2 to 10 psig (field adjustable) below cyclone pressure.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1AA-3**

System Name Gasifier Ash Handling (Botton Ash Lock Hopper,Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No. 16N25706-40-F-1AA-004

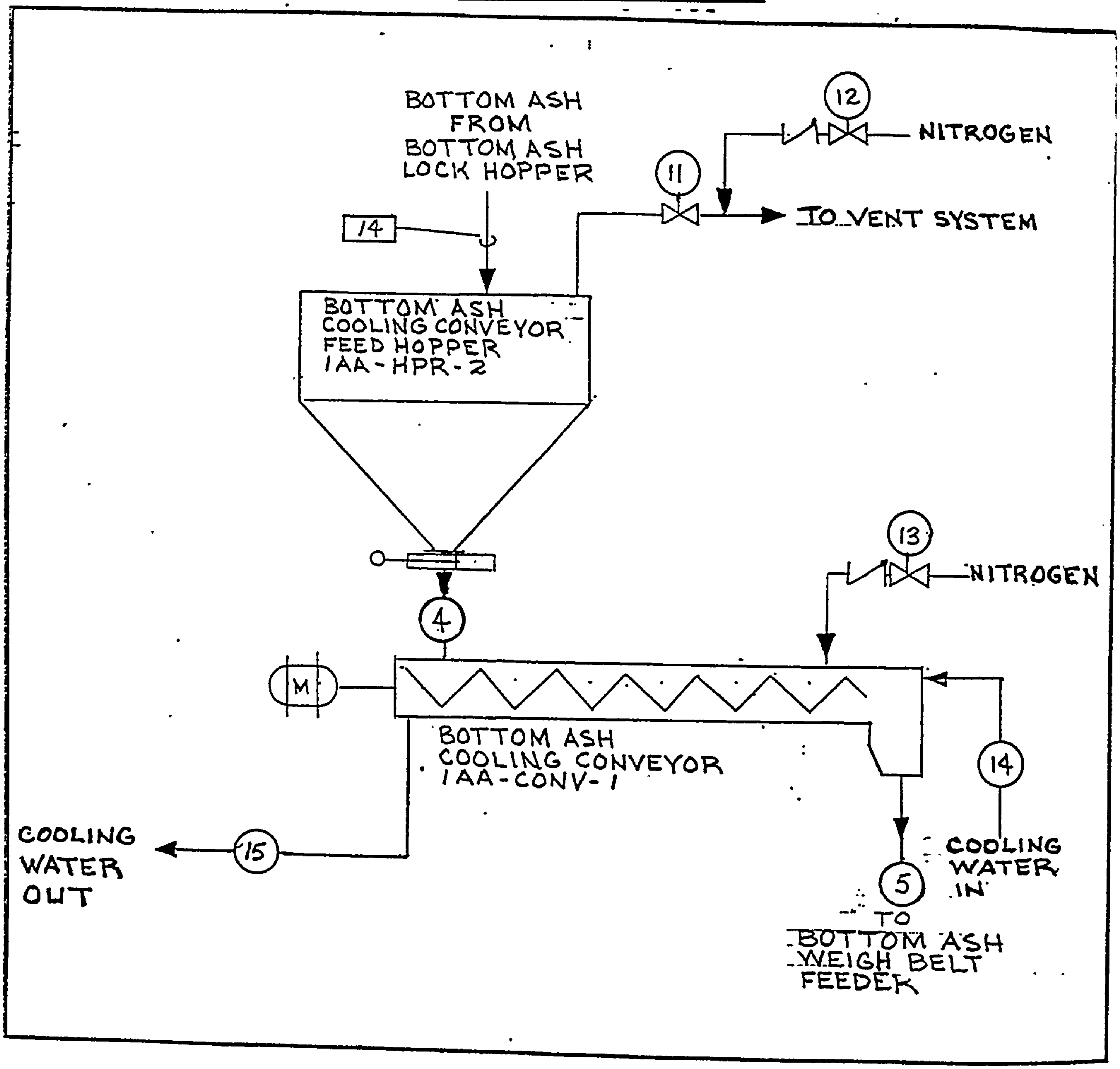


SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1AA-3**

System Name Gasifier Ash Handling (Botton Ash Lock Hopper,Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No. 16N25706-40-F-1AA-004



SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-3

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

I. DESIGN PHILOSOPHY

1. The Gasifier Ash Handling System is made-up of several key pieces of equipment which are as follows:

   a. Bottom Ash Lock Hopper
   b. Bottom Ash Cooling Conveyor Feed Hopper
   c. Bottom Ash Cooling Conveyor
   d. Weigh Belt Feeder
   e. Ash Bucket Elevator
   f. Ash Silo/Ash Dustless Unloader

   Gasifier ash that discharges from the undergrate area of the gasifier is collected in a bottom ash lock hopper. Ash from the lock hopper falls into a bottom ash cooling conveyor feed hopper where it is fed to and cooled by the bottom ash cooling conveyor. Cooled ash discharges onto a bottom ash weigh belt feeder for weighing and conveying into the ash bucket elevator. Samples of the ash are also taken from the weigh belt feeder.

   The ash bucket elevator delivers a mixture of ash and fines to an ash silo. The ash/fines mixture flows through a dustless rotary conditioner and falls into a truck for delivery to a landfill.

   This System Process Design Basis addresses a. bottom ash lock hopper, b. bottom ash cooling conveyor feed hopper, and c. the bottom ash cooling conveyor only. Other PDB's address the remaining key equipment.

2. The following is a description of the bottom ash collecting system operation.

   a. Bottom Ash Collecting System:

      1) Start Bottom Ash Cooling Conveyor. Open cooling water supply valve(s) to conveyor (Line 14 on sketch, page 2).

      2) The initial starting of the Bottom Ash Lock Hopper requires a hopper warm-up sequence that brings the hopper's internal temperature to the temperature approaching that of the super-heated steam. All valves surrounding the lock hopper are closed except the steam fill Valve 8 and the lock hopper vent Valve 6. This allows superheated steam to pass through the lock hopper for warming.

      3) Once the hopper temperature has reached a temperature that closely approaches the superheated steam temperature, shut steam Valve 8 and open nitrogen Valve 7. Nitrogen flow through the lock hopper is for dry out purposes. Dry vessel for 3 to 5 minutes.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-3

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

4) After initial warm-up and dry-out, close the nitrogen Valve 7 and vent Valve 6. Open steam fill Valve 8 to fill the hopper to its required internal pressure. This pressure will be 2 psi above the gasifier undergrate pressure to minimize coal gas migration and to prevent ash impaction. Once internal hopper pressure is reached, steam Valve 8 is closed.

5) Positive sealing inlet Valve 2 is opened, then inlet Valve 1 is opened to allow bottom ash to fall into the Bottom Ash Lock Hopper. Valve 1 blocks ash flow so that Valve 2 can provide positive without having ash on the valve. Lock hopper pressure will then equalize with gasifier pressure.

6) When hopper level has reached it's desired height of 70% full, inlet Valve 1 is closed followed by positive sealing inlet Valve 2. Hopper filling time is based on rated load of gasifier and lock hopper volume. A gain Valve 1 blocks ash from Valve 2.

7) After Valves 1 and 2 are closed and the lock hopper is going through its normal cycle, bottom ash is collecting in the pipe line between the gasifier and the lock hopper's inlet Valve 1. One cycle of fines therefore collect in the pipe.

8) Open vent Valve 6 to vent remaining steam/coal gas mixture to vent system. Vent Valve 6 remains open while the lock hopper's internal pressure is reduced to 2 PSIG or less.

9) After pressure constraint is met, open positive sealing dump Valve 3 allowing ash to drop into the bottom ash cooling conveyor feed hopper. Space has been allocated for a future sealing valve located downstream of Valve 3 as shown on sketch on page 1.

10) When the hopper is indicated empty close dump Valve 3 and vent Valve 6.

11) The lock hopper cycle time that is required to size the bottom ash connecting pipeline, i.e., between the gasifier outlet flange and the lock hopper inlet flange, will initially be established by approximation calculations on the lock hopper's vent line. An orifice in the vent line can be field modified based on actual operating tests to increase or decrease lock hopper venting time, therefore minimizing fines carryover to the vent system. The interconnecting pipe will be 10" I.D. stainless steel.

12) Open nitrogen purge Valve 10 and allow the vent line to purge for 3 to 4 seconds. Close purge Valve 10.

13) Open steam Valve 8 and allow the Bottom Ash Lock Hopper to repressurize, starting the cycle over.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-3

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

b. Interlocks

Interlocks are provided to help prevent inadvertent sequencing of the Bottom Ash Lock Hopper valves. The interlocks are as follows:

1) The lock hopper ash dump Valve 3 cannot open until pressure in lock hopper is less than 2 psig.

2) Lock hopper ash dump Valve 3 cannot open if nitrogen fill Valve 7 or steam fill Valve 8 is open.

3) Lock hopper ash dump Valve 3 cannot open unless vent Valve 6 is open.

4) Lock hopper ash dump Valve 3 and lock hopper ash inlet Valves 1 and 2 cannot be open at the same time.

5) Lock hopper ash inlet Valves 1 and 2 cannot open if steam fill Valve 8 or nitrogen fill Valve 7 is open.

6) Lock hopper ash inlet Valves 1 and 2 and lock hopper vent Valve 6 cannot be opened at the same time.

7) The steam fill Valve 8 or the nitrogen fill Valve 7 cannot be opened if the lock hopper ash inlet Valve 2 or the lock hopper ash dump Valve 3 is open.

8) Lock hopper ash inlet Valve 1 cannot be opened until lock hopper ash positive sealing Valve 2 has been opened. Lock hopper inlet Valve 2 cannot be closed until inlet valve 1 is closed.

9) Dump Valve 3 cannot be opened if water (Line 14) is not proven to bottom ash cooling screw and conveyor motor is not operating (screw is not turning).

10) Dump Valve 3 cannot be opened if low pressure nitrogen Valve 13 is closed.

11) The weigh belt feeder and bucket elevator motors will be interlocked to start when bottom ash cooling conveyor motor starts.

12) Loss of electricity or instrument air pressure will cause the bottom ash lock hopper to depressurize by opening vent Valve 6. Inlet valves 1 and 2 will also close.

SYSTEM PROCESS DESIGN BASIS

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

c. Miscellaneous

1) Nitrogen Valves 9 and 12 are used to purge or unplug ash lines or valves and the vent line.

2) The operator should use caution when using nitrogen purge valves.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-3

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAX FLOW | NORM FLOW | MIN. FLOW | MAX. TEMP. °F | NORM TEMP. °F | MAX. PRESS. PSIG | NORM PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | BOTTOM ASH L.H. INLET | 1000 LB/HR NOTE 2 AND 4 | 832 LB/HR NOTE 1 AND 4 | NOTE 3 AND 4 | 750 | 560 NOTE 10 | 440 | 324 NOTE 7 |
| 2 | BOTTOM ASH L.H. INLET | 1000 LB/HR NOTE 2 AND 4 | 832 LB/HR NOTE 1 AND 4 | NOTE 3 AND 4 | 750 | 560 NOTE 10 | 440 | 324 NOTE 7 |
| 3 | BOTTOM ASH L.H. DUMP | 1000 LB/HR NOTE 2 AND 4 | 832 LB/HR NOTE 1 AND 4 | NOTE 3 AND 4 | 750 | 560 NOTE 10 | NOTE 8 | 2 |
| 4 | BOTTOM ASH TO BOTTOM ASH COOLING CONVEYOR | 1000 LB/HR NOTE 2 AND 4 | 832 LB/HR NOTE 1 AND 4 | NOTE 3 AND 4 | 750 | 560 NOTE 10 | 10 | 2 |
| 5 | BOTTOM ASH TO WEIGH BELT FEEDER | 1000 LB/HR | 832 LB/HR | NOTE 3 | 220 | 200 | 10 | 2 |
| 6 | BOTTOM ASH L.H. VENT | NOTE 5 | NOTE 5 | NOTE 5 | 750 | 560 NOTE 10 | NOTE 5 | 326 NOTE 7 |
| 7 | BOTTOM ASH L.H. NITROGEN FILL | NOTE 6 | NOTE 6 | NOTE 6 | 465 | HOLD | 374 | 324 |
| 8 | BOTTOM ASH L.H. STEAM FILL | NOTE 6 | NOTE 6 | NOTE 6 | 560 | 600 | 374 PSIG | HOLD |
| 9 | NITROGEN PURGE - HP | NOTE 6 | NOTE 6 | NOTE 6 | 465 | HOLD | 374 | 324 |
| 10 | NITROGEN PURGE - HP | NOTE 6 | NOTE 6 | NOTE 6 | 465 | HOLD | 374 | 324 |
| 11 | BOTTOM ASH COOLING CONV. FEED HOPPER VENT | HOLD | HOLD | HOLD | 750 | 560 NOTE 10 | 10 | 0 |
| 12 | NITROGEN PURGE - LP | NOTE 6 | NOTE 6 | NOTE 6 | 100 | HOLD | 10 | 2 |
| 13 | NITROGEN PURGE - LP | NOTE 6 | NOTE 6 | NOTE 6 | 100 | HOLD | 10 | 2 |
| 14 | COOLING WATER IN | NOTE 9 | NOTE 9 | NOTE 9 | HOLD | HOLD | 100 | HOLD |
| 15 | COOLING WATER OUT | NOTE 9 | NOTE 9 | NOTE 9 | HOLD | HOLD | 100 | HOLD |

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-3

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

II. DESIGN CRITERIA - Continued

The Bottom Ash Lock Hopper System is designed to the following design criteria:

1. Ash particles

   Ash Particle Density = 60 $Lb/Ft^3$
   Ash Bed Density = 40 $Lb/Ft^3$

   Note: Particle and bed density is assumed. 40 $Lb/Ft^3$ is based on an assumed voidage of 0.33.

2. Lock hopper will be fabricated from refractory lined carbon steel or non-refractory lined stainless steel per most economical design. If refractory is used the lock hopper's skin temperature will not exceed 240°F Interconnecting piping will be made of stainless steel.

3. The lock hopper outlet cone will have an angle of 70° from horizontal to help ash flow.

4. Ash Composition: Expected composition as an oxide.

   $SiO_3$
   $AL_2O_3$
   $FE_2O_3$
   $TiO_2$
   $MgO$ "LATER"
   $MnO$
   $P_2O_5$
   $K_2O$
   $CaO$

5. Expected composition at normal output.

| | | |
|---|---|---|
| C | 19 | Lb/Hr |
| CaO | 100 | Lb/Hr |
| Inerts | 713 | Lb/Hr |
| Total Solids | 832 | Lb/Hr |

Composition at normal output taken from 325 psig mass balance dated 5-31-95, Stream 14.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1AA-3

System Name: Gasifier Ash Handing (Bottom Ash Lock Hopper, Bottom Ash Cooling Conveyor Feed Hopper, and Bottom Ash Cooling Conveyor)

Flowsheet No.: 16N25706-40-F-1AA-004

III. DESIGN NOTES

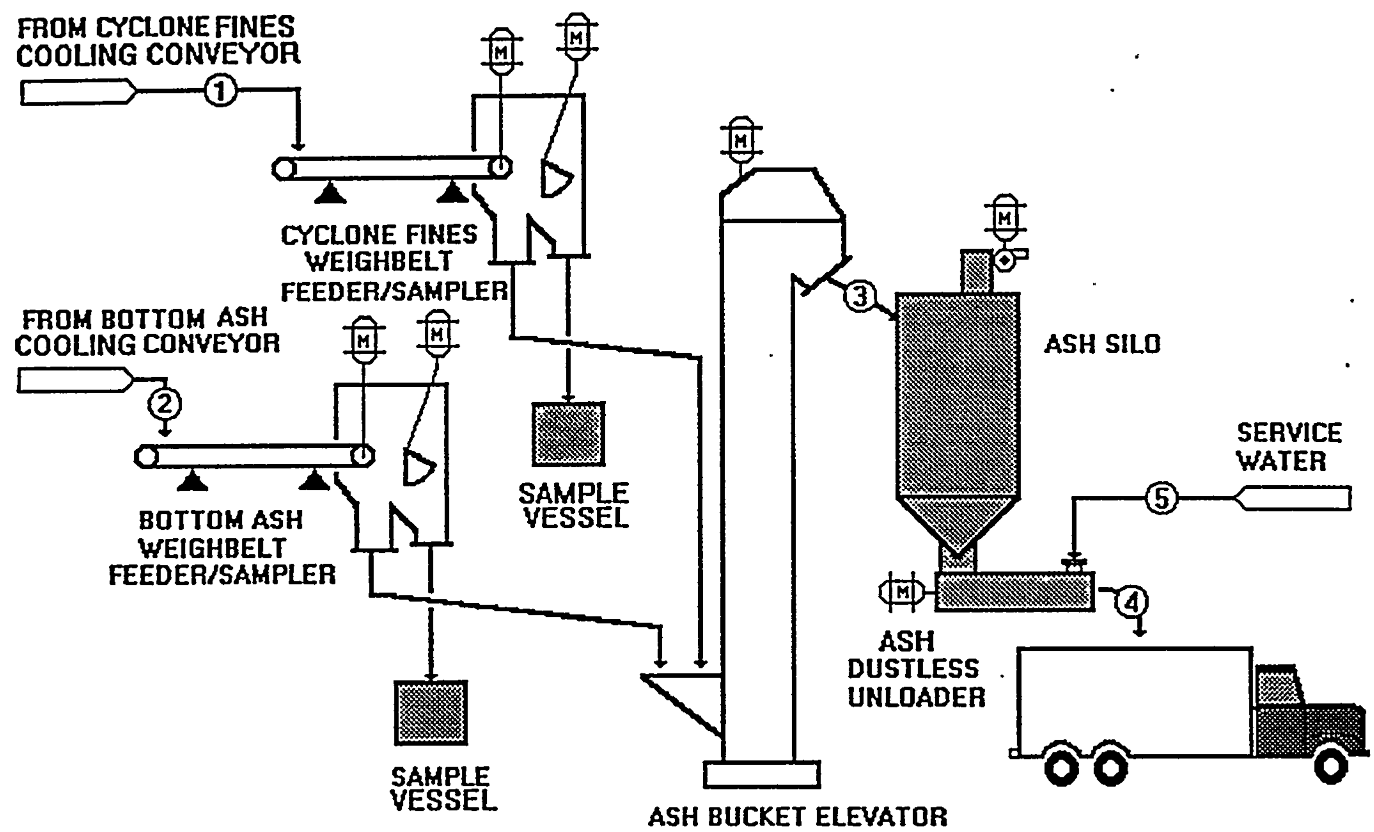
1. 832 Lb/Hr of bottom ash taken from 325 psi mass balance, Rev. 0 dated 5-31-95.
2. Maximum ash flow of 1000 Lb/Hr is 20% higher than mass balance ash flow for safety margin.
3. Minimum bottom ash flow is taken from 200 psi mass balance. Absolute minimum will be a function of gasifier turndown at 200 psig operation.
4. The lock hopper will be designed for one dump cycle per hour at 1000 Lb/Hr flow rate. The hopper will go into a dump cycle when the lock hopper level reaches 70% full. Operating experience based on actual ash flow will show the optimum cycle time for the lock hopper.
5. The vent time for a dump cycle will be based on a 1/4" orifice located in the vent pipe line adjacent to the lock hopper. The orifice will set the depressurization time and the dump cycle time.
6. Nitrogen and steam fill time of lock hopper will be based on 1/2" pipe and valve(s). Nitrogen purge will be accomplished with 1/2" pipe and valve(s). Pipe and valve size will be re-evaluated based on line loss due to routing.
7. Internal pressure of bottom ash lock hopper will be approximately 2 psi higher or 326 psig.
8. Bottom ash lock hopper dump valves must hold against maximum pressure in gasifier which is 440 psig. The valves will open normally against 2 psig or less after lock hopper is vented.
9. Flow requirements after equipment purchase.
10. Per Riley.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40-1AA - 4**

System Name Solid Waste Disposal System

Flowsheet No. 16N25706-40-F-1AA-005




EQUIPMENT

Cyclone Fines Weighbelt Feeder (Eq. No. 1AA-FDR-1)
Bottom Ash Weighbelt Feeder (Eq. No. 1AA-FDR-2)
Fines Sample Container (Eq. No. 1AA-VSL-1)
Bottom Ash Sample Vessel (Eq. No. 1AA-VSL-2)
Fines Sampler (Eq. No. 1AA-SMX-1)
Bottom Ash Sampler (Eq. No. 1AA-SMX-2)
Ash Bucket Elevator (Eq. No. 1AA-ELEV-1)
Ash Silo (Eq. No. 1AA-SILO-1)
Ash Dustless Unloader (Eq. No. 1AA-COND-1)
Ash Silo Dust Collector (Eq.No. 1AA-DCOL-1)

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40-1AA - 4**
System Name Solid Waste Disposal System
Flowsheet No. 16N25706-40-F-1AA-005

I. DESIGN PHILOSOPHY

1. The primary functions of the Solid Waste Disposal System is to weigh, collect and provide a means of disposing the process gas cyclone fines and gasifier bottom ash.

2. The bottom ash and cyclone fines are continuously transferred (individually) to the weighbelt feeders by the cyclone fines and bottom ash conveyors.

3. The weighbelt feeders weigh and record the "throughput" of cyclone fines and bottom ash.

4. Samplers on the ends of the weighbelt feeders provide a means of sampling fines and ash by diverting a portion of the fines/ash to sample bins.

5. Fines and ash discharged from the weighbelt feeders are directed to the inlet of the bucket elevator.

6. The bucket elevator lifts the combined fines and ash and discharges the mixture into the ash silo. A filter in the silo vent prevents fines from escaping to the atomosphere.

7. An unloader mounted at the bottom of the ash silo discharges the stored ash/fines into an ash removal truck.

8. Service water is injected into the unloader to reduce the dust emissions during the unloading process.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40-1AA - 4**

System Name Solid Waste Disposal System

Flowsheet No. 16N25706-40-F-1AA-005

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAXIMUM FLOW #/HR (or as noted) | NORMAL FLOW #/HR (or as noted) | MINIMUM FLOW #/HR (or as noted) | MAXIMUM TEMP. °F | NORMAL TEMP. °F | MAXIMUM PRESS. PSIG | NORMAL PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | Cyclone Fines from Conveyor | 500 | (See Mass Balance) | (See Mass Balance) | 200 | (See Mass Balance) | 2 | (See Mass Balance) |
| 2 | Bottom Ash from Conveyor | 1,000 | (See Mass Balance) | (See Mass Balance) | 750 | (See Mass Balance) | 10 | (See Mass Balance) |
| 3 | Combined Ash from Bucket Elevator | 1,500 | Hold | Hold | Hold | Hold | atmos. | atmos. |
| 4 | Ash Discharged from Unloader | 1,500 | (See Mass Balance) | (See Mass Balance) | Hold | (See Mass Balance) | atmos. | atmos. |
| 5 | Service Water | Hold | (See Mass Balance) | (See Mass Balance) | Hold | (See Mass Balance) | Hold | (See Mass Balance) |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40-1AA - 4**
System Name Solid Waste Disposal System
Flowsheet No. 16N25706-40-F-1AA-005

III. DESIGN NOTES

1. Current design is based on the Mass Balance dated 5/31/95.

2. Cyclone fines bulk density is assumed to be 25 #/ft$^3$.

3. Cyclone fines size distribution is assumed to be : 50% less than 30 microns.
50% greater than 30 microns.

4. Bottom ash bulk density is assumed to be 50 #/ft$^3$.

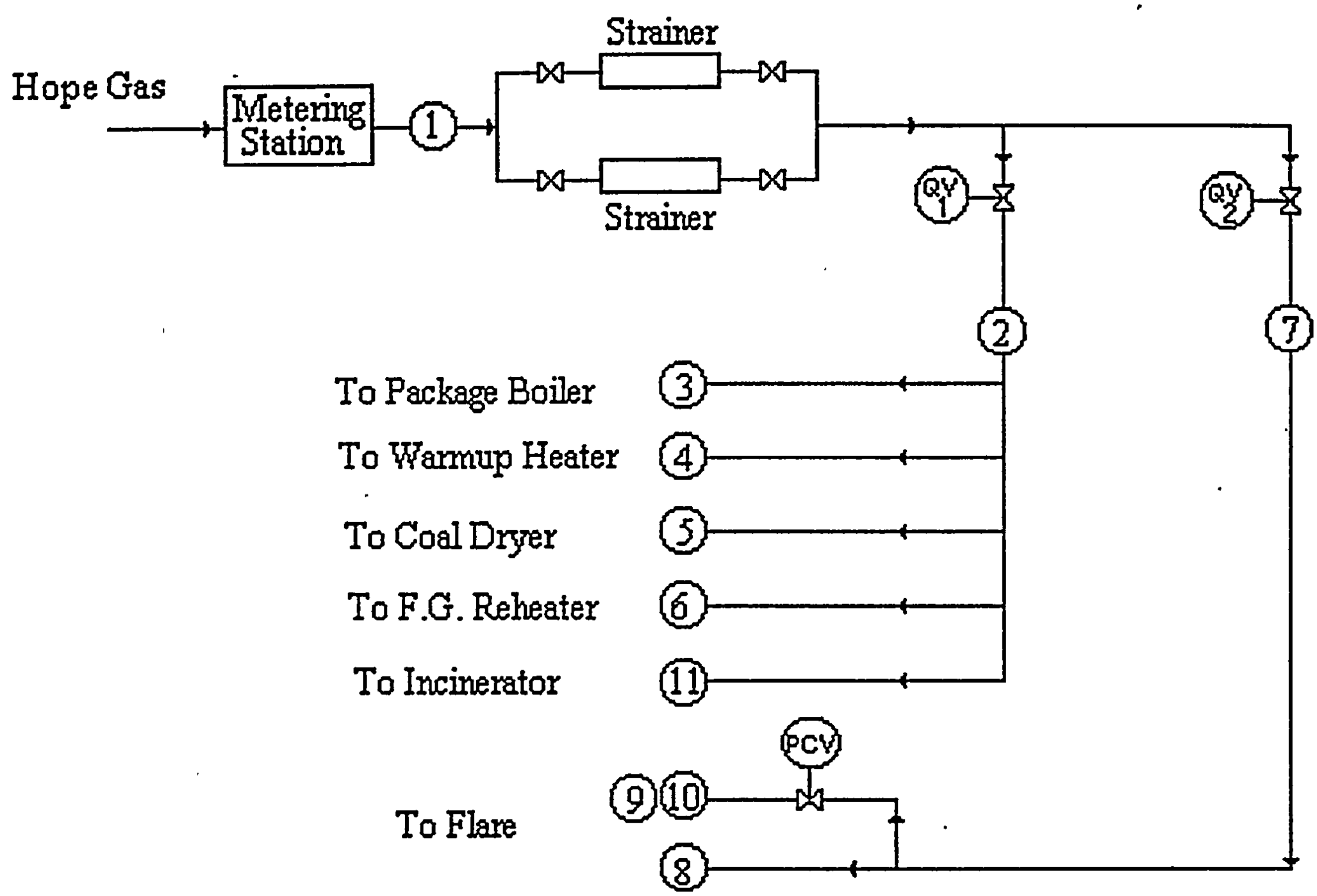
5. The ash silo is sized to allow for 45 hours of continuous bucket elevator discharge at maximum design conditions. (LATER #/hr of fines/ash ) 45 hours of storage is based on the ash removal schedule as defined in the Site Access Agreement. With normal ash hauling hours being from 7:00 a.m. to 2:30 p.m. Monday through Friday and from 7:00 a.m. to 12:00 noon Saturdays, the longest period of time when no ash is removed is 43 hours. (From 2:30 p.m. on Saturday to 7:00 a.m. on Monday) To be conservative, an additional hour was added to the beginning and the end of the 43 hour time period to allow for minor deviations from the hauling schedule.

6. A temperature drop of **LATER** °F is assumed across the weighbelt feeders.

7. A temperature drop of **LATER** °F is assumed across the ash bucket elevator.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1DG - 1**

System Name: Natural Gas Distribution
Flowsheet No.: 16N25706-40-F-1DG-001




Natural Gas Distribution

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1DG - 1**

System Name Natural Gas Distribution
Flowsheet No. 16N25706-40-F-1DG-001

## I. DESIGN PHILOSOPHY

1) Hope Gas acquires any permits required for running the pipeline to the facility. Hope Gas provides a natural gas metering station that measures the gas consumption and regulates the gas pressure. Jacobs-Sirrine is responsible for the piping design downstream of the metering station.

2) Allegheny Power grants Hope Gas an easement for Hope Gas to establish a meter site on Allegheny Power property. The approximate size of the station is 20' x 20'.

3) Natural gas supply to the facility is uninterruptable. A firm gas supply is required in order to start up, operate, and shut down the facility.

4) Gas piping is designed for the maximum pressure attainable from the Hope metering station. No safety valve is required.

5) A duplex strainer removes any foreign matter entrained within the gas.

6) The main shutoff valve (QV-1) and the flare shutoff valve (QV-2) are located downstream of the strainer. Each is interlocked to automatically close under emergency low pressure conditions (fire, explosion, etc.). Two separate lines are provided in order to always have a natural gas supply to safely incinerate coal gas. If a low pressure occurs at the coal dryer , for example, QV-1 shuts down the main gas line, but the flare is still available. Likewise, if QV-2 shuts down the flare gas supply, the HRSG is still available. Each gas line has a different routing so that an emergency condition in one part of the facility does not take down both lines.

7) Natural gas is not used for building heating. Electric unit heaters will be used.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1DG - 1**

System Name Natural Gas Distribution
Flowsheet No. 16N25706-40-F-1DG-001

## II. DESIGN CRITERIA

1) Stream Data (Note 1)

| ITEM | PROCESS STREAM | MAX FLOW MMBTU /HR | NORM FLOW MMBTU /HR | MAX FLOW SCFM | NORM FLOW SCFM | MAX PRESS PSIG | NORM PRESS PSIG |
|---|---|---|---|---|---|---|---|
| 1 | Natural Gas Supply | Note 3 | 34.00 | Note 3 | 529.00 | Note 4 | 40 |
| 2 | Main Supply Line | Note 3 | 33.80 | Note 3 | 525.90 | Note 4 | 40 |
| 3 | Package Boiler | 8.00 | 3.00 | 124.0 | 46.7 | Note 2 | Note 2 |
| 4 | Gas to Warm Up Heater | 1.00 | 0.00 | 31.1 | 0.0 | Note 2 | Note 2 |
| 5 | Gas to Coal Dryer | 3.00 | 3.00 | 46.7 | 46.7 | Note 2 | Note 2 |
| 6 | Gas to F.G. Reheater | 12.00 | 12.00 | 186.7 | 186.7 | Note 2 | Note 2 |
| 7 | Flare Supply Line | 15.35 | 0.20 | 238.8 | 3.1 | Note 4 | 40 |
| 8 | Flare Assist Gas | 15.0 | 0.00 | 233.4 | 0.0 | Note 4 | 40 |
| 9 | Flare Ignitor Gas | 0.15 | 0.00 | 2.3 | 0.0 | 15 | 10 |
| 10 | Flare Pilot Gas | 0.20 | 0.20 | 3.1 | 3.1 | 15 | 10 |
| 11 | Incinerator | Note 2 | Note 2 | Note 2 | Note 2 | Note 4 | Note 2 |

2) Composition

| CONSTITUENT | FORMULA | MASS % | VOL % |
|---|---|---|---|
| Methane | CH4 | 81.20 | 90.42 |
| Ethane | C2H6 | 9.22 | 5.48 |
| Propane | C3H8 | 3.46 | 1.40 |
| Isobutane | C4H10 | 2.42 | 0.74 |
| Nitrogen | N2 | 1.98 | 1.26 |
| Carbon Dioxide | CO2 | 1.72 | 070 |
| Total | | 100.00 | 100.00 |

3) Molecular Weight - 17.86

4) Lower Heating Value - LHV 967 BTU/SCF
20,503 BTU/LB

5) Higher Heating Value - HHV 1,071 BTU/SCF
22,711 BTU/LB

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1DG - 1**

System Name: Natural Gas Distribution
Flowsheet No.: 16N25706-40-F-1DG-001

## III. DESIGN NOTES

1) Standard conditions for natural gas are 60 deg F and 30" Hg (14.73 psia). The specific volume of Hope gas is 21.2 scf/lb.

2) Per Vendor.

3) Later.

4) Per Hope Gas.

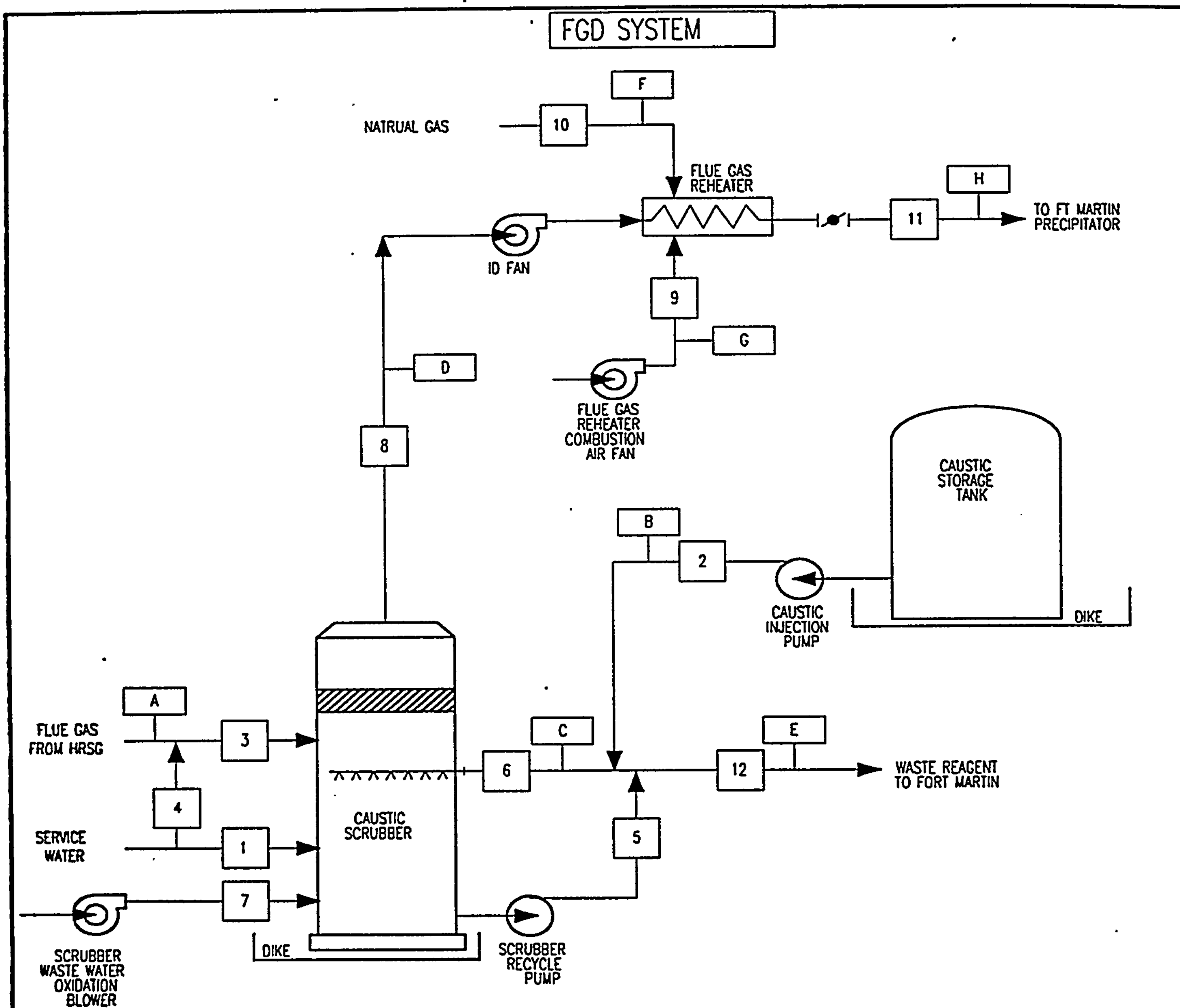
5) The gas system is designed per NFPA requirements for Seismic Zone 1.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40-1GA-1**

System Name FGD System

Flowsheet No. 16N25706-40-F-1GA-001




EQUIPMENT

Caustic Scrubber (Eq. no. 1GA-SCG-1 )
Caustic Storage Tank (Eq. No. 1GA-TK-! )
Caustic Injection Pump (Eq. No. 1GA-P-2 )
Scrubber Recycle Pump (Eq. No. 1GA-P-1 )
Flue Gas Reheater (Eq. No. 1GA-CHTR-1)

I. D. Fan (Eq. No. 1GA-FAN-1)
Caustic Heater (Eq. No. 1GA-HTR-1)
Scrubber Waste Water Oxidation Blower (Eq. No. 1GA-BLO-1)
Knife Gate Damper (Eq. No. 1GA-DMP-1 )
Flue Gas Reheater Combustion Air Fan (Eq. No. 1GA-BLO-1)

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40-1GA-1**

System Name FGD System
Flowsheet No. 16N25706-40-F-1GA-001

I. **DESIGN PHILOSOPHY**

1. The purpose of the FGD System (Flue Gas Desulfurization System) is to remove sulfur dioxide ($SO_2$) from the HRSG flue gas to assure that permit conditions are met at all times.

2. A caustic soda-based wet scrubbing system is used for ease of operation and low capital cost.

3. The scrubber is designed to achieve up to 90% removal of $SO_2$.

4. Reagent is injected into a caustic scrubber spray tower reactor where the solution absorbs the $SO_2$. The reagent reacts to form a solution of sodium sulfate and sodium sulfite.

5. Reagent is recirculated through the reactor and fresh reagent is added to maintain a pH setpoint necessary to meet the $SO_2$ emission limit. Spent reagent is bled from the system to the sewer to Fort Martin.

6. Reagent is aerated in the scrubber reactor basin with an air sparge to oxidize sulfites to sulfates prior to discharge to the Fort Martin wastewater treatment system. The spent solution contains up to 15% dissolved solids, primarily sodium sulfate, after oxidation.

7. Flue gas entering the scrubber is quenched with a water quench prior to entering the spray tower. Flue gas leaving the scrubber passes through a demister into exit ductwork saturated with moisture at 182 F.

8. The treated flue gas passes through an I.D. fan, is reheated to 250 F, and discharged to the duct running to the Fort Martin precipitator inlet breeching. The FGD system and reheater are isolated from the duct with a knife gate damper.

9. The FGD system is designed for outdoor operation, to accommodate widely varying operating conditions and for intermittent operation. The components are equipped to be flushed at the completion of and operating run to minimize corrosion and prevent solids deposits setting up between runs.

10. The system design life is five years. The materials of construction for the reactor is carbon steel with two coats of high temperature coal tar epoxy coating. Spray piping and nozzles are 304 stainless steel.

11. External piping, recycle pump and valves are FRP construction.

12. Pressure drop through the FGD system is approximately 6" WG at full load.

13. The caustic truck unloading station is curbed to prevent release of caustic in case of a spill. The caustic storage tank and scrubber tower are also diked to provide secondary containment.

14. Service water is added to the reactor basin to maintain level, replacing evaporation and spent reagent volume. Service water is also used as required to quench incoming flue gas from 1800 F to below 500 F.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40-1GA-1**

System Name FGD System
Flowsheet No. 16N25706-40-F-1GA-001

**II. DESIGN CRITERIA**

| Strm No. | Process Stream | Max Flow (#/hr) or as noted | Max Flow (acfm) | Temperature (°F) | Pressure (psig) | Consitiuent as noted |
|---|---|---|---|---|---|---|
| 1 | Service Water Make-up | 16 gpm | - | 80 | 80 | - |
| 2 | 50 % Caustic Solution | 0.67 gpm | - | 25 | 55 | 256 lbs/hr NaOH |
| 3 | Flue Gas From Burner | 67,863 | 66,683 | 1800 | -0.36 | 237 lb/hr $SO_2$ |
| 4 | Service Water Quench | 48 gpm | - | 60 | 80 | - |
| 5 | Reagent Recycle | 1,006 gpm | - | 180 | 55 | - |
| 6 | Reagent Feed | 1,000 gpm | - | 180 | 40 | - |
| 7 | Oxidation Air | 2,700 | 600 | 80 | 10 | - |
| 8 | Flue Gas to I.D. Fan | 93,682 | 26,111 | 182 | -0.58 | 22.9lb/hr $SO_2$ |
| 9 | Reheater Com-bustion Air | 2,555 | 568 | 80 | 0.36 | |
| 10 | Natural Gas to Reheater | 135 | 2 | 80 | 20 | |
| 11 | Flue Gas to Fort Martin | 96,372 | 28,636 | 250 | 0.36 | 8 lb/hr solids |
| 12 | Waste Reagent | 5.8 gpm | - | 180 | 5 | 15% TDS |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40-1GA-1**

System Name FGD System
Flowsheet No. 16N25706-40-F-1GA-001

## III. DESIGN NOTES

1. Current design is based on the Revision 1 of the Base Case, 2 TPH, Mass and Energy Balance, dated 8/24/95 for 325 psig operation.

2. Current design is based on using caustic soda as the reagent. The caustic tank is designed to hold 6,000 gallons of 50% caustic soda solution, commercial grade. The tank is insulated and heated with an electric heater to maintain the caustic in liquid form.

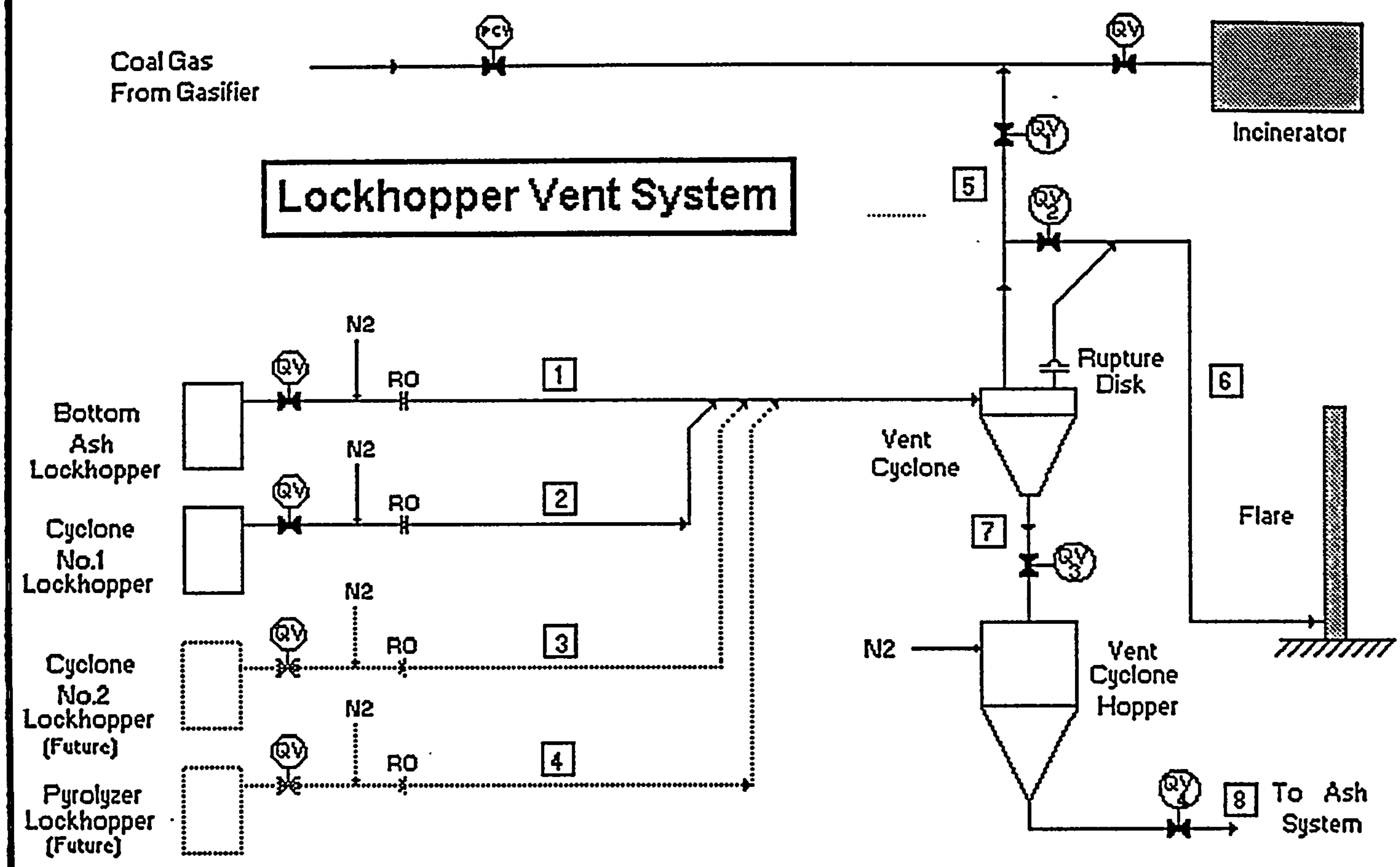
3. Current design is based on flue gas reheat to 250 F. Although this is the minimum delivery temperature allowed under the Site Access Agreement with Fort Martin, the parties have concluded that the quantity of flue gas involved is so small relative to that at the existing Fort Martin unit, that this temperature is adequate.

4. The caustic scrubber reactor tower is approximately 42 feet high and 8 feet in diameter.

5. Current design is to oxidize reagent in the scrubber basin using an air sparge. The bleed stream off of the recycle line will be about 15% sodium sulfate solution, and discharged to the Fort Martin sewer.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 1**

System Name Lockhopper Vent System
Flowsheet No. 16N25706-40-F-GG-001




EQUIPMENT:

Vent Cyclone - 1GG-CYCL-1
Vent Cyclone Hopper - 1GG-HPR-1

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 1**

System Name Lockhopper Vent System
Flowsheet No. 16N25706-40-F-GG-001

## I. DESIGN PHILOSOPHY

1) The lockhopper vent system vents coal gas from the lockhoppers to the incinerator. Under normal conditions the oxygen concentration of the gas within the system is below the limiting oxidant concentration, and the gas within the system (by itself) is noncombustible. However, if the coal gas is exposed to oxygen, it has the potential to autoignite due to its high temperature.

2) A lockhopper is depressurized by opening its vent valve. A stellite orifice in the vent line sets the vent flowrate. The depressurization rate is not precisely controlled, but it is kept within a given range. If the vessel depressurizes too quickly, then there is excessive particulate carryover. Conversely, if the vessel depressurizes too slowly, then the lockhopper emptying cycle time is excessive. The time to depressurize depends on the amount of ash / fines in the lockhopper and the amount of coal gas above the ash / fines. After the vessel depressurizes, the lockhopper is drained.

3) The lockhopper vent valves are interlocked so that only one lockhopper can be vented at a time. Each lockhopper has a separate vent line (there is not a main header) in order to minimize particulate fallout. In addition, each vent line has a nitrogen purge connection.

4) The Vent System allows the lockhoppers to depressurize to 2 psig.

5) A vent cyclone is located downstream of the lockhoppers. It removes entrained particulate that carries over into the vent system. A rupture disk on the cyclone is set at 150 psig.

6) A vent cyclone hopper beneath the vent cyclone stores the fly ash particulate that falls out in the cyclone. This hopper empties intermittently by gravity. During normal system operation QV-3 is open and QV-4 is closed. During an emptying cycle QV-3 closes and QV-4 opens. If a plug develops in the ash line, then QV-4 also closes, and the hopper is pressurized with heated nitrogen. QV-4 reopens and the plug is blown free.

7) Vent flow is diverted to the flare if the incinerator trips. QV-1 and QV-2 are interlocked. Under normal conditions QV-1 is open and QV-2 is closed. If the incinerator trips then QV-1 closes and QV-2 opens.

8) All lines and equipment within the system are insulated and heat traced in order the prevent the condensation of any vapor (condensate and particulate form mud in the system).

9) All lines within the vent system are purged with heated nitrogen on a regular basis in order to prevent the accumulation of particulate within the lines.

10) Before gasifier startup the vent system is purged of air (with nitrogen) into the incinerator. After a gasifier shutdown, the vent system is purged of coal gas (with nitrogen) into the incinerator.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 1**

System Name Lockhopper Vent System
Flowsheet No. 16N25706-40-F-GG-001

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAX FLOW LB/HR | NORM FLOW LB/HR | MAX TEMP DEG F | NORM TEMP DEG F | MAX PRESS PSIG | NORM PRESS PSIG | MIN PRESS PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | Gasifier LH Vent | 3000 | 0 | 1100 | 560 | 420 | 2 | 0 |
| 2 | No.1 Cycl. LH Vent | 1500 | 0 | 1100 | 1086 | 420 | 2 | 0 |
| 3 | No.2 Cycl. LH Vent | 1500 | 0 | 1100 | 1086 | 420 | 2 | 0 |
| 4 | Pyrolyzer LH Vent | 500 | 0 | 1100 | 650 | 420 | 2 | 0 |
| 5 | Vent to Incin | 3000 | 0 | 1100 | 400 | 150 | -1 | 0 |
| 6 | Vent to Flare | 3000 | 0 | 1100 | 400 | 150 | 0 | 0 |
| 7 | Vent Cyclone Ash | Note 1 | 0 | 1100 | 400 | 150 | 0 | 0 |
| 8 | Cyclone Hopper Ash | Note 1 | 0 | 1100 | 400 | 150 | 2 | 0 |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 1**

System Name Lockhopper Vent System
Flowsheet No. 16N25706-40-F-GG-001

**III. DESIGN NOTES**

1) Later

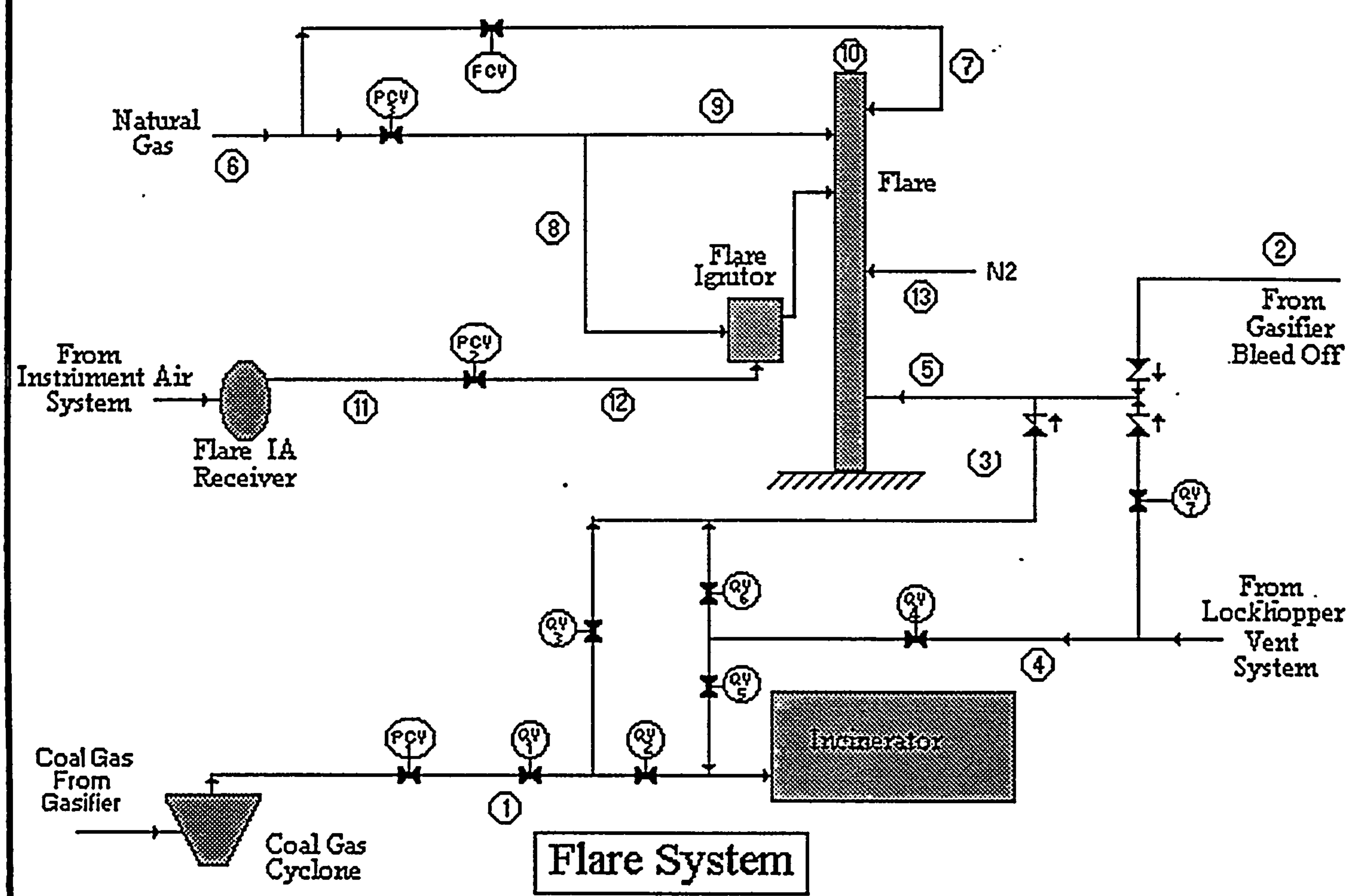
Gasification Product Improvement Facility
Fort Martin Station, West Virginia
Jacobs-Sirrine Job No. 16N25706



## SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1GG - 2**

System Name: Flare System
Flowsheet No.: 16N25706-40-F-GG-001




EQUIPMENT:

Flare - 1GG-STK-1
Instrument Air Receiver - 1GG-RCV-1

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 2**

System Name **Flare System**
Flowsheet No. 16N25706-40-F-GG-001

## I. DESIGN PHILOSOPHY

1) The flare incinerates coal gas during emergency conditions when the incinerator goes down. Whenever the incinerator is operating, coal gas is burned in the incinerator even during gasifier startup and shutdown. If the incinerator shuts down, the gasifier is interlocked to immediately trip.

2) The following streams divert to the flare if the incinerator goes down:
   a) gasifier bleed
   b) lockhopper vent system bleed
   c) incinerator bleed

3) The flare is designed for 10% of the gasifier coal gas outlet design flow and the maximum lockhopper vent system flow (both flows simultaneously).

4) The flare tip is designed for a maximum exit velocity of 60 ft/sec.

5) Assist gas (natural gas) is added to the flare tip in order to maintain a combined gas heating value of 200 Btu/scf. This heating value is needed to ensure complete combustion of the coal gas. The natural gas flow rate is adjusted based on the coal gas flow and heating value. The combined gas at the flare tip always has minimum heating value of 200 Btu/scf.

6) The flare is located on the roof of the reactor tower.

7) The flare height is based on a maximum radiation rate at the base of the stack of 1500 Btu/hr/sq ft. At this radiation rate the exposure time necessary to reach the pain threshold is 16 seconds (Note 1). Personnel wearing appropriate clothing may perform emergency action lasting several minutes. Equipment on the roof, and the roofing construction material must be capable of withstanding a heat density of 1500 Btu/hr/sq ft.

8) The minimum flare height available is 30 feet. At low tip velocities the flame may be drawn to the low pressure area on the downwind side of the stack, down along the stack. A minimum height of 30 feet ensures that the flame is always a safe distance above the roof. Low tip velocity can occur as the gasifier's pressure decays after an emergency shutdown.

9) The flare stack is constructed of stainless steel or refractory lined carbon steel. The flare stack is not insulated. Vent piping to the flare is insulated where needed for personnel protection. Coal gas flare systems that are in continuous operation are normally insulted to prevent line plugging due to condensation and particulate. Since the GPIF flare is not normally in operation, it is not insulated. When the GPIF flare system is used, the flare burner and all lines within the flare system must be purged before the flare can be brought on-line for the next test run.

10) Before each test run the entire flare vent system is purged with nitrogen. If there is oxygen in the flare system, a flashback and deflagration may occur within the flare system.

11) An integral fluidic seal (velocity seal) is incorporated into the flare tip. It is continuously purged with nitrogen to ensure that air does not enter into the flare stack. Nitrogen connections are provide on each vent line to the flare to allow continuous purging of each line if required.

12) Several pilot burners are located in the flare tip. The pilots are lit before the gasifier operation starts. Each pilot has its own thermocouple to monitor ignition and normal operation. If for some reason the pilots go out during operation, they automatically reignite. Oxygen for the continuos pilot is supplied from ambient air at the pilot.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 2**

System Name: **Flare System**
Flowsheet No.: **16N25706-40-F-GG-001**

13) A flame front generator ignites the pilots. Compressed air and natural gas are mixed outside the base of the stack to form a combustible mixture. An ignition panel at the base of the stack generates a spark, and the resulting flame front ignites the pilots. The instrument air system supplies the compressed air to the ignition system until the pilot ignites. An air receiver is located in the supply line to the flare to ensure that an adequate air supply is always available.

14) During the bid period an enclosed flare (incinerator) will be evaluated as an option.

15) During the bid period an insulated flare stack will be evaluated as an option.

16) Flare Startup

a) Nitrogen purge vent lines and flare stack.

b) Nitrogen seal the flare tip.

c) Ignite pilots. (The pilots are ignited after the system is nitrogen purged. During a shutdown oxygen and coal gas can form a combustible mixture within the vent system. This mixture can ignite when exposed to a flame (if a pilot were lit) and cause a flashback within the stack).

17) Flare Standby Operation

a) Continuously seal the flare tip with nitrogen. (The vent system may also be continuously sealed/purged with nitrogen based on recommendations from the flare vendor).

b) Continuously seal the flare vent piping with nitrogen (if flare manufacturer recommends).

c) Continuously burn flare pilots.

18) Flare Operation (Incinerator Trips)

a) QV-1, QV-2, and QV-3 are interlocked. QV-1 and QV-2 close, and QV-3 opens. Coal gas diverts to the flare.

b) QV-4, QV-5, QV-6, and QV-7 are interlocked. QV-4 and QV-5 close ,and QV-6 and QV-7 open. Lockhopper vent gas diverts to the flare.

c) Continuously monitor flowrate and heating value of the gas flow to the flare. Automatically adjust the natural gas assist flow (FCV) to maintain a combined gas heating value of greater than 200 Btu/scf.

d) Depressurize coal gas system to the flare.

e) Nitrogen purge the coal gas system to the flare.

f) Lock up coal gas system under nitrogen blanket. Shut down flare.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 2**

System Name Flare System
Flowsheet No. 16N25706-40-F-GG-001

## II. DESIGN CRITERIA

### A) Process Streams

1) Operating Conditions

| | | Flare in Standby Mode (Incinerator Running) | | | Flare in Operation (Incinerator Down) | | |
|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | NORM FLOW LB/HR | NORM PRESS PSIG | NORM TEMP DEG F | NORM FLOW LB/HR | NORM PRESS PSIG | NORM TEMP DEG F |
| 1 | Coal Gas to Incin | 18,878 | 30 | 1217 | 0 | 30 | 1217 |
| 2 | Coal Gas to Flare | 0 | 30 | 1217 | 5000 | 30 | 1217 |
| 3 | C.G. at Flare Inlet | 0 | 0 | 60 | 5000 | 2 | 1217 |
| 4 | L.H. Vent to Ejector | 3000 | 0 | 400 | 0 | 0 | 400 |
| 5 | L.H. Vent to Flare | 0 | 0 | 60 | 3000 | 10 | 400 |
| 6 | Natural Gas Supply | 8.8 | 40 | 60 | 676 | 40 | 60 |
| 7 | N.G. Assist Gas | 0 | 0 | 60 | 660 | 10 | 60 |
| 8 | N.G. Ignitor Gas | 0 | 10 | 60 | 0 | 10 | 60 |
| 9 | N.G. Pilot Gas | 8..8 | 10 | 60 | 8.8 | 10 | 60 |
| 10 | Gas to Flare Tip | 21.7 | 0 | 60 | 11,452 | 1 | 800 |
| 11 | Air from Receiver | 0 | 100 | 60 | 0 | 100 | 60 |
| 12 | Air to Ignitor | 0 | 20 | 60 | 0 | 20 | 60 |
| 13 | N2 Tip Seal | 21.7 | 30 | 60 | 21.7 | 30 | 60 |
| 14 | N2 Main Purge | 0 | 30 | 60 | 0 | 30 | 60 |
| 15 | N2 L.H. Purge | 0 | 30 | 60 | 0 | 30 | 60 |
| 16 | N2 QV-1,2 Purge | 0 | 30 | 60 | 0 | 30 | 60 |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 2**

System Name: Flare System
Flowsheet No.: 16N25706-40-F-GG-001

2) Design Conditions (Notes 2,3,4,5)

| ITEM | PROCESS STREAM | MAX FLOW LB/HR | MAX FLOW SCFM | MAX PRESS PSIG | MAX TEMP DEG F |
|---|---|---|---|---|---|
| 1 | Coal Gas to Incin | 18,878 | 5213 | 660 | 1500 |
| 2 | Coal Gas to Flare | 7770 | 2146 | 660 | 1500 |
| 3 | C.G. at Flare Inlet | 7770 | 2146 | 10 | 1500 |
| 4 | L.H. Vent to Ejector | 3000 | 829 | 150 | 1500 |
| 5 | L.H. Vent to Flare | 3000 | 829 | 150 | 1500 |
| 6 | Natural Gas Supply | 676 | 239 | Note 8 | 90 |
| 7 | N.G. Assist Gas | 660 | 233 | Note 8 | 90 |
| 8 | N.G. Ignitor Gas | 6.5 | 2.3 | 15 | 90 |
| 9 | N.G. Pilot Gas | 8.8 | 3.1 | 15 | 90 |
| 10 | Gas to Flare Tip | 11,452 | 4046 | 40 | 90 |
| 11 | Air from Receiver | 137 | 30 | 125 | 90 |
| 12 | Air to Ignitor | 137 | 30 | 30 | 90 |
| 13 | N2 Tip Seal | 21.7 | 5 | 50 | 90 |
| 14 | N2 Main Purge | 1519 | 350 | 50 | 90 |
| 15 | N2 L.H. Purge | 1519 | 350 | 50 | 90 |
| 16 | N2 QV-1,2 Purge | 434 | 100 | 50 | 90 |

B) Coal Gas Data (Note 6)

1) Composition

| CONSTITUENT | FORMULA | MASS % | VOL % |
|---|---|---|---|
| Carbon Monoxide | CO | 25.46 | 21.13 |
| Hydrogen | H2 | 1.38 | 15.91 |
| Carbon Dioxide | CO2 | 10.57 | 5.58 |
| Water | H2O | 11.41 | 14.73 |
| Methane | CH4 | 0.49 | 0.71 |
| Hydrogen Sulfide | H2S | 0.17 | 0.12 |
| Nitrogen | N2 | 49.15 | 40.80 |
| Argon | Ar | 1.09 | 0.64 |
| Ammonia | NH3 | 0.28 | 0.38 |
| Total | | 100.00 | 100.00 |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 2**

System Name **Flare System**
Flowsheet No. **16N25706-40-F-GG-001**

2) Coal Gas Properties

| | |
|---|---|
| Molecular Weight | 23.25 |
| Lower Heating Value - Btu/SCF | 118 |
| Higher Heating Value - Btu/SCF | 127 |
| Lower Heating Value - Btu/lb | 1958 |
| Higher Heating Value - Btu/lb | 2106 |

C) **Natural Gas Data** (Note 7)

1) Composition

| CONSTITUENT | FORMULA | MASS % | VOL % |
|---|---|---|---|
| Methane | CH4 | 81.20 | 90.42 |
| Ethane | C2H6 | 9.22 | 5.48 |
| Propane | C3H8 | 3.46 | 1.40 |
| Isobutane | C4H10 | 2.42 | 0.74 |
| Nitrogen | N2 | 1.98 | 1.26 |
| Carbon Dioxide | CO2 | 1.72 | 070 |
| Total | | 100.00 | 100.00 |

2) Natural Gas Properties (Note 2)

| | |
|---|---|
| Molecular Weight | 17.86 |
| Lower Heating Value - Btu/SCF | 967 |
| Higher Heating Value - Btu/SCF | 1,071 |
| Lower Heating Value - Btu/lb | 20,503 |
| Higher Heating Value - Btu/lb | 22,711 |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1GG - 2**

System Name **Flare System**
Flowsheet No. **16N25706-40-F-GG-001**

## III. DESIGN NOTES

1) Per API 521, p 35.

2) Standard conditions for natural gas are 30" Hg (14.73 psia) and 60 deg F. The specific volume of Hope gas is 21.2 scf/lb.

3) Standard conditions for nitrogen are 14.7 psia and 70 deg F. The specific volume of nitrogen is 13.8 scf/lb.

4) Standard conditions for instrument air are 14.7 psia, 59 deg F, and 36% RH. The specific volume of standard air is 13.16 scf/lb.

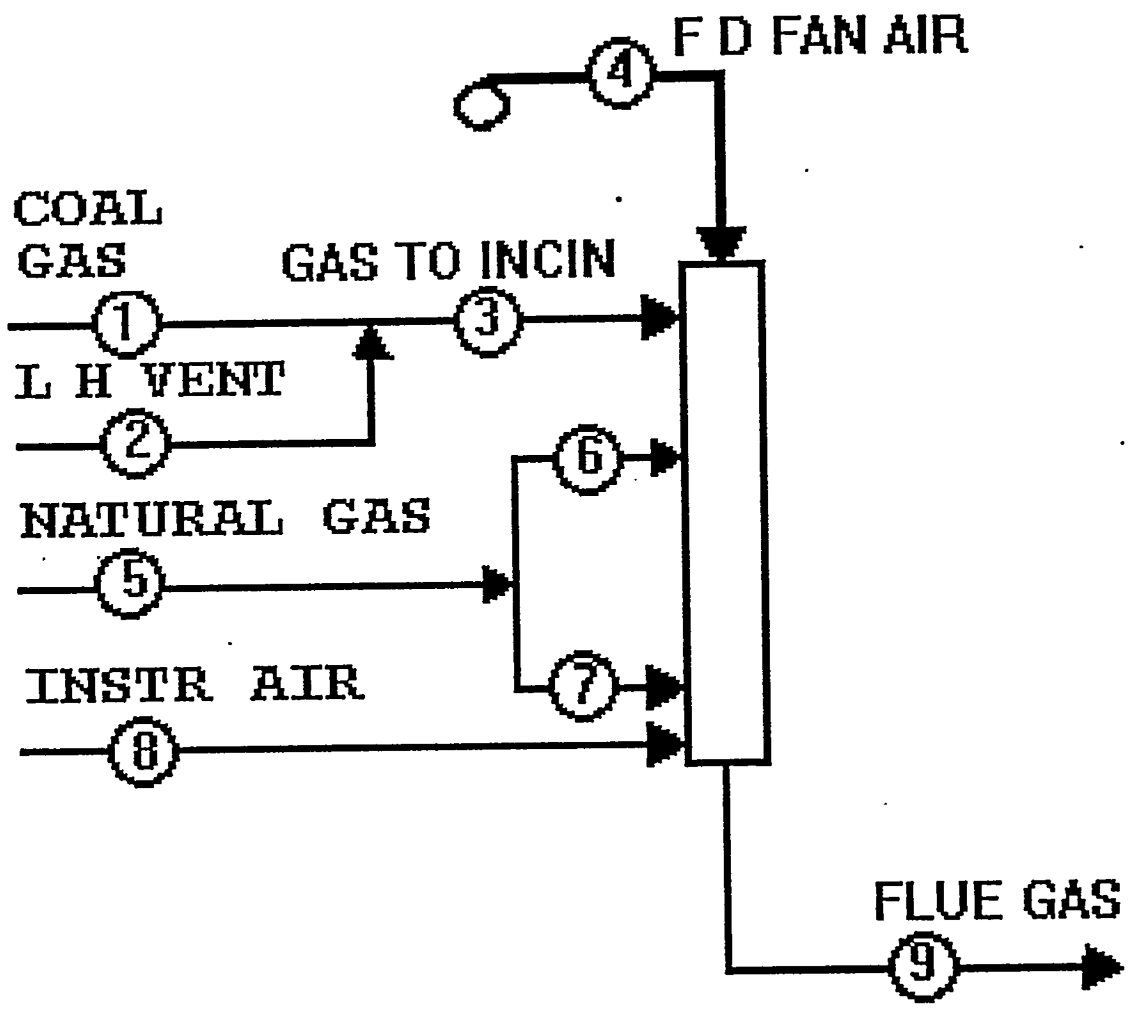
5) Standard conditions for waste gas (coal gas) to a flare are 14.7 psia and 68 deg F per 40 CFR 60.18. The specific volume of the design coal gas to the flare is 16.57 scf/lb.

6) Per Mass Balance - 3/22/95.

7) Per Natural Gas Distribution Process Design Basis.

8) Per Hope Gas.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1GH-1
System Name Incineration System
Flowsheet No. 16N25706-40-F-GH-001




EQUIPMENT:

Incinerator - 1GH-INCN-1
FD Fan - 1GH-FAN-1

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1GH-1
System Name Incineration System
Flowsheet No. 16N25706-40-F-GH-001

## I. DESIGN PHILOSOPHY

1) The incinerator burns the coal gas so that it can be safely released to the atmosphere. The residence time in the coal gas within the incinerator is one second.

2) The temperature within the incinerator is controlled to 2000 deg F. The heating loop is controlled by the natural gas fuel control valve. The cooling loop is controlled by the FD fan VFD.

3) The coal gas enters the incinerator through a stainless steel burner.

4) The forced draft fan supplies the combustion air (and quench air) to the incinerator . A variable frequency drive (VFD) controls the speed of the fan motor.

5) The incinerator is a vertical, cylindrical, down-fired unit constructed of refractory lined carbon steel. It is approximately nine feet in diameter and twenty-five feet tall. The coal gas inlet to the incinerator is approximately the same elevation as the coal gas outlet from the cyclone.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1GH-1
System Name Incineration System
Flowsheet No. 16N25706-40-F-GH-001

## II. DESIGN CRITERIA

A) **Process Streams** (Notes 1,2,3)

| ITEM | PROCESS STREAM | MAX FLOW LB/HR | MAX FLOW SCFM | MAX PRESS PSIG | MAX TEMP DEG F |
|---|---|---|---|---|---|
| 1 | Gasifier Coal Gas | 18,878 | 5213 | 30 | 1150 |
| 2 | LH Vents | 3000 | 829 | 30 | 1150 |
| 3 | Coal Gas to Incin. | 21,878 | 6042 | 30 | 1150 |
| 4 | FD Fan Air | Note 4 | Note 4 | 1 | 100 |
| 5 | Natural Gas Supply | Note 4 | Note 4 | 60 | 100 |
| 6 | N.G. Burner Gas | Note 4 | Note 4 | 60 | 100 |
| 7 | N.G. Ignitor Gas | Note 4 | Note 4 | 60 | 100 |
| 8 | Inst. Air to Ignitor | Note 4 | Note 4 | 120 | 100 |
| 9 | Flue Gas | Note 4 | Note 4 | 1 | 2100 |

B) **Coal Gas Data** (Note 5)

1) Coal Gas Composition

| CONSTITUENT | FORMULA | MASS % | VOL % |
|---|---|---|---|
| Carbon Monoxide | CO | 25.40 | 21.08 |
| Hydrogen | H2 | 1.39 | 16.04 |
| Carbon Dioxide | CO2 | 10.48 | 5.54 |
| Water | H2O | 11.23 | 14.49 |
| Methane | CH4 | 0.50 | 0.73 |
| Hydrogen Sulfide | H2S | 0.64 | 0.44 |
| Nitrogen | N2 | 48.98 | 40.65 |
| Argon | Ar | 1.10 | 0.64 |
| Ammonia | NH3 | 0.28 | 0.39 |
| Total | | 100.00 | 100.00 |

2) Coal Gas Properties

| | |
|---|---|
| Molecular Weight | 23.25 |
| Higher Heating Value - Btu/scf | 127 |

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SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1GH-1
System Name Incineration System
Flowsheet No. 16N25706-40-F-GH-001

| | |
|---|---|
| Higher Heating Value - Btu/lb | 2147 |

C) **Particulate Data** (Particulate in coal gas going to the incinerator)

1) Max Particulate - 125 lb/hr (Note 6)

2) Particulate Composition - Wt% (Note 5)

| | |
|---|---|
| Carbon | 70 |
| Ash | 30 |

3) Ash Composition - (Note 7)

| CONSTITUENT | FORMULA | MASS % |
|---|---|---|
| Silica | SiO2 | 55.19 |
| Alumina | Al2O3 | 31.11 |
| Iron (III) Oxide | Fe2O3 | 7.08 |
| Titania | TiO2 | 1.49 |
| Magnesia | MgO | 1.22 |
| Manganese Oxide | MnO | 0.08 |
| Phosphorus (V) Oxide | P2O5 | 0.27 |
| Potassium Oxide | K2O | 2.66 |
| Calcium Oxide | CaO | 0.90 |
| Total | | 100.00 |

4) Ash Fusion Temp - 2200 Deg F. (Note 7)

5) Particulate Size Distribution - It is anticipated that 95% of the particulate is between 1-5 micron (Note 8).

D) **Natural Gas Data** (Note 9)

1) Natural Gas Composition

| CONSTITUENT | FORMULA | MASS % | VOL % |
|---|---|---|---|
| Methane | CH4 | 81.20 | 90.42 |
| Ethane | C2H6 | 9.22 | 5.48 |
| Propane | C3H8 | 3.46 | 1.40 |
| Isobutane | C4H10 | 2.42 | 0.74 |
| Nitrogen | N2 | 1.98 | 1.26 |
| Carbon Dioxide | CO2 | 1.72 | 070 |
| Total | | 100.00 | 100.00 |

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1GH-1
System Name Incineration System
Flowsheet No. 16N25706-40-F-GH-001

2) Natural Gas Properties

| | |
|---|---|
| Molecular Weight | 17.86 |
| Higher Heating Value - Btu/SCF | 1,071 |
| Higher Heating Value - Btu/lb | 22,711 |

SYSTEM PROCESS DESIGN BASIS
PDB No. 40-1GH-1
System Name Incineration System
Flowsheet No. 16N25706-40-F-GH-001

## III. DESIGN NOTES

1) Standard conditions for waste gas (coal gas) are 14.7 psia and 68 deg F per 40 CFR 60.18. The specific volume of the design coal gas is 16.57 scf/lb.

2) Standard conditions for natural gas are 30" Hg (14.73 psia) and 60 deg F. The specific volume of Hope gas is 21.2 scf/lb.

3) Standard conditions for instrument air are 14.7 psia, 59 deg F, and 36% RH. The specific volume of standard air is 13.16 scf/lb.

4) Per Vendor

5) Per Mass Balance - 5/31/95.

6) Per cyclone Process Design Basis.

7) Per Task IV report.

8) Based on correlating the Bacho particulate curve with the cyclone efficiency curve.

9) Per Natural Gas Distribution Process Design Basis.

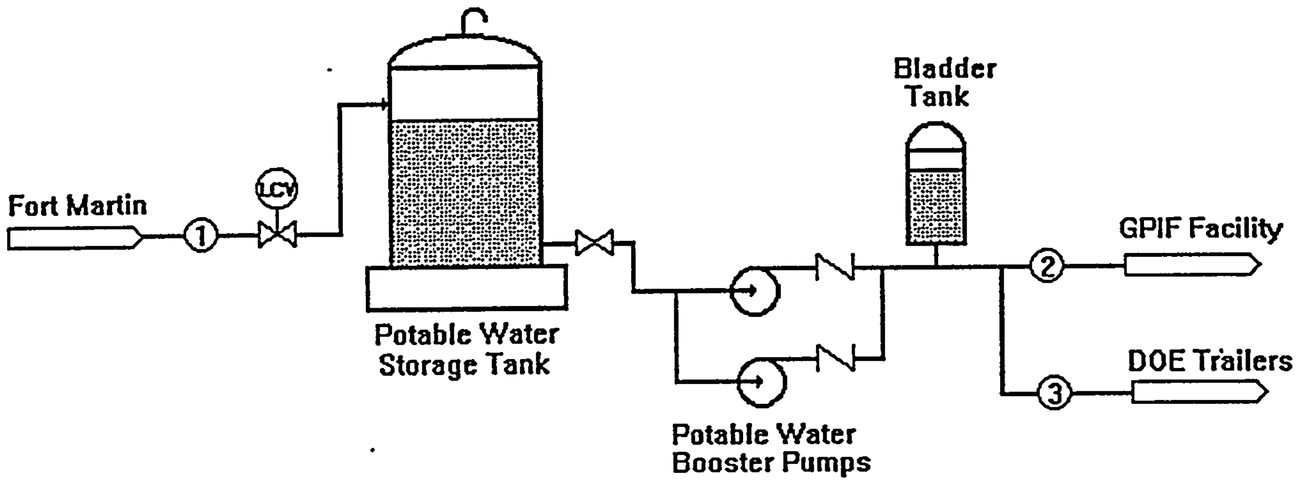
10) Incinerator will be arranged vertical with flow down, per manufacturer recommendation when particulate is present in fuel.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1KK - 1**

System Name Potable Water Sytem

Flowsheet No. 16N25706-40-F-1KK-001




EQUIPMENT

Potable Water Storage Tank (Eq. No. 1KK-TK-1)
Potable Water Booster Pumps (Eq. Nos. 1KK-P-1, 1KK-P-2)

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1KK - 1**

System Name Potable Water Sytem

Flowsheet No. 16N25706-40-F-1KK-001

I. DESIGN PHILOSOPHY

1. The function of the Potable Water System is to receive and store potable water from the Fort Martin Station and forward the water to the various GPIF users.

2. Potable water is received at 1 gpm and stored in 500 gallon capacity storage tank. With only 1 gpm of makeup flow being available, the potable water must be stored for peak use periods.

3. The Potable Water Booster Pumps take suction directly from the storage tank. The potable water is forwarded to the GPIFdistribution header and in turn, available to the users. Potable water is also forwarded to the Department of Energy (DOE) trailers.

4. A bladder tank located downstream of the pumps maintains constant pressure on the distribution header at all flow conditions. This tank monitors system pressure regulates pump operation based on increases and decreases in system pressure.

5. This system provides water for the plants safety showers, and domestic plumbing needs. (Toilets, showers, sinks, etc.)

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KK - 1**
System Name Potable Water Sytem
Flowsheet No. 16N25706-40-F-1KK-001

## II. DESIGN CRITERIA

| ITEM NO. | PROCESS STREAM | MAXIMUM FLOW GPM | NORMAL FLOW GPM | MINIMUM FLOW GPM | MAXIMUM TEMP. °F | MINIMUM TEMP. °F | MAXIMUM PRESS. PSIG | MINIMUM PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | Potable Water from Ft. Martin | Hold | 1 | 1 | 55 | 55 | 150 | 150 |
| 2 | Potable Water to GPIF | Hold | 65 | 65 | Ambient | Ambient | 30 | 30 |
| 3 | Potable Water to DOE Trailers | Hold | Hold | Hold | Ambient | Ambient | 30 | 30 |

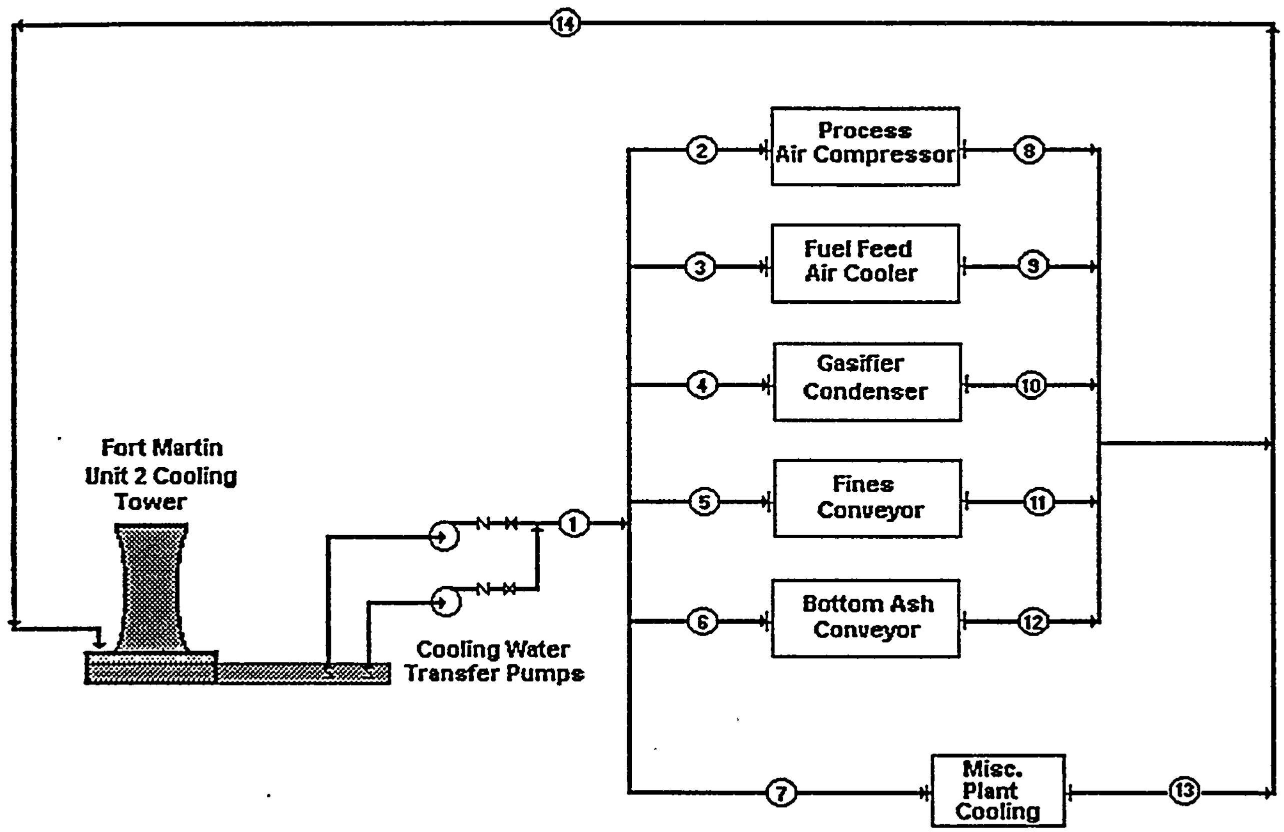
SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KK - 1**
System Name Potable Water Sytem
Flowsheet No. 16N25706-40-F-1KK-001

III. DESIGN NOTES

1. Potable water design flow rates will be determined once the plant layout and potable water users are finalized.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KV - 1**

System Name Auxiliary Water Distribution (Cooling Water)
Flowsheet No. 16N25706-40-F-KV-001




EQUIPMENT

Cooling Water Transfer Pumps (Eq. Nos. 1KV-P-1, 1KV-P-2)

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KV - 1**

System Name Auxiliary Water Distribution (Cooling Water)
Flowsheet No. 16N25706-40-F-KV-001

I. DESIGN PHILOSOPHY

1. The function of Cooling Water System is to provide cooling water to the Process Air Compressor, Fuel Feed Air Cooler, Gasifier Condenser, Fines Conveyor, Bottom Ash Conveyor and other miscellaneous plant components that require cooling water.

2. The two 50% capacity Cooling Water Transfer Pumps take suction from the existing Fort Martin Station Unit No. 2 Cooling Tower Basin and forward cooling water to the Gasification Product Improvement Facility (GPIF).

3. During normal or emergency plant shut down, only one of the two Cooling Water Transfer Pumps is required to be operational in order to provide cooling water for shutdown.

4. The Cooling Water Transer Pumps are self priming, centrifugal horizontal type pumps. Foot valves are installed on the cooling water suction line inlet to maintain prime during GPIF and system shutdown.

5. After passing through the cooling heat exchangers the cooling water is returned back to the Fort Martin cooling tower.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KV - 1**

System Name Auxiliary Water Distribution (Cooling Water)
Flowsheet No. 16N25706-40-F-KV-001

## II. DESIGN CRITERIA

| ITEM NO. | PROCESS STREAM | MAX. FLOW (gpm) | MIN. FLOW (gpm) | NORMAL FLOW (gpm) | MAX. TEMP. (°F) | MIN. TEMP. (°F) | MAX. PRESS. (psig) | MIN. PRESS. (psig) |
|---|---|---|---|---|---|---|---|---|
| 1 | Cooling Water Transfer Pump Discharge | Hold | Hold | Hold | 150 | Hold | 100 | 30 |
| 2 | Inlet to Process Air Compressor | Hold | Hold | Hold | 150 | Hold | 100 | 30 |
| 3 | Inlet to Fuel Feed Air Cooler | 50 | 35 | 10 | 150 | 85 | 100 | 40 |
| 4 | Inlet to Gasifier Condenser | Hold | Hold | Hold | 150 | 85 | 100 | 40 |
| 5 | Inlet to Fines Conveyor | Hold | Hold | Hold | 150 | 85 | 100 | 40 |
| 6 | Inlet to Bottom Ash Conveyor | Hold | Hold | Hold | 150 | 85 | 100 | 40 |
| 7 | Header to Miscellaneous Plant Cooling | Hold | Hold | Hold | 150 | 85 | 100 | 40 |
| 8 | Outlet from Process Air Compressor | Hold | Hold | Hold | 150 | 105 | 100 | 30 |
| 9 | Outlet from Fuel Feed Air Cooler | Hold | Hold | Hold | 150 | 105 | 100 | 30 |
| 10 | Outlet from Gasifier Condenser | Hold | Hold | Hold | 150 | 105 | 100 | 30 |
| 11 | Outlet from Fines Conveyor | Hold | Hold | Hold | Hold | Hold | 100 | 30 |
| 12 | Outlet from Bottom Ash Conveyor | Hold | Hold | Hold | Hold | Hold | 100 | 30 |
| 13 | Header from Miscellaneous Plant Cooling | Hold | Hold | Hold | 150 | Hold | 100 | 30 |
| 14 | Return to Fort Martin Cooling Tower | Hold | Hold | Hold | 150 | Hold | 100 | 30 |

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1KV - 1**

System Name Auxiliary Water Distribution (Cooling Water)
Flowsheet No. 16N25706-40-F-KV-001

III. DESIGN NOTES

1. Current design is based on the Mass Balance dated (later).

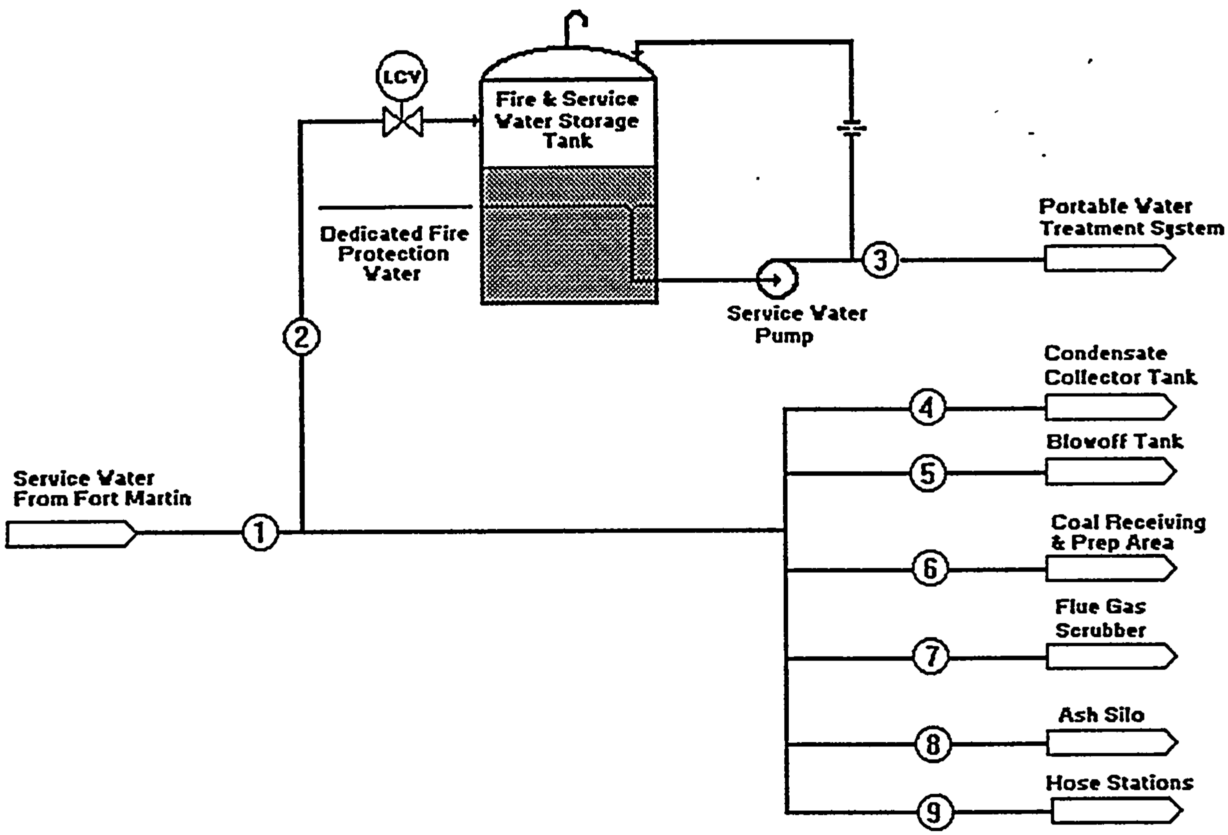
2. Design criteria will be finalized when equipment design and selection is completed.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1KW - 1**

System Name Service Water System

Flowsheet No. 16N25706-40-F-1KW-001




EQUIPMENT

Fire & Service Water Storage Tank (Eq. No. 1KW-TK-1)
Service Water Pump (Eq. No. 1KW-P-1)

SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1KW - 1**

System Name Service Water System

Flowsheet No. 16N25706-40-F-1KW-001

I. DESIGN PHILOSOPHY

1. The function of the Service Water System is to receive, store and distribute service water from Fort Martin station to the various GPIF users.

2. The Fire & Service Water Storage Tank receives and collects service water from Fort Martin. The tank provides an inventory of both fire protection water and pretreated boiler feedwater.

3. A level control valve, located at the inlet to the storage tank, maintains tank level by modulating service water inlet flow.

4. The Service Water Pump takes suction from the storage tank and forwards the water to the inlet to the portable water treatment skid. The inlet to the Service Water pump suction line is located at a tank level above the dedicated fire protection water level.

5. Required minimum flow is maintained for the Service Water Pump by continuously recirculating a portion of pump discharge flow back to the storage tank.

6. Sevice water to the Condensate Collector Tank, Blowoff Tank, coal receiving and prep area, Flue Gas Scrubber, the Ash Silo and the plant hose stations is pipe directly from the Fort Martin service water supply header. Pressure to these users is adequate as provided by the Fort Martin service water pumps.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KW - 1**
System Name Service Water System
Flowsheet No. 16N25706-40-F-1KW-001

## II. DESIGN CRITERIA

| ITEM NO. | PROCESS STEAM | MAXIMUM FLOW GPM | NORMAL FLOW GPM | MINIMUM FLOW GPM | MAXIMUM TEMP. °F | MINIMUM TEMP. °F | MAXIMUM PRESS. PSIG | MINIMUM PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | Service Water from Ft. Martin | Hold | Hold | Hold | 90 | 60 | 100 | 75 |
| 2 | Service Water to Storage Tank | Hold | Hold | Hold | 90 | 60 | 100 | 75 |
| 3 | Service Water to Portable Water Treatment System | Hold | Hold | Hold | 90 | 60 | 100 | 70 |
| 4 | Service Water to Condensate Collector Tank | Hold | Hold | Hold | 90 | 60 | 80 | 40 |
| 5 | Service Water to Blowoff Tank | Hold | Hold | 0 | 90 | 60 | 80 | 40 |
| 6 | Service Water to Coal Prep and Receiving Area | Hold | Hold | 0 | 90 | 60 | 80 | 40 |
| 7 | Service Water to Flue Gas Scrubber | Hold | Hold | 0 | 90 | 60 | 80 | 40 |
| 8 | Service Water to Ash Silo | Hold | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) |
| 9 | Service Water to Hose Stations | Hold | 0 | 0 | 90 | 60 | 80 | 40 |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1KW - 1**
System Name Service Water System
Flowsheet No. 16N25706-40-F-1KW-001

III. DESIGN NOTES

1. Current design is based on Mass Balance dated (later).

2. This document does not describe the Fire Protection System.

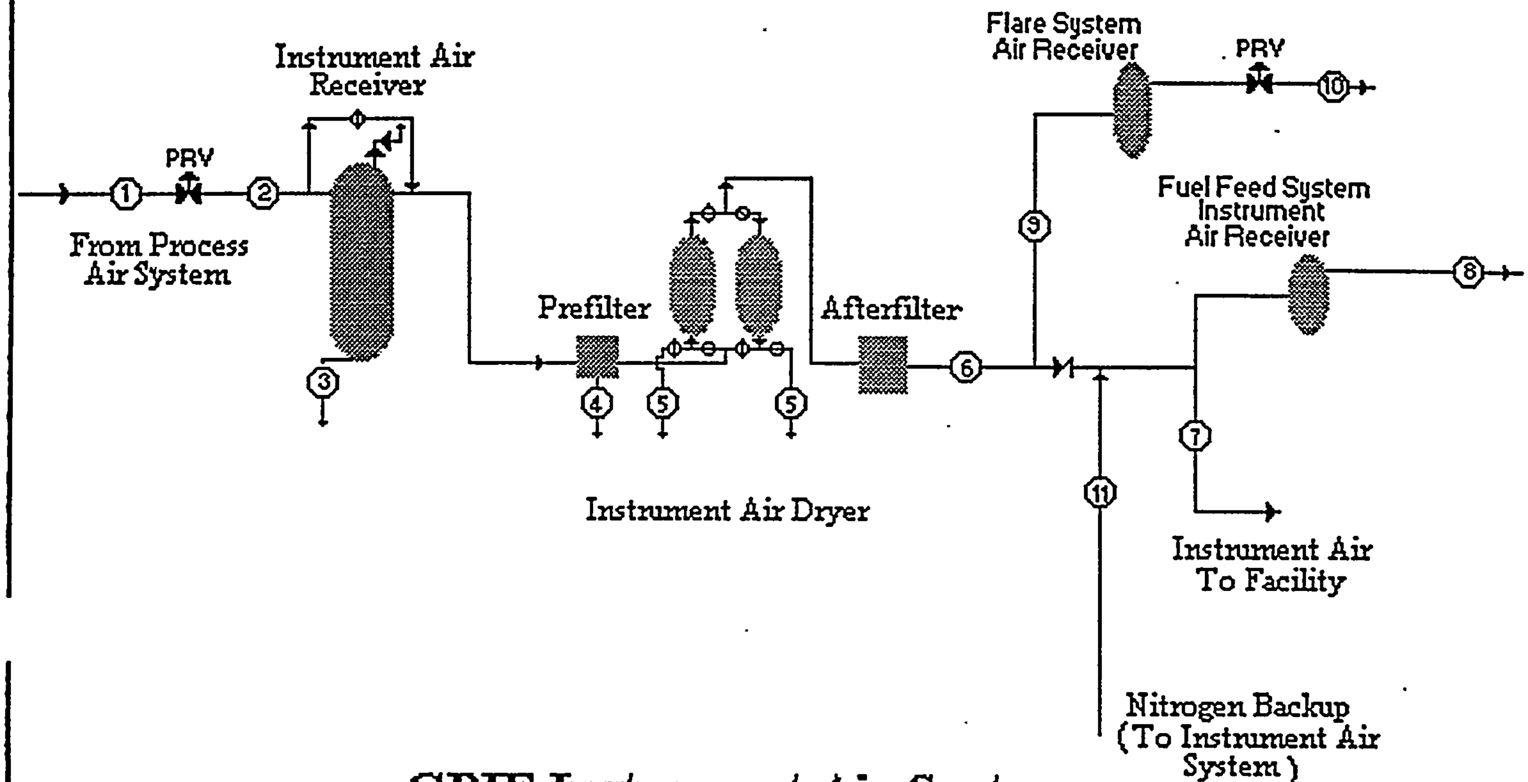
3. The capacity of the Fire & Service Water Storage Tank is (later) gallons. This is based on (later) gallons of fire protection water and (later) gallons of service water.

**SYSTEM PROCESS DESIGN BASIS**

**PDB No. 40 - 1LD - 1**

System Name **Plant and Instrument Air Systems**

Flow sheet No. **16N25706-40-F-1LD-001**




## GPIF Instrument Air System

EQUIPMENT

Dryer Prefilter (Eq. No. 1LD-FLT-1)
Instrument Air Dryer (Eq. No. 1LD-DRY-1)
Dryer Afterfilter (Eq. No. 1LD-FLT-2)
Instrument Air Receiver (Eq. No. 1LD-TK-1)
Fuel Feed System Instrument Air Receiver (1LD-TK-2)
Flare System Air Receiver (Eq. No. 1GG-TK-1)

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1LD - 1**

System Name Plant and Instrument Air Systems

Flow sheet No. 16N25706-40-F-1LD-001

DESIGN PHILOSOPHY

1. The Instrument Air System shall be designed to provide instrument quality air (-40 °F pressure dew point) to users in the GPIF facility.

2. While the GPIF will operate on a schedule of two weeks operating and down for six weeks, the Instrument Air System shall be designed to operate continuously.

3. Instrument Air shall be provided from an interface with the Process Air System A pressure reducing value shall be used to reduce Process Air pressure to approximately 100 psig for use in the Instrument Air System.

4. The design pressure of the Instrument Air System shall be 125 psig. All piping, vessels, and equipment shall have an ASME pressure rating of this value.

5 The capacity of the **Instrument Air Dryer** shall be determined, in part, by the purge flow technology used by the dryer ultimately selected. Instrument Air System Vendors will recommend a system configuration based upon specified system requirements and economic parameters agreed to by JSE, R/S, and the DOE.

6. The **Instrument Air Receiver** volume in cubic feet shall equal **30 seconds** (.5 minutes) of additional flow at a rate of **100 scfm**.. This flow shall be adequate for meeting the anticipated flow surges in the Instrument Air System.

7. The **Instrument Air Dryer** shall be a dual tower desiccant-type dryer. This dryer shall be designed to deliver **350 SCFM** to the facility's Instrument Air System. During normal operation, one tower will be in service while the other is undergoing regeneration. Regeneration shall be controlled on either a timed cycle or by monitoring the exit humidity of the regenerating bed.. The dried compressed air will have a pressure dew point of at least **-40 °F.**

8. The maximum pressure drop across the instrument air dryer shall be **5 psi** at rated flow and pressure.

9. The dryer prefilter shall be designed to capture all liquid and solid particles greater than **0.9 microns** in size. The maximum pressure drop associated with a saturated filter at rated flow and pressure shall be **2 psi**.

10. The dryer afterfilter shall be designed to capture all desiccant particles greater than **0.9 microns** in size that may escape from the desiccant towers. The maximum pressure drop associated with a completely saturated afterfilter shall be **3 psi.**

11. The Instrument Air System will supply the instrument air needs of the Coal Preparation Facility. The interface with this facility shall be the **Fuel Feed System Instrument Air Receiver Tank** sized to handle the intermittent air flows associated with the air cannons and dustbins on the coal silo. The current estimate for size of this receiver is 14.5 $ft^3$.

12. Instrument Air will also be supplied to the Flare System. Instrument air will be required for the flame front ignitors. The interface with this system will also be an air receiver (**Flare System Air Receiver**) tank sized to handle the air requirements of the Flare System. It is currently estimated that this receiver will be approximately 8 $ft^3$. Air for this purpose will come off the Instrument Air System at a location upstream of the interface between the Instrument Air and Nitrogen Backup System. A check valve will prevent nitrogen from getting into the Flare System's ignitors.

13. Because the Instrument Air System will not be on emergency power, the backup system for instruments shall be nitrogen from the nitrogen distribution system. At least one nitrogen pump shall be on standby power so that nitrogen will always be available for critical uses.

14. The conversion between **SCF** and **lbs.** for this document is 0.076 $lbs/ft^3$.

**SYSTEM PROCESS DESIGN BASIS**
**PDB No. 40 - 1LD - 1**
System Name **Plant and Instrument Air Systems**
Flow sheet No. **16N25706-40-F-1LD-001**

## Instrument Air System Profile

| Stream No. | Process Stream | Normal Flow (PPH) | Maximum Flow ** (PPH) | Normal Temp. (°F) | Maximum Temp. (°F) | Normal Pressure (psig) | Maximum Pressure (psig) |
|---|---|---|---|---|---|---|---|
| 1 | Process Air | 1,058 | 1,603 | 70 | 100 | 487 | 550 |
| 2 | Process Air | 1,058 | 1,603 | 70 | 100 | 105 | 125 |
| 3 | Condensate | 0 | 25 | 70 | 100 | 105 | 125 |
| 4 | Condensate | 0 | 5 | 70 | 100 | 103 | 125 |
| 5 | Dryer Purge | 80 | 80 | 70 | 100 | 10 | 125 |
| 6 | Instrument Air | 978 | 1,493 | 70 | 100 | 95 | 125 |
| 7 | Instrument Air To Facility | 932 | 1,219 | 70 | 100 | 93 | 125 |
| 8 | Instrument Air To Fuel Feed | 46 | 274 | 70 | 100 | 93 | 125 |
| 9 | Instrument Air To Flare | 0 | 90 | 70 | 100 | 93 | 125 |
| 10 | Instrument Air To Flare | 0 | 90 | 70 | 100 | 20 | 25 |
| 11 | Nitrogen To Instrument Air | 0 | 1,493 | 60 | 90 | 95 | 125 |

DESIGN NOTES

1. ** The following is the basis for Instrument Air System component sizing: These flow are the basis for system design (see Average Useage column below). Note that individual flows are not necessarily cumulative

**GPIF Instrument Air Estimates (PPH)**

| | (a) Minimum Usage During Shutdown | (b) Minimum Usage During Normal Operation | (c) Average Usage During Normal Operation (Assumes 60% Utilization) | (d) Maximum Air Demand (100 % Utilization) |
|---|---|---|---|---|
| Instrument Air To Facility | 18 | 18 | 1089 | 1796 |
| Instrument Air To MH | 23 | 91 | 274 | 456 |
| Instrument Air To Flare | -- | -- | -- | -- |
| Losses (5 % Dryer Purge) | 2.35 | 6 | 80 | 131 |
| (10% Leakage) | 5 | 13 | 160 | 265 |
| Total | 47 | 128 | 1603 | 2649 |

a These figures represent the facility's instrument requirement when the GPIF is down during the six week data evaluation period. Because the process air compressors will not be operating during this time, this flowrate also represents the base nitrogen demand by the Instrument Air System.
b These figures represent the estimated minimum instrument air demand during normal GPIF operation.
c Normal instrument air demand is based upon a conservative estimate of equipment utilization of 60% of system maximum demand.
d These figures represent all instrumentation and other users in operation concurrently.

**SYSTEM PROCESS DESIGN BASIS**
**PDB No. 40 - 1LD - 1**
System Name **Plant and Instrument Air Systems**
Flow sheet No. **16N25706-40-F-1LD-001**

2. Instrument air requirements were estimated by summarizing all instruments loops and the air requirements of each type.

3. An Instrument Air Dryer size of 350 SCFM is recommended based upon the estimate air requirements of the facility. This unit sizing reflects very little contingency when compared to the normal usage figure. However, the utilization figure used to estimate normal usage is very conservative and therefore has contingency already included. In addition, the Instrument Air System will have a nitrogen backup that will supplement the system to maintain optimum system operating pressure.

4. Plant Air shall be provided by a separate compressor / receiver / dryer designed to provide air for less critcal uses . The capacity of this system shall be 100 SCFM. Compressed air from this system shall be used for pneumatic tools and housekeeping. The following is an estimate of anticipated plant air users and their consumption.

## Estimated Plant Air Usage

**Pneumatic Tools**

| Tool | No. | Air Requirement (SCFM) Per Tool | Total |
|---|---|---|---|
| Drills | 2 | 35 | 70 |
| Grinders | 2 | 50 | 100 |
| Sm. Screw Driver | 3 | 12 | 36 |
| Lrg.. Screw Driver | 2 | 30 | 60 |
| Riveters | 1 | 35 | 35 |
| Hoist | 3 | 35 | 105 |
| Sub-Total = | | | 406 |
| Tool Utilization Factor (15%) | | | 61 |

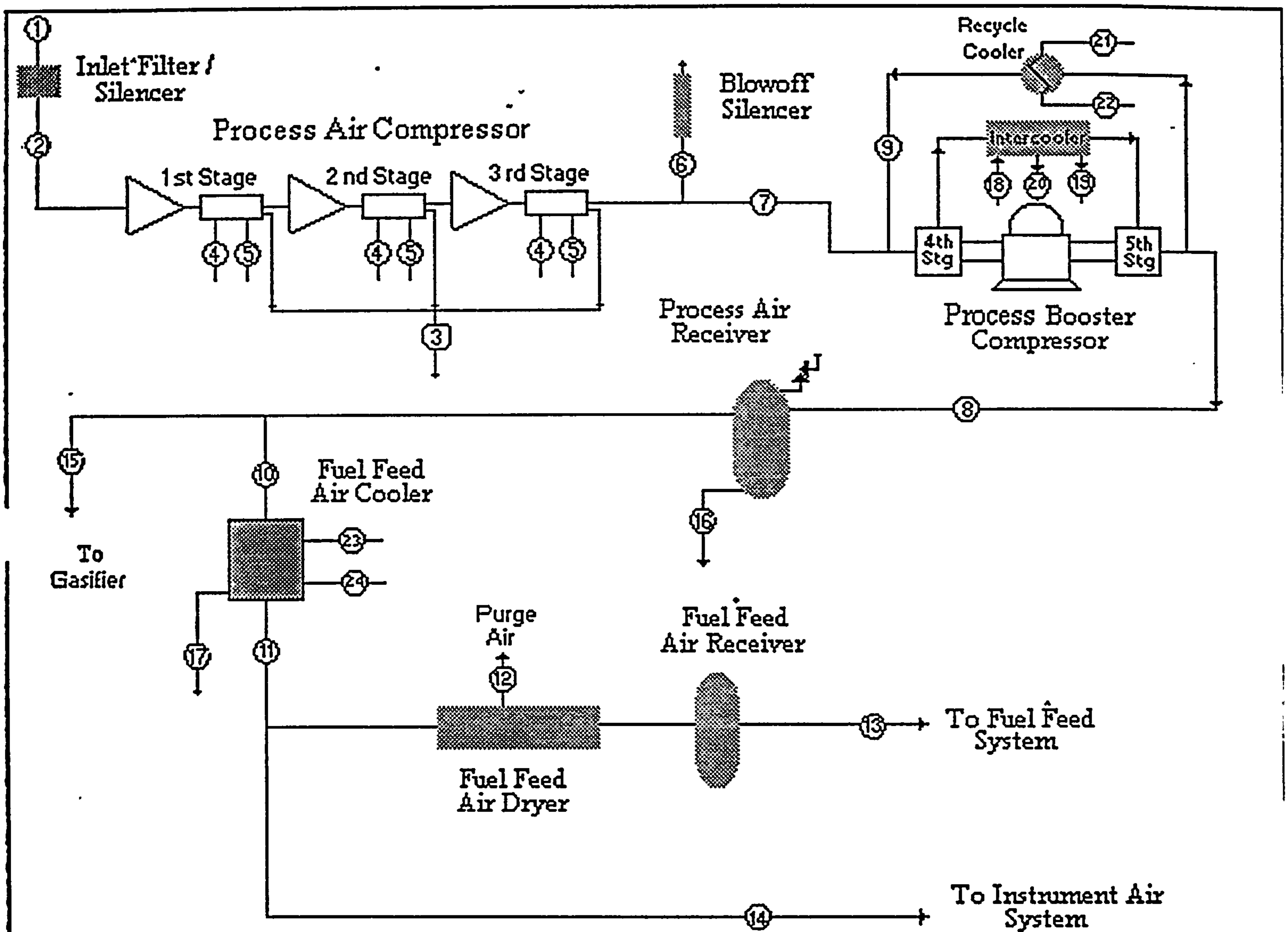
| Total Plant Air Usage | SCFM |
|---|---|
| Pneumatic Tools | 61 |
| Hose Stations (Cleaning) | 20 |
| Leakage ( 15% ) | 14 |
| Total = | 95 |

**SYSTEM PROCESS DESIGN BASIS**

**PDB No. 40 - 1LF - 1**

System Name Process Air System

Flow sheet No. 16N25706-40-F-1LF-001




EQUIPMENT

Inlet Filter / Silencer (Eq. No. 1LF-FLT-1)
Process Air Compressor (Eq. No. 1LF-CMP-1)
Process Booster Compressor (Eq. No. 1LF-CMP-2)
1st Stage Intercooler (Eq. No. 1LF-HX-1)
2nd Stage Intercooler (Eq. No. 1LF-HX-2)
3rd Stage Intercooler (Eq. No. 1LF-HX-3)
th Stage Intercooler (Eq. No. 1LF-HX-4)
Recycle Cooler (Eq. No. 1LF-HX-5)

Blowoff Silencer (Eq. No. 1LF-SIL-1)
Process Air Receiver (Eq. No. 1LF-TK-1)
Fuel Air Cooler (Eq. No. 1LF-HX-7)
Fuel Feed Air Dryer (Eq. No. 1LF-DRY-1)
Fuel Feed Air Receiver (Eq. No. 1LF-Tk-2)

**SYSTEM PROCESS DESIGN BASIS**
**PDB No. 40 - 1LF - 1**
System Name **Process Air System**
Flow sheet No. **16N25706-40-F-1LF-001**

## DESIGN PHILOSOPHY

1. The process air compressors provide high pressure compressed air to the pyrolizer coal feed system , the Pygas Gasifier, and the Instrument Air System.

2. The process air compressors shall be a multi-stage centrifugal compressor followed by a two stage, balanced-opposed, reciprocating booster compressor designed to take atmospheric air and compress it to varying operating pressures. While the "design" discharge of the final stage of this system shall be 500 psig, the system shall be designed to operate from pressures near atmospheric up to the design pressure.

3. The varying flow and pressure requirements of the process shall be regulated by the operation of the air compressors' inlet guide vanes, blow-off system, recycle system and process pressure / flow control valves. The two compressors shall be designed to operate independently of each other. Capacity control of the reciprocating compressor shall be achieved by a pressure/flow controller sensing the process requirements and regulating a bypass valve that will direct the compressor's discharge to either the process or recycle it back to the compressor's suction. The recycled flow shall be cooled in the recycle cooler to prevent overheating of the compressor. The centrifugal compressor's capacity control system will also sense the changing flow/pressure requirements simultaneously and will regulate its inlet guide vanes and blowoff valve as necessary to maintain process conditions and prevent compressor surging.

4. Each air compressor shall be a complete, self contained units with all necessary controls for continuous, multi-pressure operation, and unit protection.

5. The air compressors shall be designed to support the facility schedule of two weeks operating and down for six weeks throughout the year.

6. The compressor shall be equipped with intercoolers between each stage of compression to cool inlet air and eliminate moisture. Each cooler shall be equipped with automatic condensate drainage traps.

7. The Process Air System will be designed to allow the discharge temperature from the final stage compression to vary from a low temperature of approximately 150 °F to a maximum temperature of approximately 400 °F. The discharge temperature will be adjusted by the regulation of cooling water flow to the intercoolers of the centrifugal and reciprocating compressors. The final temperature will be limited only by the site requirement that no single motor can exceed 2000 HP.

8. The high temperature, high pressure, compressed air leaving the air compressors is anticipated to have less than a 3 % degree of saturation due to intercooling between stages.

9. Compressor Design Ambient Conditions:

| | | | |
|---|---|---|---|
| Dry Bulb: | 0 °F | Winter |
| | 90 °F | Summer |
| Humidity: | 49 % | RH |

10. The air compressors shall be shop assembled. Due to the anticipated size of these units, some disassembly maybe necessary to get them into the building.

11. The air compressors shall be designed for indoor operation.

**SYSTEM PROCESS DESIGN BASIS**
**PDB No. 40 - 1LF - 1**
System Name **Process Air System**
Flow sheet No. **16N25706-40-F-1LF-001**

12. The **Process Air Receiving Tank** will act as a dampener for process flow transients. The receiver shall be designed to supply the intermittent air requirements of process users to minimize compressor capacity. Current estimates of system receiver capacity are **~ 300 $ft^3$**. This volume is equivalent to approximately 100 SCFM of additional capacity assuming a 10 psi drop in system operating pressure over two minutes. Any moisture accumulating in the receiver shall be removed with automatic condensate traps. The air receiving tank shall be a carbon steel, ASME coded vessel. It shall be equipped with a safety valve set at 10% above compressor design pressure.

13. The **Fuel Feed Air Cooler** will reduce the hot process and instrument air temperature to approximately 100 °F to allow desiccant air drying. This cooler shall be a water cooled shell and tube heat exchanger designed for high pressure air applications Air will flow in the tubes and water on the shell-side of this exchanger. A relief valve shall be installed on the shell-side to prevent over-pressurization due to thermal expansion. The cooler shall be equipped with moisture separating equipment to allow the removal of condensation. Moisture accumulating in the air cooler shall be removed with moisture traps. The Fuel Feed Air Cooler sizing shall be based upon the final capacity of the Fuel Feed Air Dryer and the air requirements of the Instrument Air System (see Design Note (1) below).

14. The **Fuel Feed Air Dryer** shall be designed to dry the saturated, high pressure compressed air from approximately 100 °F to a pressure dew point of -40 °F. This air quality is necessary to prevent instrumentation freeze-up and the "caking" of the crushed coal in the pneumatic convey system. The dryer shall be a dual tower type with one desiccant bed undergoing regeneration at all times. The anticipated purge flow will be ~ 5% of dryer throughput. Final dryer sizing shall be based upon the dryer technology selected and the dryer's actual purge requirements (see Design Note (1) below).

15. The **Fuel Feed Air Receiving Tank** shall be designed to accommodate the transient flows associated with the fuel feed system. On the basis of the latest information from the fuel feed conveyor vendor, the flow rate due to lock vessel pressurization/depressurization is estimated to be 39 SCFM. Based upon a repressurization time of 130 seconds, the air receiver will have a volume of **60 $ft^3$**. The air receiver shall be an ASME coded vessel designed for the maximum system operating pressure. Since this system will be design for instrument quality air, no condensate traps shall be installed on the receiver. However, the receiver shall be equipped with drain plugs.

**SYSTEM PROCESS DESIGN BASIS**
**PDB No. 40 - 1LF - 1**
System Name Process Air System
Flow sheet No. 16N25706-40-F-1LF-001

## Design Criteria
## 325 Psig Gasifier Operation

| Steam No. | Process Stream | Normal Flow (#/hr) Appx. A-8 | Maximum Flow (#/hr) (Design *) | Normal Temp. (°F) | Maximum. Temp. (°F) | Normal Pressure (psig) | Maximum Pressure (psig) |
|---|---|---|---|---|---|---|---|
| 1 | Inlet Air | 16,277 | 19,212 | 70 | 90 | 14.52 ** | 14.6 ** |
| 2 | Inlet Air | 16,277 | 19,212 | 70 | 90 | 14.21** | 14.3 ** |
| 3 | Condensate | 300 | 360 | - | - | - | - |
| 4 | C.W. Supply | 23,725 | 28,000 | 85 | 85 | 40 | 60 |
| 5 | C.W. Return | 23,725 | 28,000 | 105 | 105 | 30 | 60 |
| 6 | Compressor Blowoff | 0 | 0 | 105 | 105 | 120 | 138 |
| 7 | Centrifugal Discharge | 15,977 | 18,852 | 105 | 105 | 120 | 138 ❖ |
| 8 | Recip. Discharge | 15,893 | 18,752 | 350 | 400 | 500 | 550 |
| 9 | Recip. Recycle | 0 | 0 | 105 | 105 | 120 | 138 |
| 10 | Air Cooler Inlet | 5,837 | 7,551 | 350 | 400 | 492 | 550 |
| 11 | Air Cooler Outlet | 5,812 | 7,521 | 70 | 100 | 487 | 550 |
| 12 | Dryer Purge | 247 **** | 296 **** | 70 | 100 | 484 | 550 |
| 13 | Air To Fuel Feed | 4,492 *** | 5,622 | 70 | 100 | 474 | 550 |
| 14 | Air To Instr. Air System | 1,058 | 1,603 | 70 | 100 | 487 | 550 |
| 15 | Air To Gasifier | 9,506 | 11,407 | 350 | 400 | 492 | 550- |
| 16 | Condensate | 5 | 6 | 350 | 400 | 500 | 550 |
| 17 | Condensate | 25 | 30 | 350 | 400 | 492 | 550 |
| 18 | C.W. Supply | 11,860 | 14,000 | 85 | 95 | 40 | 60 |
| 19 | C.W. Return | 11,860 | 14,000 | 105 | 115 | 30 | 60 |
| 20 | Condensate | 84 | 100 | 200 | 215 | 500 | 550 |
| 21 | C.W. Supply | 0 | 14,000 | 85 | 95 | 40 | 60 |
| 22 | C.W. Return | 0 | 14,000 | 105 | 115 | 30 | 60 |
| 23 | C.W. Supply | 17,500 | 22,650 | 85 | 95 | 40 | 60 |
| 24 | C.W. Return | 17,500 | 22,650 | 105 | 115 | 30 | 60 |

* This data reflects a 20 % contingency added to " normal " flow (process flow only) requirements @ 325 psig gasifier operation.
** Units for these data are psia.
*** These flows will occasionally be increased by ~ 39 SCFM when the charge and transfer hoppers in the fuel conveying system undergo pressure equalization.
**** Actual dryer purge flow will depend upon the dryer technology eventually chosen. Compressor sizing calculations have assumed a 5% purge flowrate.
❖ Assumes that the rise to surge pressure is 15% above design pressure.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 40 - 1LF - 1**

System Name Process Air System

Flow sheet No. 16N25706-40-F-1LF-001

**DESIGN NOTES:**

1) The following is the basis for process air compressors, air cooler, and air dryer sizing.

**Estimated Based Upon 5/31/95 Mass Balance**
**Unless Otherwise Noted.**

| Process | | Air Flowrate | |
|---|---|---|---|
| Pyrolyzer | (Stream No. [ 9c ]) | 3,579 | lb/hr |
| Gasifier | (Steam No. [ 9d ]) | 5,927 | lb/hr |
| Coal Conveying ( [9b ] ) | | 4,492 * | lb/hr |
| | Sub-total = | 14,013 | lb/hr |
| Air Receiver Losses | | 5 | lb/hr |
| Fuel Feed Air Dryer Purge | | 247 | lb/hr |
| Mass Loss From Fuel Feed Air Cooler | | 25 | lb/hr |
| Compressor Losses | | 384 | lb/hr |
| | Sub-total = | 661 | lb/hr |
| | Total = | 14,674 | lb/hr |
| **Instrument Air Requirement** | | 1,603 | lb/hr |

| Fuel Feed Air Dryer Capacity | | |
|---|---|---|
| To Process | 5,622 ** | lb/hr |
| Purge | 296 | lb/hr |
| Total | 5,918 | lb/hr |

(Includes 20% Contingency)

| Fuel Feed Air Cooler Capacity | | |
|---|---|---|
| To Air Dryer | 5,918 | lb/hr |
| To P & I Air | 1,603 | lb/hr |
| Condensate Losses | 5 | lb/hr |
| Total = | 7,526 | lb/hr |

Sub-total Inlet Air Flow = 16,277 lb/hr (Without Contingency)

| **Design Basis** | | | | |
|---|---|---|---|---|
| | Total Inlet Air Flow = | 19,212 | lb/hr | (Value includes a 20% contingency for process air requirements only) |
| | Delivered Air Flow = | 18,750 | lb/hr | |

* Data from the 5/31/95 Rich Sadowski Mass Balance estimates this value to be 3309 lbs/hr, however Clyde Pneumatic Conveying's estimate is 4492 lbs/hr (985.4 SCFM) per 6/9/95 memo to Joe Bushek.

** This value includes an additional 178 lbs/hr (39 SCFM) of air losses from lock vessels.(per Clyde memo dated 6/9/95 to Joe Bushek)

2) The "Design" discharge pressure of the air compressor is 500 psig. This pressure was defined as follows:

| | |
|---|---|
| Minimum pressure to fuel delivery system: | 441 psig |
| Line loss between fuel feed dryer and convey system | 8 psi |
| Fuel Feed Dryer and Filter $\Delta$ P | 10 psi |
| Line loss between fuel feed air dryer and air cooler | 3 psi |
| Fuel Feed Cooler $\Delta$ P | 5 psi |
| Line loss between fuel feed air cooler and receiver | 3 psi |
| Air Receiver $\Delta$ P | 2.5 psi |
| Line loss between receiver and compressor discharge | 2.5 psi |
| Contingency | 25 psi |
| Total = | 500 psig. |

**SYSTEM PROCESS DESIGN BASIS**
**PDB No. 40 - 1LF - 1**
System Name **Process Air System**
Flow sheet No. **16N25706-40-F-1LF-001**

** All line loss values include at least a 30% contingency on equivalent length values.

3) A 20 % contingency has been added to the flow data. Process flow data is from Mass Balance for 325 psig Base Operation dated 5/31/95..

4) Minimum compressor flow is based on a 60 % turndown capability in air compressor throughput before encountering compressor surge limitations.

5) Normal operation assumes process operating as illustrated in Design Note (1) without miscellaneous conveyor system losses.

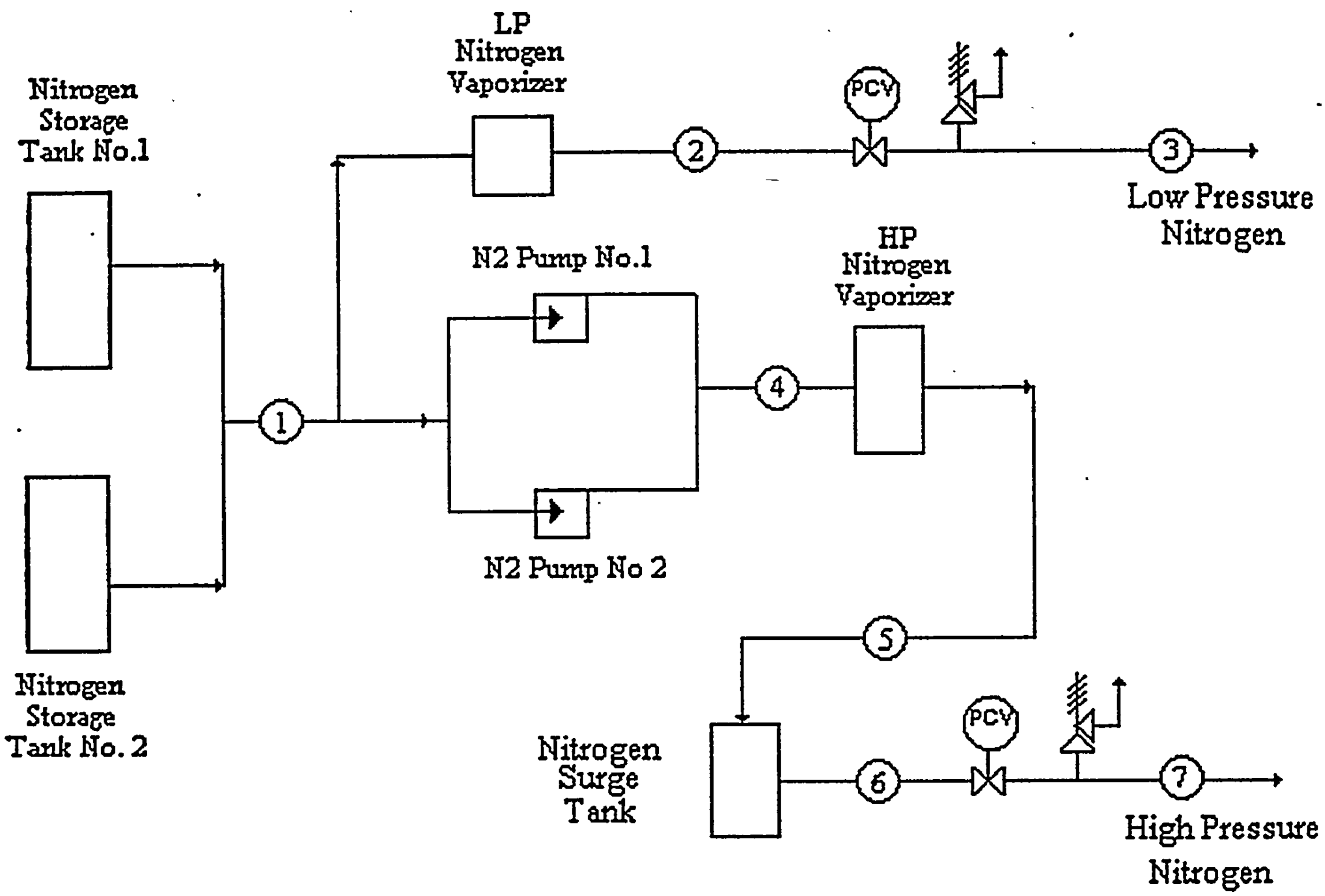
6) The periodic instantaneous air requirements of the miscellaneous conveyor system users and other non-continuous users have not been added to the air compressor capacity. This requirement is being designed into the Process and Fuel Feed Air Receiving Tanks' capacity.

7) Compressor mass losses are estimated to be approximately 2%. These losses are those associated with moisture/air removal in the intercoolers between stages of compression.

8) The maximum system pressure is based upon a compressor / system safety valve setting of 110 % of the compressor design pressure of 500 psig (i.e. safety valve setting of 550 psig).

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name: Nitrogen Storage & Distribution
Flowsheet No.: 16N25706-40-F-LK-001



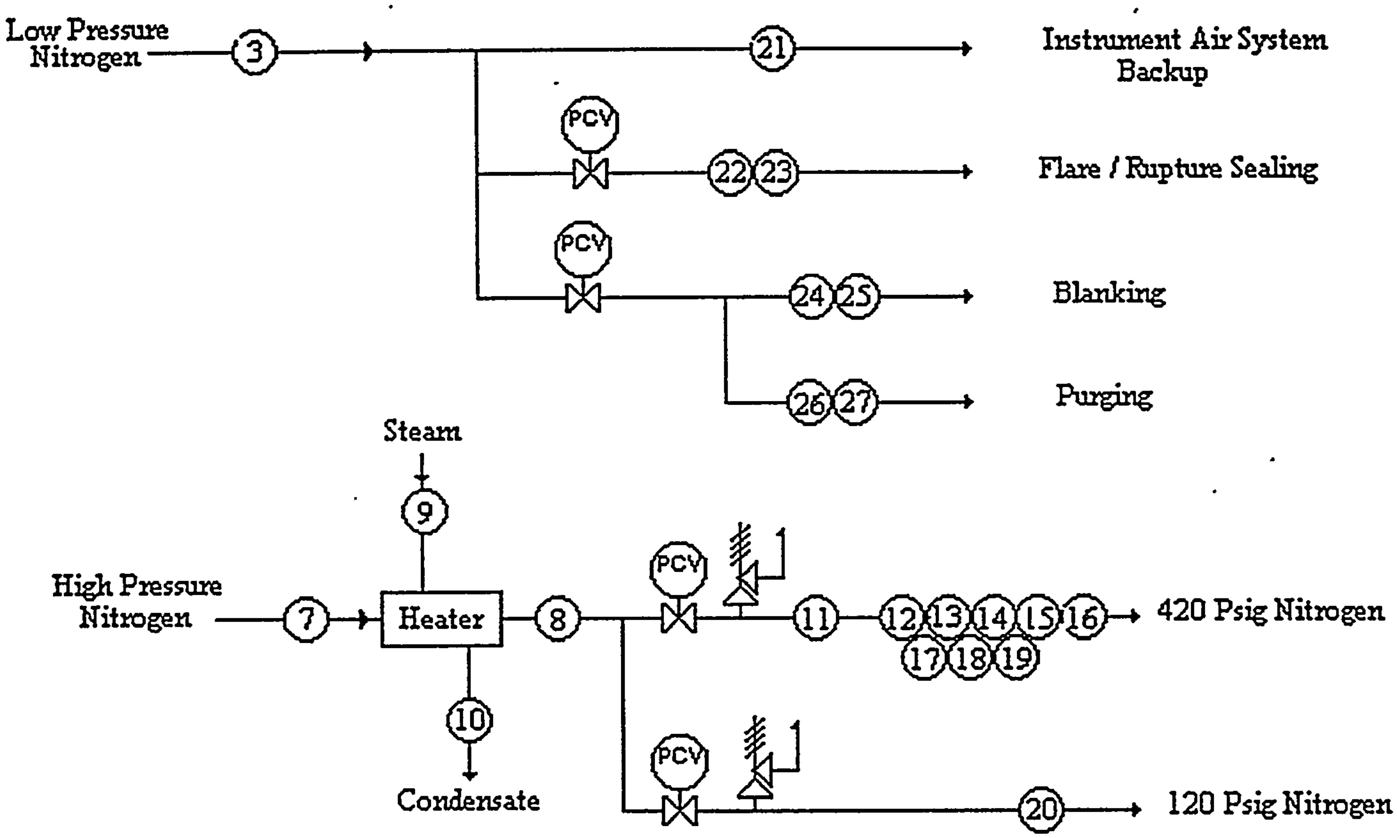

Nitrogen Storage and Distribution

EQUIPMENT:

Nitrogen Storage Tank No. 1 - 1LK-TK-1
Nitrogen Storage Tank No. 2 - 1LK-TK-2
Low Pressure Nitrogen Vaporizer - 1LK-VAP-1
High Pressure Nitrogen Vaporizer - 1LK-VAP-2
Nitrogen Pump No. 1 - 1LK-P-1
Nitrogen Pump No. 2 - 1LK-P-2
High Pressure Nitrogen Surge Tank - 1LK-TK-1
Nitrogen Heater - 1LK-HX-1

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name Nitrogen Storage & Distribution
Flowsheet No. 16N25706-40-F-LK-001




Nitrogen Storage and Distribution

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name Nitrogen Storage & Distribution
Flowsheet No. 16N25706-40-F-LK-001

## I. DESIGN PHILOSOPHY

1) The facility requires nitrogen during four time periods; normal operation, gasifier transition, facility downtime, and utilities upset. Nitrogen use during these periods is as follows:

A) **Normal Operation**

a) Inert Cyclone Lockhoppers - Depressurize lockhopper to vent system. Dump ash. Pressurize lockhopper with nitrogen.

b) Inert Pyrolyzer Lockhopper - Depressurize lockhopper to vent system. Dump ash. Pressurize lockhopper with nitrogen.

c) Seal Flare Tip - Continuously supply nitrogen to the flare tip to prevent air from entering into the flare vent system (the flare vent system is an inert atmosphere).

d) Seal Rupture Disk Stack - Continuously supply nitrogen to the rupture disk stack tip to prevent air from entering into rupture disk stack vent system.

e) Purge Lockhopper Vent System - Intermittently purge lockhopper vent system in order to prevent plugging from coal and ash particles.

f) Purge Pressure Transmitters - Continuously seal pressure transmitter tubing in order to keep clear of coal and ash particles.

g) Seal/Cool Equipment - Nitrogen seal and/or cool equipment in contact with coal gas (ash/fines conveyor, gasifier rupture disk, high temperature valves, etc.)

B) **Gasifier Transition** (Note 4)

1) **Startup**

a) Pressure Test - Pressurize the gasifier system with nitrogen and monitor the leak rate.

b) Vent Purge - Purge the flare vent piping and the rupture disk stack vent piping with nitrogen.

c) Purge/Dry-out - Heat lockhoppers and lockhopper vent system with steam. Dry-out lockhoppers and vent system with nitrogen.

d) Pyrolyzer Bed Building - Feed coke to pyrolyzer to build the pyrolyzer bed. Add nitrogen and steam to the fixed bed to maintain the oxygen concentration below the combustion limit.

2) **Hot Hold** - *No nitrogen required* (Note 5).

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name Nitrogen Storage & Distribution
Flowsheet No. 16N25706-40-F-LK-001

3) **Normal Shutdown**

a) Purge Pyrolyzer Solids - Stop coal flow. Purge pyrolyzer solids with steam. *No nitrogen required.*

b) Burn-out Fixed Bed - Air and steam to fixed bed. *No nitrogen flow to fixed bed.* Nitrogen inert lockhoppers and vent system.

c) Purge and Inert - Steam purge gasifier system. Nitrogen to pyrolyzer and fixed bed for 15 minutes to dry out entire system. Lock up system under a nitrogen blanket unless personnel entry is anticipated.

4) **Emergency Shutdown via Flare Stack**

a) Reduce pressure via Flare - Depressurize system to 6 psig through the gasifier bleed control valve. *No nitrogen required.*

b) Dump Pyrolyzer Solids / Inert Fixed Bed - Minimum steam flow to pyrolyzer and fixed bed. *No nitrogen flow to gasifier.* Nitrogen inert lockhoppers and vent system.

c) Inert - Nitrogen to pyrolyzer and fixed bed for 15 minutes to inert and dry out the gasifier. Lock up system under a nitrogen blanket unless personnel entry is anticipated.

5) **Emergency Shutdown via Rupture Disk**

a) Reduce pressure via Rupture Disk - Depressurize system to 6 psig through the gasifier rupture disk. Add steam to pyrolyzer and fixed bed to control the rate of pressure decay. *No nitrogen required.*

b) Dump Pyrolyzer Solids / Inert Fixed Bed - Minimum steam flow to pyrolyzer and fixed bed. *No nitrogen flow to gasifier.* Nitrogen inert lockhoppers and vent system.

c) Inert - Nitrogen to pyrolyzer and fixed bed for 15 minutes to inert and dry out the gasifier. Replace rupture disk. Nitrogen purge and blanket coal gas system unless personnel entry is anticipated.

C) **Facility Downtime** - Nitrogen is used during plant downtime to blanket the following systems for corrosion protection (unless personnel entry is anticipated):

a) water side of gasifier
b) gas side of gasifier
c) cooling water system

D) **Utilities Upset**

a) Nitrogen is used as the backup fluid for the instrument air system if the instrument air compressor fails.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name Nitrogen Storage & Distribution
Flowsheet No. 16N25706-40-F-LK-001

2) The system (except for the heater) is leased from a nitrogen supplier. The initial lease duration is seven years.

3) Liquid nitrogen is shipped to the facility and is stored in two cryogenic nitrogen storage tanks.

4) A low pressure ambient vaporizer gasifies the liquid nitrogen. A PCV downstream of the vaporizer maintains the low pressure nitrogen system at 120 psig. The low pressure nitrogen system is used for instrument air backup, flare and rupture disk stack purging and sealing, and equipment blanketing. During the bid period the low pressure system is evaluated to determine its cost effectiveness (Depending on the lease cost of the low pressure vaporizer, it may be more economical to take everything from the high pressure system, and eliminate the low pressure system).

5) Two full size, cryogenic, rotary, positive displacement pumps are located downstream of the liquid storage tank. One pump cycles on and off based on the nitrogen demand. The other pump serves as a backup. Pump discharge pressure is approximately 2350 psig.

6) A high pressure ambient vaporizer gasifies the high pressure liquid nitrogen. The vaporizer is sized so that it can handle the total flow from both pumps running simultaneously.

7) High pressure nitrogen storage tubes are located downstream of the vaporizer. The tubes have enough storage capacity to handle peak nitrogen requirements. (One high pressure nitrogen storage tank may be more economical than high pressure storage tubes. This option is evaluated during the bid period). A PCV downstream of the storage tubes maintains the high pressure nitrogen system at 420 psig. A safety valve is locate downstream of the PCV and is set at 460 psig.

8) High pressure steam heats the nitrogen to 400 deg F (the same as process air) in a carbon steel shell and tube heat exchanger. The nitrogen is heated so that it does not condense any vapors when admitted into the system. Steam supply to the heater is from the 400 psig steam header. In addition, natural gas and electric heaters are evaluated during the bid period.

9) A PCV maintains the 420# header at 420 psig. A safety valve downstream of the PCV is set at 460 psig. The 420# header supplies nitrogen to the gasifier, lockhoppers, lockhopper vent system, and transmitter purge header.

10) A PCV maintains the 120# header at 120 psig. A safety valve downstream of the PCV is set at 150 psig. The 120# header supplies nitrogen to the vent system hoppers.

11) Nitrogen Purging:
   a) Purging is accomplished by mixing (dilution purging), and requires ten volumes to assure that the vessel is completely purged.

   b) When purging a vessel into service (air to nitrogen to coal gas) the goal is to reduce the oxygen level to less than 25% of the LOC (limiting oxidant concentration) of the coal gas. Proper instrumentation is required to ensure that purging requirements are met.

   c) When purging a vessel out of service (coal gas to nitrogen to air) the goal is to reduce the fuel concentration to less than 25% of the LEL (lower explosive limit) of the coal gas. Proper instrumentation is required to ensure that purging requirements are met.

   d) NFPA 325M (Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids) states that at high temperatures the LEL of a fuel is lowered and NFPA 69 (Explosion Prevention Systems) states that at high temperatures the LOC of a fuel is lowered. However, no published data exist quantifying by how much these limits are reduced. To account for this uncertainty, the purge system is designed to reduce both the LOC and the LEL to 25% of their values at standard conditions.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name Nitrogen Storage & Distribution
Flowsheet No. 16N25706-40-F-LK-001

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAX FLOW SCFM | NORM FLOW SCFM (Note 6) | AVG FLOW SCFM (Note 7) | NORM PRESS PSIG | NORM TEMP DEG F |
|---|---|---|---|---|---|---|
| 1 | Liquid Nitrogen | Note 2 | Note 2 | Note 2 | 150 | -270 |
| 2 | From LP Vaporizer | Note 2 | Note 2 | Note 2 | 150 | 50 |
| 3 | LP Nitrogen | 400 | 10 | 10 | 120 | 50 |
| 4 | From Cryogenic Pumps | Note 2 | Note 2 | Note 2 | 2350 | -250 |
| 5 | From HP Vaporizer | Note 2 | Note 2 | Note 2 | 2300 | 50 |
| 6 | From Surge Tank | Note 3 | Note 3 | Note 3 | 2300 | 60 |
| 7 | HP Nitrogen | Note 3 | Note 3 | Note 3 | 700 | 60 |
| 8 | From N2 Heater | Note 3 | Note 3 | Note 3 | 700 | 400 |
| 9 | HP Steam | Note 2 | Note 2 | Note 2 | 400 | 475 |
| 10 | Condensate | Note 2 | Note 2 | Note 2 | 400 | 475 |
| 11 | 420# Nitrogen | Note 3 | Note 3 | Note 3 | 420 | 400 |
| 12 | To Pyrolyzer | Note 3 | 0 | 0 | 420 | 400 |
| 13 | To Pyro Fluid Nozzles | Note 3 | 0 | 0 | 420 | 400 |
| 14 | To Grate | Note 3 | 0 | 0 | 420 | 400 |
| 15 | Pyrolyzer LH | 300 | 0 | 1 | 420 | 400 |
| 16 | Bottom Ash LH Vent | 5000 | 0 | 92 | 420 | 400 |
| 17 | No. 1 Cyclone LH | 3000 | 0 | 14 | 420 | 400 |
| 18 | No. 2 Cyclone LH | 3000 | 0 | 7 | 420 | 400 |
| 19 | Transmit Purge Hdr. | Note 3 | Note 3 | Note 3 | 420 | 400 |
| 20 | Vent Cycl. Hopper | 100 | 0 | 0 | 120 | 400 |
| 21 | Instrument Air Backup | 350 | 0 | 0 | 120 | 50 |
| 22 | To Flare Seal | 5 | 5 | 5 | 30 | 50 |
| 23 | To Rupture Disk Stack | 5 | 5 | 5 | 30 | 50 |
| 24 | Deaerator Blanket | 350 | 0 | 0 | 30 | 50 |
| 25 | Cooling Jacket Blanket | 350 | 0 | 0 | 30 | 50 |
| 26 | To Flare Vent Piping | 350 | 0 | 0 | 30 | 50 |
| 27 | To Rupture Vent Piping | 350 | 0 | 0 | 30 | 50 |
| 28 | 120# Nitrogen | 3000 | 18 | 18 | 120 | 400 |
| 29 | No. 1 Cycl. LH Vent | 3000 | 0 | 25 | 420 | 400 |
| 30 | No. 2 Cycl. LH Vent | 3000 | 0 | 13 | 420 | 400 |
| 31 | Pyrolyzer LH Vent | 300 | 0 | 1 | 420 | 400 |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1LK - 1**

System Name Nitrogen Storage & Distribution
Flowsheet No. 16N25706-40-F-LK-001

## III. DESIGN NOTES

1) Standard conditions for nitrogen are 14.7 psia and 70 deg F. The specific volume of nitrogen is 13.8 scf/lb.

2) Per Vendor.

3) Later.

4) Per Process States Map in Rev. "0" Gasifier Process Design Basis. All of the process transition states are not listed. Only those transition states that relate to nitrogen usage are listed in this document. For a complete list of process transitions, refer to the Process States Map.

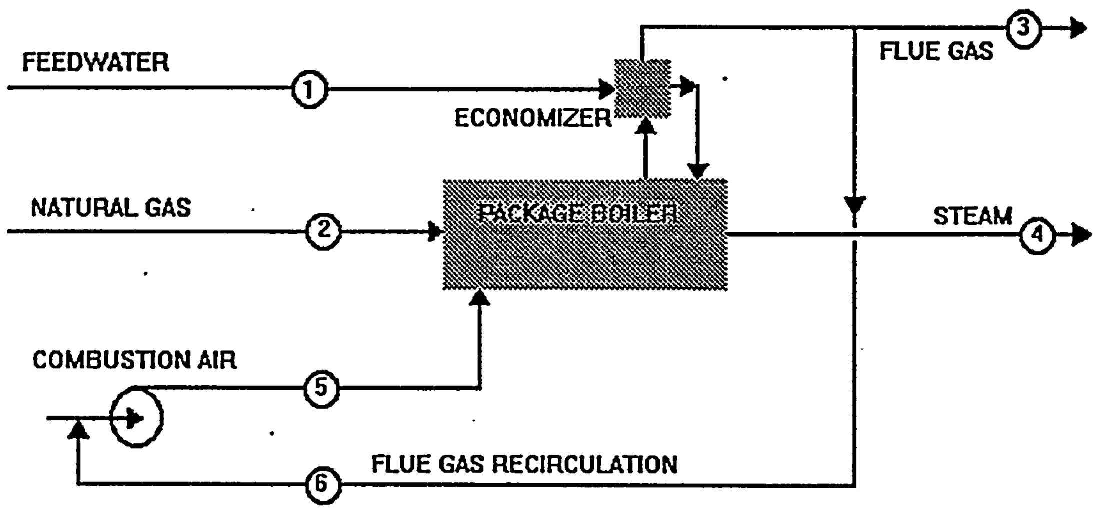
5) Per "Hot Hold" Mass Balance, 3/22/95.

6) "Normal Flow" is the typical stream flow rate during normal GPIF operation. A normal flow of zero implies that the stream is not normally in operation.

7) "Average Flow" is the average stream flow rate during normal GPIF operation.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SB - 1**

System Name Package Boiler Sytem
Flowsheet No. 16N25706-40-F-1SB-001




EQUIPMENT

Package Boiler (Equipment No. 1SJ-BLR-001 )

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SB - 1**

System Name Package Boiler Sytem
Flowsheet No. 16N25706-40-F-1SB-001

I. DESIGN PHILOSOPHY

1. Product gas to be burned in an incinerator without heat recovery, and steam generation.

2. Export no steam to Fort Martin host.

3. Utilize a small package boiler to provide steam for the gasifier process, and for utilities.

4. Package boiler outlet steam conditions will match gasifier requirements rather than any "host" requirements.

5. Use natural gas as fuel for the package boiler.

6. Exhaust package boiler flue gas directly to the atmosphere withou;t any enviromental treatmen

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SB - 1**

System Name Package Boiler Sytem
Flowsheet No. 16N25706-40-F-1SB-001

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAXIMUM FLOW #/HR(or as noted) | NORMAL FLOW #/HR(or as noted) | MINIMUM FLOW #/HR(or as noted | MAXIMUM TEMP. F | NORMAL TEMP. F | MAXIMUM PRESSURE PSIG | MIMIMUM PRESSURE PRIG |
|---|---|---|---|---|---|---|---|---|
| 1 | FEEDWATE R | 6000 | (See mass balance) | LATER | 212 | 212 | LATER VENDOR | LATER VENDOR |
| 2 | NATURAL GAS | LATER VENDOR | LATER VENDOR | LATER | Ambient | Ambient | 40 | LATER |
| 3 | FLUE GAS | LATER VENDOR | LATER VENDOR | LATER | 300 | 250 | LATER VENDOR | LATER VENDOR |
| 4 | STEAM | 6000 | (See mass balance) | LATER | 560 | 550 | 500 | 400 |
| 5 | COMBUST. AIR | LATER VENDOR | LATER VENDOR | LATER VENDOR | 100 | 80(normal) | LATER VENDOR | LATER VENDOR |
| 6 | FLUE GAS RECIRC. | LATER VENDOR | LATER VENDOR | LATER VENDOR | 300 | 250 | LATER VENDOR | LATER VENDOR |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SB - 1**

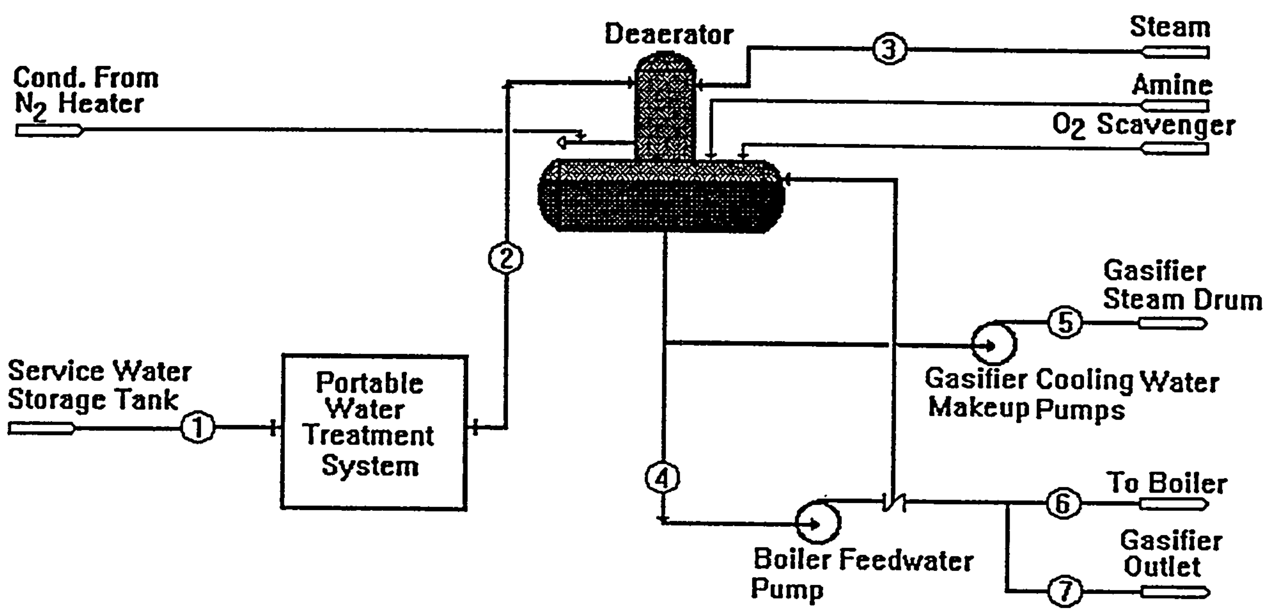
System Name Package Boiler Sytem
Flowsheet No. 16N25706-40-F-1SB-001

III. DESIGN NOTES

1. Some package boiler manufacturers will require a separate, natural gas fired superheater, to provide superheated steam.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SJ - 1**

System Name Condensate/Deaerator/Feedwater
Flowsheet No. 16N25706-40-F-1SJ-001




EQUIPMENT

Deaerator (Eq. No. 1SJ-DEA-1)
Boiler Feedwater Pump (Eq. No. 1SJ-P-1)
Gasifier Cooling Water Pumps 1 and 2 (Eq. Nos. 1SJ-P-2, 1SJ-P-3)

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SJ - 1**

System Name Condensate/Deaerator/Feedwater
Flowsheet No. 16N25706-40-F-1SJ-001

## I. DESIGN PHILOSOPHY

1. The function of the Deaerator/Feedwater System is to provide deaerated feedwater to the boiler steam drum. Deaerated feedwater is also utilized for makeup to the gasifier cooling water system, and for gasifier outlet temperature control during upset conditions.

2. Fort Martin service water is utilized as the raw water supply for the feedwater system.

3. The service water is forwarded from the Service & Fire Water Storage tank to the inlet to the Portable Water Treatment System. The treated water is then forwarded to Deaerator.

4. Boiler steam, in conjunction with the deaerator internals, reduces the levels of dissolved gases in the treated water. The expunged gases are vented to atmosphere. The deaerated water is then stored in the storage tank section of the deaerator unit for use as feedwater.

5. An oxygen scavenger is injected into the feedwater storage tank to further reduce the oxygen content. A neutralizing amine is added for pH control.

6. The Boiler Feedwater Pump takes suction from the storage tank. The feedwater pump suction line also provides water to the two Gasifier Cooling Water Makeup Pumps.

7. The boiler feedwater pump discharge line is piped to the economizer section of the Package Boiler.

8. A branch of the boiler feedwater provides high pressure water to the gasifier out for temperature control. Spray water to the gasifier outlet is not required during normal conditions.

9. An ARC valve is located downstream of the feedwater pump discharge in order to maintain minimum flow requirements at all plant conditions. The ARC valve recirculates all or a portion of feedwater pump flow back to the feedwater storage tank.. A backpressure regulator located in the recirculation line at the deaerator, provides constant backpressure on the ARC valve and prevents steam flashing in the recirculation line.

10. The Portable Water Treatment system is a "once-through" system..

11. Elevation of Deaerator/Feedwater Storage Tank will be based on required net positive suction head of the boiler feedwater pump at deaerator operating pressure with a minimum 10% margin of safety added.

12. The storage capacity of the deaerator is sized to provide 15 minutes of feedwater and gasifier cooling water makeup flows with zero condensate makeup flow. Normal level in the storage tank will be 2/3 of the tank diameter above the tank bottom. The storage tank is equipped with a high level dump line that discharges to the Blowoff Tank.

13. The operating pressure of the Deaerator is 5 psig. This produces a feedwater temperature of 227 °F.

14. The feedwater pump flow is based on requirements to the boiler. A margin of 10% was added to the calculated value in determining this value. The feedwater pumps total head is based on system losses, static head and drum pressure. A margin of 25% was added to the calculated pressure drop in determining this number.

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SJ - 1**

System Name Condensate/Deaerator/Feedwater
Flowsheet No. 16N25706-40-F-1SJ-001

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAXIMUM FLOW #/HR (or as noted) | NORMAL FLOW #/HR (or as noted) | MINIMUM FLOW #/HR (or as noted) | MAXIMUM TEMP. °F | MINIMUM TEMP. °F | MAXIMUM PRESS.. PSIG | MINIMUM PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | Service Water from Storage Tank | Hold | Hold | Hold | 90 | 70 | 100 | (See Mass Balance) |
| 2 | Treated Water from Water Treatment System | Hold | (See Mass Balance) | (See Mass Balance) | 90 | (See Mass Balance) | 100 | (See Mass Balance) |
| 3 | Steam | Hold | (See Mass Balance) | (See Mass Balance) | 250 | (See Mass Balance) | 10 | (See Mass Balance) |
| 4 | FW Pump Suction | Hold | (See Mass Balance) | (See Mass Balance) | 250 | (See Mass Balance) | 10 | (See Mass Balance) |
| 5 | FW from Gasifier Cooling Water Pumps | 10 | (See Mass Balance) | (See Mass Balance) | 250 | (See Mass Balance) | Hold | (See Mass Balance) |
| 6 | FW to Boiler | Hold | (See Mass Balance) | (See Mass Balance) | 250 | (See Mass Balance) | Hold | (See Mass Balance) |
| 7 | FW to Gasifier Outlet | Hold | 0 | 0 | 250 | 227 | Hold | Hold |

SYSTEM PROCESS DESIGN BASIS
**PDB No. 40 - 1SJ - 1**

System Name Condensate/Deaerator/Feedwater
Flowsheet No. 16N25706-40-F-1SJ-001

III. DESIGN NOTES

1. Current design is as based on Mass Balance dated (later). Design will be finalized when detailed information on the boiler is received from the manufacturer.

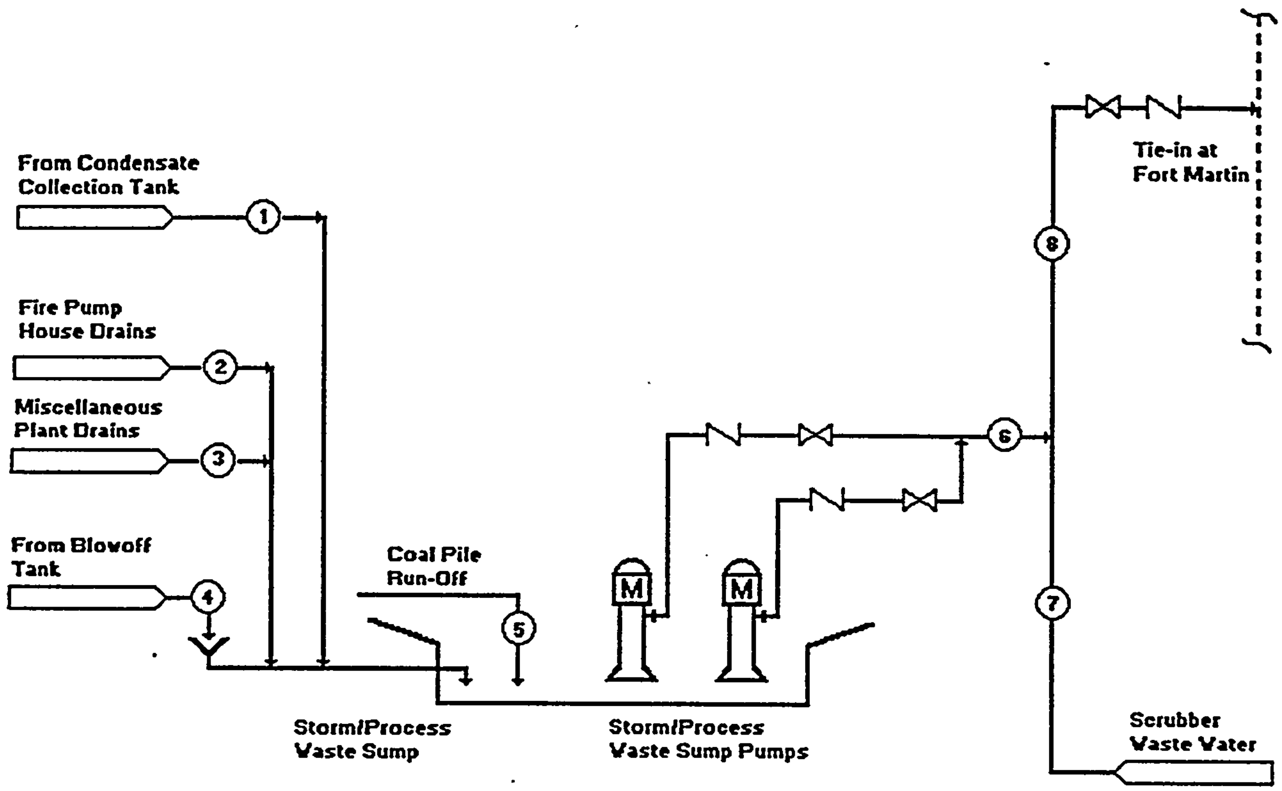
2. Steam flow to the Deaerator was estimated at 5% of the feedwater outlet flow. The actual amount will be finalized once design on the feedwater system is complete.

3. The elevation of the Deaerator normal water level is estimated at 20 feet above grade.

4. Conductivity of the drum water will be controlled by continuously blowing down the steam drum. A blowdown of 1% of steam outlet flow has been assumed.

5. Steam produced by the Gasifier Cooling Water System is independent from steam generated in the boiler. Steam generated in the gasifier cooling water system is used strictly condensed, except for a very small flow into the gasifier..

SYSTEM PROCESS DESIGN BASIS
PDB No. 40 - 1WS - 1
System Name Process Waste Water Distribution
Flowsheet No. 16N25706-40-F-1WS-002




EQUIPMENT

Storm/Process Waste Sump Pumps (Eq. Nos. 1WS-P-1, 1WS-P-2)

SYSTEM PROCESS DESIGN BASIS
PDB No. 40 - 1WS - 1
System Name Process Waste Water Distribution
Flowsheet No. 16N25706-40-F-1WS-002

## I. DESIGN PHILOSOPHY

1. The function of the Process Waste Water Distribution System is to collect and forward the GPIF waste water to the Fort Martin waste water system.

2. The Storm/Process Waste Sump collects condensate from the GPIF to Fort Martin steam line, waste water from the fire pump house floor drains, waste water from the miscellaneous plant floor drains, process water from the boiler blowoff tank. and coal pile runoff (rain) water.

3. One of two 100% capacity Storm/Process Waste Sump Pumps forwards the waste water along the pipe bridge to the Fort Martin waste water system.

4. Flue gas scrubber waste water ties into the storm/process waste water line downstream of the sump pumps and is also forwarded to Fort Martin.

SYSTEM PROCESS DESIGN BASIS
PDB No. 40 - 1WS - 1
System Name Process Waste Water Distribution
Flowsheet No. 16N25706-40-F-1WS-002

## II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | MAXIMUM FLOW GPM | NORMAL FLOW GPM | MINIMUM FLOW GPM | MAXIMUM TEMP. °F | MINIMUM TEMP. °F | MAXIMUM PRESS.. PSIG | MINIMUM PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | From Condensate Collection Tank | Hold | Hold | Hold | Hold | Hold | Hold | Hold |
| 2 | From Fire Pump House Drains | Hold | Hold | Hold | Hold | Hold | Hold | Hold |
| 3 | From Miscellaneous Drains | Hold | Hold | Hold | Hold | Hold | Hold | Hold |
| 4 | From Blowoff Tank | Hold | Hold | Hold | Hold | Hold | Hold | Hold |
| 5 | Coal Pile Run-off | Hold | Hold | Hold | Hold | Hold | Hold | Hold |
| 6 | Process Waste Pump Discharge | Hold | Hold | Hold | Hold | Hold | Hold | Hold |
| 7 | Scrubber Waste Water | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) | (See Mass Balance) |
| 8 | Waste Water to Fort Martin | Hold | Hold | Hold | Hold | Hold | Hold | Hold |

SYSTEM PROCESS DESIGN BASIS
PDB No. 40 - 1WS - 1
System Name Process Waste Water Distribution
Flowsheet No. 16N25706-40-F-1WS-002

## III. DESIGN NOTES

1. Current design is based on Mass Balance dated (later).

2. The Storm/Process Waste Sump is sized to hold 20,000 gallons of water. This capacity along with the rainwater storage capability of the coal yard is based on the 10 year 24 hour storm as depicted in West Virginia Erosion and Sediment Control Handbook for Developing Areas.

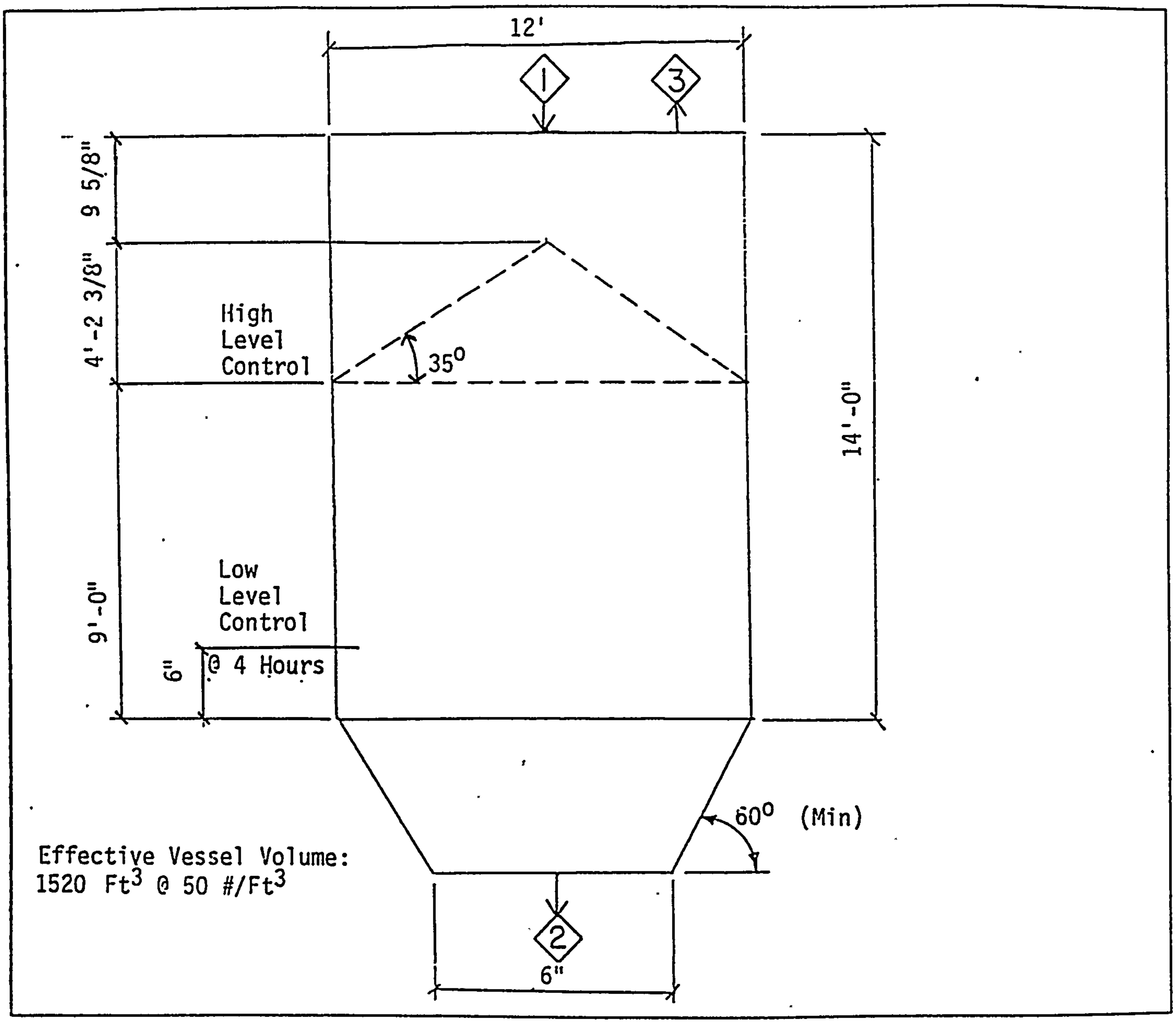
Gasification Product Improvement Facility
Fort Martin Station, West Virginia
Sirrine Job No. 16N25706


Date 08/28/95
Rev. 1

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 1**

Equipment Name Coal Storage Bin
Equipment No. 1DH-TK-1
System Name Coal Receiving, Storage & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001

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## PROCESS DESIGN BASIS
**PDB No. 82-IDH-1**

| | |
|---|---|
| Equipment Name | Coal Storage Bin |
| Equipment No. | 1DH-TK-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

### I. DESIGN PHILOSOPHY

1. The Coal Storage Bin provides several hours of live fuel inventory for the PyGas™ Coal Gasifier.

2. The PyGas™ Coal Gasifier and Coal Storage Bin will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.

3. The Coal Storage Bin will be installed outdoors. See Design Notes for ambient weather criteria.

4. Coal feed to the bin will be continuous 8 hours per day 7 days per week during each two week period of operation.

5. The minimum and maximum capacity of coal flow to the Coal Storage Bin will be based on the 7 day, 24 hour average operating capacity of the Mass Balance being handled in a 8 hour operating period, 7 days per week.

6. The Coal Storage Bin discharge will be assisted utilizing a Vibratory Bin Discharger and multiple Air Cannons.

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-1**

| | |
|---|---|
| Equipment Name | Coal Storage Bin |
| Equipment No. | 1DH-TK-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

## II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COAL IN | 18878 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |
| 2 | PRODUCT COAL OUT | 6675 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |
| 3 | BIN VENT (SOLIDS) | 4 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |
| | BIN VENT (GAS) | 6188 | | | | | | |

1. Hours Storage Available — 19
2. Effective Bin Volume — 1520 $Ft^3$, 38 Tons
3. Bin Diameter — 12'-0"
4. Discharge Cone Angle — 60° (Min)
5. Bin Discharger Size — 6'-0" Dia. (Min)

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-1**

| | |
|---|---|
| Equipment Name | Coal Storage Bin |
| Equipment No. | 1DH-TK-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

II. DESIGN CRITERIA - (cont'd.)

6. Basic design loads include live, wind, and earthquake in addition to dead loads. Minimum basic loads shall be:

| | |
|---|---|
| Roof Load: | Roof Live Load = 100 psf (No Reduction Allowed) |
| Snow Load: | PG = 30 psf Ground Snow Load, Snow Exposure Factor Ce = 0.9 |
| Wind Load: | 70 mph, Exposure C |
| Seismic: | Av = < 0.05, Aa = < 0.05, Hazard Exposure Group = 1 Soil - Profile Type = $S_3$ |
| Importance Factor (I): | I (Snow) = 1.0, I (Wind) = 1.0 |

7. Snow and wind loading shall be in accordance with the West Virginia State Building Code (BOCA), latest edition, and Factory Mutual Standards.

8. Combinations of the loads shall be as specified in the West Virginia State Building Code (BOCA), latest edition.

PROCESS DESIGN BASIS

**PDB No. 82-IDH-1**

| | |
|---|---|
| Equipment Name | Coal Storage Bin |
| Equipment No. | 1DH-TK-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

III. DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.

2. Coal Type — Bituminous
3. Coal Moisture — 6%
4. Coal Specific Heat — 0.30 Btu/Lb.-F
5. Coal Bulk Density — 50 #/Ft$^3$
6. Angle of Repose — 35 deg.
7. Coal Grindability Index — 40-90
8. Coal Feed:

| Size Analysis (As Received) | | Sample (Estimated) |
|---|---|---|
| +1-1/2" | | 0.0% |
| -1-1/2 | +1 | 6.3% |
| -1 | +3/4 | 7.3% |
| -3/4 | +1/2 | 8.5% |
| -1/2 | +3/8 | 8.4% |
| -3/8 | +1/4 | 11.7% |
| -1/4 | +#4 (Mesh) | 8.2% |
| -4 | +6 | 7.7% |
| -6 | +16 | 19.6% |
| -16 | +30 | 8.3% |
| -30 | +50 | 5.1% |
| -50 | +100 | 3.6% |
| -100 | +200 | 2.1% |
| -200 | | 3.2% |

Note: The coal size gradation analysis shown above is taken from the Riley Fuels Laboratory Test Report for three coals used at the Fort Martin Facility dated February 1, 1994. The size gradation for Consol #2 coal was used.

9. Design Operating Temperature — 100°F

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-1**

| | |
|---|---|
| Equipment Name | Coal Storage Bin |
| Equipment No. | 1DH-TK-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

III. DESIGN NOTES (cont'd.)

10. Ambient Weather Criteria

Design Temperature:

Dry Bulb:

| | |
|---|---|
| Winter - | -20°F (lowest on record-use for freeze protection) |
| Winter - | 4° F (99%) |
| Summer - | 90° (99%) |
| Wet Bulb: | 74° (99%) |
| Performance Temperature: | 80° |
| Performance Relative Humidity: | 60% |

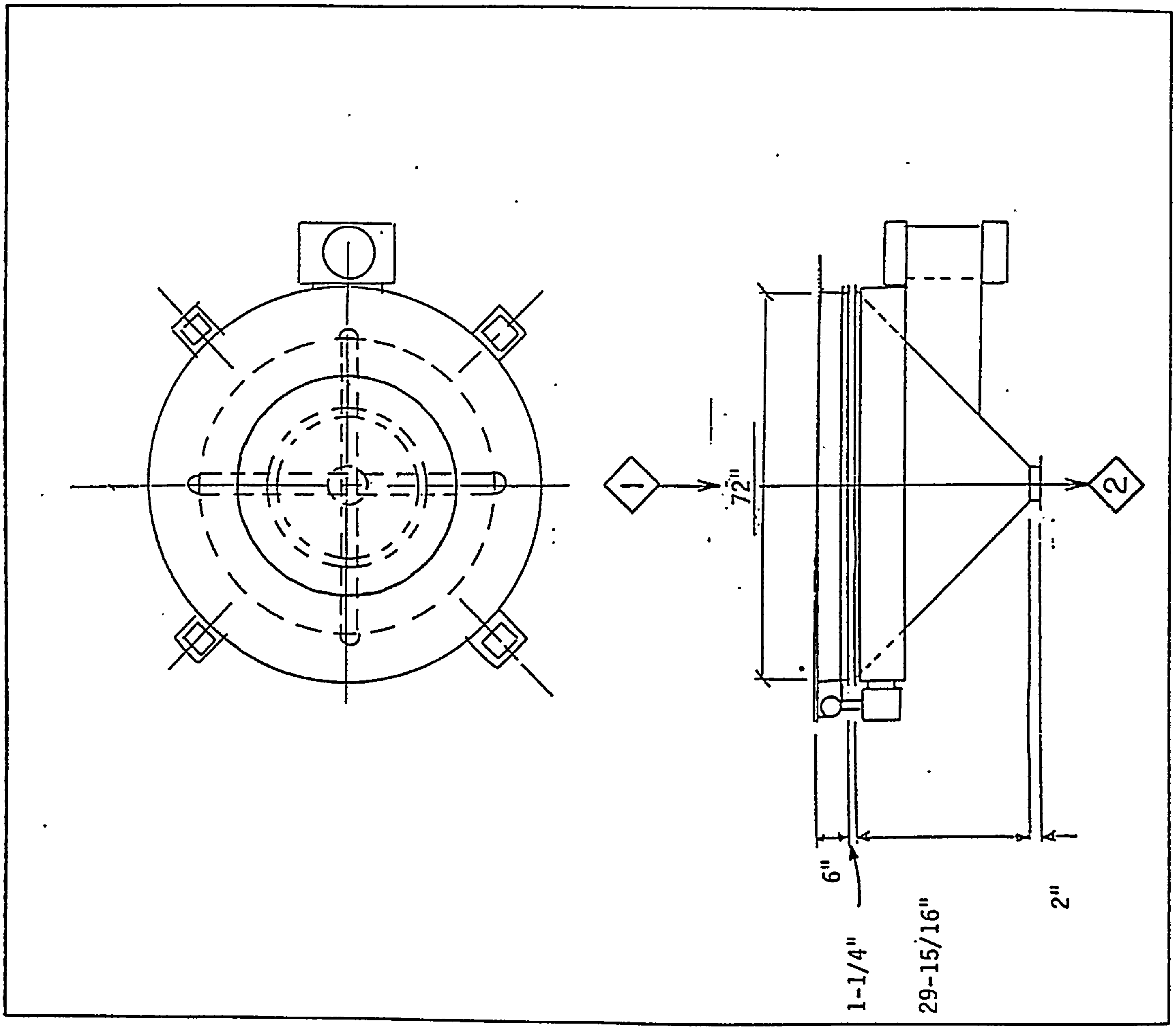
11. All data, i.e. capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum required.

12. Bin nozzles required for:
    - Material Inlet
    - Dust Collector
    - Top Manway
    - Continuous Level Monitor
    - Vac/Press. Relief Hatch
    - High Level Control
    - Low Level Control
    - Bottom Manway
    - Air Cannons (4)
    - Bin Discharger
    - Vent from Bucket Elevator

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 2**

Equipment Name Coal Storage Bin Discharger
Equipment No. 1DH-CONV-2
System Name Coal Receiving, Storage & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001



PROCESS DESIGN BASIS
**PDB No. 82-IDH-2**

| | |
|---|---|
| Equipment Name | Coal Storage Bin Discharger |
| Equipment No. | 1DH-CONV-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-F-1DH-001 |

## I. DESIGN PHILOSOPHY

1. The Coal Storage Bin Discharger will promote coal feed from the Coal Storage Bin and deliver it to the Coal Screw Feeder.

2. The PyGas ™Coal Gasifier and Coal Storage Bin Discharger will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.

3. The Coal Storage Bin Discharger will be installed outdoors. See Design Notes for ambient weather criteria.

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-2**

Equipment Name: Coal Storage Bin Discharger
Equipment No.: 1DH-CONV-2
System Name: Coal Receiving, Storage & Reclaim
Flowsheet No.: 16N25706-82-F-1DH-001

## II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Product Coal In | 6675 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |
| 2 | Product Coal Out | 6675 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |

## PROCESS DESIGN BASIS

**PDB No. 82-IDH-2**

| | |
|---|---|
| Equipment Name | Coal Storage Bin Discharger |
| Equipment No. | 1DH-CONV-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

### III. DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.

| | | |
|---|---|---|
| 2. | Coal Type | Bituminous |
| 3. | Coal Moisture | 6% |
| 4. | Coal Specific Heat | 0.30 Btu/Lb-F |
| 5. | Coal Bulk Density | 50 #/Ft$^3$ |
| 6. | Coal Grindability Index | 40-90 |
| 7. | Angle of Repose | 35 deg. |

8. Coal Feed

| Size Analysis (As Received) | Sample (Estimated) |
|---|---|
| + 1-1/2 | 0.0% |
| -1-1/2 + 1 | 6.3% |
| -1 + 3/4 | 7.3% |
| -3/4 + 1/2 | 8.5% |
| -1/2 + 3/8 | 8.4% |
| -3/8 + 1/4 | 11.7% |
| -1/4 + #4 (mesh) | 8.2% |
| -4 + 6 | 7.7% |
| -6 + 16 | 19.6% |
| -16 + 30 | 8.3% |
| -30 + 50 | 5.1% |
| -50 + 100 | 3.6% |
| -100 + 200 | 2.1% |
| -200 | 3.2% |

Note: The coal size gradation analysis shown above is taken from the Riley Fuels Laboratory Test Report for three coals used at the Fort Martin Facility dated February 1, 1994. The size gradation for Consol #2 was used.

PROCESS DESIGN BASIS

**PDB No. 82-IDH-2**

| | |
|---|---|
| Equipment Name | Coal Storage Bin Discharger |
| Equipment No. | 1DH-CONV-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

III. DESIGN NOTES (cont'd.)

9. Design Operating Temperature — 100°F

10. Ambient Weather Criteria

    Design Temperature:

    Dry Bulb:

    | | |
    |---|---|
    | Winter - | -20°F (lowest on record-use for freeze protection) |
    | Winter - | 4° F (99%) |
    | Summer - | 90° (99%) |

    Wet Bulb: 74° (99%)

    Performance Temperature: 80°

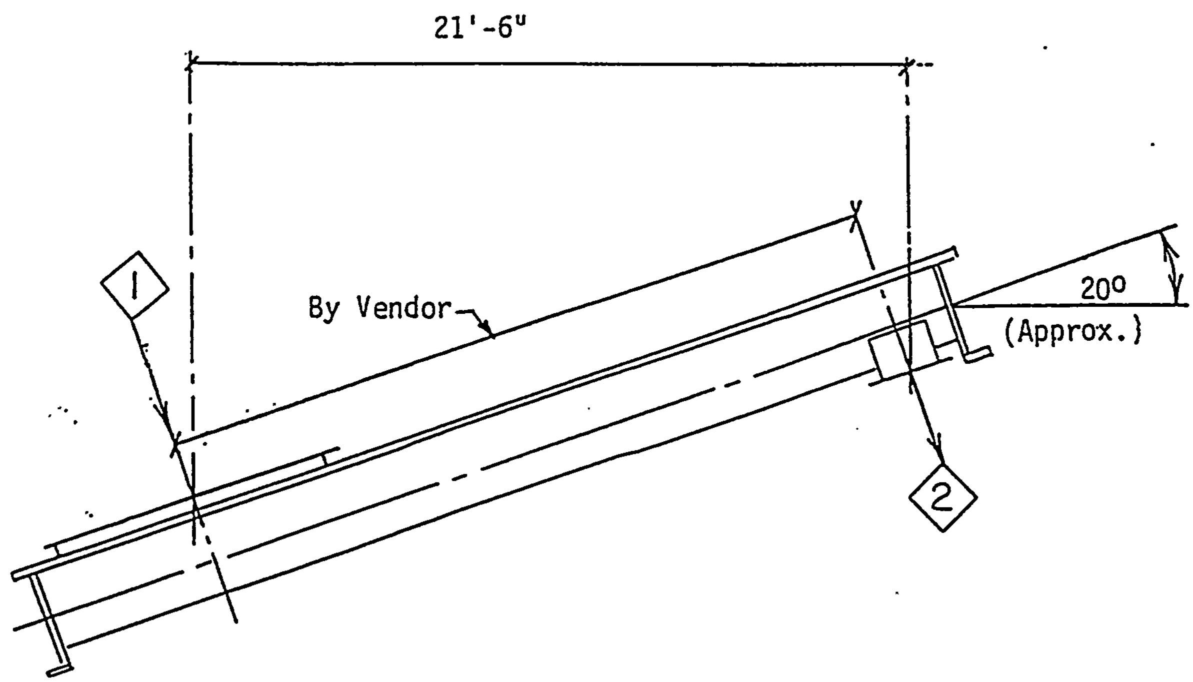
    Performance Relative Humidity: 60%

11. All data, i.e. capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum required.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 3**

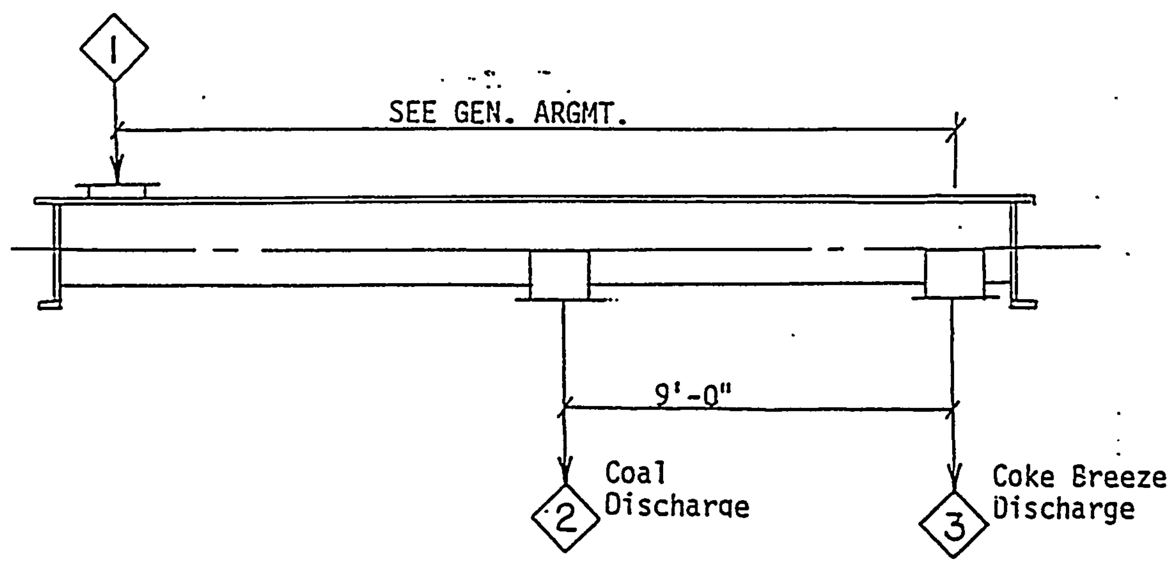
Equipment Name Coal Screw Feeder
Equipment No. 1DH-FDR-1
System Name Coal Receiving, Storage, & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001



SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 3**

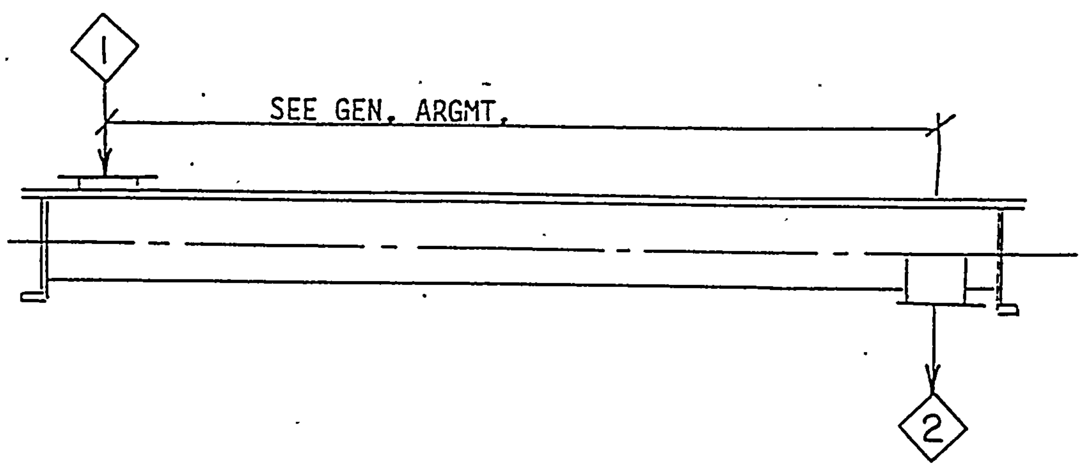
Equipment Name Coal Screw Conveyor
Equipment No. 1DH-CONV-1
System Name Coal Receiving, Storage, & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001



SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 3**

Equipment Name Coal Screw Feeder
Equipment No. 1DH-FDR-2
System Name Coal Receiving, Storage, & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001



PROCESS DESIGN BASIS

**PDB No. 82-IDH-3**

| | |
|---|---|
| Equipment Name | Screw Conveyors & Feeders |
| Equipment No. | 1DH-FDR-1; 1DH-CONV-1; 1DH-FDR-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

I. DESIGN PHILOSOPHY

1. The screw conveyors and feeders transport coal or coke breeze from point to point in the process.

2. The PyGas™ Coal Gasifier and Coal Screw Feeder 1DH-FDR-2 will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period. The Coal Screw Feeder 1DH-FDR-1 and Coal Screw Conveyor 1DH-CONV-1 will operate continuously 8 hours per day, 7 days per week for the two week periods.

3. The minimum and maximum capacity of the Coal Screw Feeder 1DH-FDR-1 and Coal Screw Conveyor 1DH-CONV-1 will be based on the 7 day, 24-hour average operating capacity of the Mass Balance being handled in a 8-hour operating period, 7-days per week.

4. The screw conveyors and feeders will be installed outdoors. See Design Notes for ambient weather criteria.

5. The minimum conveyor and feeder size is 12" diameter.

6. Coke breeze will be handled by the coal handling equipment for use as a start-up fuel and potentially as a "Hot Hold" condition fuel in the PyGas™ Coal Gasifier at a reduced capacity.

PROCESS DESIGN BASIS
**PDB No. 82-IDH-3**

| | |
|---|---|
| Equipment Name | Coal Screw Feeder |
| Equipment No. | 1DH-FDR-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

## II. DESIGN CRITERIA

| COAL HANDLING OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COAL IN | 18878 | 15102 | 15102 | 130 | (SEE MASS BAL.) | | |
| 2 | PRODUCT COAL OUT | 18878 | 15102 | 15102 | 130 | (SEE MASS BAL.) | | |

| COKE HANDLING OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COKE BREEZE IN | 9439 | 7551 | 7551 | 130 | (SEE MASS BAL.) | | |
| 2 | PRODUCT COKE BREEZE OUT | 9439 | 7551 | 7551 | 130 | (SEE MASS BAL.) | | |

## PROCESS DESIGN BASIS
## PDB No. 82-IDH-3

| | |
|---|---|
| Equipment Name | Coal Screw Conveyor |
| Equipment No. | 1DH-CONV-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

## II. DESIGN CRITERIA

| COAL HANDLING OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | PRODUCT COAL IN | 18878 | 15102 | 15102 | 130 | (SEE MASS BAL.) | | |
| 2 | PRODUCT COAL OUT | 18878 | 15102 | 15102 | 130 | (SEE MASS BAL.) | | |

| COKE HANDLING OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | PRODUCT COKE BREEZE IN | 9439 | 7551 | 7551 | 130 | (SEE MASS BAL.) | | |
| 3 | PRODUCT COKE BREEZE OUT | 9439 | 7551 | 7551 | 130 | (SEE MASS BAL.) | | |

PROCESS DESIGN BASIS
**PDB No. 82-IDH-3**

| | |
|---|---|
| Equipment Name | Coal Screw Feeder |
| Equipment No. | 1DH-FDR-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-00 |

## II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COAL IN | 6675 | (SEE MASS BAL.) | | 130 | (SEE MASS BAL.) | | |
| 2 | PRODUCT COAL OUT | 6675 | (SEE MASS BAL.) | | 130 | (SEE MASS BAL.) | | |

## PROCESS DESIGN BASIS

**PDB No. 82-IDH-3**

| | |
|---|---|
| Equipment Name | Screw Conveyors & Feeders |
| Equipment No. | 1DH-FDR-1; 1DH-CONV-1; 1DH-FDR-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

### III. DESIGN NOTES

1. Product coal and coke breeze flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal and coke breeze flows, Mass and Energy Balance results, to allow for operation variations.

2. The maximum and minimum flow rates for coke breeze are based on the coal feed capacity with a density of 50 pcf and are reduced by 50% when handling coke breeze with a density of 25 pcf.

| | | |
|---|---|---|
| 3. | Coal Type | Bituminus |
| 4. | Coal Moisture | 6% |
| | Coke Moisture | 0% |
| 5. | Coal Specific Heat | 0.30 Btu/lb. -F |
| 6. | Coal Bulk Density | 50#/Ft$^3$ |
| | Coke Breeze Bulk Density | 25-35#/Ft$^3$ |
| 7. | Coal Grindability Index | 40 - 90 |
| 8. | Coke Breeze Size | -1/4" x 0" |
| 9. | Coal Feed: | |

| Size Analysis (As Received) | | Sample |
|---|---|---|
| | +1-1/2" | 0.0% |
| -1-1/2 | +1 | 6.3% |
| -1 | +3/4 | 7.3% |
| -3/4 | +1/2 | 8.5% |
| -1/2 | +3/8 | 8.4% |
| -3/8 | +1/4 | 11.7% |
| -1/4 | +#4 (Mesh) | 8.2% |
| -4 | +6 | 7.7% |
| -6 | +16 | 19.6% |
| -16 | +30 | 8.3% |
| -30 | +56 | 5.1% |
| -50 | +100 | 3.6% |
| -100 | +200 | 2.1% |
| -200 | | 3.2% |

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-3**

| | |
|---|---|
| Equipment Name | Screw Conveyors & Feeders |
| Equipment No. | 1DH-FDR-1; 1DH-CONV-1; 1DH-FDR-2 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

III DESIGN NOTES - Continued

Note: The coal size gradation analysis shown above is taken from the Riley Fuels Laboratory Test Report for three coals used at the Fort Martin Facility dated February 1, 1994. The size gradation for Consol #2 coal was used.

10. Design Operating Temperature — 130°F

11. Ambient Weather Criteria

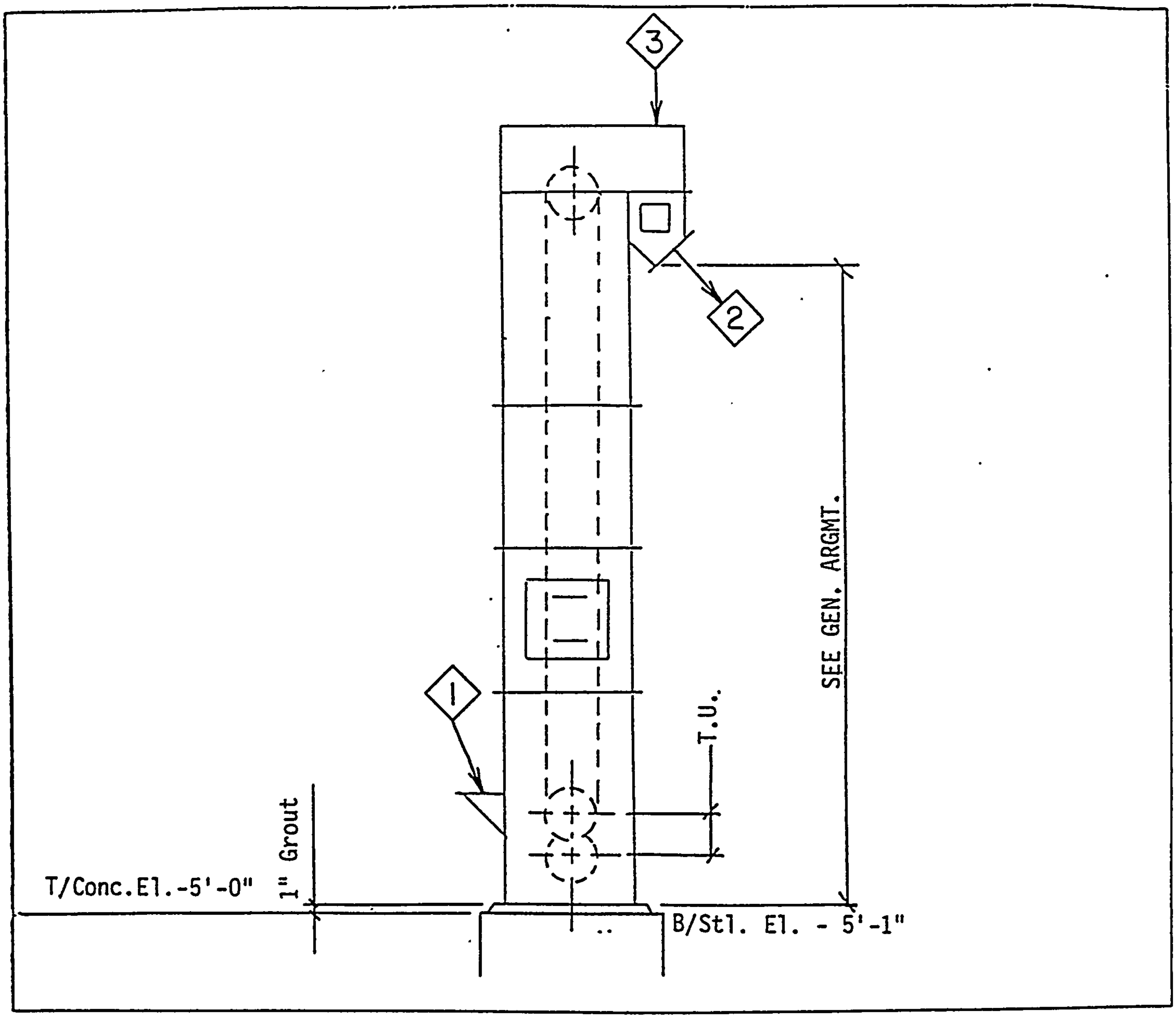
| | |
|---|---|
| Design Temperature: | |
| Dry Bulb: | |
| Winter | -20°F (lowest on record-use for freeze protection) |
| Winter | 4°F (99%) |
| Summer | 90°F (99%) |
| Wet Bulb: | 74°F (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

12. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 4**

Equipment Name Coal Bucket Elevator
Equipment No. 1DH-ELEV-1
System Name Coal Receiving, Storage, & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001



PROCESS DESIGN BASIS
**PDB No. 82-IDH-4**

| | |
|---|---|
| Equipment Name | Coal Bucket Elevator |
| Equipment No. | 1DH-ELEV-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

## I. DESIGN PHILOSOPHY

1. The Coal Bucket Elevator will receive the coal or coke breeze from the Coal Screw Feeder and raise the coal or coke breeze and discharge to the Coal Screw Conveyor.

2. The PyGas ™ Coal Gasifier and Coal Bucket Elevator will operate continuously, 8 hours per day, 7 days per week for two week periods and be out of service for six weeks between each period.

3. The minimum and maximum capacity of the Coal Bucket Elevator will be based on the 7 day, 24-hour average operating capacity of the Mass Balance being handled in a 8-hour operating period, 7 days per week.

4. The Coal Bucket Elevator will be installed outdoors. See Design Notes for ambient weather design criteria.

5. The vent gas from the Coal Bucket Elevator will be piped to the Coal Storage Bin.

6. The Coal Bucket Elevator will be free standing design with bracing to the Coal Storage Bin for stability.

7. Coke breeze will be handled by the Coal Bucket Elevator for use as a start-up fuel and potentially as a "Hot Hold" condition fuel in the PyGas™Coal Gasifier at a reduced capacity.

PROCESS DESIGN BASIS

**PDB No. 82-IDH-4**

| | |
|---|---|
| Equipment Name | Coal Bucket Elevator |
| Equipment No. | 1DH-ELEV-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

## II. DESIGN CRITERIA

| NORMAL COAL HANDLING OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR | MAX. FLOW #/HR | MIN. FLOW #/HR | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS. PSIG |
| 1 | Product Coal In | 18878 | 15102 | 15102 | 130 | (SEE MASS BAL.) | | |
| 2 | Product Coal Out | 18689 | 14951 | 14951 | 130 | (SEE MASS BAL.) | | |
| 3 | Dust Vent (Solids) | 189 | 151 | 151 | 130 | (SEE MASS BAL.) | | |

| COKE HANDLING OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR | MAX. FLOW #/HR | MIN. FLOW #/HR | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS. PSIG |
| 1 | Product Coke Breeze In | 9439 | 7551 | 7551 | 130 | (SEE MASS BAL.) | | |
| 2 | Product Coke Breeze Out | 9345 | 7475 | 7475 | 130 | (SEE MASS BAL.) | | |
| 3 | Dust Vent (Solids) | 94 | 76 | 76 | 130 | (SEE MASS BAL.) | | |

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-4**

| | |
|---|---|
| Equipment Name | Coal Bucket Elevator |
| Equipment No. | 1DH-ELEV-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

### III. DESIGN NOTES

1. Product coal and coke breeze flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal and coke breeze flows, Mass and Energy Balance results, to allow for operation variations.

2. The maximum and minimum flow rates for coke breeze are based on the coal feed capacity with a density of 50 pcf and are reduced by 50% when handling coke breeze with a density of 25 pcf.

| | | |
|---|---|---|
| 3. | Coal Type | Bituminous |
| 4. | Coal Moisture | 6% |
| | Coke Breeze Moisture | 0% |
| 5. | Coal Specific Heat | 0.30 Btu/Lb-F |
| 6. | Coal Bulk Density | 50 #/Ft3 |
| | Coke Breeze Bulk Density | 25-35 #/ft$^3$ |
| 7. | Coal Grindability Index | 40-90 |
| 8. | Coke Breeze Size | -1/4" x 0 |
| 9. | Coal Feed: | |

| Size Analysis (As Received) | | Sample |
|---|---|---|
| | +1-1/2" | 0.0% |
| -1-1/2 | +1 | 6.3% |
| -1 | +3/4 | 7.3% |
| -3/4 | +1/2 | 8.5% |
| -1/2 | +3/8 | 8.4% |
| -3/8 | +1/4 | 11.7% |
| -1/4 | +#4 (Mesh) | 8.2% |
| -4 | +6 | 7.7% |
| -6 | +16 | 19.6% |
| -16 | +30 | 8.3% |
| -30 | +56 | 5.1% |
| -50 | +100 | 3.6% |
| -100 | +200 | 2.1% |
| -200 | | 3.2% |

PROCESS DESIGN BASIS
**PDB No. 82-IDH-4**

| | |
|---|---|
| Equipment Name | Coal Bucket Elevator |
| Equipment No. | 1DH-ELEV-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

III. DESIGN NOTES - Continued

Note: The coal size gradation analysis shown above is taken from the Riley Fuels Laboratory Test Report for three coals used at the Fort Martin Facility dated February 1, 1994. The size gradation for Consol #2 coal was used.

10. Design Operating Temperature — 130°F

11. Ambient Weather Criteria

Design Temperature:

Dry Bulb:

Winter - -20°F (lowest on record-use for freeze protection)

Winter - 4°F (99%)

Summer - 90°F (99%)

Wet Bulk: 74°F (99%)

Performance Temperature: 80°F

Performance Relative Humidity: 60%

12. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

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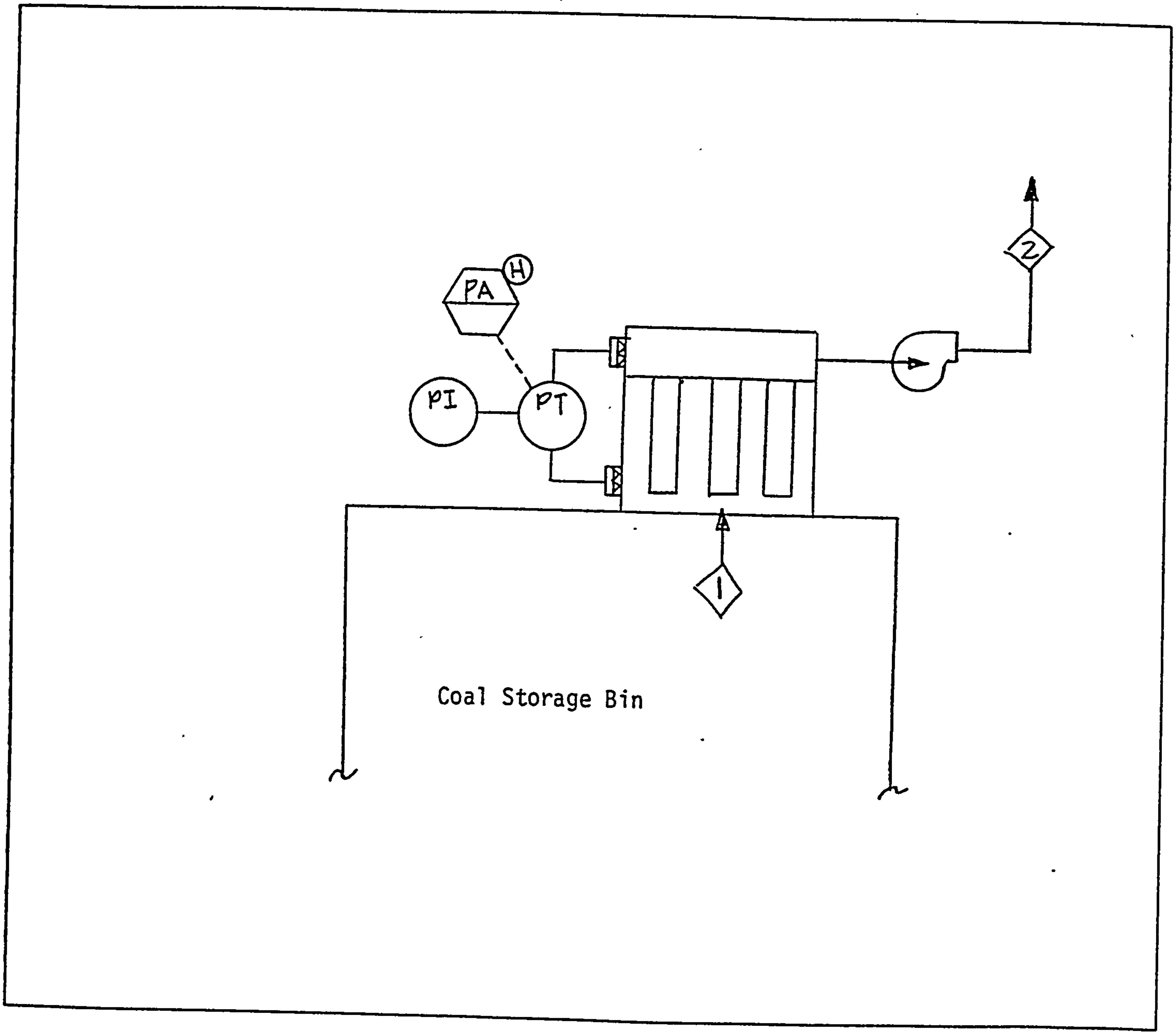
SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DH - 5**

Equipment Name Coal Storage Bin Vent Dust Collector w/Exhaust Fan
Equipment No. 1DH-DCOL-1 and 1DH-FAN-2
System Name Coal Receiving, Storage & Reclaim
Flowsheet No. 16N25706-82-F-1DH-001



PROCESS DESIGN BASIS
**PDB No. 82-IDH-5**

| | |
|---|---|
| Equipment Name | Coal Storage Bin Vent Dust Collector w/Exhaust Fan |
| Equipment No. | 1DH-DCOL-1 and 1DH-FAN-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DH-001 |

## I. DESIGN PHILOSOPHY

1. The Coal Storage Bin Vent Dust Collector with exhaust fan will gather coal dust from the Coal Storage Bin.

2. The dust collector will operate continuously, 24 hours per day, for two week periods, and be out of service for six weeks between each period.

3. The dust collector will be installed outdoors. See Design Notes for ambient weather criteria.

4. Sensors will be provided on the dust collector for monitoring the differential pressure across the filter bags. A high differential pressure detected will sound an audible alarm and shut down the storage bin feed equipment.

5. The dust collector filter bags will include an integral grounding wire to prevent dust ignition from a static charge. All other areas of the dust collector exposed to dust and/or gas flow will include grounding devices to prevent the development and conductance of a static charge.

## PROCESS DESIGN BASIS
**PDB No. 82-IDH-5**

Equipment Name: Coal Storage Bin Vent Dust Collector w/Exhaust Fan
Equipment No.: 1DH-DCOL-1 and 1DH-FAN-1
System Name: Coal Receiving, Storage & Reclaim
Flowsheet No.: 16N25706-82-F-1DJ-001

II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Dust Vent (Solids) (Gas) | 1992<br>6188 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |
| 2 | Exhaust Vent (Solids) (Gas) | 3.98<br>6188 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |

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# PROCESS DESIGN BASIS
**PDB No. 82-IDH-5**

| | |
|---|---|
| Equipment Name | Coal Storage Bin Vent Dust Collector w/Exhaust Fan |
| Equipment No. | 1DH-DCOL-1 and 1DH-FAN-1 |
| System Name | Coal Receiving, Storage & Reclaim |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

## III DESIGN NOTES

1. Coal dust and exhaust flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum flow, Mass and Energy Balance results, to allow for operation variations.

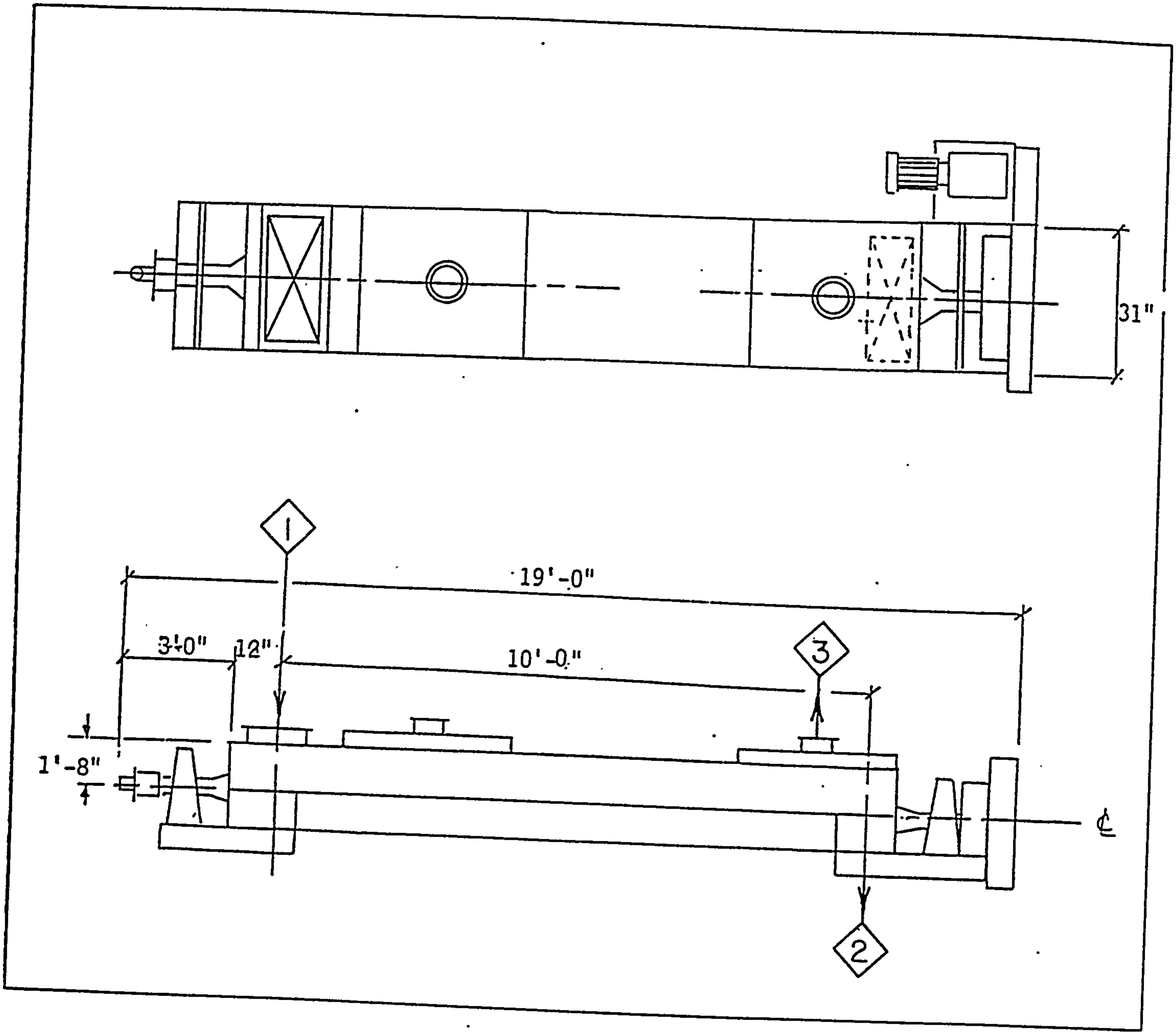
| | |
|---|---|
| 2. Material Handling | Coal dust from storage bin loading via bucket elevator and screw conveyor and vent from high pressure charge hopper. |
| 3. Particle Size | 100 mesh to and including 0.5 micron. |
| 4. Moisture Content | 1 to 6% |
| 5. Design Operating Temperature | 100°F |
| 6. Efficiency Required | 99.8% |
| 7. Cloth to Air Ratio | 6 to 1 minimum |
| 8. Bag Cleaning | Reverse pulse jet compressed air |
| 9. Compressed Air Available | Instrument air - 100 psig @ 100°F |
| 10. Classification | Class II, Division 2, Groups E & F |
| 11. Motor Voltage Available | 460 voltage, 3 phase, 60 hertz |
| 12. Control Voltage Available | 120 volt AC |
| 13. Ambient Weather Criteria | |
| Design Temperature: | |
| Dry Bulb: | |
| Winter | -20°F (lowest on record-use for freeze protection) |
| Winter | 4°F (99%) |
| Summer | 90°F (99%) |
| Wet Bulb: | 74°F (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

14. The dust collector will be complete with internal fire protection system.
15. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 1**

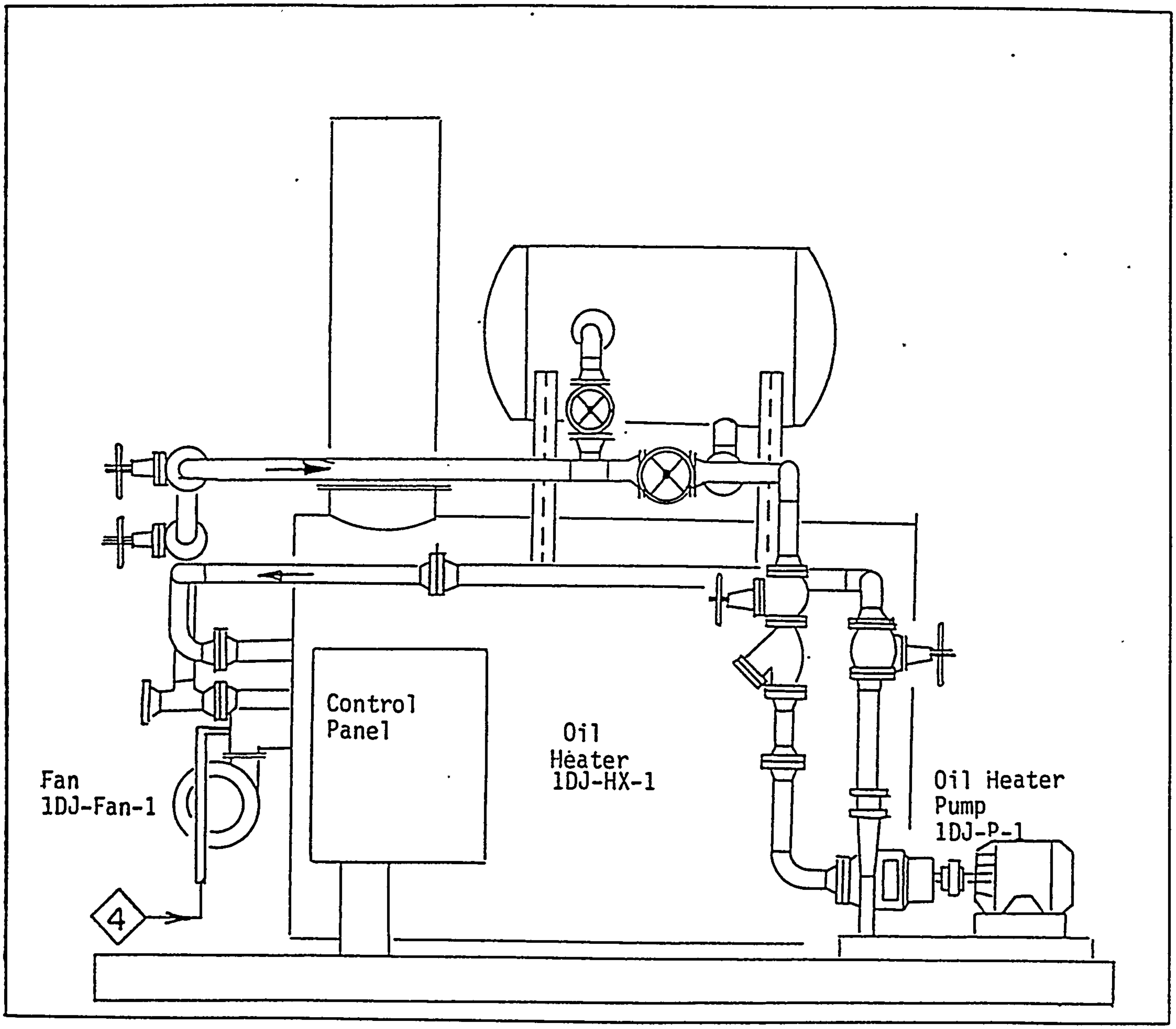
Equipment Name: Coal Screw Dryer
Equipment No.: 1DJ-DRY-1
System Name: Coal Preparation, & Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001



## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 1**

Equipment Name: Oil Heater
Equipment No.: 1DJ-HX-1
System Name: Coal Preparation, & Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

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PROCESS DESIGN BASIS
**PDB No. 82-IDJ-1**

| | |
|---|---|
| Equipment Name | Coal Screw Dryer |
| Equipment No. | 1DJ-DRY-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coal Screw Dryer will reduce the moisture of the crushed coal to less than 1%.
2. The PyGas™ Coal Gasifier and Coal Screw Dryer will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.
3. The Coal Screw Dryer will be installed outdoors. See Design Notes for ambient weather design criteria.
4. The vent gas from the Coal Screw Dryer will be piped to the Coal Preparation Dust Collector.
5. Hot oil will be circulated through hollow flight screws in the dryer. The oil will be heated in a natural gas fired oil heater.
6. Oil heater controls will include a flame safety system.

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-1**

| | |
|---|---|
| Equipment Name | Coal Screw Dryer |
| Equipment No. | 1DJ-DRY-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Process Stream | Design Flow #/Hr. | Max. Flow #/Hr. | Min. Flow #/Hr. | Max. Temp. °F | Min. Temp °F | Max. Press Psig | Min. Press Psig |
| 1 | Product Coal In | 6608 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 2 | Product Coal Out | 6542 | (See Mass Bal.) | | 250 | (See Mass Bal.) | | |
| 3 | Dust Vent (Solids) | 66 | (See Mass Bal.) | | 150 | (See Mass Bal.) | | |
| 4 | Natural Gas | By Vendor | (See Mass Bal.) | | N/A | (See Mass Bal.) | | |

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PROCESS DESIGN BASIS
**PDB No. 82-IDJ-1**

| | |
|---|---|
| Equipment Name | Coal Screw Dryer |
| Equipment No. | 1DJ-DRY-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

III. DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow the operation variations.

| | |
|---|---|
| 2. Coal Type | Bituminous |
| 3. Coal Moisture | 6% |
| 4. Coal Specific Heat | 0.30 Btu/Lb-F |
| 5. Coal Bulk Density | $50\#/Ft^3$ |
| 6. Coal Grindability Index | 40-90 |
| 7. Crushed Coal Feed: | |

| Size Analysis (Anticipated) | Sample (Estimated) |
|---|---|
| -3/8 + 1/4 | 3% |
| -1/4 + 1/8 | 14% |
| -1/8 + 10 (mesh) | 15% |
| -10 + 20 | 30% |
| -20 + 40 | 20% |
| -40 + 100 | 9% |
| -100 + 200 | 5% |

| | |
|---|---|
| 8. Target Outlet Moisture | <1.0% |
| 9. Natural Gas | Available at 35 to 60 psig |
| 10. Ambient Weather Criteria | |

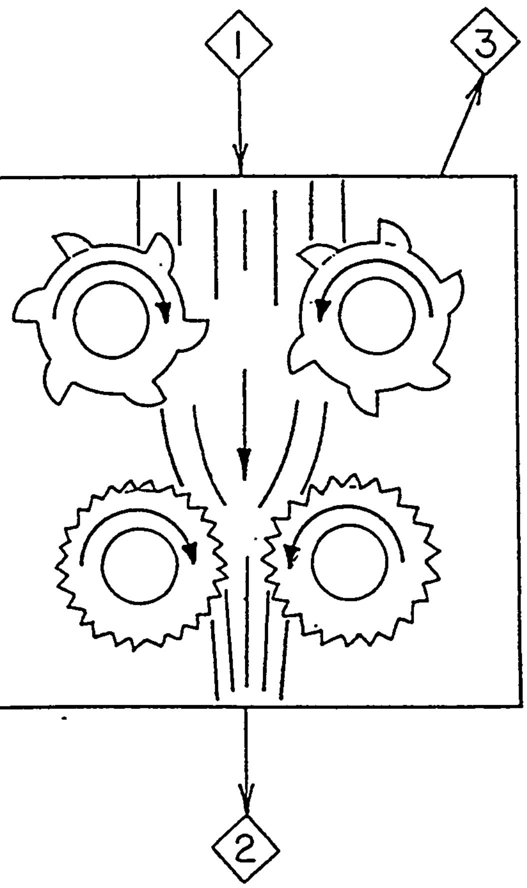
| | |
|---|---|
| Design Temperature: | |
| Dry Bulb: | |
| Winter | -20°F (lowest on record-use for freeze protection) |
| Winter | 4°F (99%) |
| Summer | 90°F (99%) |
| Wet Bulb: | 74°F (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

11. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 2**

Equipment Name Coal Crusher
Equipment No. 1DJ-CRSH-1
System Name Coal Preparation, & Limestone System
Flowsheet No. 16N25706-82-F-1DJ-001



PROCESS DESIGN BASIS
**PDB No. 82-IDJ-2**

| | |
|---|---|
| Equipment Name | Coal Crusher |
| Equipment No. | 1DJ-CRSH-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coal Crusher will reduce the incoming coal size to between -1/4 x 50 mesh for burning in the PyGas™ Coal Gasifier.
2. The Coal Crusher will be installed outdoors. See Design Notes for ambient weather design criteria.
3. The vent gas from the Coal Crusher will be piped to the Coal Preparation Dust Collector.
4. The Coal Crusher will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.
5. The crusher will be roll or ring type with two stage crushing to minimize fines generation.
6. The coal grindability and sulfur content will vary with the specific test to be conducted.
7. A screw feeder will provide flow rate control to the coal crusher.

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-2**

| | |
|---|---|
| Equipment Name | Coal Crusher |
| Equipment No. | 1DJ-CRSH-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Product Coal In | 6675 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |
| 2 | Product Coal Out | 6608 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 3 | Dust Vent (Solids) | 67 | (See Mass Bal.) | | 150 | (See Mass Bal.) | | |

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-2**

| | |
|---|---|
| Equipment Name | Coal Crusher |
| Equipment No. | 1DJ-CRSH-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

III DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.
2. Coal Type — Bituminous
3. Coal Moisture — 6%
4. Coal Specific Heat — 0.30 Btu/Lb-F
5. Crushed Coal Target Size — -1/4 x 50 mesh
6. Coal Bulk Density — 50 #/Ft$^3$
7. Coal Grindability Index — 40-90
8. Coal Feed:

| Size Analysis (As Received) | | Sample (Estimated) |
|---|---|---|
| +1-1/2" | | 0.0% |
| -1-1/2 | +1 | 6.3% |
| -1 | +3/4 | 7.3% |
| -3/4 | +1/2 | 8.5% |
| -1/2 | +3/8 | 8.4% |
| -3/8 | +1/4 | 11.7% |
| -1/4 | +#4 (Mesh) | 8.2% |
| -4 | +6 | 7.7% |
| -6 | +16 | 19.6% |
| -16 | +30 | 8.3% |
| -30 | +50 | 5.1% |
| -50 | +100 | 3.6% |
| -100 | +200 | 2.1% |
| -200 | | 3.2% |

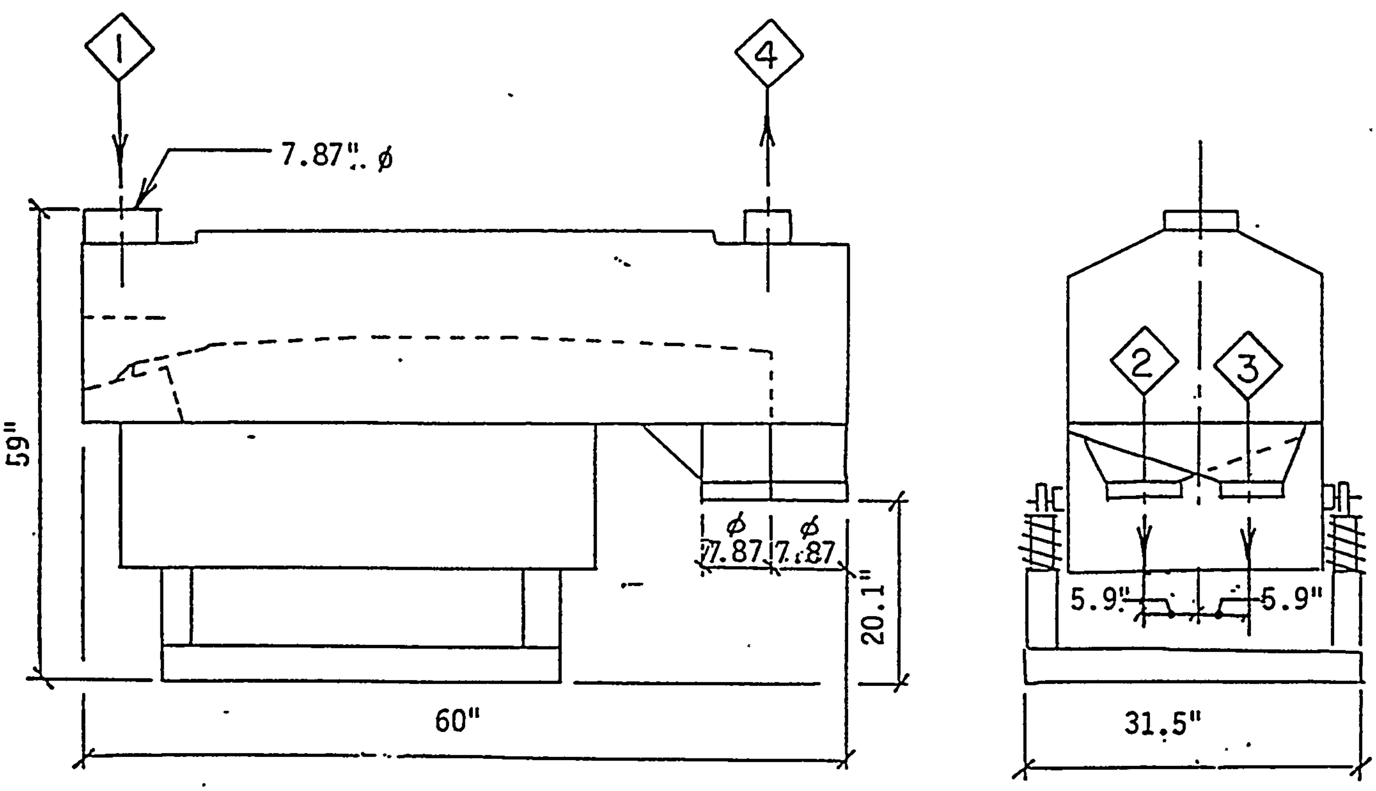
9. Design Operating Temperature — 150°F
10. Ambient Weather Criteria
    Design Temperature:
    Dry Bulb:
    - Winter — -20°F (lowest on record-use for freeze protection)
    - Winter — 4°F (99%)
    - Summer — 90°F (99%)

    Wet Bulb: 74°F (99%)
    Performance Temperature: 80°F
    Performance Relative Humidity: 60%
11. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 3**

Equipment Name Coal Classifier
Equipment No. 1DJ-CLF-1
System Name Coal Preparation, & Limestone System
Flowsheet No. 16N25706-82-F-1DJ-001

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PROCESS DESIGN BASIS
**PDB No. 82-IDJ-3**

| | |
|---|---|
| Equipment Name | Coal Classifier |
| Equipment No. | 1DJ-CLF-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coal Classifier will separate out the fines fraction (<50 mesh) of the crushed coal stream in preparation for burning in the PyGas™ Coal Gasifier.
2. The PyGas™ Coal Gasifier and Coal Classifier will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period..
3. The Coal Classifier will be installed outdoors. See Design Notes for ambient weather design criteria.
4. The vent gas from the Coal Classifier will be piped to the Coal Preparation Dust Collector.

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-3**

| | |
|---|---|
| Equipment Name | Coal Classifier |
| Equipment No. | 1DJ-CLF-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Product Coal In | 6412 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 2 | Product Coal Out | 5205 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 3 | Coal Fines | 1143 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 4 | Dust Vent (Solids) | 64 | (See Mass Bal.) | | 150 | (See Mass Bal.) | | |

## PROCESS DESIGN BASIS
**PDB No. 82-IDJ-3**

| | |
|---|---|
| Equipment Name | Coal Classifier |
| Equipment No. | 1DJ-CLF-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

### III DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.

| | |
|---|---|
| 2. Coal Type: | Bituminous |
| 3. Coal Moisture: | <1% |
| 4. Coal Specific Heat: | 0.30 Btu/Lb-F |
| 5. Coal Bulk Density: | 50#/Ft$^3$ |
| 6. Coal Grindability Index: | 40-90 |
| 7. Crushed Coal Size (Target): | -1/4 x 50 mesh |
| 8. Crushed Coal Feed: | |

| Size Analysis (Anticipated) | | Sample (Estimated) |
|---|---|---|
| -3/8 | +1/4 | 3% |
| -1/4 | +1/4 | 14% |
| -1/8 | +10 (mesh) | 15% |
| -10 | +20 | 30% |
| -20 | +40 | 20% |
| -40 | +100 | 9% |
| -100 | +200 | 8.2% |

9. Ambient Weather Criteria

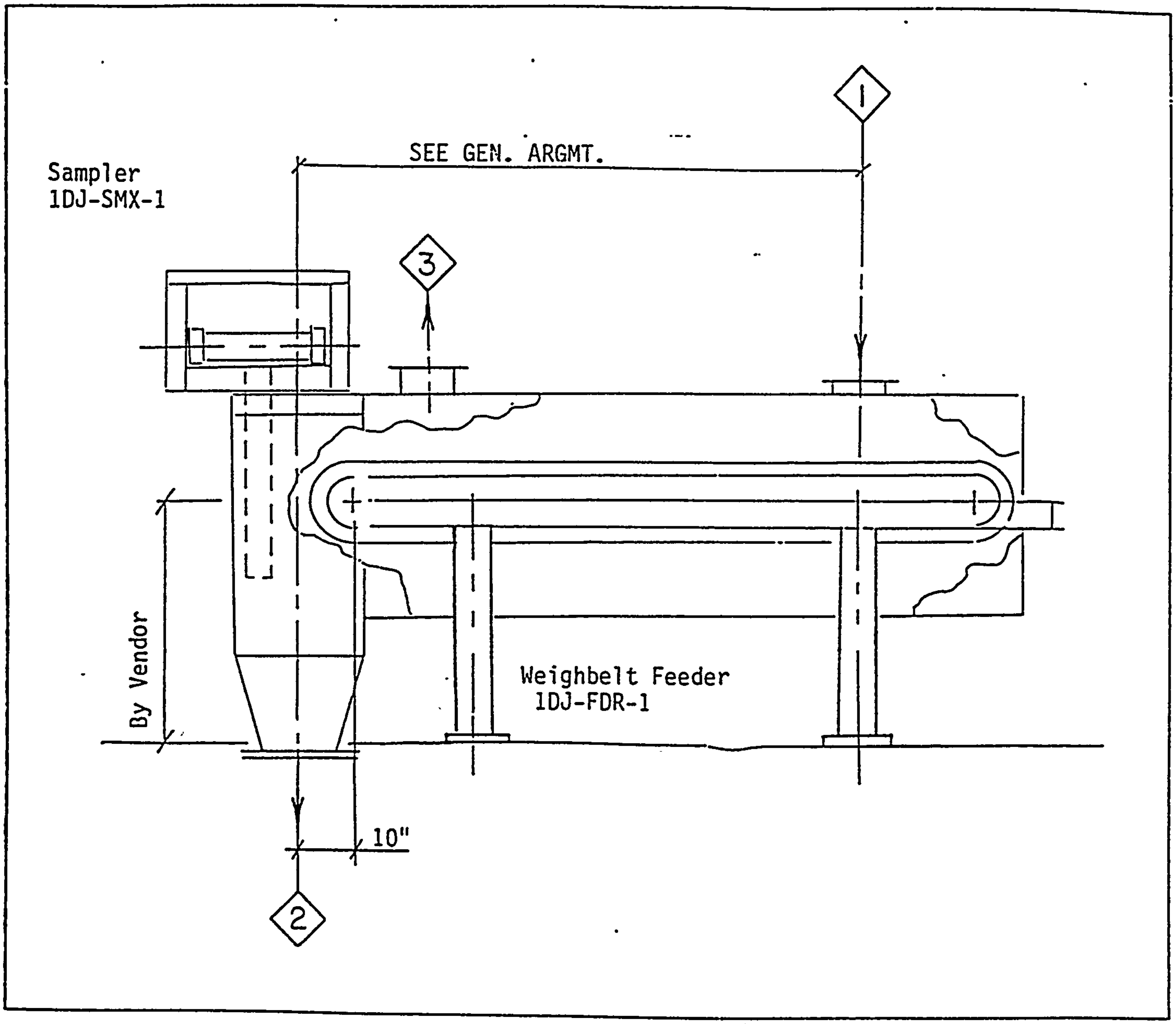
| | |
|---|---|
| Design Temperature: | |
| Winter | -20°F (lowest on record-use for freeze protection) |
| Winter | 4°F (99%) |
| Summer | 90°F (99%) |
| Wet Bulb: | 74°F (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

10. All data, i.e., capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 4**

Equipment Name Coal Weighbelt Feeder / Sampler
Equipment No. 1DJ-FDR-1, 1DJ-SMX-1
System Name Coal Preparation, & Limestone System
Flowsheet No. 16N25706-82-F-1DJ-001



PROCESS DESIGN BASIS
PDB No. IDJ-4

| | |
|---|---|
| Equipment Name | Coal Weightbelt Feeder/Sampler |
| Equipment No. | 1DJ-FDR-1, 1DJ-SMX-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coal Weighbelt Feeder/Sampler provides an accurate metering of coal fuel for combustion in the PyGas™Coal Gasifier.

2. The PyGas™Coal Gasifier and Coal Weighbelt Feeder/Sampler will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.

3. The Coal Weighbelt Feeder/Sampler will be installed outdoors. See Design Notes for ambient weather design criteria.

4. The vent gas from the Coal Weighbelt Feeder/Sampler will be piped to the Coal Preparation Dust Collector.

5. The Coal Weighbelt Feeder will provide a controlled continuous feed rate to the Surge Bin of the Pyrolizer Feed System.

6. A cross-cut Sampler will be integrated into the discharge chute of the Coal Weighbelt Feeder.

7. Cross-cut samples of the coal discharge will be taken at intervals in accordance with ASTM requirements. Samples will be discharged to containers on the ground floor for lab analysis pick-up.

8. The Coal Weighbelt Feeder/Sampler will be totally enclosed and dust tight.

## PROCESS DESIGN BASIS
**PDB No. IDJ-4**

| | |
|---|---|
| Equipment Name | Coal Weightbelt Feeder/Sampler |
| Equipment No. | 1DJ-FDR-1, 1DJ-SMX-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COAL IN | 5153 | (SEE MASS BAL.) | | 200 | (SEE MASS BAL.) | | |
| 2 | PRODUCT COAL OUT | 5102 | (SEE MASS BAL.) | | 175 | (SEE MASS BAL.) | | |
| 3 | DUST VENT (SOLIDS) | 51 | (SEE MASS BAL.) | | 125 | (SEE MASS BAL.) | | |

## PROCESS DESIGN BASIS

### PDB No. IDJ-4

| | |
|---|---|
| Equipment Name | Coal Weightbelt Feeder/Sampler |
| Equipment No. | 1DJ-FDR-1, 1DJ-SMX-1 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

III. DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.
2. Coal Type — Bituminous
3. Coal Moisture — <1%
4. Coal Specific Heat — 0.30 Btu/lb-F
5. Crushed Coal Size — -1/4 x 50 mesh
6. Coal Bulk Density — 50 #/Ft$^3$
7. Coal Grindability Index — 40-90
8. Crushed Coal Feed to Classifier

| Size Analysis (As Received) | | Sample (Estimated) |
|---|---|---|
| -3/8 | +1/4 | 3% |
| -1/4 | 1/8 | 14% |
| -1/8 | +10 (mesh) | 15% |
| -10 | +20 | 30% |
| -20 | +40 | 20% |
| -40 | +100 | 9% |
| -100 | +200 | 5% |

Note: The estimated coal size gradation shown above after crushing is based on the American Pulverizer analysis of a crusher discharge to produce 1/4" top size coal with the feed as depicted in the Riley Fuels Laboratory Test Report dated February 1, 1994.

9. Ambient Weather Criteria

Design Temperature:

| | | |
|---|---|---|
| Dry Bulb: | Winter: | -20°F (lowest on record-use for freeze protection) |
| | Winter: | 4°F (99%) |
| | Summer: | 90°F (99%) |
| Wet Bulb: | | 74°F (99%) |

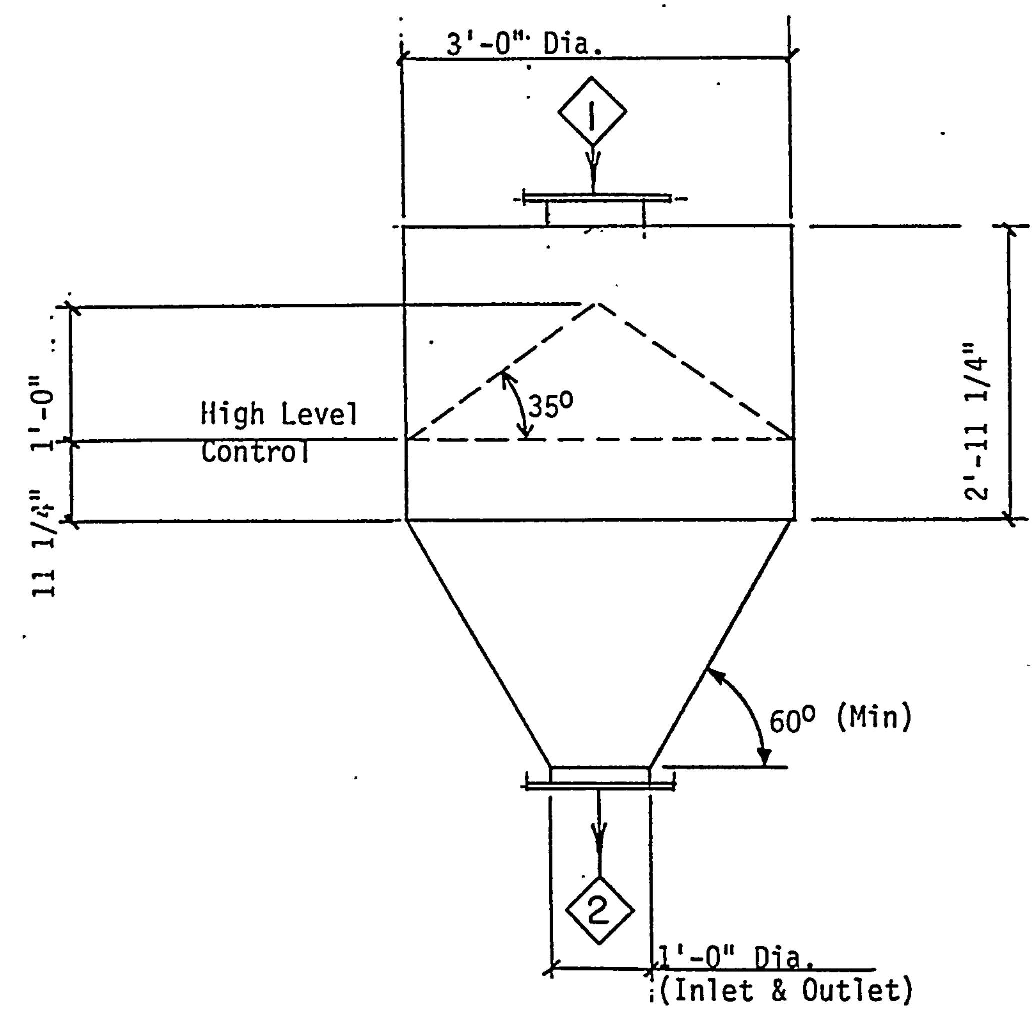
Performance Temperature: 80°F
Performance Relative Humidity: 60%

10. All data, i.e., capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum requirement.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 5**

Equipment Name Coal Surge Bin
Equipment No. 1DJ-TK-2
System Name Coal Preparation, & Limestone System
Flowsheet No. 16N25706-82-F-1DJ-001




Effective Vessel Volume:
15 $Ft^3$ @ 50#/$Ft^3$

sj/form

## PROCESS DESIGN BASIS
**PDB No. 82-IDJ-5**

| | |
|---|---|
| Equipment Name | Coal Surge Bin |
| Equipment No. | 1DJ-TK-2 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

### I. DESIGN PHILOSOPHY

1. The Coal Surge Bin provides temporary surge capacity for feed to the Coal Weighbelt Feeder.

2. The PyGas™Coal Gasifier and Coal Surge Bin will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.

3. The Coal Surge Bin will be installed outdoors. See Design Notes for ambient weather criteria.

**PROCESS DESIGN BASIS**
**PDB No. 82-IDJ-5**

Equipment Name: Coal Surge Bin
Equipment No.: 1DJ-TK-2
System Name: Coal Preparation & Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

## II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COAL IN | 5205 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 2 | PRODUCT COAL OUT | 5153 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 3 | DUST VENT (SOLIDS) | 52 | (See Mass Bal.) | | 150 | (See Mass Bal.) | | |

1. Hours Storage Available — 0.167 (10 Minutes)
2. Effective Bin Volume — 15 $Ft.^3$
3. Bin Diameter — 3'-0" (Min)
4. Discharge Cone Angle — 60° (Min)

## PROCESS DESIGN BASIS
**PDB No. 82-IDJ-5**

| | |
|---|---|
| Equipment Name | Coal Surge Bin |
| Equipment No. | 1DJ-TK-2 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

### III. DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.

| | | |
|---|---|---|
| 2. | Coal Type | Bituminous |
| 3. | Coal Moisture | <1% |
| 4. | Coal Specific Heat | 0.30 Btu/Lb.-F |
| 5. | Coal Bulk Density | 50 #/$Ft^3$ |
| 6. | Coal Angle of Repose | 35 deg. |
| 7. | Coal Grindability Index | 40-90 |

8. Size Analysis (As Received) — Sample (Estimated)

| Size Analysis (As Received) | | Sample (Estimated) |
|---|---|---|
| -3/8 | +1/4 | 3% |
| -1/4 | +1/4 | 14% |
| -1/8 | +10(mesh) | 15% |
| -10 | +20 | 30% |
| -20 | +40 | 20% |
| -40 | +100 | 9% |
| -100 | +200 | 5% |

Note: The estimated coal size gradation shown above after crushing is based on the American Pulverizer analysis of a crusher discharge to produce 1/4" top size coal with the feed as depicted in the Riley Fuels Laboratory Test Report dated February 1, 1994.

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-5**

| | |
|---|---|
| Equipment Name | Coal Surge Bin |
| Equipment No. | 1DJ-TK-2 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

III. DESIGN NOTES (cont'd.)

9. Ambient Weather Criteria

Design Temperature:

Dry Bulb:

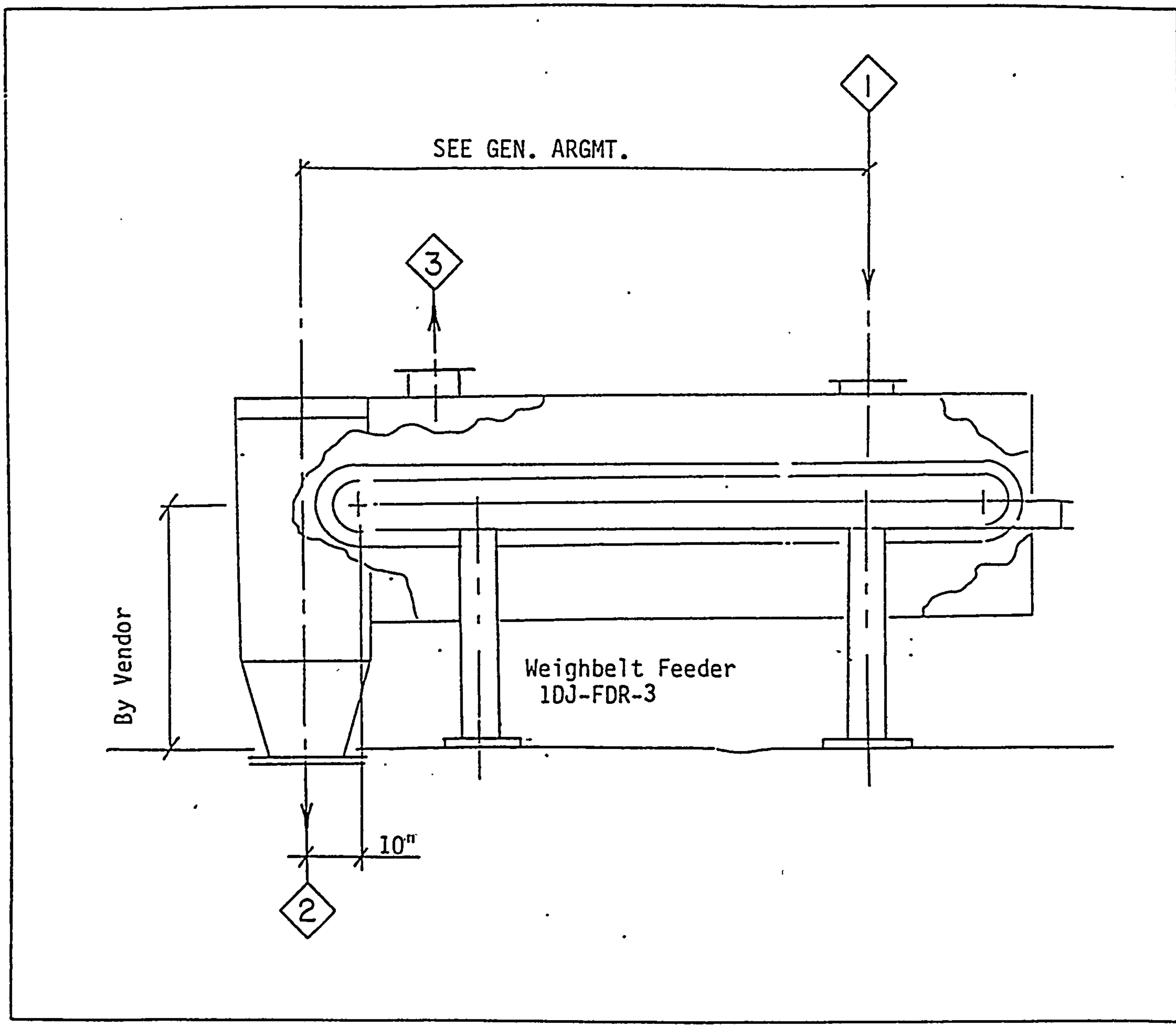
| | |
|---|---|
| Winter - | -20°F (lowest on record-use for freeze protection) |
| Winter - | 4° F (99%) |
| Summer - | 90° (99%) |
| Wet Bulb: | 74° (99%) |
| Performance Temperature: | 80° |
| Performance Relative Humidity: | 60% |

10. All data, i.e. capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum required.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 6**

Equipment Name Coke Weighbelt Feeder
Equipment No. 1DJ-FDR-3
System Name Coal Preparation and Limestone System
Flowsheet No. 16N25706-82-F-1DJ-001



PROCESS DESIGN BASIS
**PDB No. 82-IDJ-6**

| | |
|---|---|
| Equipment Name | Coke Weightbelt Feeder |
| Equipment No. | 1DJ-FDR-3 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coke Weighbelt Feeder provides an accurate metering of coke breeze for combustion in the PyGas™Coal Gasifier during the start-up mode.

2. During desulfurization testing, the Coke Weighbelt Feeder provides an accurate metering of limestone for combustion in the gasifier.

3. The PyGas™Coal Gasifier and Coke Weighbelt Feeder will operate continuously during the start-up phase.

4. Upon reaching the desired temperature and pressure in the gasifier start-up mode for coal feed, the feed of coke breeze will be reduced as the coal feed is increased.

5. The Coke Weighbelt Feeder will be installed outdoors. See Design Notes for ambient weather criteria.

6. The vent gas from the Coke Weighbelt Feeder will be piped to the Coal Preparation Dust Collector.

7. The Coke Weighbelt Feeder will provide a controlled continuous feed rate to the Surge Bin of the Pyrolizer Feed System.

8. The Coke Weighbelt Feeder will be totally enclosed and dust tight.

9. Coke breeze will be handled by the coal handling equipment for use as a start-up fuel and potentially as a "Hot Hold" condition fuel in the PyGas™ Coal Gasifier at a reduced capacity.

## PROCESS DESIGN BASIS
**PDB No. 82-IDJ-6**

Equipment Name: Coke Weightbelt Feeder
Equipment No.: 1DJ-FDR-3
System Name: Coal Preparation & Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

II. DESIGN CRITERIA

GASIFIER START-UP OPERATION

| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | PRODUCT COKE IN | 505 | (SEE MASS BAL.) | | 130 | (SEE MASS BAL.) | | |
| 2 | PRODUCT COKE OUT | 500 | (SEE MASS BAL.) | | 130 | (SEE MASS BAL.) | | |
| 3 | DUST VENT (SOLIDS) | 5 | (SEE MASS BAL.) | | 100 | (SEE MASS BAL.) | | |

GASIFIER START-UP OPERATION

| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | PRODUCT LIMESTONE IN | 1215 | (See Mass Bal.) | | 130 | 80 | 14.9 | 10 |
| 2 | PRODUCT LIMESTONE OUT | 1203 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |
| 3 | DUST VENT (SOLIDS) | 12 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |

# PROCESS DESIGN BASIS
## PDB No. 82-IDJ-6

| | |
|---|---|
| Equipment Name | Coke Weightbelt Feeder |
| Equipment No. | 1DJ-FDR-3 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

## III. DESIGN NOTES

1. Product coke breeze flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coke breeze flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.

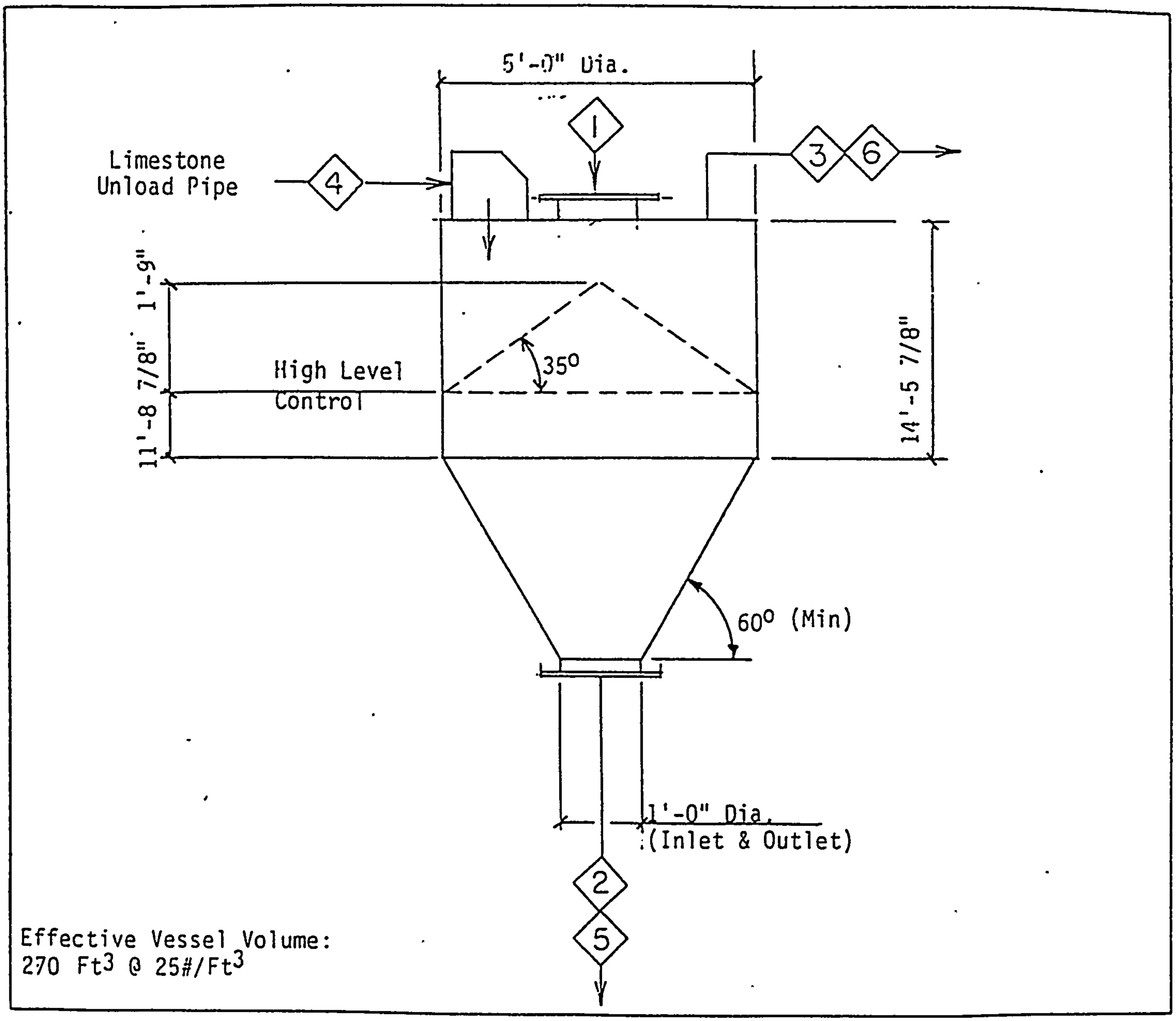
| | | |
|---|---|---|
| 2. | Coke Moisture | 0% |
| | Limestone Moisture | 1% |
| 3. | Coke Breeze Size | -1/4" x 0 |
| | Limestone Size | -1/8" x 200 Mesh |
| 4. | Coke Bulk Density | 25-35 $\#/Ft^3$ |
| | Limestone Bulk Density | 68 $\#/ft^3$ |

5. All data, i.e., capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 7**

Equipment Name: Coke Surge Bin
Equipment No.: 1DJ-TK-7
System Name: Coal Preparation and Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001



# SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 7**

Equipment Name: Coke Surge Bin
Equipment No.: 1DJ-TK-7
System Name: Coal Preparation and Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

## I. DESIGN PHILOSOPHY

1. The Coke Bin provides live storage of coke breeze for feed to the Coke Weighbelt Feeder during the start-up mode and potential "Hot Hold" condition of the PyGas™ Coal Gasifier.

2. During desulfurization testing, the Coke Bin will provide several hours of live sorbent inventory for the PyGas™ Coal Gasifier.

3. The PyGas™ Coal Gasifier and Coke Bin will operate continuously, during the start-up mode and desulfurizaiton testing.

4. The Coke Bin will be installed outdoors. See Design Notes for ambient weather criteria.

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 7**

Equipment Name: Coke Surge Bin
Equipment No.: 1DJ-TK-7
System Name: Coal Preparation and Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

II. DESIGN CRITERIA

| GASIFIER START-UP OPERATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 1 | PRODUCT COKE BREEZE IN | 9439 | 7551 | 7551 | 130 | (See Mass Bal.) | | |
| 2 | PRODUCT COKE BREEZE OUT | 505 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |
| 3 | DUST VENT (SOLIDS) | 94 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |

| DESULFURIZATION TESTING | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS. PSIG | MIN. PRESS. PSIG |
| 4 | PRODUCT LIMESTONE IN | 20,000 | 8080* | 4040 | 130 | 80 | 14.9 | 10 |
| 5 | PRODUCT LIMESTONE OUT | 1215 | (See Mass Bal.) | | 130 | (See Mass Bal.) | | |
| 6 | DUST VENT (SOLIDS) | 200 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |

* Maximum flow is based on actual truck unloading duration of 4 hours in a 8 hour day.

| | |
|---|---|
| 1. Hours Storage Available | 16.875 Hours |
| 2. Effective Bin Volume | 270 Ft.$^3$ |
| 3. Bin Diameter | 5'-0" (Min) |
| 4. Discharge Cone Angle | 60° (Min) |

## SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 7**

Equipment Name: Coke Surge Bin
Equipment No.: 1DJ-TK-7
System Name: Coal Preparation and Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

### III. DESIGN NOTES

1. Product coke breeze and limestone flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coke breeze and limestone flows, Mass and Energy Balance results, to allow for operation variations.

2. The maximum and minimum flow rates for coke breeze are based on the coal feed capacity with a density of 50 pcf and are reduced by 50% when handling coke breeze with a density of 25 pcf.

| | | |
|---|---|---|
| 3. | Coke Breeze Moisture | 0% |
| | Limestone Moisture | 1% |
| 4. | Coke Breeze Bulk Density | 25-35#/Ft$^3$ |
| | Limestone Bulk Density | 68#/Ft$^3$ |
| 5. | Coke Breeze Angle of Repose | 45 deg. |
| | Limestone Angle of Repose | 45 deg. |
| 6. | Coke Breeze Size | -1/4" x 0 |
| | Limestone Size | -1/8" x 200 mesh |
| 7. | Ambient Weather Criteria | |

Design Temperature:

Dry Bulb:

| | |
|---|---|
| Winter - | -20°F (lowest on record-use for freeze protection) |
| Winter - | 4° F (99%) |
| Summer - | 90° (99%) |

| | |
|---|---|
| Wet Bulb: | 74° (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 7**

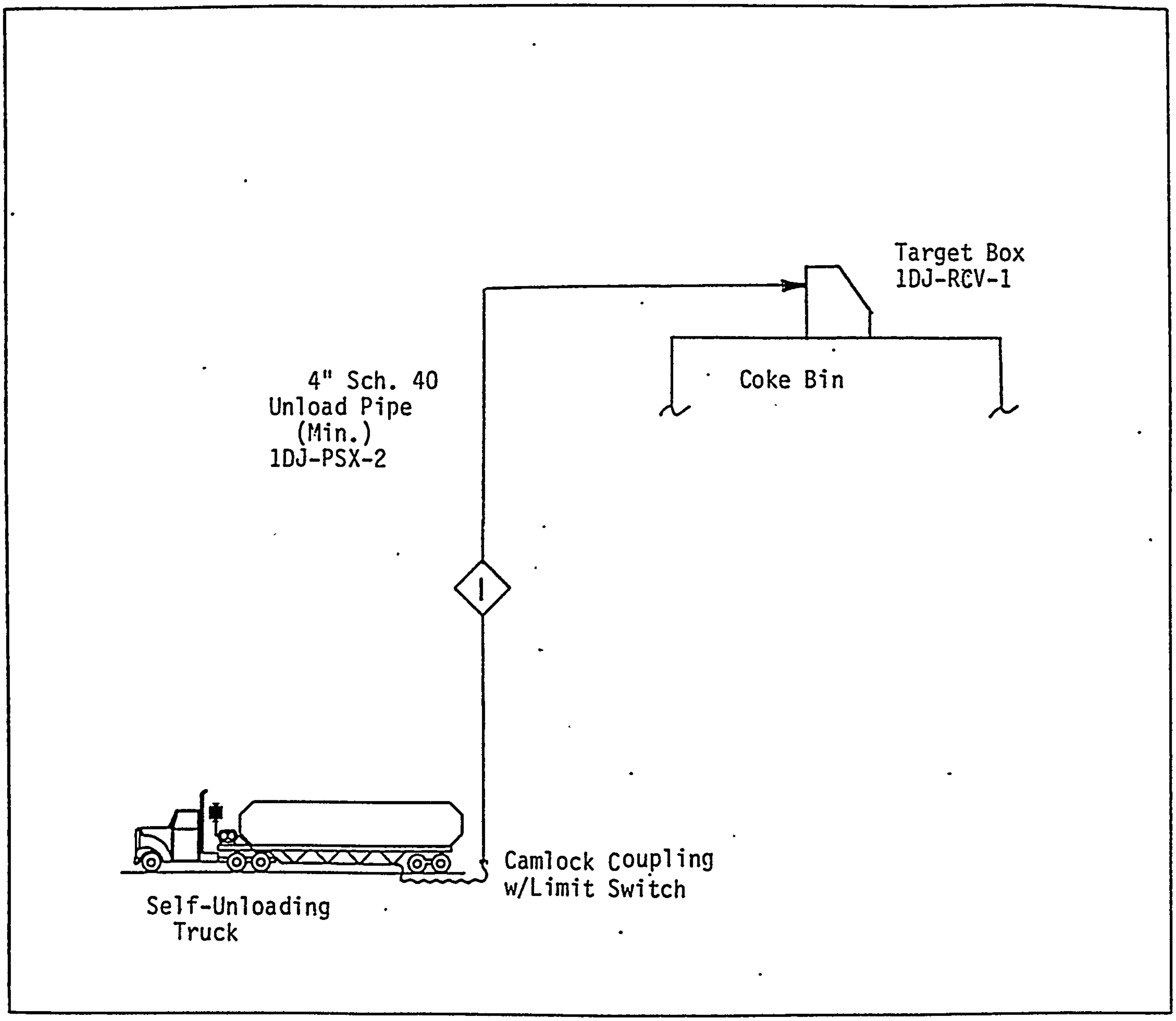
Equipment Name: Coke Surge Bin
Equipment No.: 1DJ-TK-7
System Name: Coal Preparation and Limestone System
Flowsheet No.: 16N25706-82-F-1DJ-001

8. All data, i.e. capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum required.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 8**

Equipment Name Truck Unload Pipe and Target Box
Equipment No. 1DJ-PSX-2 & 1DJ-RCV-1
System Name Limestone Unloading System
Flowsheet No. 16N25706-82-F-1DJ-001



PROCESS DESIGN BASIS
**PDB No. 82-IDJ-8**

| | |
|---|---|
| Equipment Name | Truck Unload Pipe and Target Box |
| Equipment No. | 1DJ-PSX-2 and 1DJ-RCV-1 |
| System Name | Limestone Unloading System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

## I. DESIGN PHILOSOPHY

1. The Limestone Unloading System receives bulk limestone from a self-unloading truck at ground elevation and directs to the top inlet of the Coke Storage Bin.

2. The Limestone Unloading System will operate intermittently, 8 hours per day, 5 days per week for two week periods and be out of service for six weeks between each period.

3. The minimum and maximum capacity of limestone flow through the Limestone Unloading System to the Coke Storage Bin will be based on the 7 day, 24 hour average operating capacity of the Mass Balance being handled in a 8 hour operating period, 5 days per week.

4. The Limestone Unloading System will be installed outdoors. See Design Notes for ambient weather criteria.

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-8**

Equipment Name: Truck Unload Pipe and Target Box
Equipment No.: 1DJ-PSX-2 and 1DJ-RCV-1
System Name: Limestone Unloading System
Flowsheet No.: 16N25706-82-F-1DJ-001

II. DESIGN CRITERIA

| ITEM | PROCESS STREAM | DESIGN FLOW #/HR | MAX FLOW #/HR | MIN FLOW #/HR | MAX TEMP °F | MIN TEMP °F | MAX PRESS PSIG | MIN PRESS PSIG |
|---|---|---|---|---|---|---|---|---|
| 1 | Product Limestone In | 20000 | 8080* | 4040 | 130 | 80 | 14.9 | 10 |

* Maximum flow rate is based on actual truck unloading duration of 4 hours in a 8 hour day.

**PROCESS DESIGN BASIS**
**PDB No. 82-IDJ-8**

| | |
|---|---|
| Equipment Name | Truck Unload Pipe and Target Box |
| Equipment No. | 1DJ-PSX-2 and 1DJ-RCV-1 |
| System Name | Limestone Unloading System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

III. DESIGN NOTES

1. Product limestone flow rates are from the Mass and Energy Balances. Design condition is approximately 95 percent above the maximum limestone flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations, 7 day material receipts in 5 days and rapid truck turnaround..

| | | |
|---|---|---|
| 2. | Limestone Size | -1/8 x 200 mesh |
| 3. | Limestone Bulk Density | 68 #/Ft$^3$ |
| 4. | Angle of Repose | 30 deg. |
| 5. | Moisture Content | 1 % |
| 6. | Limestone Feed Rate to Gasifier (325 psig operation) | 962 #/hour<br>23,088 #/day @ 24 hours/day<br>161,616 #/week @ 24 hours/day |
| 7. | Limestone Truck Capacity | 20,000# |
| 8. | Limestone Truck Unload Capacity | 20,000 #/hour maximum |
| 9. | Truck Delivery Schedule | 1.62 (2) per day @ 5 days/week for 7 days |
| 10. | Truck Turnaround | 4.95 (4) hrs/truck |
| 11. | Ambient Weather Criteria | |

Design Temperature:

Dry Bulb:

| | |
|---|---|
| Winter - | -20°F (lowest on record-use for freeze protection) |
| Winter - | 4° F (99%) |
| Summer - | 90° (99%) |

| | |
|---|---|
| Wet Bulb: | 74° (99%) |

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-8**

| | |
|---|---|
| Equipment Name | Truck Unload Pipe and Target Box |
| Equipment No. | 1DJ-PSX-2 and 1DJ-RCV-1 |
| System Name | Limestone Unloading System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

III. DESIGN NOTES (cont'd.)

Performance Temperature: 80°

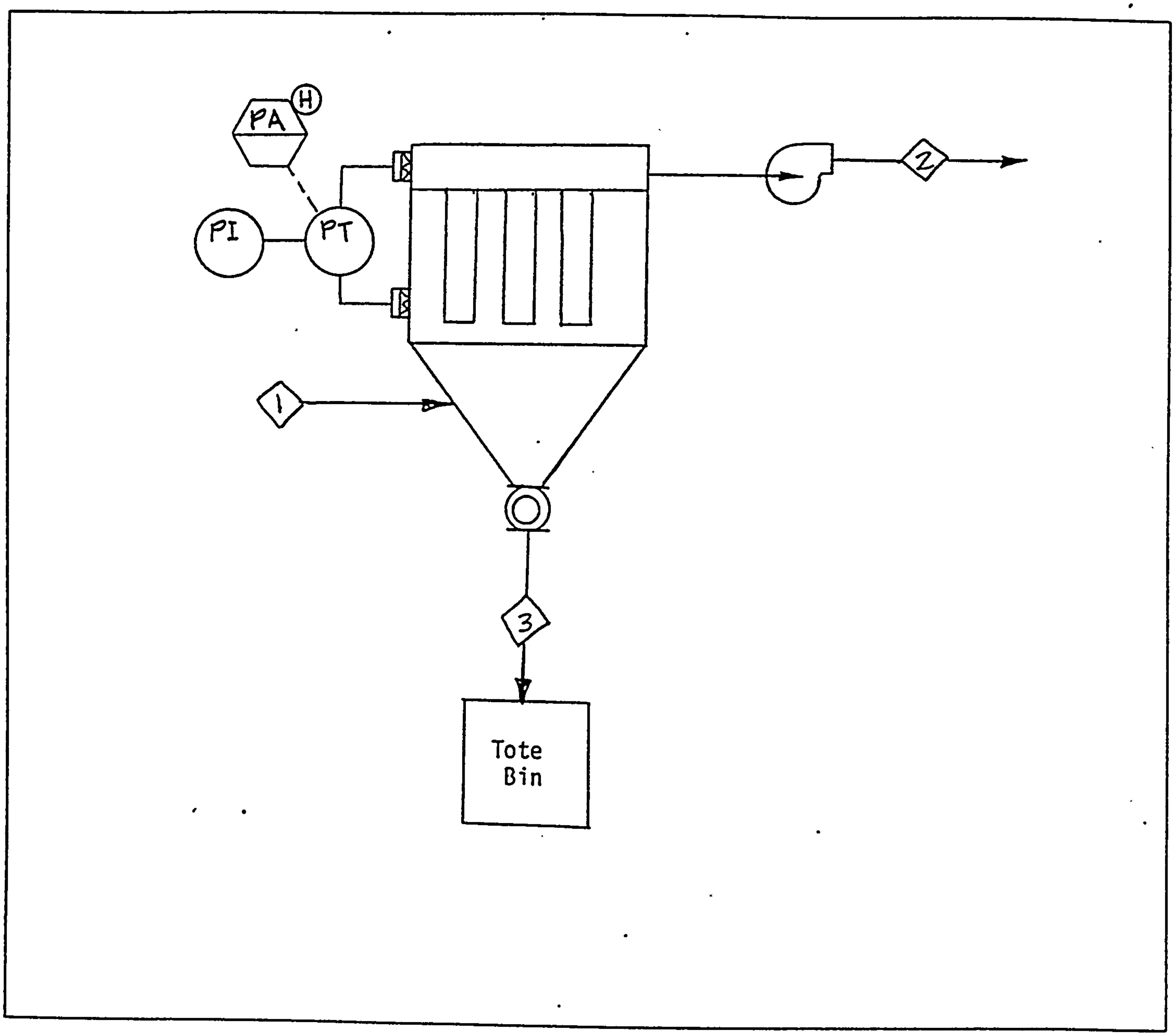
Performance Relative Humidity: 60%

12. All data, i.e. capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum required.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 9**

Equipment Name Coal Preparation Dust Collector w/Exhaust Fan
Equipment No. 1DJ-DCOL-1 and 1DJ-FAN-2
System Name Coal Preparation & Limestone System
Flowsheet No. 16N25706-82-F-1DJ-001



PROCESS DESIGN BASIS
**PDB No. 82-IDJ-9**

| | |
|---|---|
| Equipment Name | Coal Preparation Dust Collector w/Exhaust Fan |
| Equipment No. | 1DJ-DCOL-1 and 1DJ-FAN-2 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coal Preparation Dust Collector with exhaust fan will gather dust from the Coal Crusher, Coal Dryer, Coal Transfer System, Coal Weighbelt Feeder, Charge Hopper, Coke Bin And Coke Weighbelt Feeder, Coal Classifier, and Coal Surge Bin.

2. The dust collector will operate continuously, 24 hours per day, for two week periods, and be out of service for six weeks between each period.

3. The dust collector will be installed outdoors. See Design Notes for ambient weather criteria.

4. The Coal Preparation Dust Collector will include an airlock rotary valve for discahrge of the collected dust to a tote bin. The dust collector discharge hopper will be sized to allow the airlock to be stopped for 15 minutes during tote bin change out.

5. A high level control will be provided in the dust collector discharge hopper to prevent exessive back-up of material.

6. Sensors will be provided on the dust collector for monitoring the differential pressure across the filter bags. A high differential pressure detected will sound an audible alarm and shutdown the coal preparation system equipment.

7. The dust collector filter bags will include an integral grounding wire to prevent dust ignition from a static charge. All other areas of the dust collector exposed to dust and/or gas flow will include grounding devices to prevent the development and conductance of a static charge.

# PROCESS DESIGN BASIS
## PDB No. 82-IDJ-9

Equipment Name: Coal Preparation Dust Collector w/Exhaust Fan

Equipment No.: 1DJ-DCOL-1 and 1DJ-FAN-2

System Name: Coal Preparation & Limestone System

Flowsheet No.: 16N25706-82-F-1DJ-001

## II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Dust Vent (Solids) (Gas) | 1089<br>16875 | (See Mass Bal.) | | 250 | (See Mass Bal.) | | |
| 2 | Exhaust Vent (Solids) (Gas) | 2.18<br>16875 | (See Mass Bal.) | | 250 | (See Mass Bal.) | | |
| 3 | Fines to Tote Bin | 1086.8 | (See Mass Bal.) | | 250 | (See Mass Bal.) | | |

PROCESS DESIGN BASIS
**PDB No. 82-IDJ-9**

| | |
|---|---|
| Equipment Name | Coal Preparation Dust Collector w/Exhaust Fan |
| Equipment No. | 1DJ-DCOL-1 and 1DJ-FAN-2 |
| System Name | Coal Preparation & Limestone System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

## III DESIGN NOTES

1. Coal dust and exhaust flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum flow, Mass and Energy Balance results, to allow for operation variations.

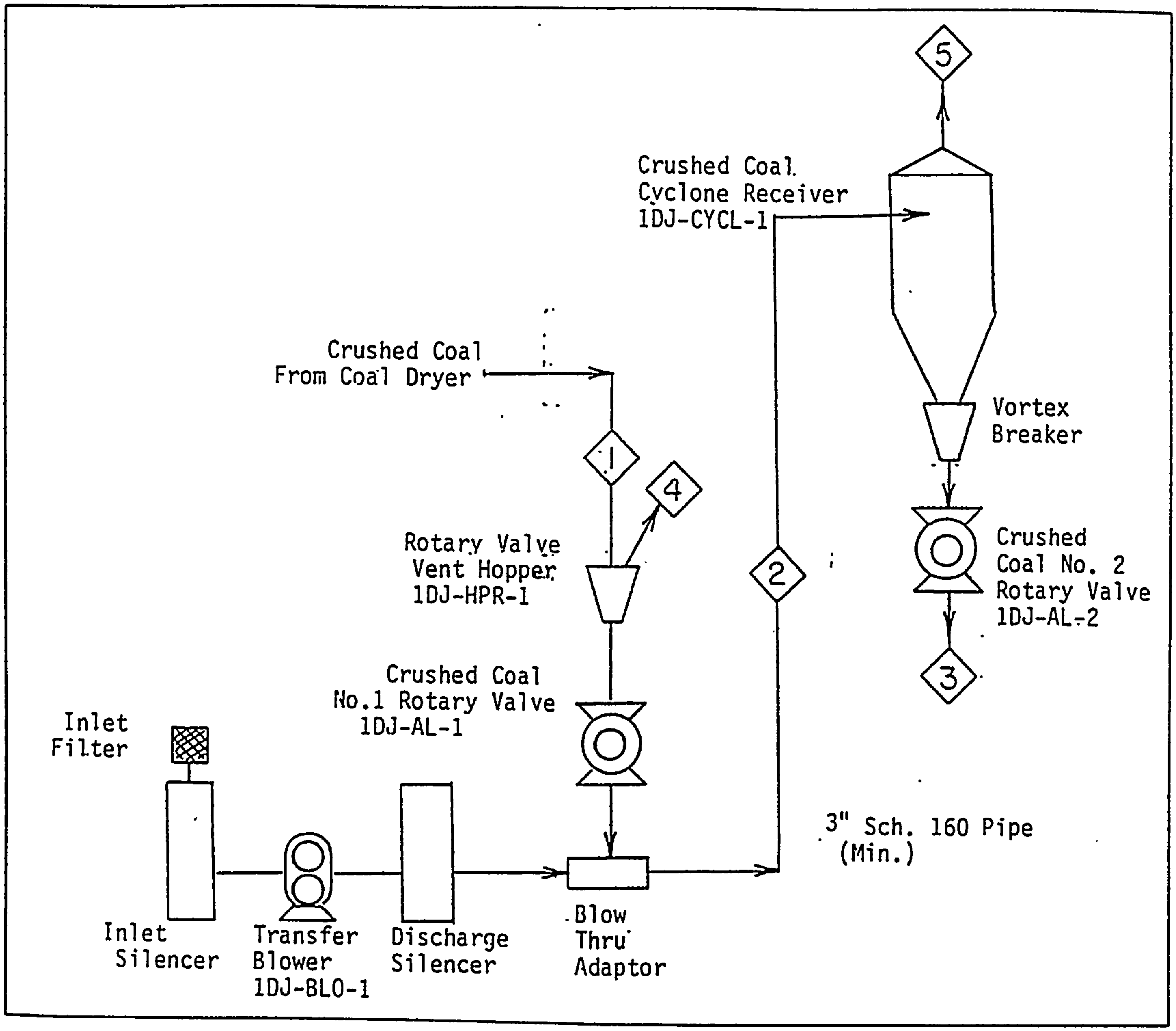
| | |
|---|---|
| 2. Material Handling | Coal dust collected from the coal preparation process of crushing, drying, and handling for feed to the gasifier. |
| 3. Particle Size | 100 mesh to and including 0.5 micron. |
| 4. Moisture Content | 1 to 6% |
| 5. Design Operating Temperature | 250°F |
| 6. Efficiency Required | 99.8% |
| 7. Cloth to Air Ratio | 6 to 1 minimum |
| 8. Bag Cleaning | Reverse pulse jet compressed air |
| 9. Compressed Air Available | Instrument air - 100 psig @ 100°F |
| 10. Classification | Class II, Division 2, Groups E & F |
| 11. Motor Voltage Available | 460 voltage, 3 phase, 60 hertz |
| 12. Control Voltage Available | 120 volt AC |
| 13. Ambient Weather Criteria | |
| Design Temperature: | |
| Dry Bulb: | |
| Winter | -20°F (lowest on record-use for freeze protection) |
| Winter | 4°F (99%) |
| Summer | 90°F (99%) |
| Wet Bulb: | 74°F (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

14. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DJ - 10**

System Name Coal Transfer System
Flowsheet No. 16N25706-82-F-1DJ-001



PROCESS DESIGN BASIS
**PDB No. 82-1DJ-10**

| | |
|---|---|
| Equipment Name | |
| Equipment No. | |
| System Name | Coal Transfer System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

I. DESIGN PHILOSOPHY

1. The Coal Transfer System conveys dried, crushed coal to the next unit operation which is classification (fines removal).

2. The PyGas™ Coal Gasifier and Coal Transfer System will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.

3. The Coal Transfer System will be installed outdoors. See Design Notes for ambient weather criteria.

4. The vent gas from the Coal Transfer System will be piped to the Cal Preparation Dust Collector.

PROCESS DESIGN BASIS
**PDB No. 82-1DJ-10**

| | |
|---|---|
| Equipment Name | |
| Equipment No. | |
| System Name | Coal Transfer System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR. | MAX. FLOW #/HR. | MIN. FLOW #/HR. | MAX. TEMP. °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Product Coal In | 6542 | (See Mass Bal.) | | 250 | (See Mass Bal.) | | |
| 2 | Product Coal Transfer | 6477 | (See Mass Bal.) | | 225 | (See Mass Bal.) | | |
| 3 | Product Coal Out | 6412 | (See Mass Bal.) | | 200 | (See Mass Bal.) | | |
| 4 | Dust Vent (Solids) | 65 | (See Mass Bal.) | | 150 | (See Mass Bal.) | | |
| 5 | Dust Vent (Solids) | 65 | (See Mass Bal.) | | 150 | (See Mass Bal.) | | |

## PROCESS DESIGN BASIS
**PDB No. 82-1DJ-10**

| | |
|---|---|
| Equipment Name | |
| Equipment No. | |
| System Name | Coal Transfer System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

### III DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 20 percent above the maximum coal flow, Appendix A-8, Mass and Energy Balance results, to allow for operation variations.

2. Coal Type: Bituminous

3. Coal Moisture: <1%

4. Coal Specific Heat: 0.30 Btu/Lb-F

5. Coal Bulk Density: 50#/Ft$^3$

6. Coal Grindability Index: 40-90

7. Crushed Coal Feed

| Size Analysis (Anticipated) | | Sample (Estimated) |
|---|---|---|
| -3/8 | +1/4 | 3% |
| -1/4 | +1/4 | 14% |
| -1/8 | +10 (mesh) | 15% |
| -10 | +20 | 30% |
| -20 | +40 | 20% |
| -40 | +100 | 9% |
| -100 | +200 | 5% |

Note: The estimated coal size gradation shown above after crushing is based on the American Pulverizer analysis of a crusher discharge to produce 1/4" top size coal with the feed as depicted in the Riley Fuels Laboratory Test Report dated February 1, 1994.

## PROCESS DESIGN BASIS

**PDB No. 82-1DJ-10**

| | |
|---|---|
| Equipment Name | |
| Equipment No. | |
| System Name | Coal Transfer System |
| Flowsheet No. | 16N25706-82-F-1DJ-001 |

8. Ambient Weather Criteria

Design Temperature:

Dry Bulb:

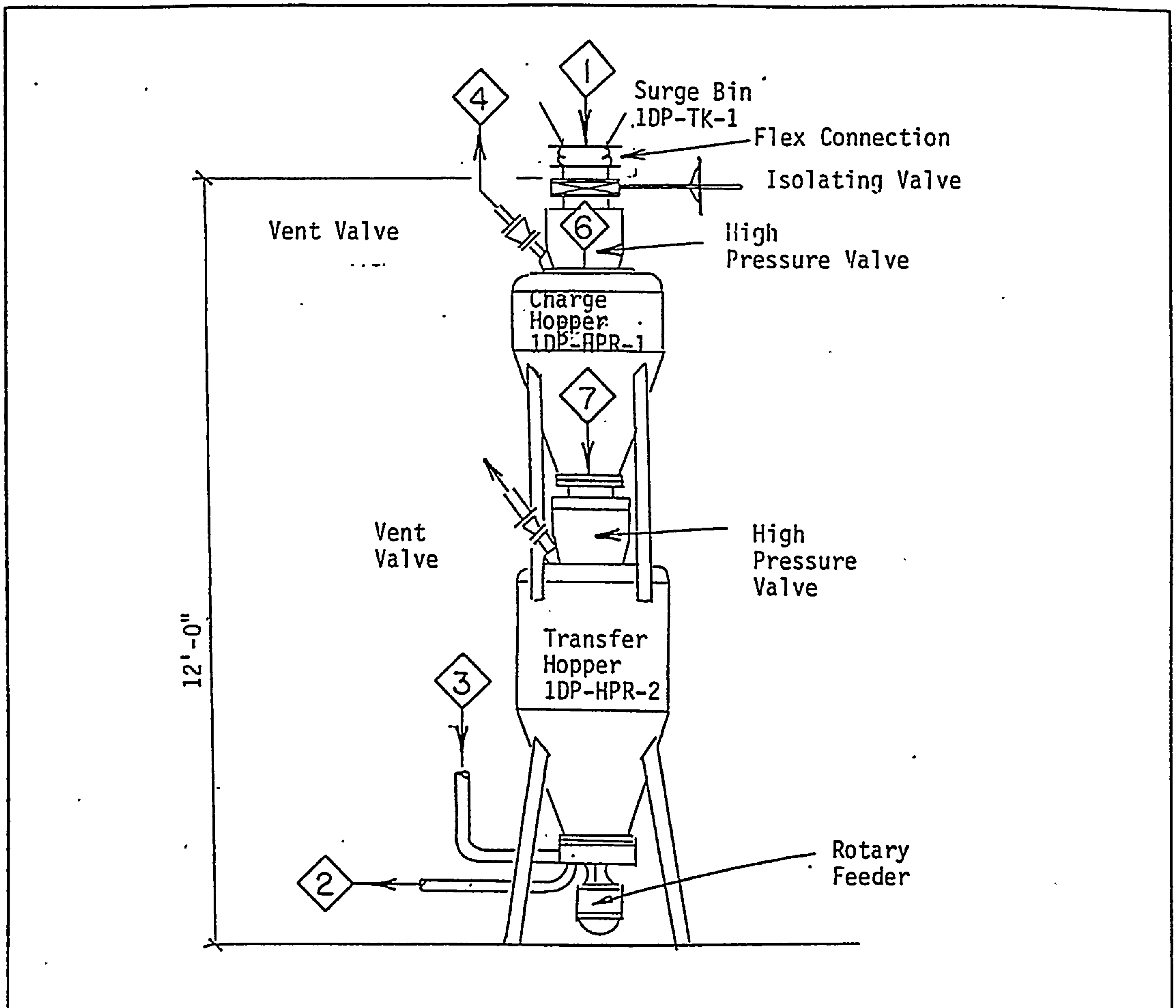
| | |
|---|---|
| Winter - | -20°F (lowest on record-use for freeze protection) |
| Winter - | 4°F (99%) |
| Summer - | 90°F (99%) |
| Wet Bulb: | 74°F (99%) |
| Performance Temperature: | 80°F |
| Performance Relative Humidity: | 60% |

9. All data, i.e., capacities, flows, sizes, etc., indicated in the Process Design Basis is to be considered the minimum requirement.

SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DP - 1**

Equipment Name Charge Hopper / Transfer Hopper
Equipment No. 1DP-HPR-1, 1DP-HPR-2, & 1DP-TK-1
System Name Pyrolizer Feed System
Flowsheet No. 16N25706-82-F-1DP-001

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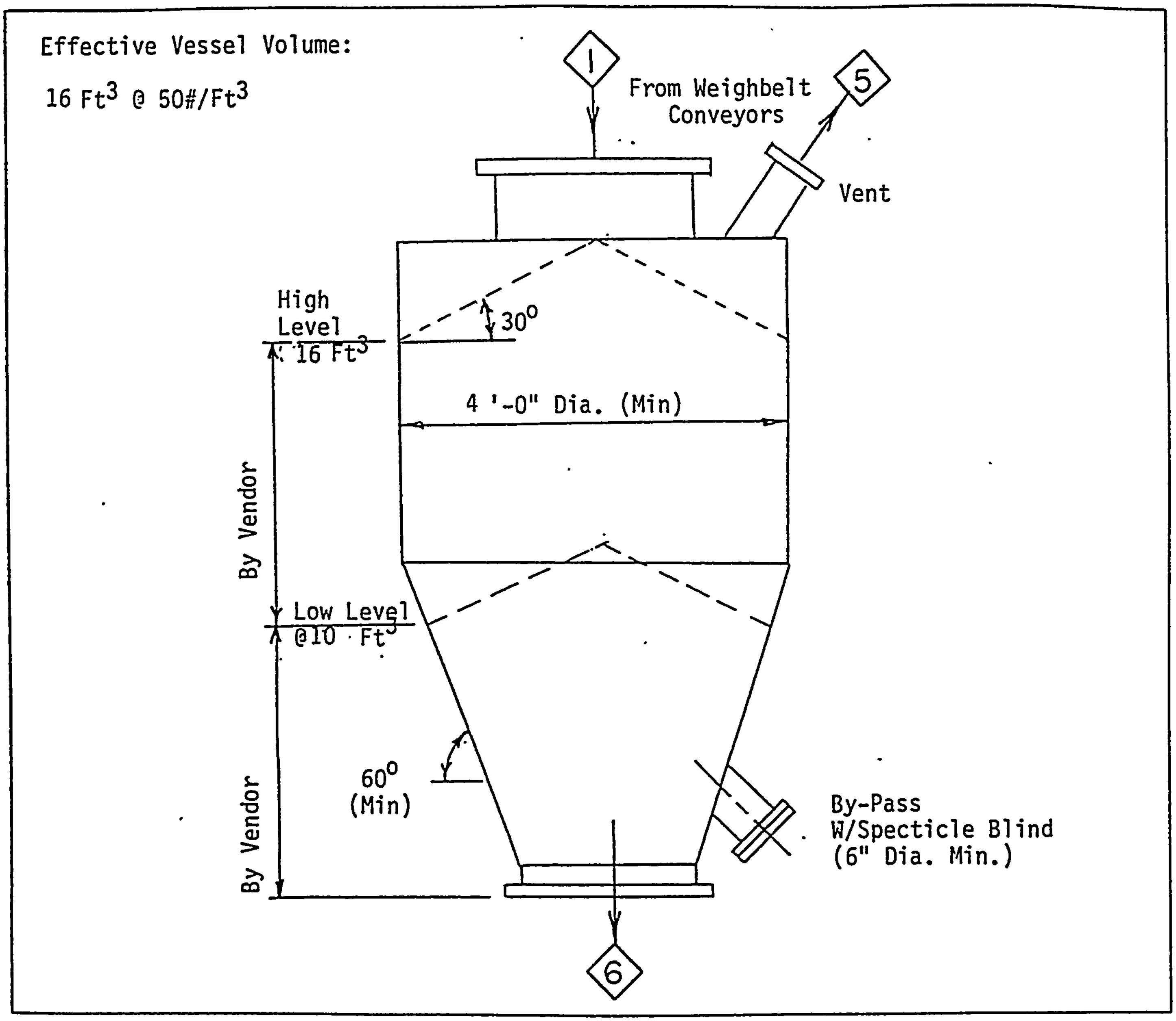
SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DP - 1**

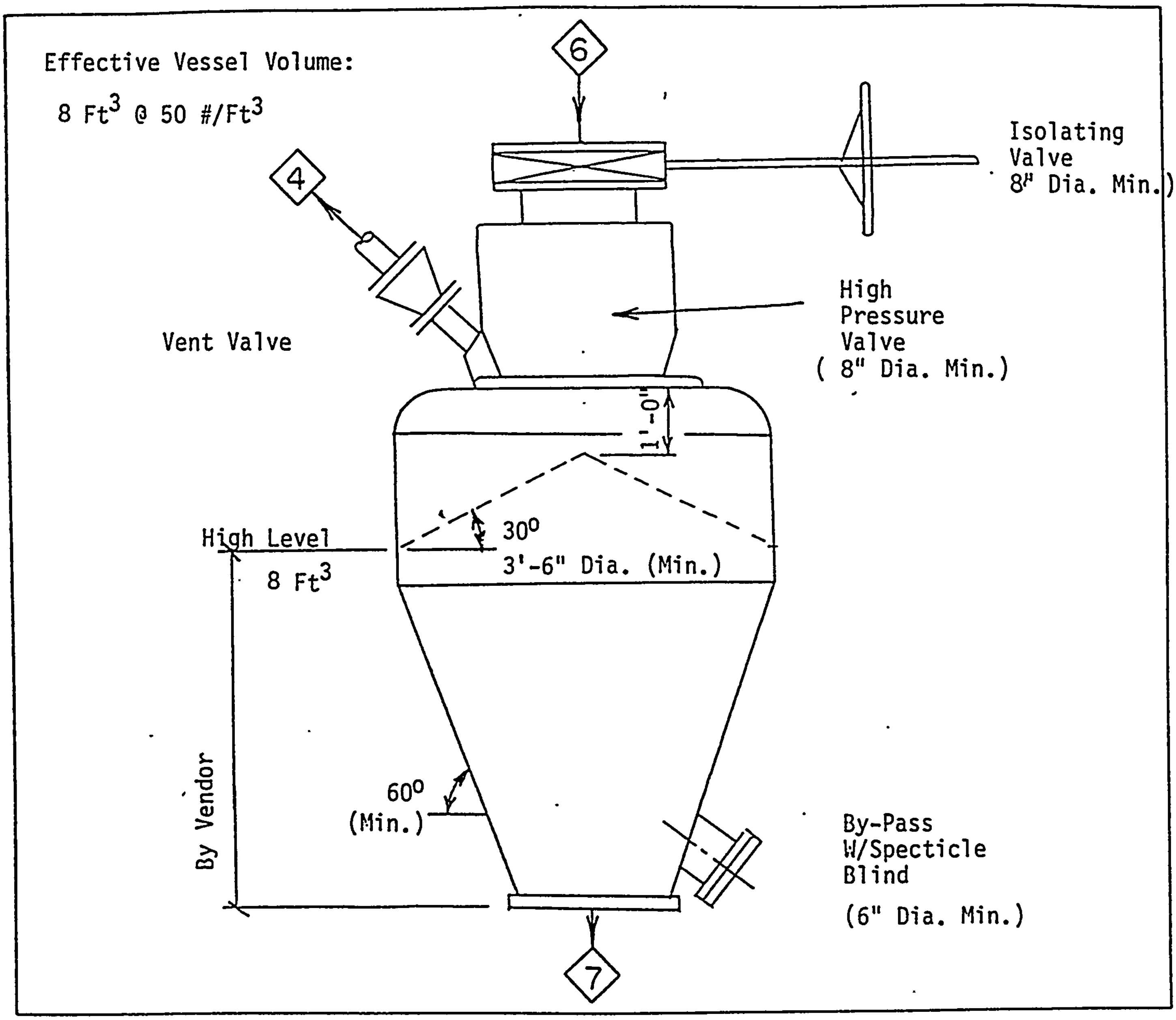
Equipment Name: Surge Bin
Equipment No.: 1DP-TK-1
System Name: Pyrolizer Feed System
Flowsheet No.: 16N25706-82-F-1DP-001



SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DP - 1**

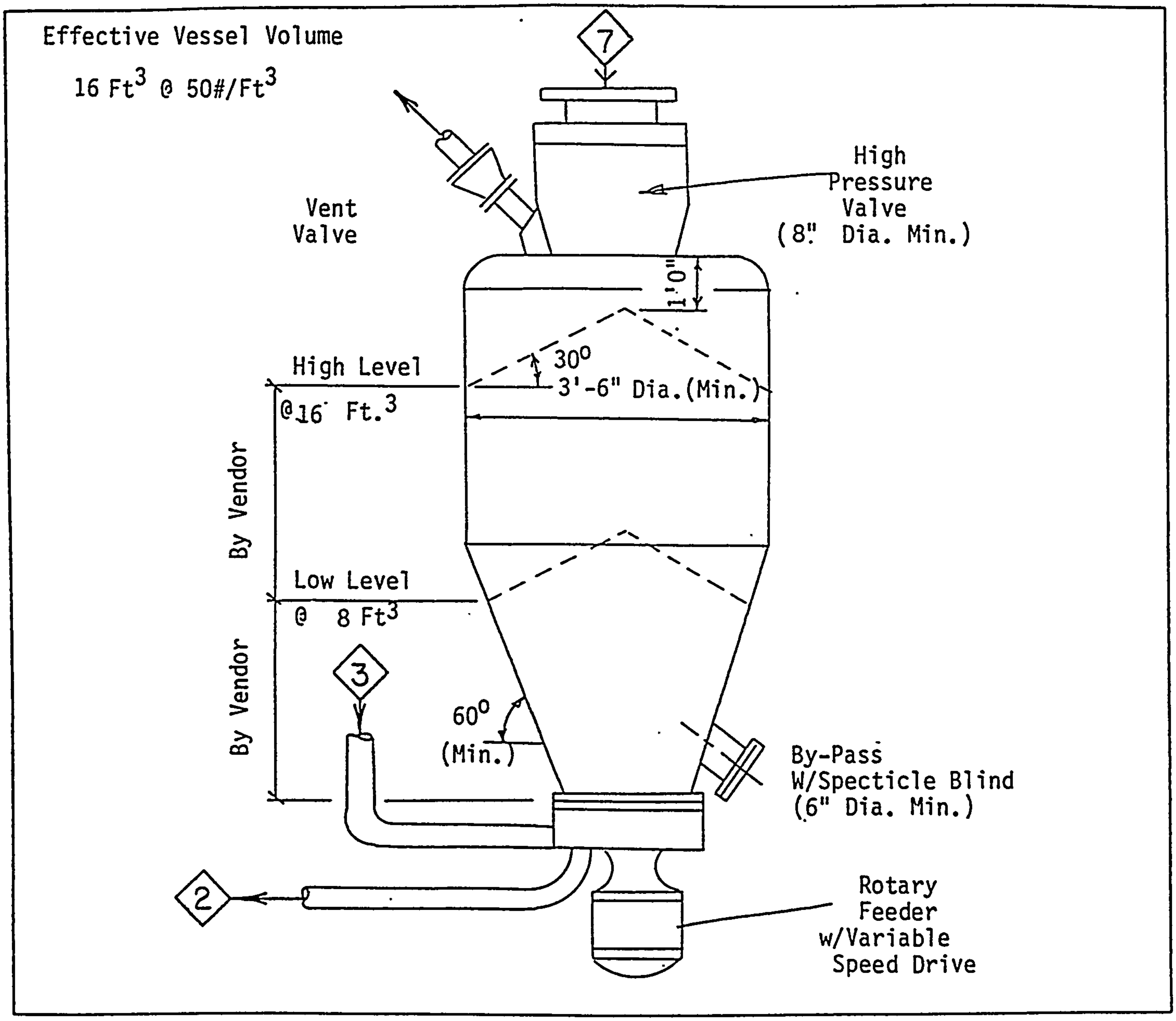
Equipment Name: Charge Hopper
Equipment No.: 1DP-HPR-1
System Name: Pyrolizer Feed System
Flowsheet No.: 16N25706-82-F-1DP-001



SYSTEM PROCESS DESIGN BASIS

**PDB No. 82 - 1DP - 1**

Equipment Name Transfer Hopper
Equipment No. 1DP-HPR-2
System Name Pyrolizer Feed System
Flowsheet No. 16N25706-82-F-1DP-001



## PROCESS DESIGN BASIS
## PDB No. 82-1DP-1

| | |
|---|---|
| Equipment Name | Charge Hopper, Transfer Hopper, Surge Bin |
| Equipment No. | 1DP-HPR-1, 1DP-HPR-2, 1DP-TK-1 |
| System Name | Pyrolizer Feed System |
| Flowsheet No. | 16N25706-82-F-1DP-001 |

### I. DESIGN PHILOSOPHY

1. The Pyrolizer Feed System will transport coal to the PyGas™ Coal Gasifier fuel inlet with 325 psig back pressure under normal operation. During desulfurization testing, the Pyrolizer Feed System will transport a mixture of coal and limestone to the gasifier.

2. The Pyrolizer Feed System will provide a continuous feed of coal to the PyGas™ Coal Gasifier from the Transfer Hopper. Transfer of material from the Surge Bin to the Charge Hopper and Charge Hopper to Transfer Hopper will be on a batch basis. A batch is discharged to the Transfer Hopper from the Charge Hopper when the Transfer Hopper reaches a half full state.

3. The Rotary Feeder below the Transfer Hopper and Charge Hopper discharge cycles per hour will provide feed rate control to the PyGas™ Coal Gasifier.

4. The PyGas™ Coal Gasifier and Pyrolizer Feed System will operate continuously, 24 hours per day, for two week periods and be out of service for six weeks between each period.

5. The Pyrolizer Feed System will be installed outdoors. See Design Notes for ambient weather design criteria.

6. The vent gas from the Charge Hopper will be piped to the Coal Storage Bin. The vent line will be sized for increasing gas volume as pressure decreases.

7. The start-up pressure of the PyGas™ Coal Gasifier will be approximately 30 psig. The gasifier pressure and fuel flow rate will increase as the gasifier reaches operating temperature.

8. Coke breeze will be handled by the Pyrolizer Feed System for use as a start-up fuel in the PyGas™ Coal Gasifier at a reduced capacity. During start-up, as the pressure and temperature increases in the PyGas™ Coal Gasifier, the coke breeze feed will be reduced while introducing the coal or coal/limestone mixture into the Pyrolizer Feed System until operating parameters are achieved.

PROCESS DESIGN BASIS
**PDB No. 82-1DP-1**

Equipment Name: Charge Hopper, Transfer Hopper, Surge Bin
Equipment No.: 1DP-HPR-1, 1DP-HPR-2, 1DP-TK-1
System Name: Pyrolizer Feed System
Flowsheet No.: 16N25706-82-F-1DP-001

## II. DESIGN CRITERIA

| NORMAL 325# GASIFIER OPERATION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | PROCESS STREAM | DESIGN FLOW #/HR | MAX. FLOW #/HR | MIN. FLOW #/HR | MAX. TEMP °F | MIN. TEMP. °F | MAX. PRESS PSIG | MIN. PRESS PSIG |
| 1 | Product Coal In | 5,102 | (See Mass Bal.) | | 175 | (See Mass Bal..) | | |
| 2 | Product Coal Out | 4,445 | (See Mass Bal.) | | 175 | (See Mass Bal.) | | |
| 3 | Conveying Gas In | 390 | (See Mass Bal.) | | 100 | (See Mass Bal.) | | |
| 4 | Dust Vent (Solids) | 45 | (See Mass Bal.) | | 125 | (See Mass Bal.) | | |
| 5 | Dust Vent (Solids) | 51 | (See Mass Bal.) | | 125 | (See Mass Bal.) | | |

6. The coal instantaneous discharge rate from Surge Bin to Charge Hopper is 130,909 lbs/hr based on discharging 8 $ft^3$ of 50 $lb/ft^3$ material (400 lbs.) in 11 seconds.

7. During desulfurization testing, the coal/limestone mixture instantaneous discharge rate from Surge Bin to Charge Hopper is 141,382 lbs/hr based on discharging 8 $ft^3$ of 54 $lb/ft^3$ material (432 lbs.) in 11 seconds.

8. The coal instantaneous discharge rate from Charge Hopper to Transfer Hopper is 31,304 lbs/hr based on discharging 8 $ft^3$ of 50 $lb/ft^3$ material (400 lbs) in 46 seconds.

9. During desulfurization testing, the coal/limestone mixture instantaneous discharge rate from Charge Hopper to Transfer Hopper is 33,809 lbs/hr based on discharging 8 $ft^3$ of 54 $lb/ft^3$ material (432 lbs.) in 46 seconds.

10. Compressed conveying gas to the Pyrolizer Feed System will be at minus 40 degrees F dew point to prevent condensation from forming in the conveying pipe during winter operation.

## PROCESS DESIGN BASIS
## PDB No. 82-1DP-1

| | |
|---|---|
| Equipment Name | Charge Hopper, Transfer Hopper, Surge Bin |
| Equipment No. | 1DP-HPR-1, 1DP-HPR-2, 1DP-TK-1 |
| System Name | Pyrolizer Feed System |
| Flowsheet No. | 16N25706-82-F-1DP-001 |

### III. DESIGN NOTES

1. Product coal flow rates are from the Mass and Energy Balances. Design condition is approximately 10 percent above the maximum coal flow, Mass and Energy Balance results, to allow for operation variations.

| | | |
|---|---|---|
| 2. | Coal Moisture | < 1.0% |
| 3. | Coal Specific Heat | 0.30 Btu/lb-F |
| 4. | Crushed Coal Size | -1/4 x 50 mesh |
| 5. | Coal Bulk Density | 50 #/Ft$^3$ |
| 6. | Coal Grindability Index | 40-90 |
| 7. | Limestone Size | -1/8 x 200 mesh |
| 8. | Limestone Bulk Density | 68 #/Ft$^3$ |
| 9. | Angle of Repose | 30 deg. |
| 10. | Fuel Mixture to Gasifier | 81% coal, 19% limestone |
| 11. | Coal/Limestone Bulk Density | 54 #/cubic feet (average) |
| 12. | Crushed Coal Feed: | |
| | Size Analysis (Anticipated) | Sample (Estimated) |
| | -3/8 + 1/4 | 3% |
| | -1/4 + 1/8 | 14% |
| | -1/8 + 10 (mesh) | 15% |
| | -10 + 20 | 30% |
| | -20 + 40 | 20% |
| | -40 + 100 | 9% |
| | -100 + 200 | 5% |
| 13. | Ambient Weather Criteria | |
| | Design Temperature: | |
| | Dry Bulb: | |
| | Winter | |
| | Winter | -20°F (lowest on record for freeze protection) |
| | Summer | 4°F (99%) |
| | Wet Bulb: | 90°F (99%) |
| | Performance Temperature: | 74°F (99%) |
| | Performance Relative Humidity: | 80°F |
| | | 60% |
| 14. | Surge Bin Capacity | 16 cubic feet (effective volume required) |
| 15. | Charge Hopper Capacity | 8 cubic feet (effective volume required) |
| 16. | Transfer Hopper Capacity | 16 cubic feet (effective volume required) |

## PROCESS DESIGN BASIS

| | |
|---|---|
| Equipment Name | Charge Hopper, Transfer Hopper, Surge Bin |
| Equipment No. | 1DP-HPR-1, 1DP-HPR-2, 1DP-TK-1 |
| System Name | Pyrolizer Feed System |
| Flowsheet No. | 16N25706-82-F-1DP-001 |

III. DESIGN NOTES - Continued

| | | |
|---|---|---|
| 17. | Gasifier Operating Pressure | 325 psig |
| 18. | System Operating Pressure (Anticipated) | 390 psig |
| 19. | Design Operating Temperature | 175 deg. F. |
| 20. | Charge Hopper Cycles | 9.26 per hr. |
| | Charge Hopper Fill Time | 5 seconds |
| | Transfer Hopper Fill Time | 46 seconds |
| | Pressure Balance Time | 60 sec. |
| | Charge Hopper Vent Time | 60 sec. |
| | Total Cycle Time | 177 sec. |
| 21. | Coke Breeze | |
| | Bulk Density | 25-35#/$Ft^3$ |
| | Size | 1/4 inch minus |

22. All data, i.e., capacities, flows, sizes etc., indicated in the Process Design Basis is to be considered the minimum requirement.

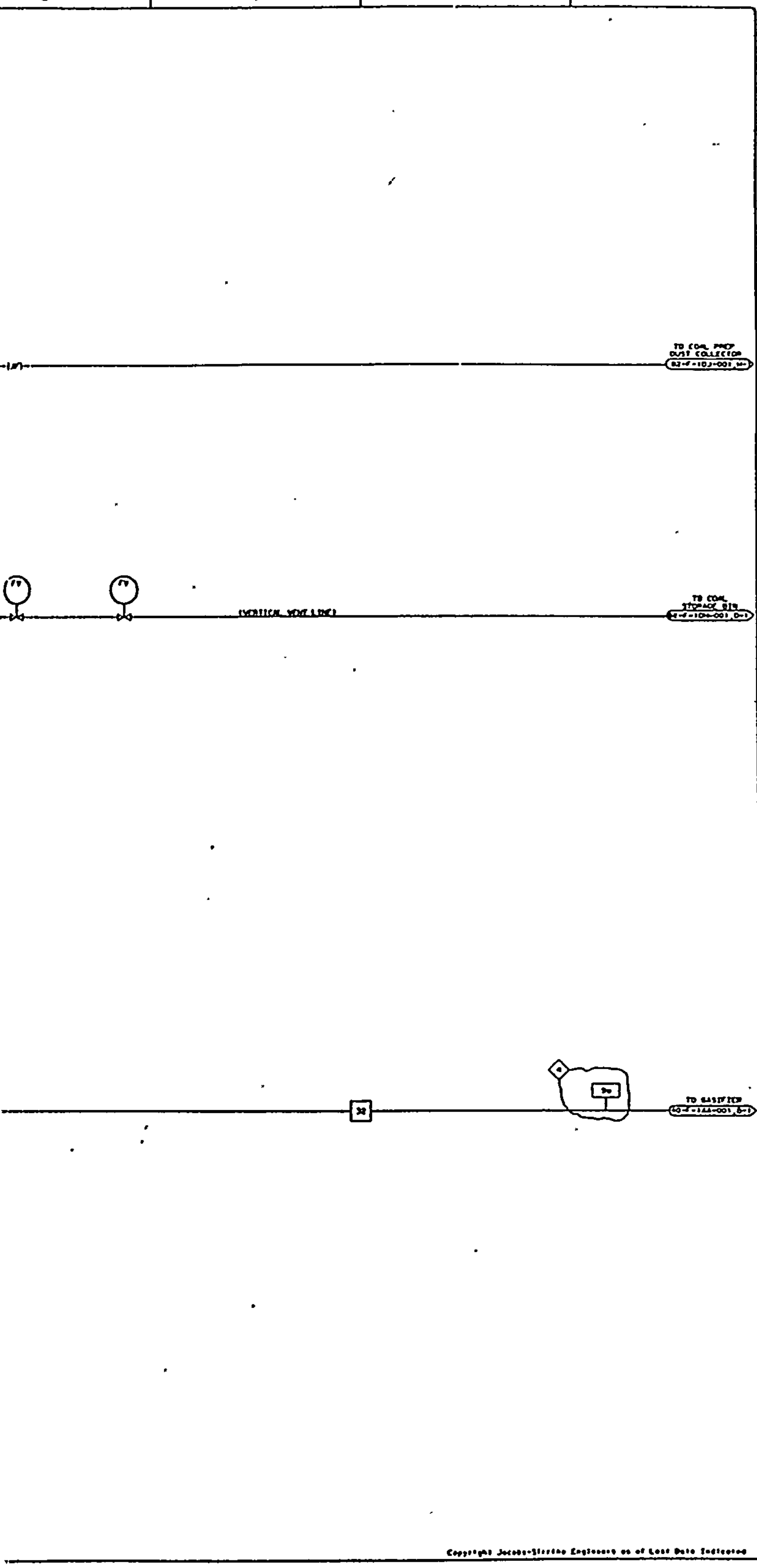
23. The Surge Bin, Charge Hopper and Transfer Hopper will be complete with a fire protection system.

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

# Drawing List

| Drawing Number | Drawing Description |
|---|---|
| 16N25706-40-LE-001 | Flow Diagram Legend |
| 16N25706-40-1AA-001 | Flow Diagram Gasifier System |
| 16N25706-40-1AA-002 | Flow Diagram Gasifier Gas Clean-Up System |
| 16N25706-40-1AA-003 | Flow Diagram Gasifier Cooling Water |
| 16N25706-40-1AA-004 | Flow Diagram Gasifier Ash Handling |
| 16N25706-40-1AA-005 | Flow Diagram Solid Waste Disposal System |
| 16N25706-40-1DG-001 | Flow Diagram Natural Gas Distribution |
| 16N25706-40-1GA-001 | Flow Diagram Flue Gas Desulfurization System |
| 16N25706-40-1GG-001 | Flow Diagram Process Vent Distribution |
| 16N25706-40-1GH-001 | Flow Diagram Incinerator |
| 16N25706-40-1KD-001 | Flow Diagram Chemical Feed System |
| 16N25706-40-1KK-001 | Flow Diagram Potable Water System |
| 16N25706-40-1KV-001 | Flow Diagram Auxiliary Water Distribution |
| 16N25706-40-1KW-001 | Flow Diagram Service Water System |
| 16N25706-40-1LD-001 | Flow Diagram Plant and Instrument Air System |
| 16N25706-40-1LF-001 | Flow Diagram Process Air System |
| 16N25706-40-1LK-001 | Flow Diagram Nitrogen Storage and Distribution |
| 16N25706-40-1SB-001 | Flow Diagram Natural Gas Package Boiler |
| 16N25706-40-1SB-002 | Flow Diagram Steam Distribution |
| 16N25706-40-1SJ-001 | Flow Diagram Feedwater System |
| 16N25706-40-1WS-001 | Flow Diagram Solid Waste Treatment System |
| 16N25706-40-1WS-002 | Flow Diagram Process Waste Water Distribution |
| 16N25706-82-1DJ-001 | Flow Diagram Coal Preparation and Limestone System |
| 16N25706-82-1DH-001 | Flow Diagram Coal Receiving, Storage, and Reclaim |
| 16N25706-82-1DP-001 | Flow Diagram Pyrolizer Feed System |

| 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|




**NOTES**

1. STREAM NUMBERS DENOTED [ ] REFERS TO TABULAR STREAM NUMBERS IN APPENDIX "A" OF THE CONCEPTUAL DESIGN REPORT.
2. COAL MOISTURE CONTENT IS 8 PERCENT AND DRIED TO 1 PERCENT AT THE SCREW DRYER
3. NORMAL OPERATING IN THE OPERATING/DESIGN CONDITIONS TABLE REFERS TO 325 PSIG GASIFIER OPERATION
4. THE CAPACITIES SHOWN ARE BASED ON HANDLING A COAL/LIMESTONE MIXTURE AT 50 PCF AND IS REDUCED BY 50 PER CENT WHEN HANDLING COKE BREEZE AT 25 PCF
5. COAL AND COKE BREEZE ARE FED SEPARATELY THROUGH A COMMON INLET CHUTE TO THE SURGE BIN. BOTH FUELS ARE KEPT SEPARATED EXCEPT DURING START-UP CHANGE OVER FROM COKE BREEZE TO COAL.
6. LIMESTONE WILL BE FED TO THE GASIFIER THROUGH THE COKE SYSTEM FOR DESULFURIZATION TESTS

| REV. NO. | CODE | REV. BY | DATE | DESCRIPTION |
|---|---|---|---|---|
| 4 | B | JJB | 04 29 95 | REVISED CONTROL SCHEME, ADD SERVICE WATER HOSE STATION. ISSUED AS REV. 1 |
| 3 | D | JJB | 05 23 95 | REVISED PER DOE COMMENTS ISSUED FOR DESIGN |
| 2 | B | JJB | 05 31 95 | REVISED PER 5/19/95 SCOPE REVIEW. ISSUED FOR COMMENTS |
| 1 | B | JJB | 03 29 95 | REVISED STREAM SYMBOLS ISSUED FOR DESIGN |
| E | B | JJB | 02 17 95 | ISSUED FOR APPROVAL COMMENTS. |
| D | A | JJB | 04 29 94 | PRELIMINARY FOR INFORMATION |
| C | A | WHS | 02 07 94 | ISSUED FOR TASK 4 REPORT |
| B | A | JJB | 06 01 93 | ISSUED FOR REVIEW |
| A | A | JJB | 04 23 93 | ISSUED FOR COMMENTS |

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

| ISSUE CODE | | | |
|---|---|---|---|
| A PRELIMINARY | C MAT'L T.O. | D MAT'L PURC | F CONST'N |
| B DESIGN | E BIDS | G | H |

SEAL

SIGNATURE

DATE

| | |
|---|---|
| CP. LANCE BAILEY | DATE 04-19-93 |
| DWN J.J. BURCH | JACOBS FILE NUMBER |
| CK. | |
| APC J.J. BURCH | JOB NO. 16N25706 |

CAD FILE NO.16_ALDWC100:[2471223]OP001.DGF;1

JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

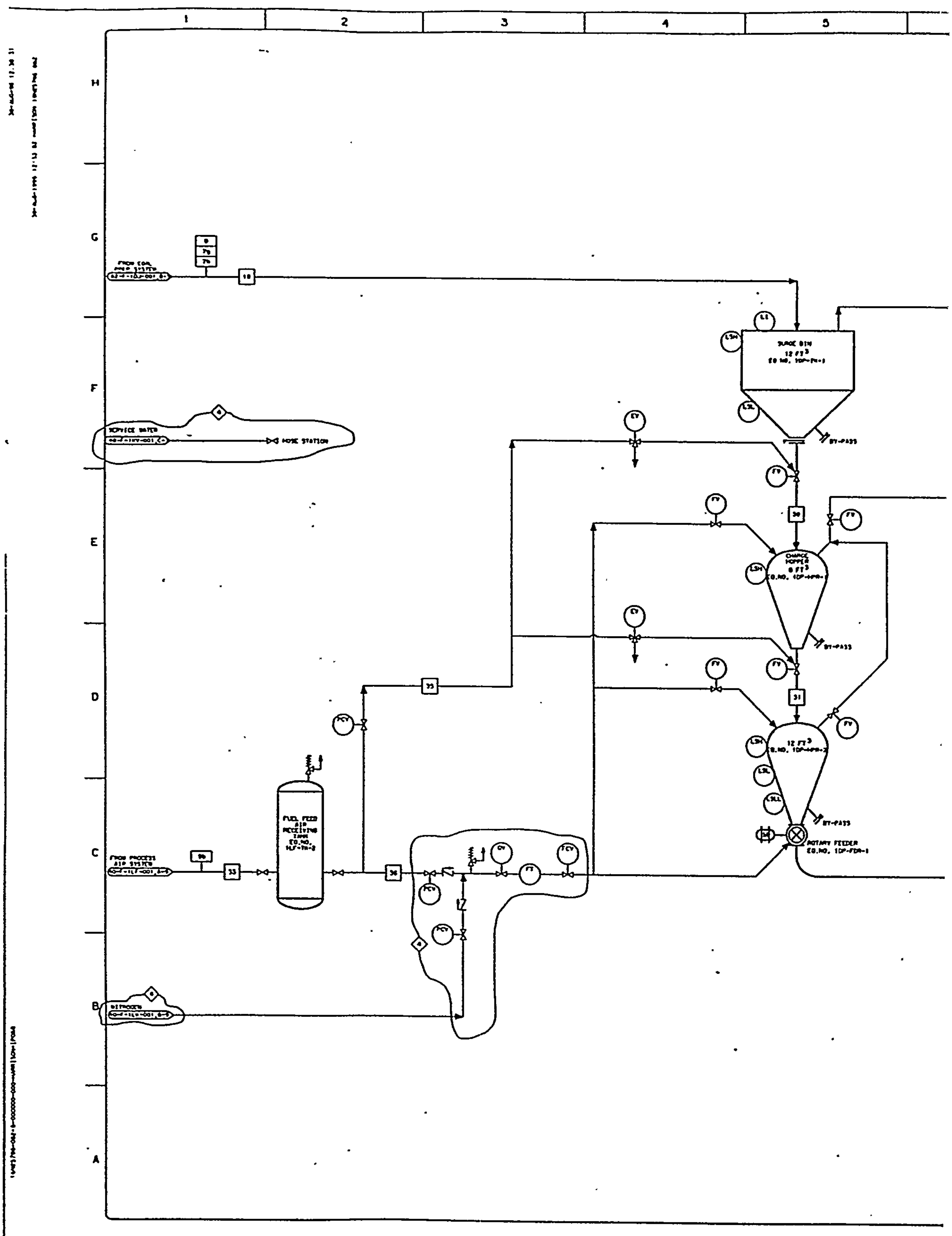
**FLOW DIAGRAM PYROLYZER FEED SYSTEM**

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-82-F-10P-001

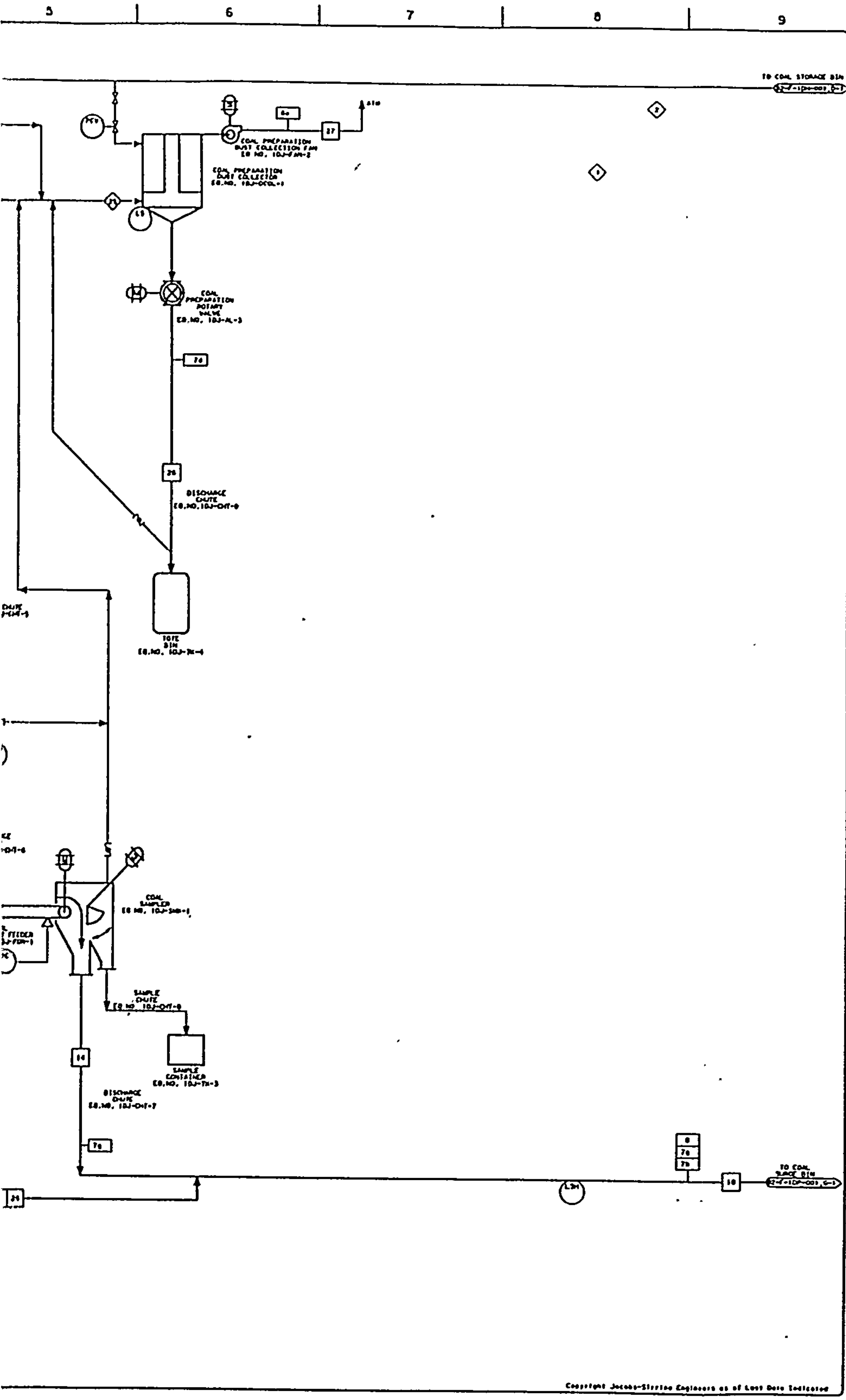
| 35 | | 36 | | | 37 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VE SEAL AIR | | CONVEYING AIR | | | (DELETED) | | | | | | | |
| PSIG | DEG.F | PPH | PSIG | DEG.F | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 440 | 100 | (SEE MASS BALANCE) | | | | | | | | | | |
| 350 | 100 | (SEE MASS BALANCE) | | | | | | | | | | |

363




| LINE NUMBER | 30 (NOTE 4) | | | 31 (NOTE 4) | | | 32 (NOTE 4) | | | 33 | | | 34 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION. | COAL/LIMESTONE/COKE | | | COAL/LIMESTONE/COKE | | | COAL/LIMESTONE/COKE | | | DRY AIR | | | (DELETED) | | | VA |
| UNITS | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | | | | PPH |
| MAXIMUM DESIGN | | | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | | | |
| NORMAL OPERATING | VENDOR | 0 | 150 | VENDOR | 350 | 150 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | | | | 0 |
| MINIMUM OPERATING | VENDOR | 0 | 125 | VENDOR | 30 | 125 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | | | | 0 |
| REVISION DATE | | | | | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | | | |




NOTES

1. STREAM NUMBERS DENOTED [ ] REFERS TO TABULAR STREAM NUMBERS IN APPENDIX "A" OF THE CONCEPTUAL DESIGN REPORT.
2. COAL MOISTURE CONTENT IS 8 PERCENT AND DRIED TO 3 PERCENT AT THE SCREW DRYER.
3. NORMAL OPERATING IN THE OPERATING/TO DESIGN CONDITIONS TABLE REFERS TO 325 PSIG GASIFIER OPERATION.
4. THE CAPACITIES SHOWN ARE BASED ON HANDLING A COAL/LIMESTONE MIXTURE AT 50 PCF AND IS REDUCED BY 50 PER CENT WHEN HANDLING COKE BREEZE AT 25 PCF.
5. COAL AND COKE BREEZE ARE FED SEPARATELY THROUGH A COMMON INLET CHUTE TO THE SURGE BIN. BOTH FUELS ARE KEPT SEPARATED (EXCEPT DURING START-UP CHANGE OVER FROM COKE BREEZE TO COAL.
6. LIMESTONE WILL BE FED TO THE GASIFIER THROUGH THE COKE SYSTEM FOR DESULFURIZATION TESTS.

| REV. NO. | CODE | CIRCLES | DATE | DESCRIPTION |
|---|---|---|---|---|
| 5 | B / JJB | - | 09 29 95 | REVISED LATEST DESIGN DATA. ISSUED AS REV. 5 |
| 4 | B / JJB | - | 08 23 95 | REVISED PER DOE COMMENTS ISSUED FOR DESIGN |
| 3 | B / JJB | - | 08 31 95 | REVISED PER 5/19/95 SCOPE REVIEW. ISSUED FOR COMMENTS |
| 2 | B / JJB | 00 | 03 29 95 | REVISED STREAM SYMBOLS ADDED LINE CONTINUATION ADDED INSTR. AIR TO COAL STORAGE BIN ISSUED FOR DESIGN |
| 1 | A / MBI | 65 | 03 10 95 | REVISED TO VENT TO ATM |
| 0 | A / JJB | - | 02 15 95 | ISSUED FOR APPROVAL |
| D | A / JJB | - | 09 28 94 | PRELIMINARY FOR INFORMATION |
| C | A / BKG | - | 02 04 94 | ISSUED FOR TASK 4 REPORT |
| B | A / JJB | - | 06 01 93 | ISSUED FOR REVIEW |
| A | A / JJB | - | 04 23 93 | ISSUED FOR COMMENTS |

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

| ISSUE CODE | | | |
|---|---|---|---|
| A PRELIMINARY | B MAT'L T.O. | C MAT'L PURC | F CONST'N |
| B DESIGN | E BIDS | | |

SEAL

SIGNATURE

DATE

DR. LANCE BAILEY — DATE 04-19-93
DSGN. J. J. BURCH — JACOBS FILE NUMBER
CK.
APE J. J. BURCH — JOB NO. 16N25706
CAD FILE NO 87...

JE JACOBS-SIRRINE ENGINEERS, A division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

# FLOW DIAGRAM COAL PREPARATION AND LIMESTONE SYSTEM

CLIENT DRAWING NUMBER

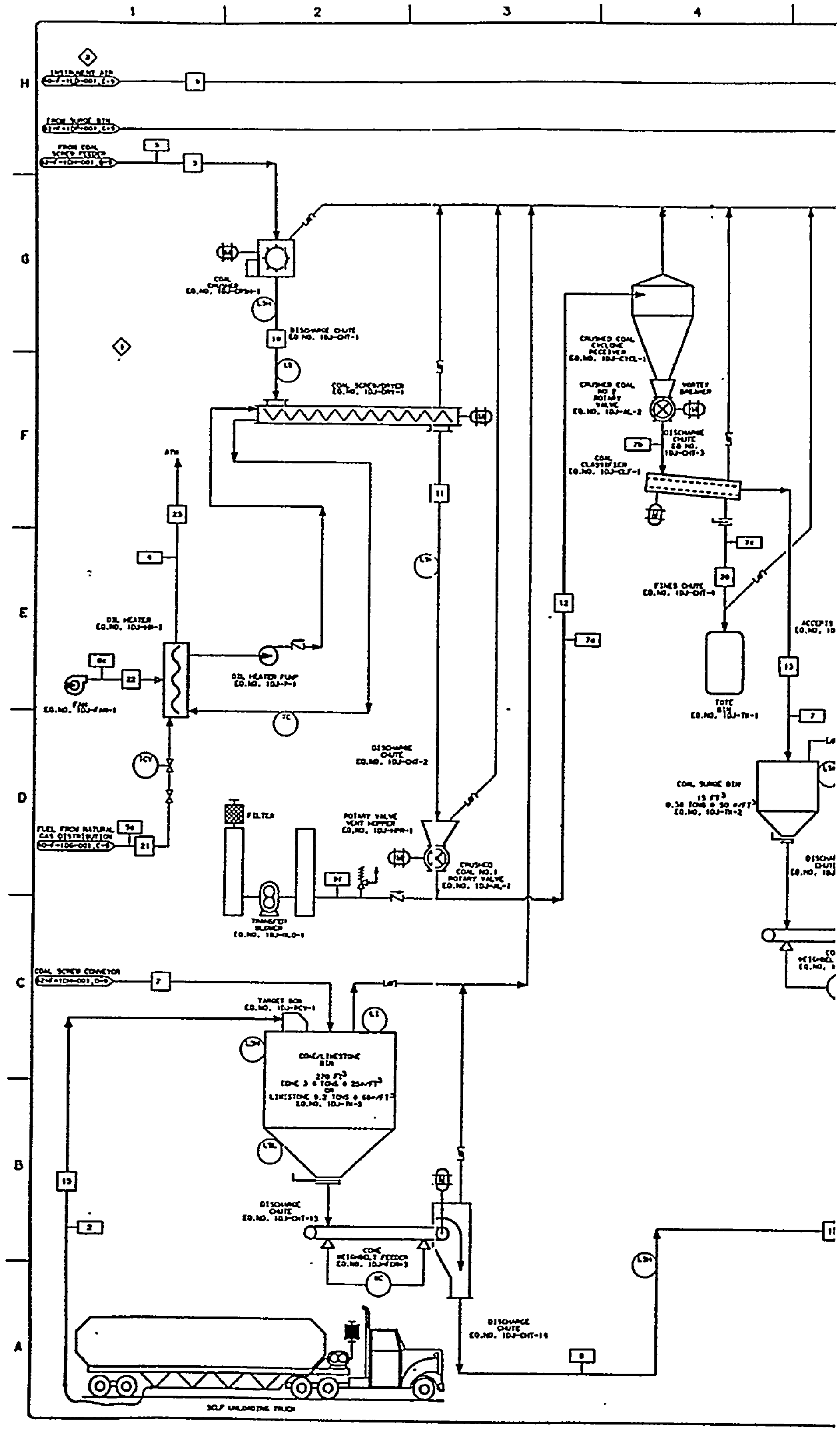
JACOBS-SIRRINE DRAWING NUMBER
16N25706-B2-F-1DJ-001



| 13 COAL | | | 14 COAL | | | 15 (NOTE 6) LIMESTONE | | | 16 LIMESTONE | | | 17 (NOTE 6) LIMESTONE | | | 18 (NOTE 4 & 5) COAL/LIMESTONE/COKE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | 4040 | VENDOR | 80 | | 0 | 125 | 962 | 0 | 125 | (SEE | MASS BAL | ANCE) |
| (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | 4040 | VENDOR | 80 | | 0 | 125 | 962 | 0 | 125 | (SEE | MASS BAL | ANCE) |

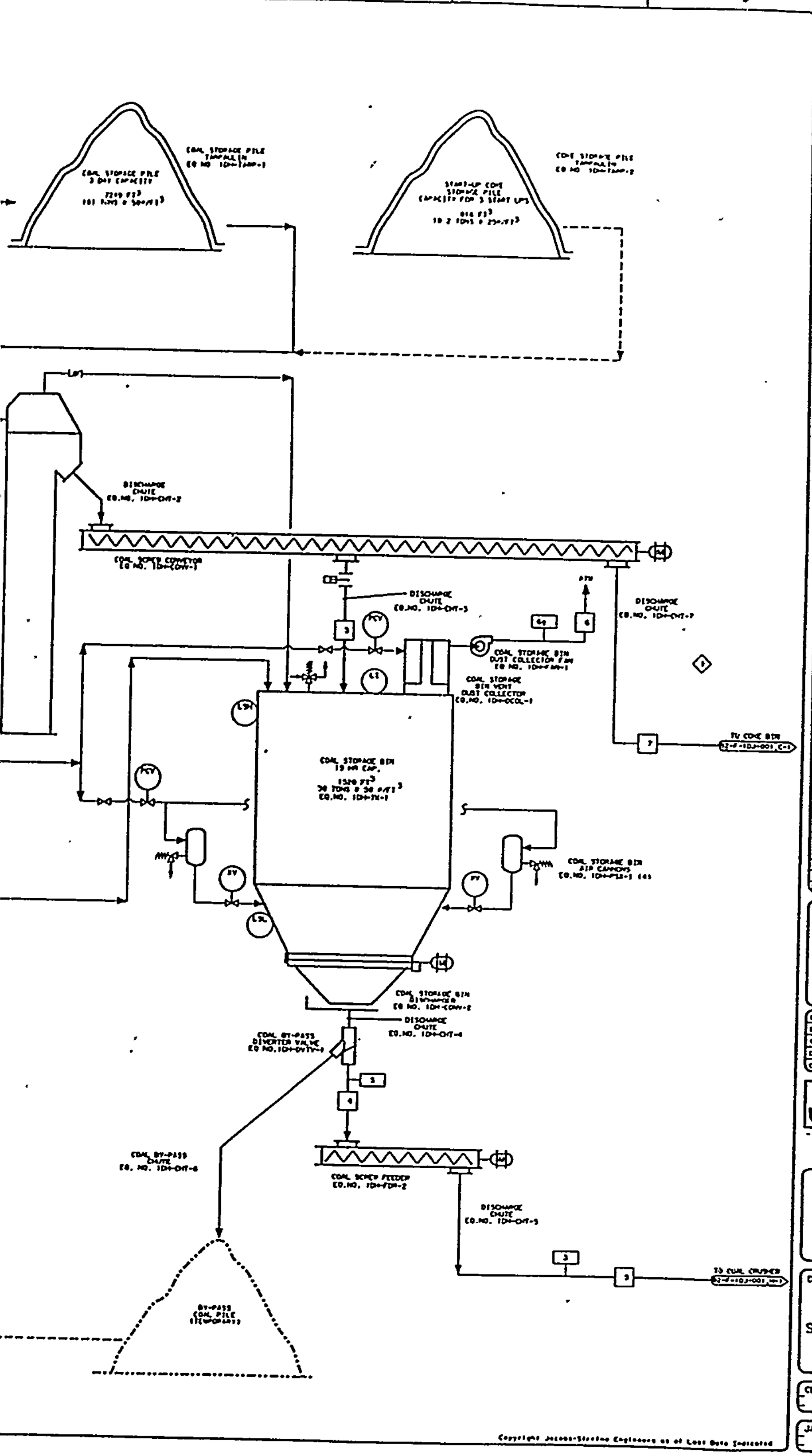
| 23 HEATER VENT | | | 24 (NOTE 6) COKE | | | 25 DUST VENT | | | 26 COAL/COKE FINES | | | 27 EXHAUST VENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PPH | PSIG | DEG.F | PPH | PSIG | DEG F | PPH | PSIG | DEG.F | PPH | PSIG | DEG F | PPH | PSIG | DEG F | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | -- | | | | | | | | | | |
| (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | 13365 | VENDOR | 100 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | | | |
| (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | 13365 | VENDOR | 100 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | | | |

362




| LINE NUMBER | 9 | | | 10 | | | 11 | | | 12 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | INSTRUMENT AIR | | | COAL | | | COAL | | | COAL | | |
| UNITS | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F |
| MAXIMUM DESIGN | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | VENDOR | 100 | 100 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| MINIMUM OPERATING | VENDOR | 100 | 100 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| REVISION DATE | | | | | | | | | | | | |

| LINE NUMBER | 19 | | | 20 | | | 21 | | | 22 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | EXHAUST VENT | | | COAL FINES | | | NATURAL GAS | | | COMBUSTION AIR | | |
| UNITS | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F |
| MAXIMUM DESIGN | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| REVISION DATE | | | | | | | | | | | | |




## NOTES

1. STREAM NUMBERS DENOTED [ ] REFERS TO TABULAR STREAM NUMBERS IN APPENDIX "A" OF THE CONCEPTUAL DESIGN REPORT
2. COAL MOISTURE CONTENT IS 6 PERCENT AS RECEIVED
3. NORMAL OPERATING IN THE OPERATING/DESIGN CONDITIONS TABLE REFERS TO 325 PSIG GASIFIER OPERATION
4. THE COAL HANDLING CAPACITY SHOWN IS BASED ON THE 24 HOUR AVERAGE OPERATING CAPACITY OF THE MASS BALANCE BEING HANDLED IN A 8 HOUR OPERATING PERIOD, 7 DAYS PER WEEK
5. THE CAPACITIES SHOWN ARE BASED ON HANDLING COAL AT 50 PCF AND IS REDUCED BY 50 PERCENT WHEN HANDLING COKE BREEZE AT 25 PCF
6. COAL AND COKE BREEZE WILL BE HANDLED SEPARATELY THROUGH THE COAL HANDLING SYSTEM. THE GATE VALVE IN THE CHUTEWORK TO THE COAL STORAGE BIN WILL BE CLOSED TO PREVENT COMBINING OF FUELS DURING COKE BIN LOADING

| REV. NO. | CODE | REV. BY | DATE | DESCRIPTION |
|---|---|---|---|---|
| 5 | B | JJB | 06 20 95 | REVISED LATEST DESIGN DATA. ISSUED AS REV 5 |
| 4 | B | JJB | 06 23 95 | REVISED PER DOE COMMENTS ISSUED FOR DESIGN |
| 3 | A | JJB | 05 24 95 | REVISED PER 5/19/95 SCOPE REVIEW. ISSUED FOR COMMENTS. |
| 2 | B | JJB | 03 29 95 | REVISED STREAM SYMBOLS ADDED DISTR. AIR HEADER ISSUED FOR DESIGN |
| 1 | A | MHS | 03 10 95 | REVISED TO VENT TO ATM |
| 0 | A | JJB | 06 15 95 | ISSUED FOR APPROVAL. |
| D | A | JJB | 09 20 94 | ISSUED FOR INFORMATION. |
| C | A | MHS | 02 04 94 | ISSUED FOR TASK 4 REPORT |
| B | A | JJB | 06 01 93 | ISSUED FOR REVIEW |
| A | A | JJB | 04 22 93 | ISSUED FOR COMMENTS |

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

ISSUE CODE: A PRELIMINARY, B DESIGN, C MAT'L. I.O., D MAT'L. PURC., E BIDS, F CONST'N, G, H

SEAL

SIGNATURE

DATE

DR. LANCE BAILEY — DATE 04-16-93

DSGN. J.J. BUSKER — JACOBS FILE NUMBER

CK.

DPC J.J. BUSKER — JOB NO 16N25706

CAD FILE NO. 16_JL DWC100:12471221D-001 02F_1

JE JACOBS-SIRRINE ENGINEERING, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

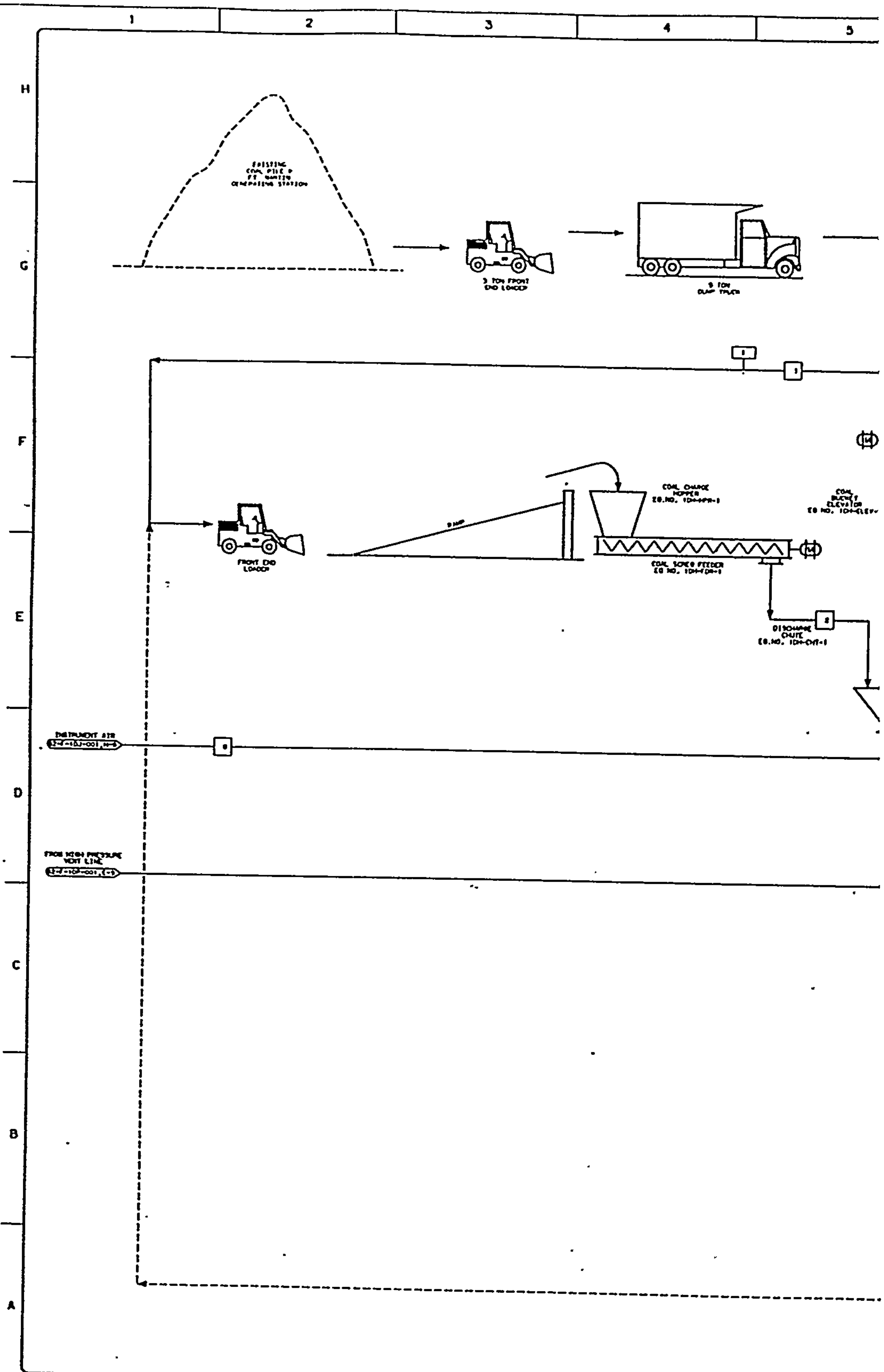
# FLOW DIAGRAM COAL RECEIVING, STORAGE, AND RECLAIM

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER 16N25706-82-F-1DH-001

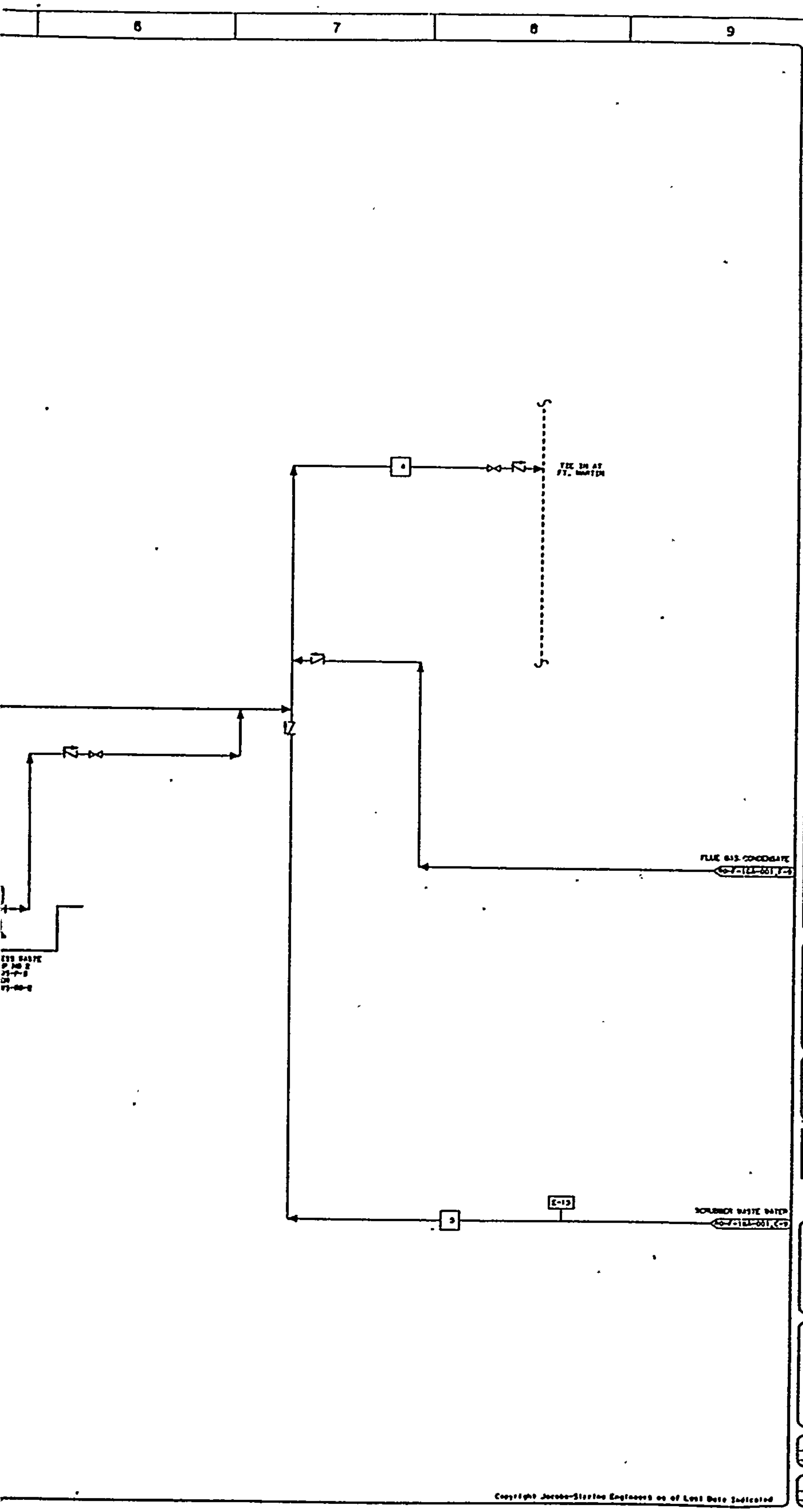


| | 6 | | | 7 | | | 8 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EXHAUST VENT | | | COKE | | | INSTRUMENT AIR | | | | | | | | |
| DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG F | | | | | | |
| CE) | (SEE MASS BALANCE) | | | 7551 | 0 | 80 | VENDOR | 100 | [illegible] | | | | | | |
| CE) | (SEE MASS BALANCE) | | | 7551 | 0 | 80 | VENDOR | 100 | 100 | | | | | | |




| LINE NUMBER | 1 (NOTE 4 & 5) | | | 2 (NOTE 4 & 5) | | | 3 (NOTE 4 & 5) | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | COAL/COKE | | | COAL/COKE | | | COAL | | | COAL | | | COAL | |
| UNITS | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG | DEG.F | PPH | PSIG |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | 15102 | 0 | 80 | 15102 | 0 | 80 | 15102 | 0 | 80 | | | | | |
| MINIMUM OPERATING | 15102 | 0 | 80 | 15102 | 0 | 80 | 15102 | 0 | 80 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL |
| REVISION DATE | | | | | | | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL |

| LINE NUMBER | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | | | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | |




NOTES

1. STREAM NUMBERS DENOTED REFERS TO TABLE OF STREAM NUMBERS IN MASS BALANCES

| REV. NO. | CODE | CIRCLES | DATE | DESCRIPTION | CHECKED BY | APPROVED BY |
|---|---|---|---|---|---|---|
| 5 | B | 2 | 06 | REVISED OFFPAGE CONNECTORS ISSUED AS REV. 1 | | |
| 4 | A | - | 06 | REVISED PER DEPARTMENT OF ENERGY COMMENTS ISSUED FOR DESIGN | | |
| 3 | A | - | 07 | REVISED PER 5/19/95 SCOPE REVIEW, ISSUED FOR COMMENTS | | |
| 2 | A | | 03 | REVISED EQ.NO., STREAM SYMBOLS, | | |
| 1 | A | | 03 | ADDED FLUE GAS SCRUBBER WATER | | |
| 0 | A | - | | CHANGE DWG NO. ISSUED FOR APPROVAL | | |
| E | A | - | 10 | ISSUED FOR INFORMATION ONLY | | |
| D | A | - | 06 | ISSUED FOR REVIEW | | |
| C | A | - | 07 | ISSUED FOR INTERNAL REVIEW | | |
| B | A | - | | ISSUED FOR TASK 4 REPORT | | |
| A | A | - | 06 | ISSUED FOR REVIEW. | | |

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH REV. NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

| ISSUE CODE | | | |
|---|---|---|---|
| A PRELIMINARY | C MAT'L. F.O. | F CONST'N | |
| B DESIGN | D MAT'L. PURC. | G | |
| | E BIDS | H | |

SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERS,
a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

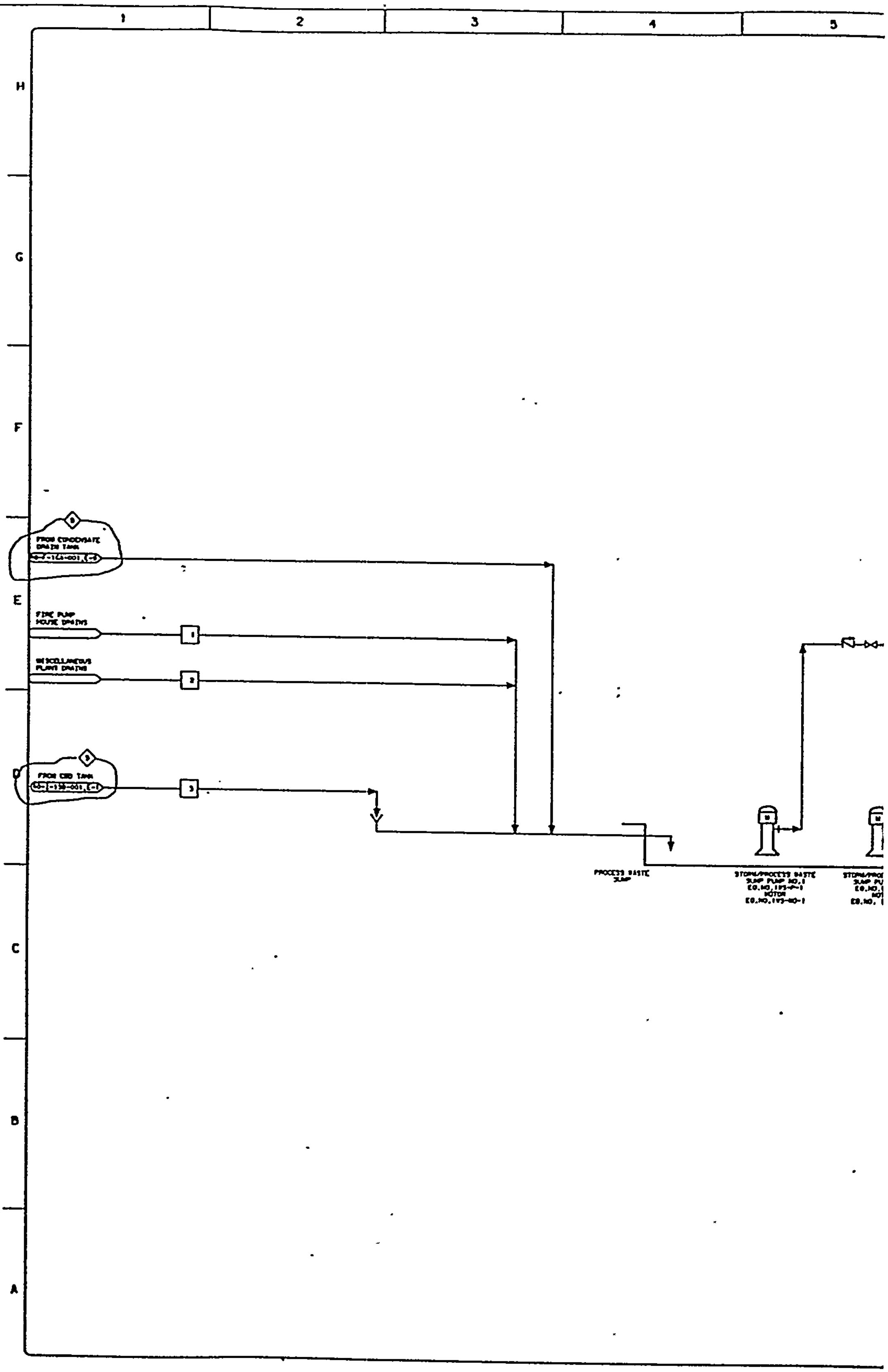
DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
PROCESS
WASTE WATER
DISTRIBUTION

CLIENT DRAWING NUMBER

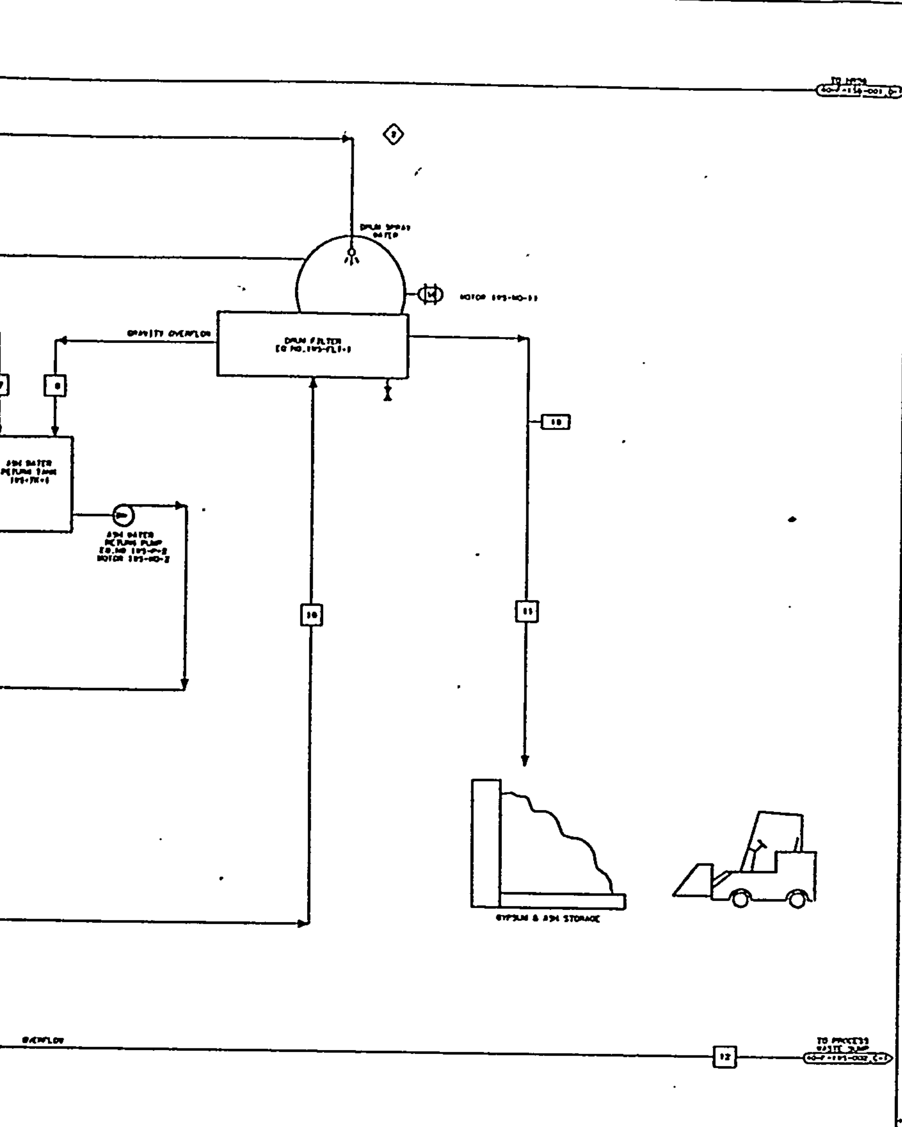
JACOBS-SIRRINE DRAWING NUMBER
16M25706-40-F-195-002




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | FIRE PUMP HOUSE DRAINS | | | MISC. PLANT DRAINS | | | WAST FROM BLOWDOWN TANK | | | PROCESS WASTE TO FT MARTIN | | | SCRUBBER WASTE WA | | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | D |
| MAXIMUM DESIGN | | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | | |
| NORMAL OPERATING | LATER | 0 | AMB | LATER | 0 | AMB | LATER | 0 | 104 | HOLD | HOLD | HOLD | (SEE | MASS BA | AN |
| MINIMUM OPERATING | LATER | 0 | AMB | LATER | 0 | AMB | LATER | 0 | 104 | HOLD | HOLD | HOLD | (SEE | MASS BA | AN |
| REVISION DATE | | | | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | | | | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | | |

| 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|




"OBSOLETE"
6/23/95

SUPPERSEDED BY
DWG 16N25706-40-F-1AA-005

NOTES

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
SOLIDS WASTE
TREATMENT
SYSTEM

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1HS-001

SEAL

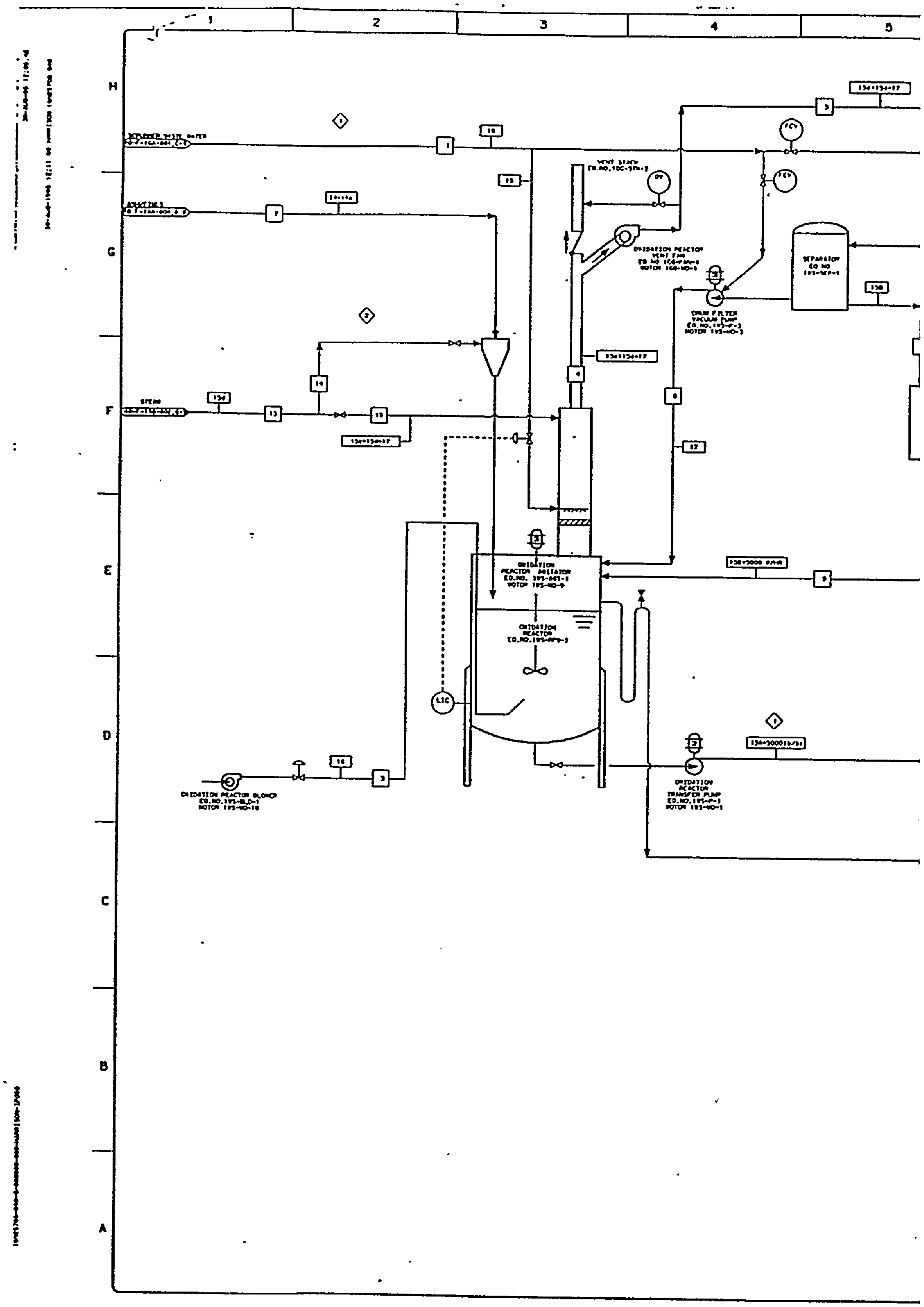
SIGNATURE

DATE

| | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VACUUM PUMP DISCHARGE | | | SEPERATOR TO ASH WATER RETURN TANK | | | DRUM FILTER TO ASH WATER RETURN TANK | | | ASH WATER RETURN TANK TO O2 REACTOR | | | O2 REACTOR TO DRUM FILTER | | |
| Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ANCE) | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) | 10 | 0 | 110 | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) |
| ANCE) | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) | 10 | 0 | LATER | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) |

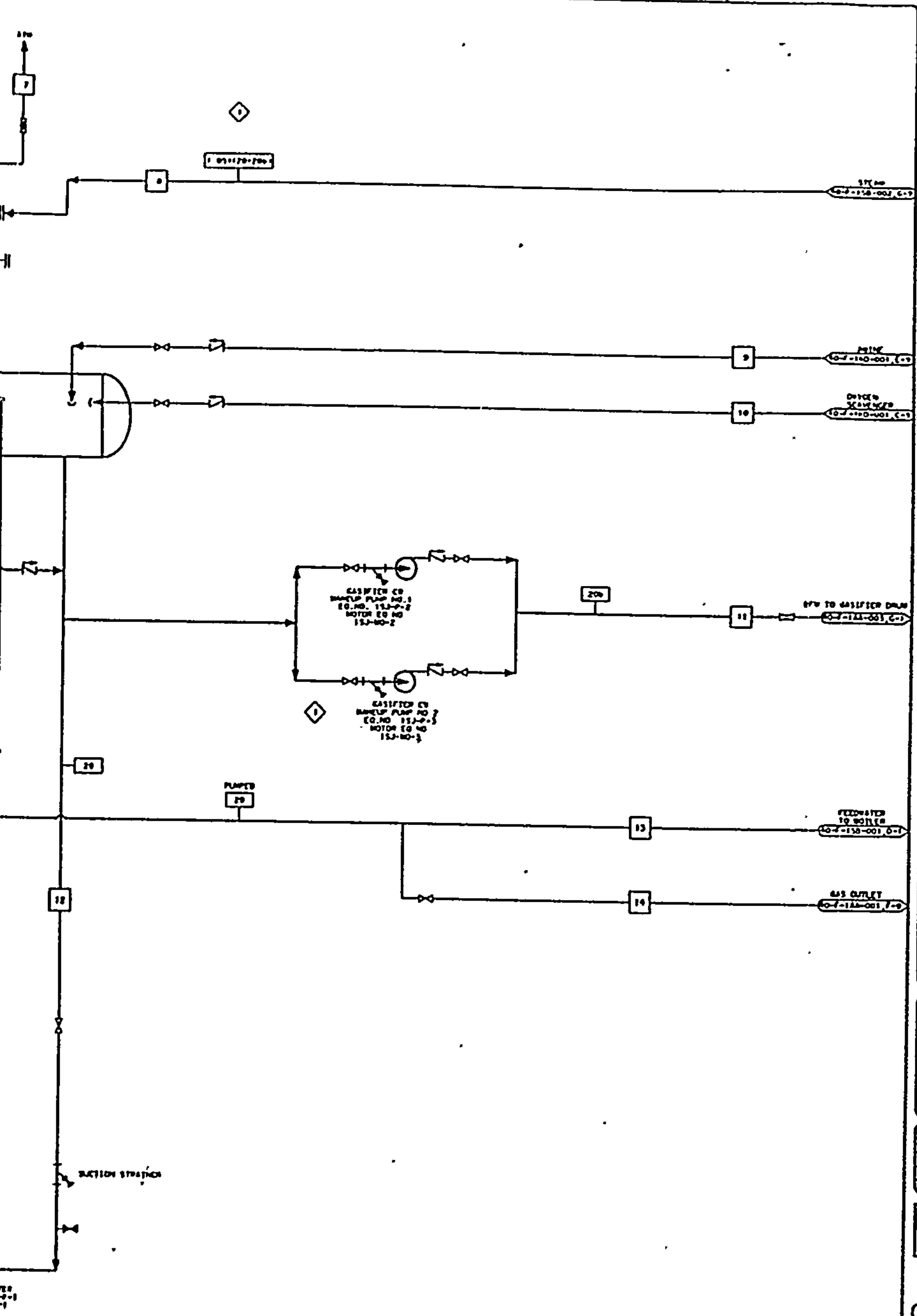
| | 16 | | | 17 | | | 18 | | | 19 | | | 20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SCRUBBER WASTE WATER | | | SCRUBBER WASTE WATER | | | SCRUBBER WASTE WATER | | | - | | | | | |
| Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| ANCE) | | HOLD | | | HOLD | | | HOLD | | | | | | | |
| ANCE) | | | | | | | | | | | | | | | |

359




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | SCRUBBER WASTE WATER | | | GRATE ASH/CYCLONE FINES | | | OXIDATION AIR | | | VENT | | | VENT | |
| UNITS | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) | (SEE | MASS BA |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) | (SEE | MASS BA |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | ASH WASTE | | | OVERFLOW | | | STEAM | | | STEAM | | | STEAM | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BA | ANCE) | 0 | 0 | 120 | (SEE | MASS BA | ANCE) | 500 | 5 | 325 | (SEE | MASS BALA |
| MINIMUM OPERATING | (SEE | MASS BA | ANCE) | 0 | 0 | WATER | (SEE | MASS BA | ANCE) | 500 | 5 | 325 | (SEE | MASS BALA |
| REVISION DATE | | | | | | | | | | | | | | |




NOTES

| 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|



SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
FEEDWATER
SYSTEM

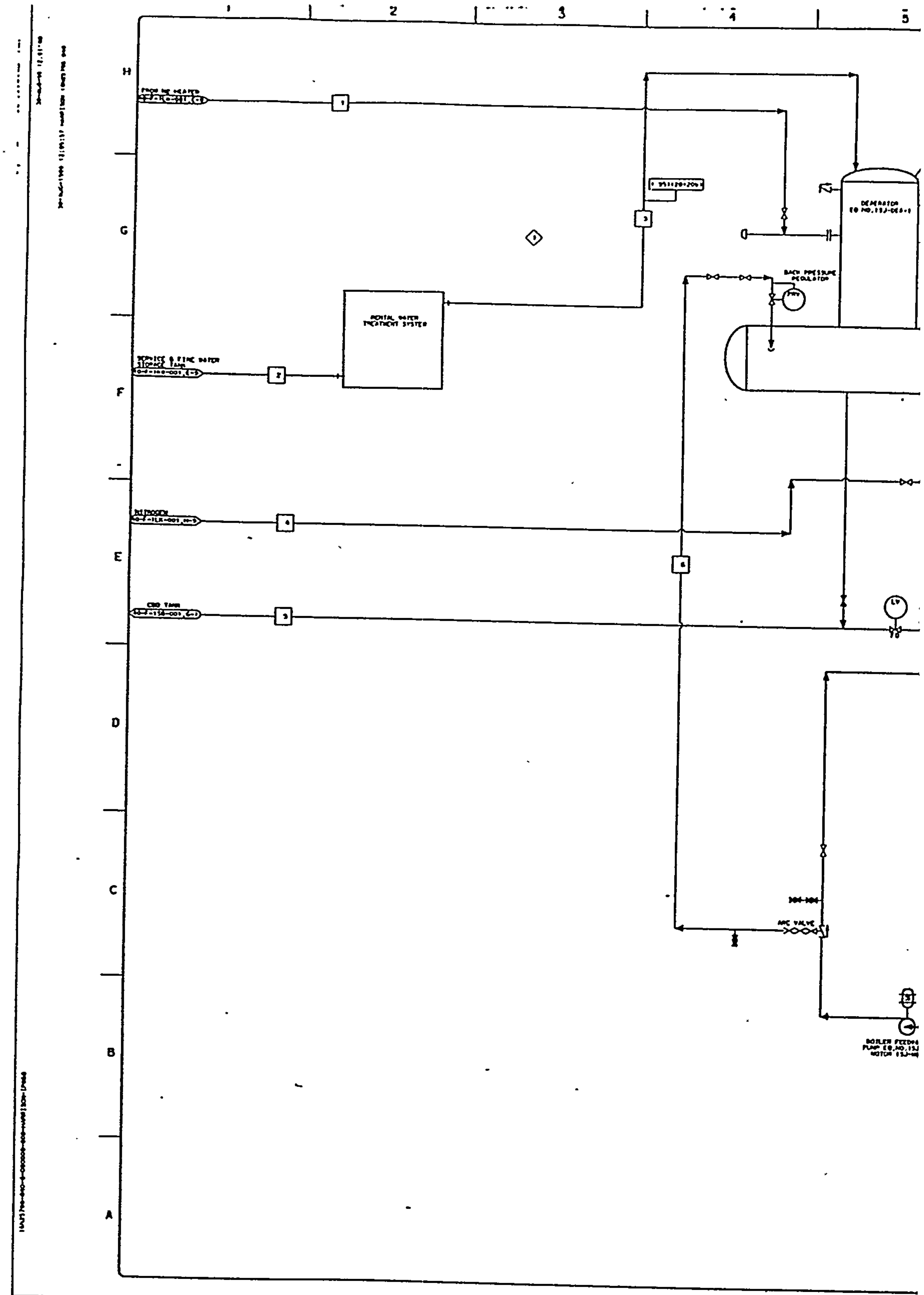
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-15J-001

| ...DRAIN | 6 BOILER FEEDWATER RECIRCULATION | | | 7 DEAERATOR VENT | | | 8 STEAM | | | 9 NEUTRALIZING AMINE | | | 10 O2 SCAVENGER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| 250 | HOLD | 10 | 250 | HOLD | 10 | 250 | HOLD | 10 | 250 | 15 | 10 | 250 | 15 | 10 | 250 |
| | | | | | | | | | | | | | | | |
| 227 | 0 | 5 | 227 | HOLD | 5 | 227 | (SEE | MASS BA | LANCE) | HOLD | 5 | 80 | HOLD | 5 | 80 |
| 227 | 0 | 5 | 227 | 500 | 5 | 227 | (SEE | MASS BA | LANCE) | HOLD | 5 | 80 | HOLD | 5 | 80 |

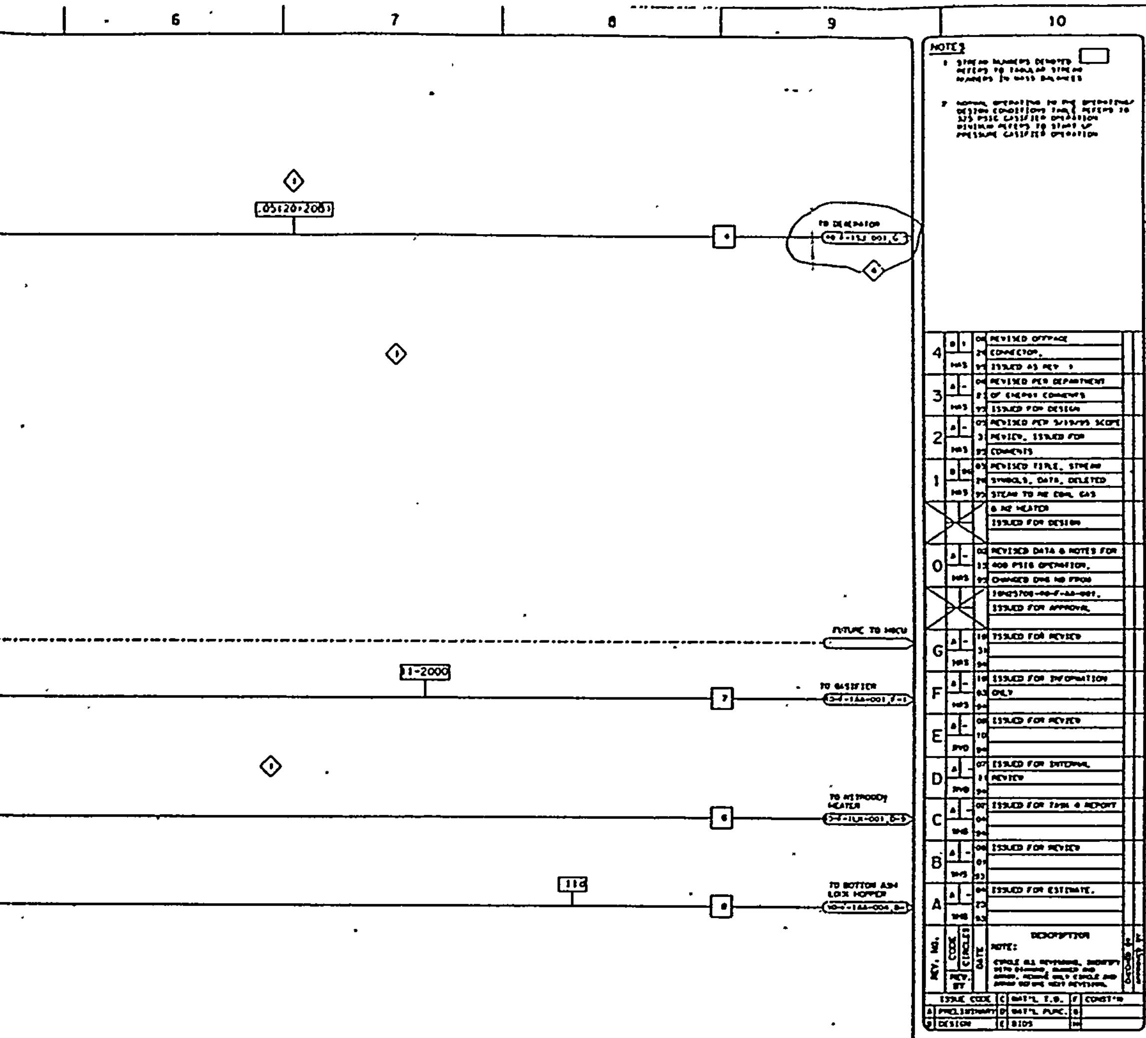
| | 16 | 17 | 18 | 19 | |
|---|---|---|---|---|---|
| | | | | | |

358




| LINE NUMBER | 1 | | | 2 | | | 3 | | | ◇1 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | H2 HEATER CONDENSATE | | | SERVICE WATER | | | TREATED SERVICE WATER | | | NITROGEN | | | DA OVERFLOW | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG |
| MAXIMUM DESIGN | HOLD | 420 | 650 | HOLD | 100 | 90 | HOLD | 100 | 90 | HOLD | 150 | 100 | 15 | 10 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 420 | 550 | HOLD | HOLD | 80 | (SEE | MASS BA | LANCE) | HOLD | 30 | 50 | 0 | 5 |
| MINIMUM OPERATING | HOLD | 300 | 500 | HOLD | HOLD | 70 | (SEE | MASS BA | LANCE) | HOLD | 20 | 50 | 0 | 5 |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | GASIFIER COOLING WATER MAKEUP | | | BFW SUCTION | | | FEEDWATER TO BOILER | | | GAS OUTLET SPRAY WATER | | | | |
| UNITS | GPM | PSIG | Deg F | GPM | PSIG | Deg F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | | |
| MAXIMUM DESIGN | 10 | HOLD | 250 | HOLD | 10 | 250 | HOLD | HOLD | 250 | HOLD | HOLD | 250 | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | --- | |
| NORMAL OPERATING | (SEE | MASS BA | LANCE) | (SEE | MASS BA | LANCE) | (SEE | MASS BA | LANCE) | 0 | HOLD | 227 | | |
| MINIMUM OPERATING | (SEE | MASS BA | LANCE) | (SEE | MASS BA | LANCE) | (SEE | MASS BA | LANCE) | 0 | HOLD | 227 | | |
| REVISION DATE | | | | | | | | | | | | | | |




Copyright Jacobs-Sirrine Engineers as of Last Date Indicated

SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERING, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
STEAM
DISTRIBUTION

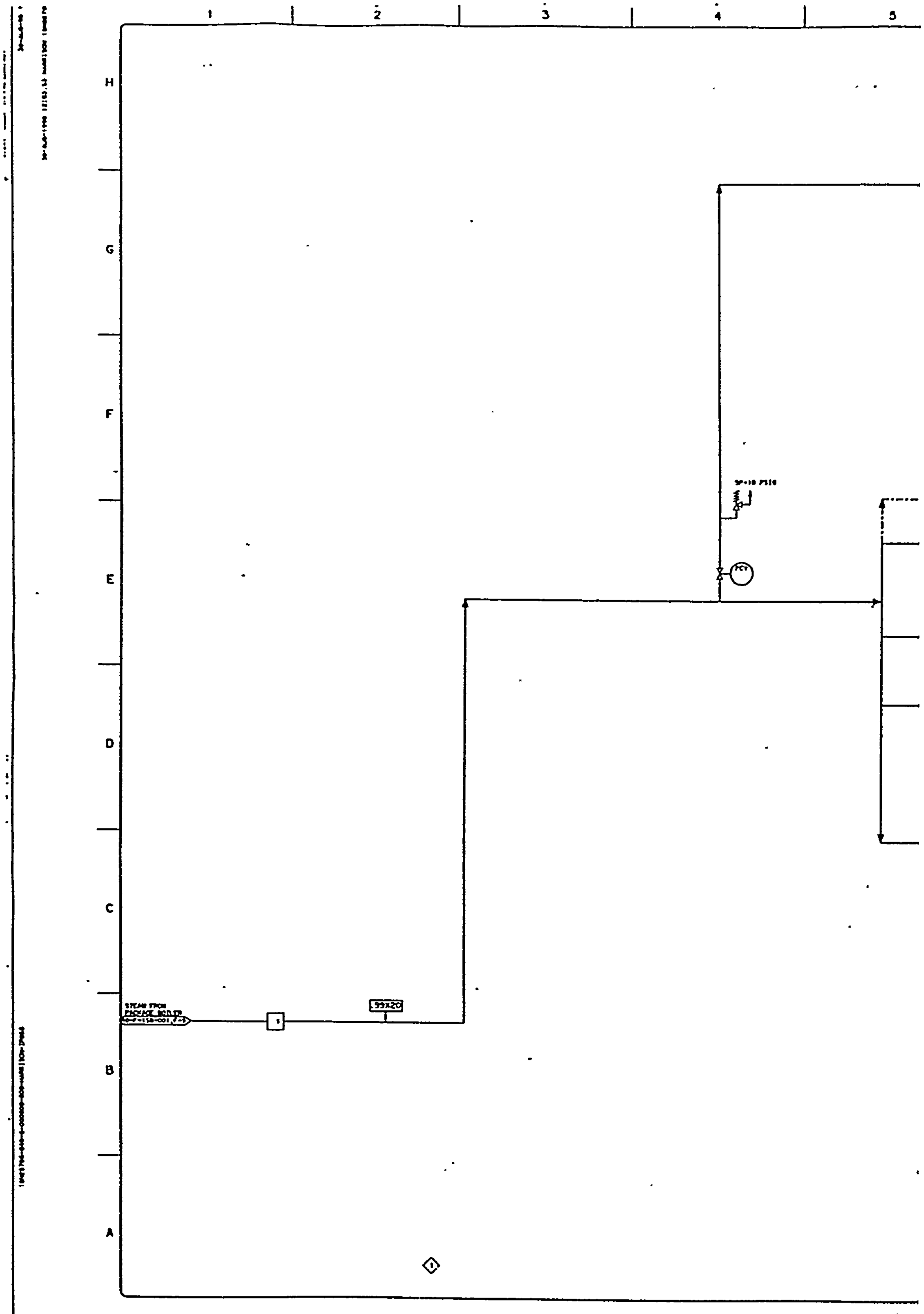
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-158-002

| | | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ...SH PURGE | | STEAM TO H.P. N2 HTR | | | STEAM TO GASIFIER | | | STEAM TO GRATE ASH L.H. | | | STEAM TO GASIFIER COOLING HX | | | | | |
| ...G | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | | | |
| | | 2000 | 460 | 600 | | | | HOLD | 460 | 600 | HOLD | 460 | 600 | | | |
| | | | | | | | | | | | | | | | | |
| BALANCE) | | HOLD | 420 | 550 | (SEE MASS BALANCE) | | | 3000 | 420 | 550 | RILEY | 420 | 550 | | | |
| BALANCE) | | HOLD | 360 | 500 | (SEE MASS BALANCE) | | | 3000 | 360 | 500 | RILEY | 360 | 500 | | | |

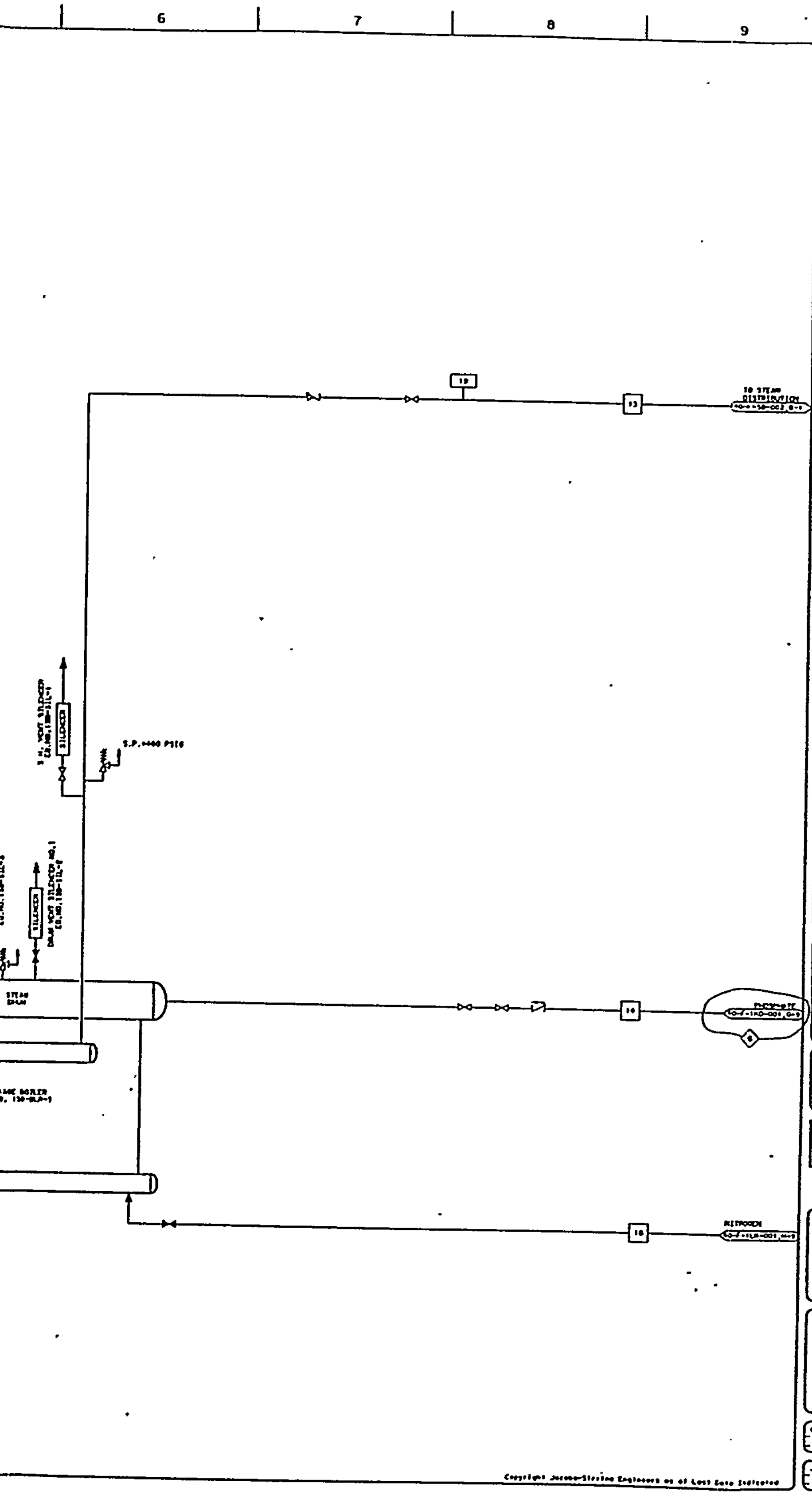
| | | 16 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ...G | Deg°F | PPH | PSIG | Deg°F | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

357




| LINE NUMBER | 1 | | | | | | | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION. | STEAM FROM BOILER | | | | | | | | | STEAM TO DEAERATOR | | | STEAM TO | |
| UNITS | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PS |
| MAXIMUM DESIGN | 6000 | 460 | 600 | | | | | | | 1000 | 10 | 600 | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BA | ANCE) | | | | | | | (SEE | MASS BA | ANCE) | (SEE | MASS |
| MINIMUM OPERATING | (SEE | MASS BA | ANCE) | | | | | | | (SEE | MASS BA | ANCE) | (SEE | MASS |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | | | |
| UNITS | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSI |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | |




NOTES
1. STREAM NUMBERS DENOTED REFERS TO TABULAR STREAM NUMBERS IN MASS BALANCES
2. NORMAL GASIFIER OPERATING IS 370 PSIG, MINIMUM IS START UP PRESSURE GASIFIER OPERATION

SEAL

SIGNATURE

DATE

JE JACOBS-SIRRINE ENGINEERING

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
NATURAL GAS
PACKAGE BOILER

CLIENT DRAWING NUMBER

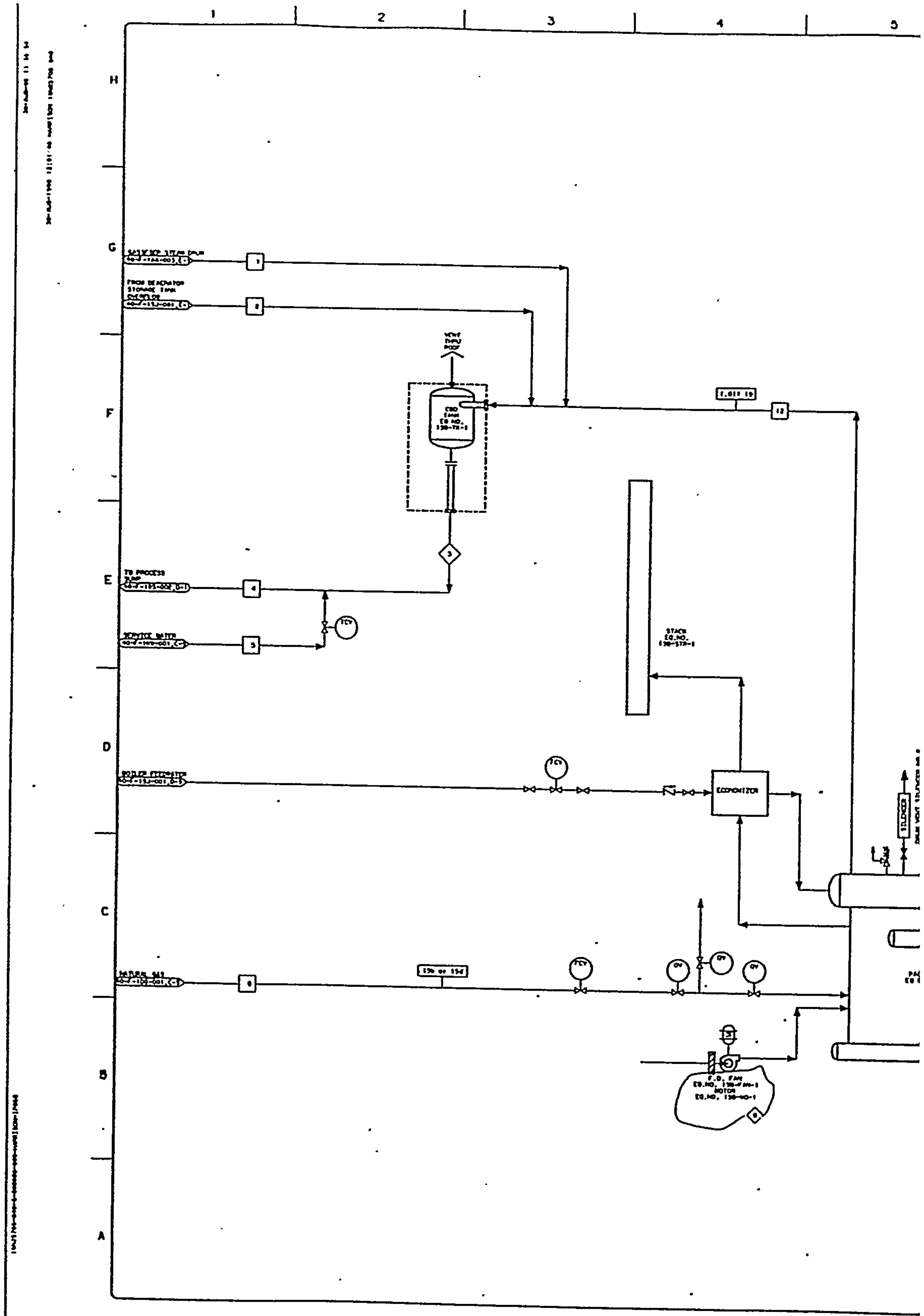
JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-158-001



| TER | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LH VENT FROM EJECTOR | | | O2 REACTOR /VENT PUMP | | | N.G. TO PACKAGE BOILER | | | PYGAS TO PACKAGE BOILER | | | COMB AIR | | |
| Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | IN WG | Deg.F |
| | | | | | | | | 60 | 100 | | | | | | |
| | | HOLD | | | | | | | | | | | | | |
| | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |

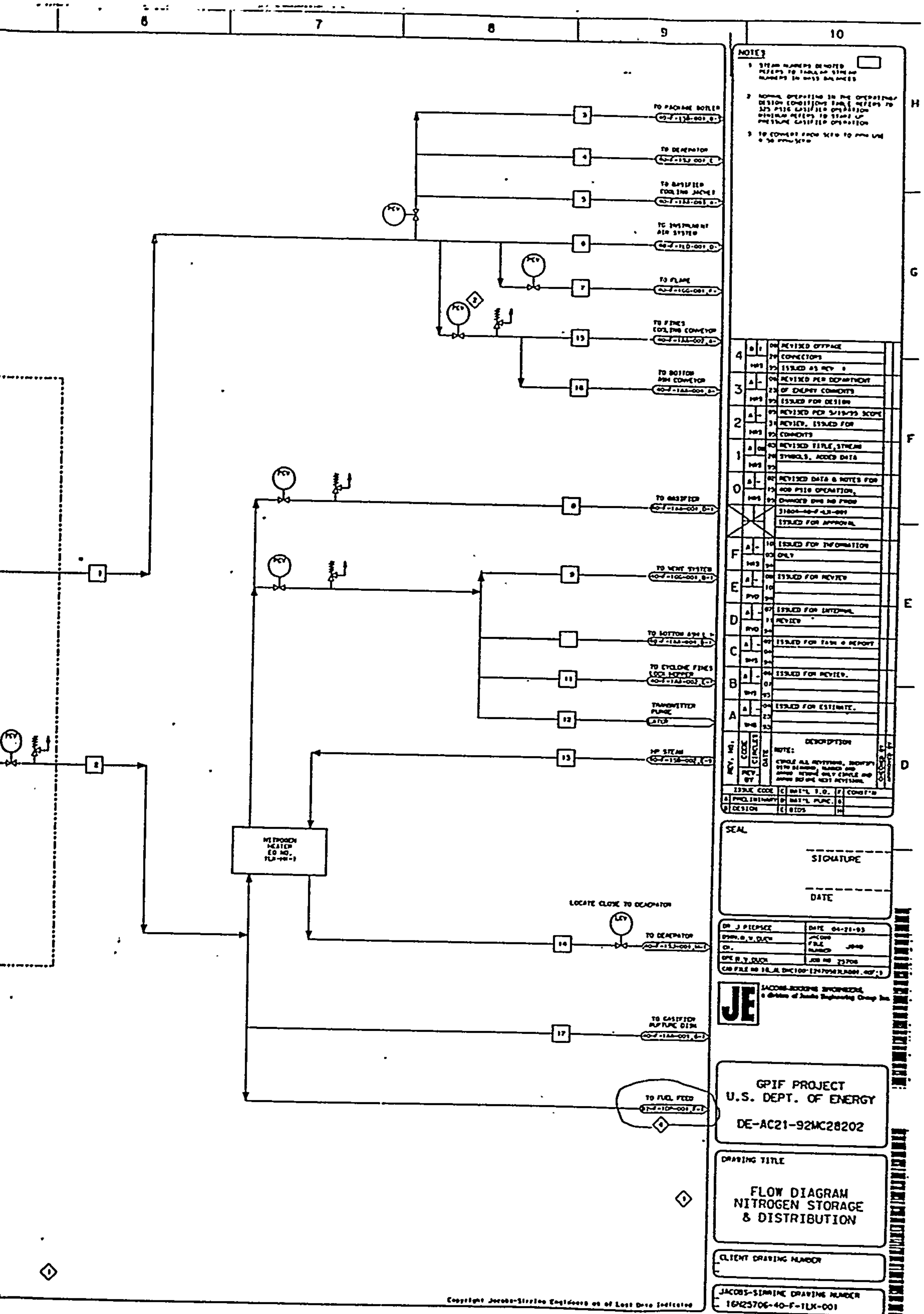
| | 16 | | | 17 | | | 18 | | | 19 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HRSG EXH. TO FT MARTIN | | | PYGAS TO FLARE | | | N2 PURGE | | | | | | | | |
| Deg F | PPH | IN.WG. | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | | | |
| | HOLD | HOLD | | | | | | | | | | | | | |
| | | | | | | | | HOLD | | | | | | | |
| ANCE) | (SEE | MASS BAL | ANCE) | 0 | VENDOR | 1105 | 0 | | | | | | | | |
| ANCE) | (SEE | MASS BAL | ANCE) | 0 | VENDOR | 1105 | 0 | | | | | | | | |

356




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION. | GASIFIER BLOWDOWN | | | DEA. OVERFLOW | | | BLOWOFF DRAIN | | | TO PROCESS SUMP | | | SERVICE W | |
| UNITS | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | 0 | 414 | 452 | 0 | 5 | 227 | HOLD | 3 | 222 | HOLD | .5 | 104 | | HOLD |
| MINIMUM OPERATING | 0 | 214 | 394 | 0 | 5 | 227 | HOLD | 3 | 222 | HOLD | 5 | 104 | | |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION. | AIR | | | CDD | | | TOTAL STEAM | | | PHOSPHATE | | | BFW | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG |
| MAXIMUM DESIGN | ---- | ---- | | | | | 6000 | 460 | 600 | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | LATER | LATER | [illegible] | (SEE | MASS BA |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | LATER | LATER | [illegible] | (SEE | MASS BA |
| REVISION DATE | | | | | | | | | | | | | | |

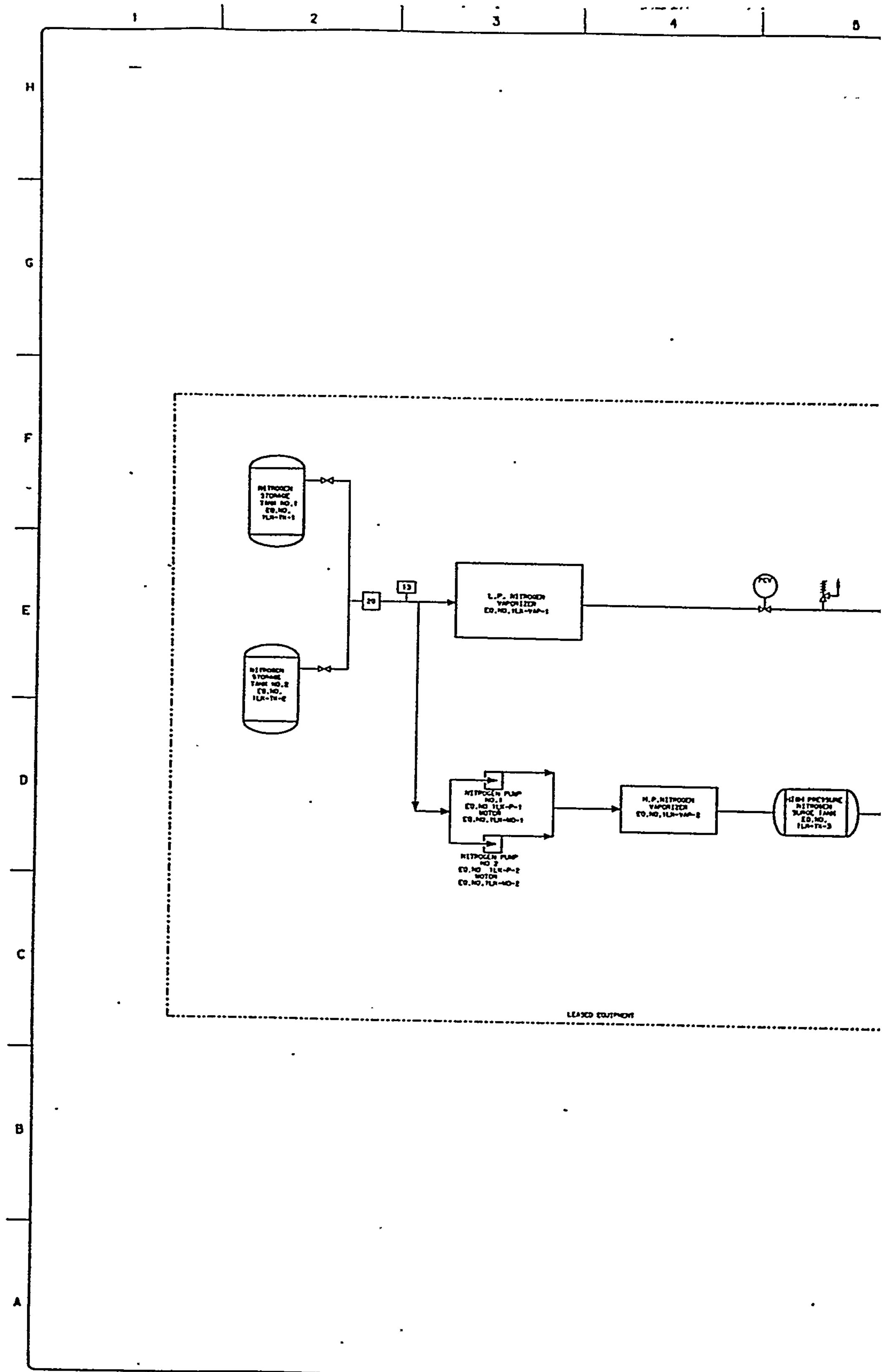





| | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JACKET | N2 TO INSTRUMENT AIR | | | N2 TO FLARE | | | N2 TO GASIFIER | | | N2 TO VENT SYSTEM | | | N2 TO BOTTOM ASH L.H. | | |
| Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F |
| 100 | 438 | 150 | 100 | HOLD | 150 | 100 | HOLD | 374 | 465 | HOLD | 374 | 465 | HOLD | 374 | 465 |
| | | | | | | | | | | | | | | | |
| 50 | 0 | 120 | 50 | HOLD | 50 | 50 | HOLD | 353 | 400 | HOLD | 353 | 400 | HOLD | 353 | 400 |
| 50 | 0 | 160 | 50 | HOLD | 20 | | HOLD | HOLD | 360 | HOLD | HOLD | 360 | HOLD | HOLD | 360 |

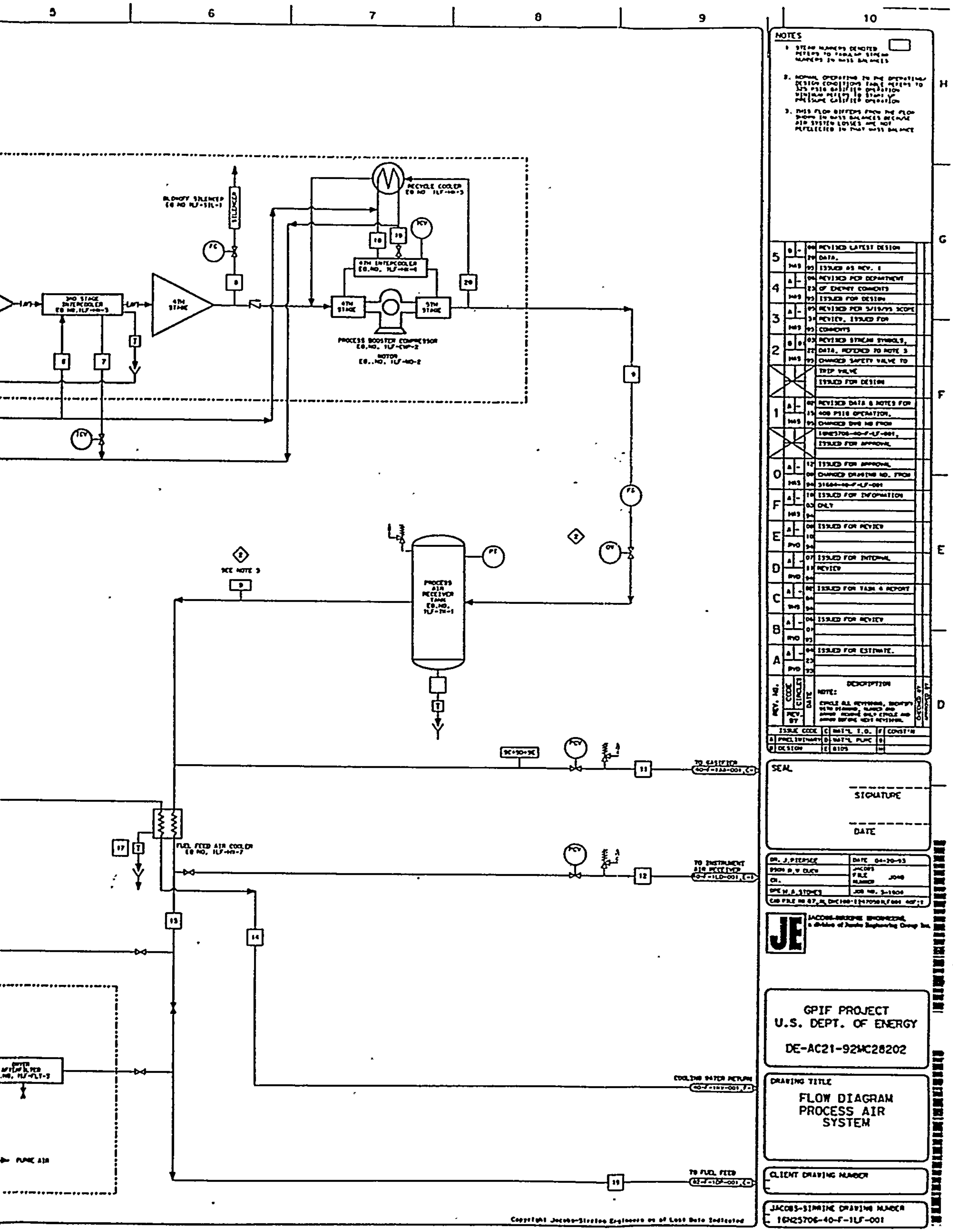
| | 16 | | | 17 | | | 18 | | | 19 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NVEYOR | N2 TO BOTTOM ASH CONVEYOR | | | N2 TO GASIFIER RUPTURE DISK | | | | | | | | | | | |
| Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F | | | | | | | | | |
| 100 | | 10 | 100 | HOLD | 420 | 100 | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 50 | | 5 | 50 | HOLD | 420 | 50 | | | | | | | | | |
| 50 | | 5 | 50 | HOLD | 360 | 50 | | | | | | | | | |

355




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION. | LP N2 USERS | | | HP N2 USERS | | | N2 TO HRSG | | | N2 TO DEAERATOR | | | N2 TO COOLING | |
| UNITS | PPH | PSIG | Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG | Deg.F | SCFM | PSIG |
| MAXIMUM DESIGN | HOLD | 150 | 100 | HOLD | 460 | 100 | HOLD | 150 | 100 | HOLD | 150 | 100 | HOLD | 150 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 120 | 50 | HOLD | 420 | 50 | HOLD | 30 | 50 | HOLD | 30 | 50 | HOLD | 30 |
| MINIMUM OPERATING | HOLD | 100 | 50 | HOLD | 400 | 50 | HOLD | 20 | 50 | HOLD | 20 | 50 | HOLD | 20 |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION | N2 TO CYCLONE LH | | | N2 TO TRANSMITTER PURGE | | | HP STEAM | | | CONDENSATE | | | N2 TO FINES C | |
| UNITS | SCFM | PSIG | Deg F | SCFM | PSIG | Deg F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | SCFM | PSIG |
| MAXIMUM DESIGN | HOLD | 374 | 465 | HOLD | 374 | 465 | 2000 | 460 | 600 | 2000 | 420 | 465 | HOLD | 10 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 353 | 400 | HOLD | 353 | 400 | HOLD | 420 | 550 | HOLD | 420 | 454 | HOLD | 5 |
| MINIMUM OPERATING | HOLD | HOLD | 340 | HOLD | HOLD | 360 | HOLD | 420 | 500 | HOLD | 180 | 444 | HOLD | 5 |
| REVISION DATE | | | | | | | | | | | | | | |




GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
PROCESS AIR
SYSTEM

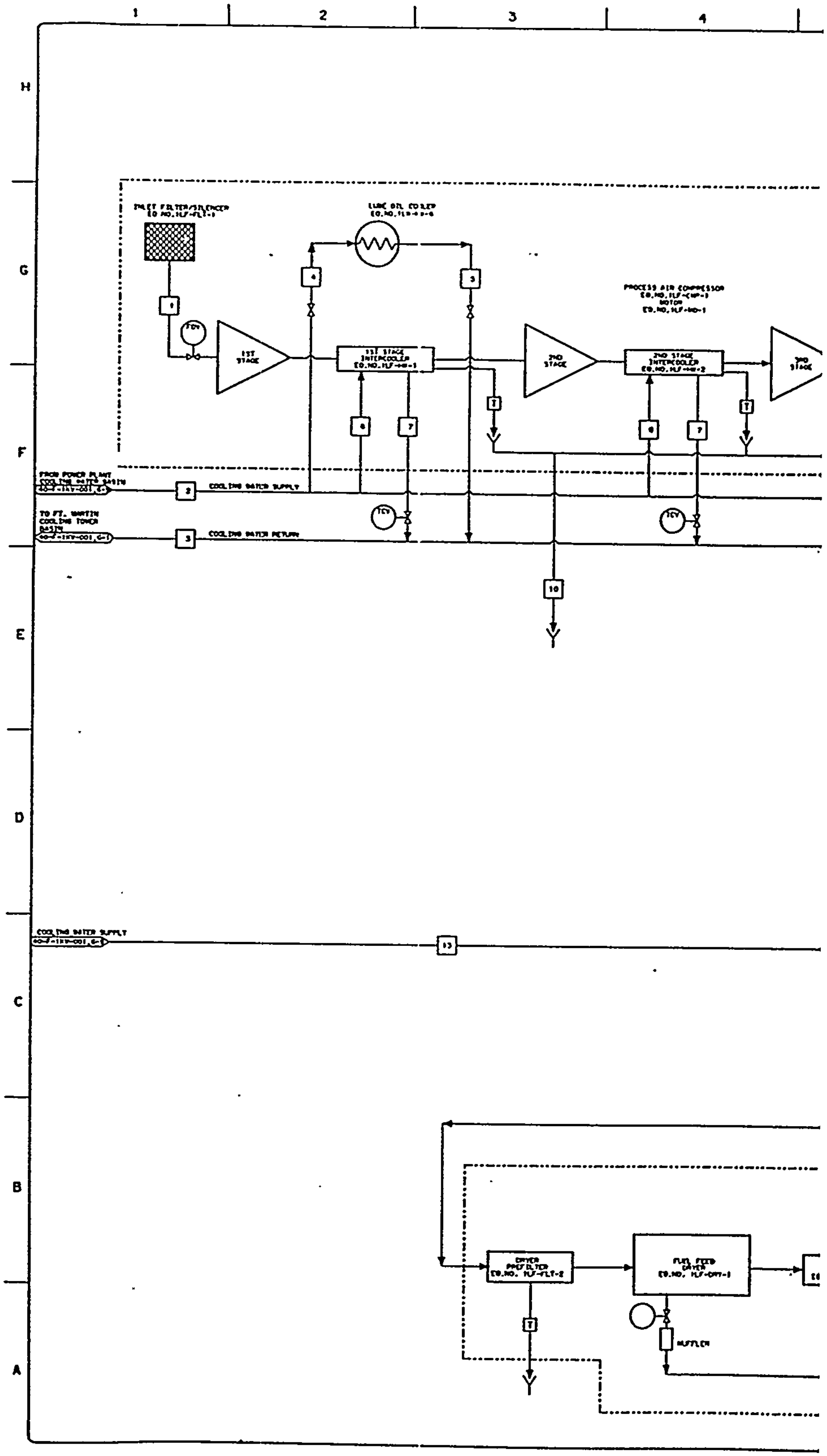
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1LF-001

| 5 | | | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CW RETURN | | | CW SUPPLY | | | CW RETURN | | | COMPRESSOR BLOW OFF | | | COMPRESSOR DISCHARGE | | | COND | | |
| GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| 50 | 100 | 150 | 100 | 100 | 150 | 100 | 100 | 150 | 19250 | 138 | 120 | 19250 | 567 | 400 | 500 | 150 | 300 |
| | | | | | | | | | | | | | | | | | |
| 20 | 30 | 105 | 47 | 40 | 85 | 47 | 30 | 105 | 0 | 120 | 165 | 15893 | 515 | 350 | 300 | 75 | 105 |
| HOLD | 30 | 105 | HOLD | 40 | 85 | HOLD | 30 | 105 | HOLD | 120 | 165 | HOLD | 350 | 400 | 0 | HOLD | HOLD |

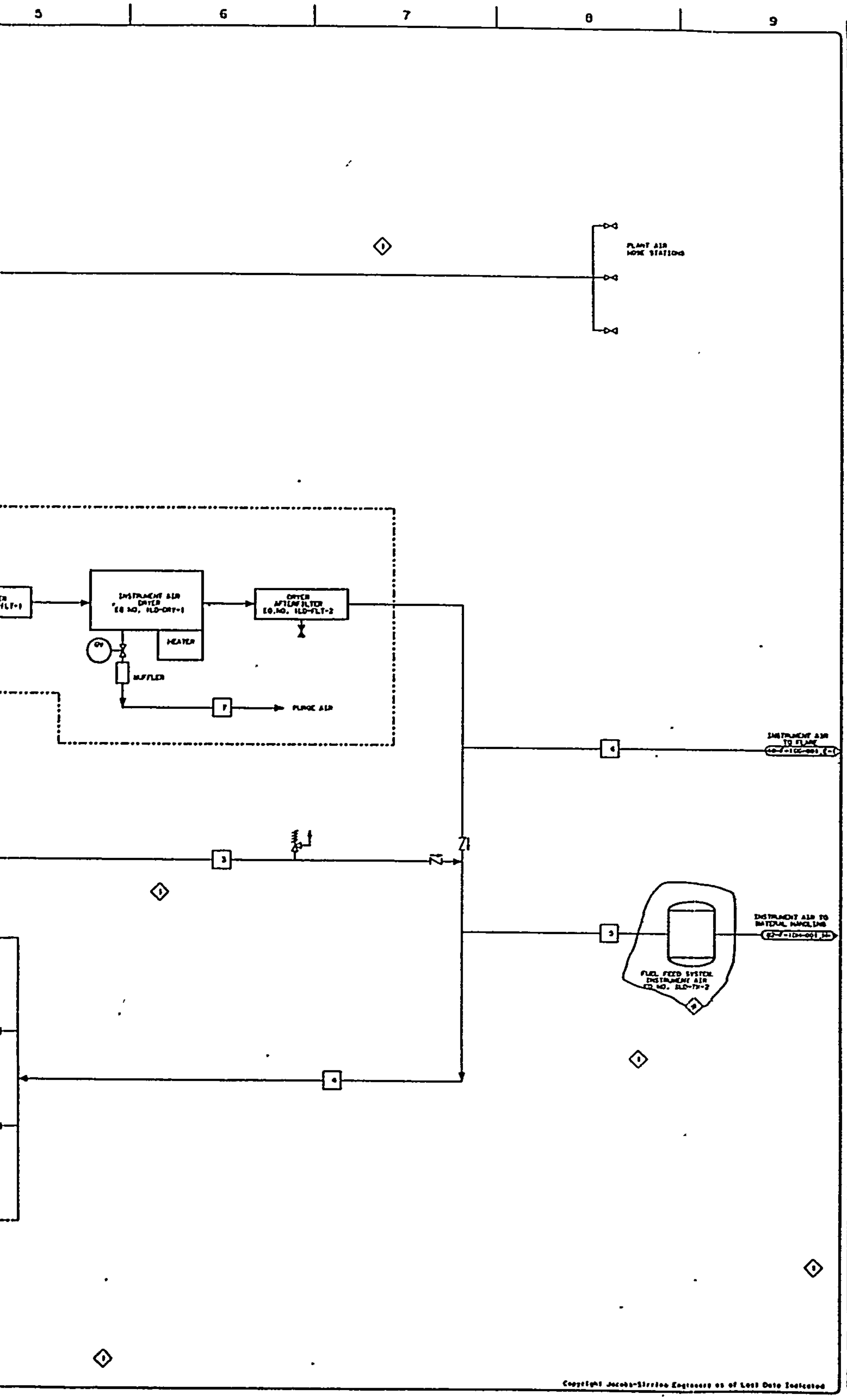
| 15 | | | 16 | | | 17 | | | 18 | | | 19 | | | 20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AIR TO AIR DRYER | | | AIR TO CONVEYOR SYSTEM | | | COND | | | CW SUPPLY | | | CW RETURN | | | RECYCLE AIR | | |
| PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F |
| 7000 | 567 | 150 | 7000 | 567 | 150 | 53 | 567 | 250 | 50 | 100 | 100 | 50 | 100 | 150 | 19250 | 567 | 400 |
| | | | | | | | | | | | | | | | | | |
| 4734 | 499 | 95 | 4567 | 489 | 100 | 25 | 560 | 100 | 24 | 40 | 85 | 24 | 30 | 105 | 0 | 515 | 350 |
| HOLD | HOLD | 70 | HOLD | HOLD | 90 | 2 | 560 | 100 | HOLD | 40 | 85 | HOLD | 30 | 105 | 0 | HOLD | HOLD |

354




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | INLET AIR | | | CW SUPPLY | | | CW RETURN | | | CW SUPPLY | | |
| UNITS | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg. |
| MAXIMUM DESIGN | 19212 | 0 | 90 | 500 | 100 | 150 | 500 | 100 | 105 | 50 | 100 | 15 |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | 16277 | 0 | 90 | 185 | 40 | 85 | 185 | 30 | 105 | 20 | 40 | 85 |
| MINIMUM OPERATING | HOLD | 0 | 90 | HOLD | 40 | 85 | HOLD | 30 | 105 | HOLD | 40 | 85 |
| REVISION DATE | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | AIR TO GASIFIER | | | INSTRUMENT AIR SUPPLY | | | CW SUPPLY | | | CW RETURN | | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg |
| MAXIMUM DESIGN | 12000 | 567 | 400 | 1603 | 125 | 100 | 50 | 100 | 150 | 50 | 100 | 15 |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | 9506 | 338 | 350 | 1058 | 105 | 70 | 35 | 40 | 85 | 35 | 30 | 10 |
| MINIMUM OPERATING | HOLD | HOLD | 400 | HOLD | HOLD | HOLD | 10 | 40 | 85 | 10 | 30 | 10 |




NOTES

1. STREAM NUMBERS DENOTED ▭ REFERS TO TABULAR STREAM NUMBERS IN MASS BALANCES
2. NORMAL OPERATING IN THE OPERATING/DESIGN CONDITIONS TABLE REFERS TO 325 PSIG GASIFIED OPERATION, MINIMUM REFERS TO START UP PRESSURE GASIFIED OPERATION
3. TO CONVERT PPH TO SCFM USE [illegible]

| 5 | | | 6 | | | 6 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INSTRUMENT AIR TO MATERIAL HANDLE | | | INSTRUMENT AIR TO FLARE | | | DRYER PURGE | | | | | | | | | | | |
| PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | SCFM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| 274 | 125 | 100 | 90 | 125 | 100 | 80 | 125 | 100 | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 46 | 93 | 70 | 0 | 93 | 70 | 80 | 10 | 70 | | | | | | | | | |
| 0 | 93 | 60 | 0 | 93 | 60 | HOLD | HOLD | HOLD | | | | | | | | | |

SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERING, a division of Jacobs Engineering Group Inc.

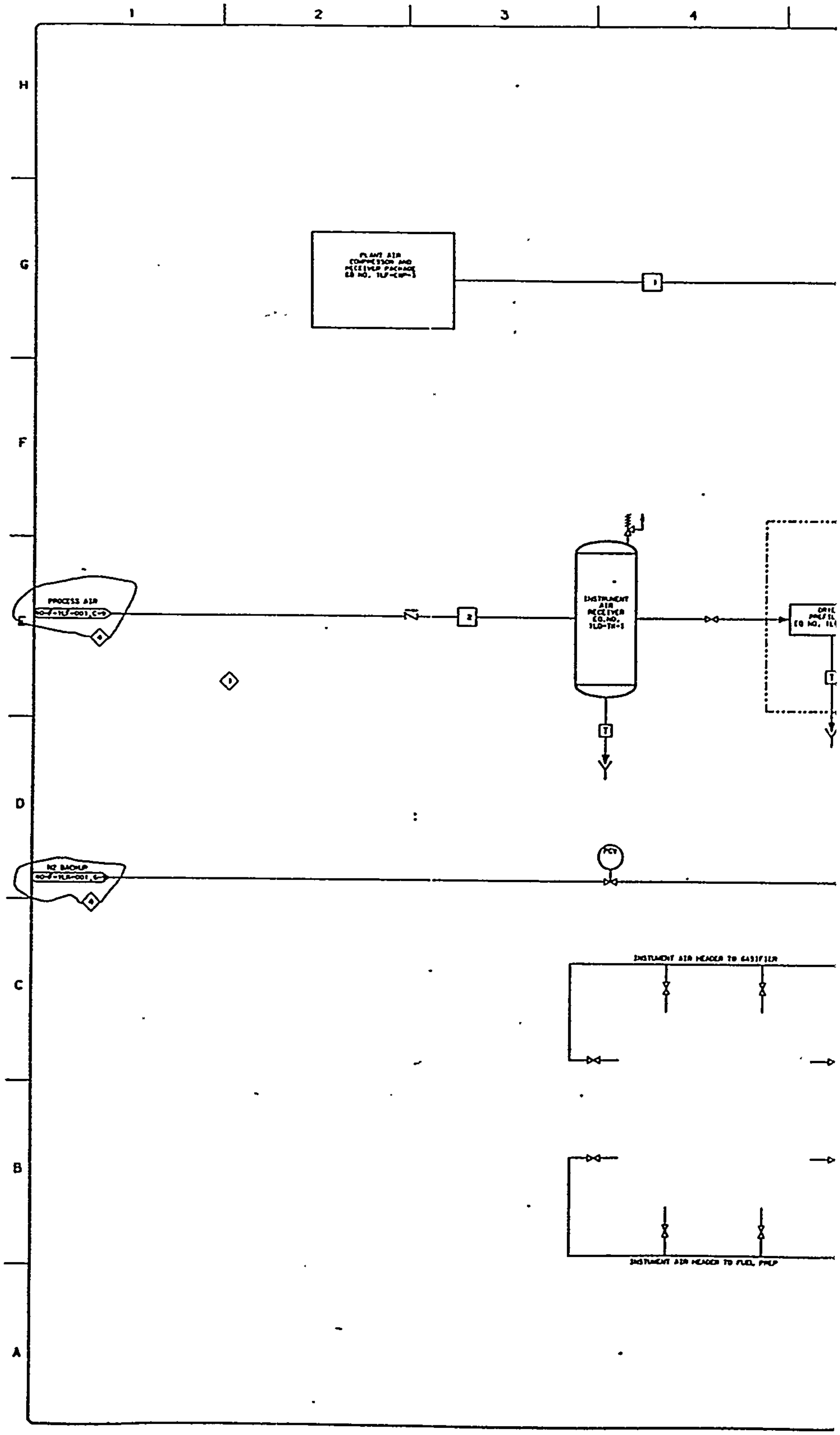
GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE
FLOW DIAGRAM
PLANT AND
INSTRUMENT AIR
SYSTEM

CLIENT DRAWING NUMBER

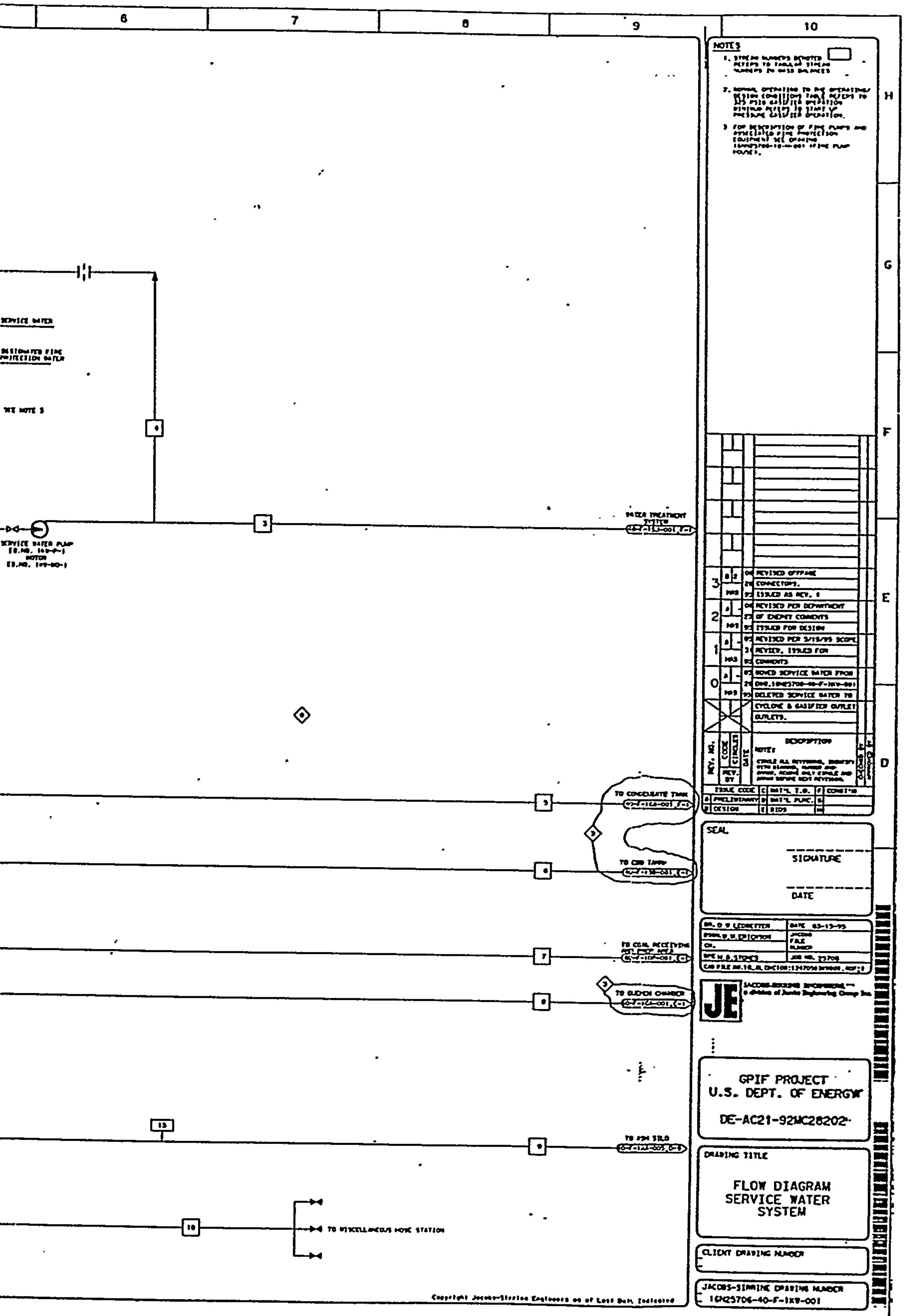
JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-ILD-001

353



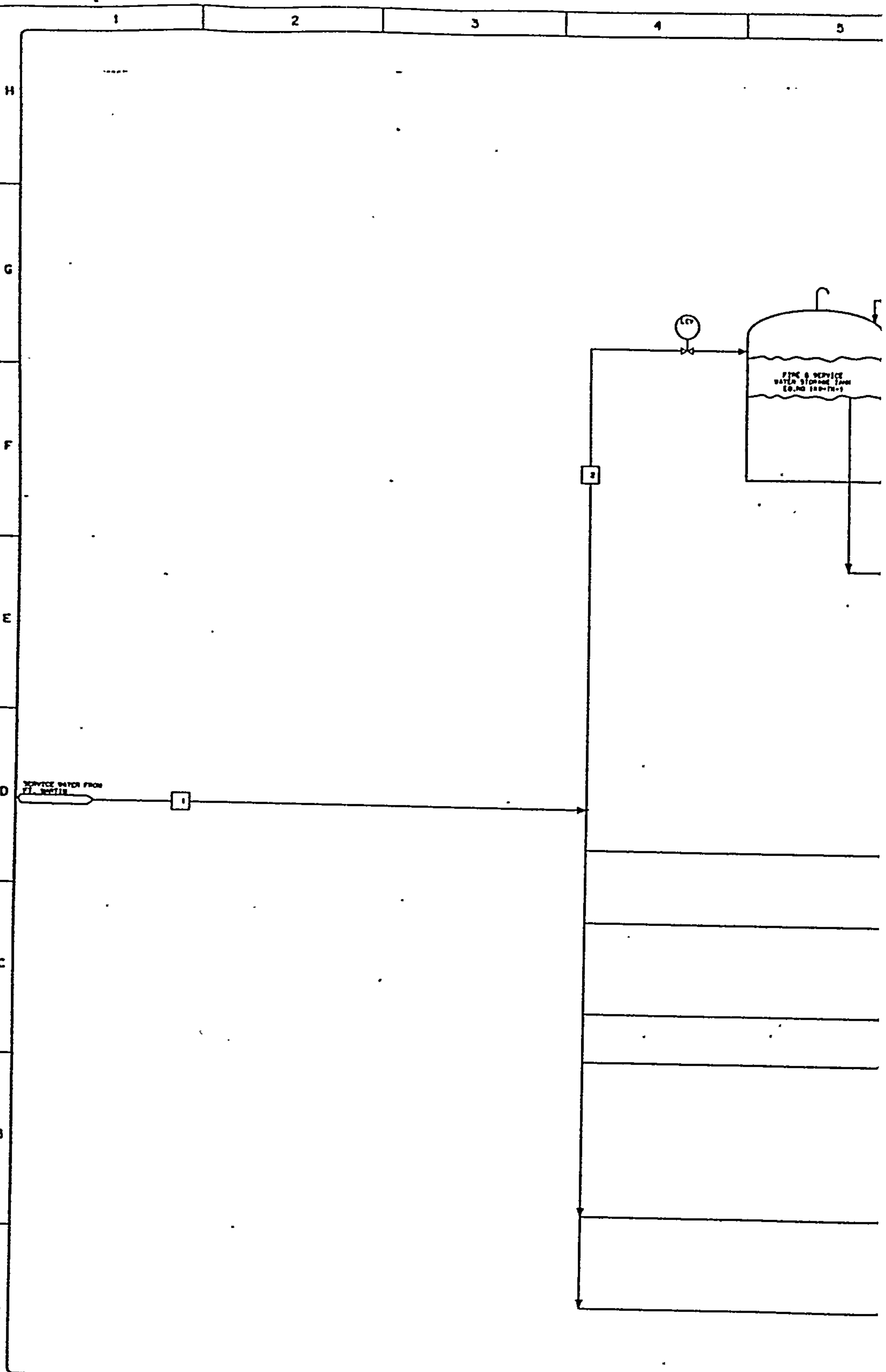

| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | PLANT AIR | | | PROCESS AIR | | | N2 BACKUP | | | INSTRUMENT AIR | | |
| UNITS | SCFM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| MAXIMUM DESIGN | 100 | 125 | 100 | 160'. | 125 | 100 | 1493 | 150 | 100 | 2000 | 125 | 100 |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | 0 | 100 | 85 | 1050 | 105 | 70 | 0 | 120 | 50 | 932 | 93 | 70 |
| MINIMUM OPERATING | HOLD | 100 | 1058 | HOLD | HOLD | HOLD | 0 | 100 | 50 | HOLD | 93 | 60 |
| REVISION DATE | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | |



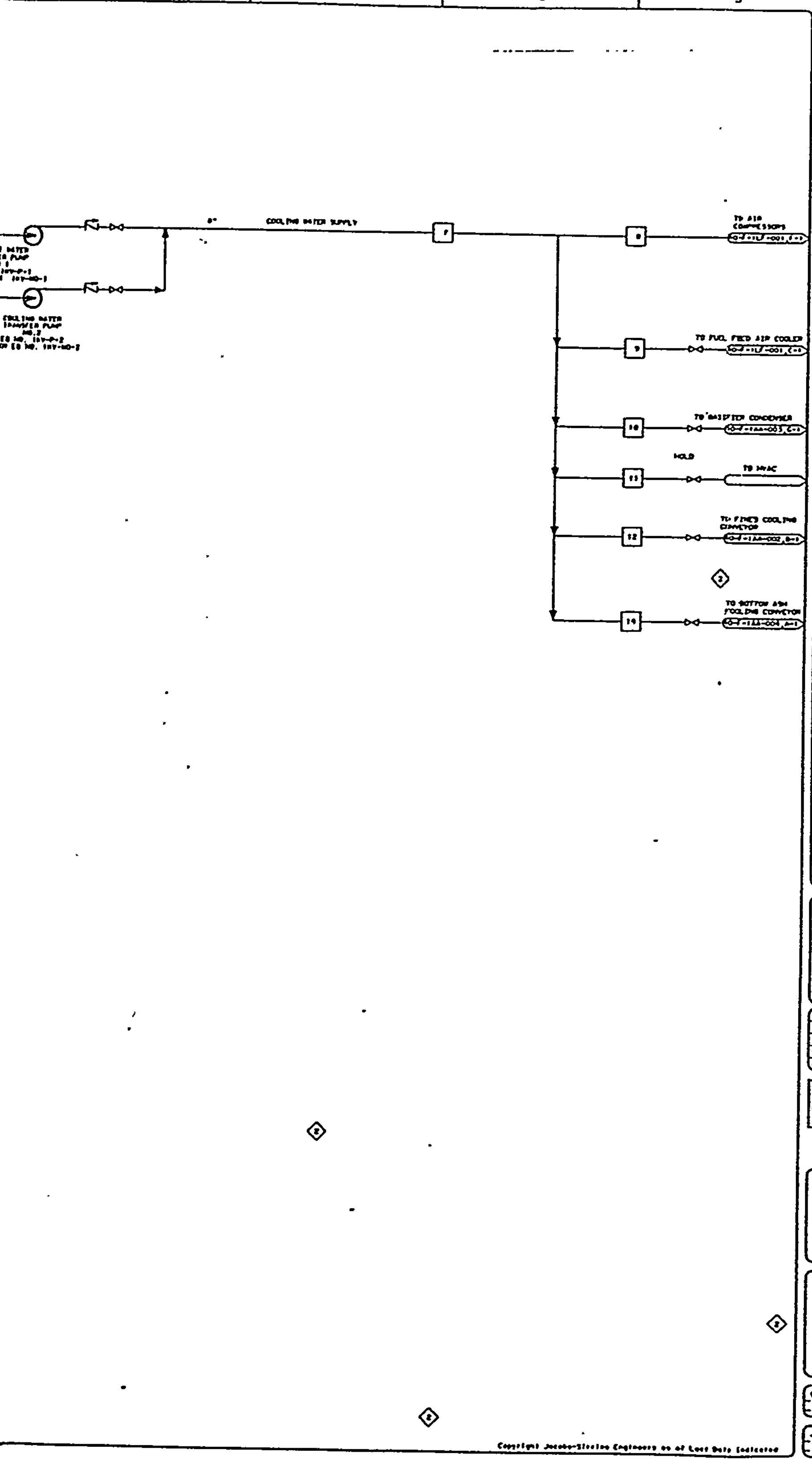

| | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deg.F | SW TO BLOWOFF TANK | | | SW TO COAL RECEIVING | | | SW TO SCRUBBER | | | SW TO ASH SILO | | | SW TO HOSE STATION | | |
| | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| 90 | HOLD | 80 | 90 | HOLD | 80 | 90 | HOLD | 80 | 90 | HOLD | 80 | 90 | HOLD | 80 | 90 |
| | | | | | | | | | | | | | | | |
| 80 | HOLD | 60 | 80 | HOLD | 60 | 80 | HOLD | 60 | 80 | (SEE | MASS BALANCE) | | 0 | 60 | 60 |
| 60 | 0 | 40 | 60 | 0 | 40 | 60 | 0 | 40 | 60 | (SEE | MASS BALANCE) | | 0 | 40 | 60 |

352




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | SW FROM FT MARTIN | | | SW TO STORAGE TANK | | | SW TO WATER. TREATMENT SYSTEM | | | SW PUMP RECIRC. | | | SW TO CONDENSA[TE] COLLECTOR TA[NK] | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG |
| MAXIMUM DESIGN | HOLD | 100 | 90 | HOLD | 100 | 90 | HOLD | 100 | 90 | HOLD | 100 | 90 | HOLD | 80 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 75 | 80 | HOLD | 75 | 80 | HOLD | 80 | AMB | HOLD | 80 | 80 | HOLD | 60 |
| MINIMUM OPERATING | HOLD | 75 | 60 | HOLD | 75 | 60 | HOLD | 70 | AMB | HOLD | 70 | 60 | HOLD | 90 |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | |




NOTES

| REV. NO. | DESCRIPTION |
|---|---|
| 5 | REVISED LASTED DESIGN DATA. ISSUED AS REV. 1 |
| 4 | REVISED PER DEPARTMENT OF ENERGY COMMENTS ISSUED FOR DESIGN |
| 3 | REVISED PER 5/19/95 SCOPE REVIEW, ISSUED FOR COMMENTS |
| 2 | REMOVED POTABLE WATER AND SERVICE WATER, ADDED COOLING WATER TO AND FROM HVAC UNITS, REVISED TITLE & STEAM SYMBOL. |
| 1 | ADDED SERVICE WATER TO FLUE GAS SCRUBBER |
| 0 | REVISED DATA & NOTES FOR 400 PSIG OPERATION. CHANGED DWG NO FROM 31606-40-F-KY-001 ISSUED FOR APPROVAL |
| F | ISSUED FOR INFORMATION ONLY |
| E | ISSUED FOR REVIEW |
| D | ISSUED FOR INTERNAL REVIEW |
| C | ISSUED FOR TASK 4 REPORT |
| B | ISSUED FOR REVIEW. |
| A | ISSUED FOR ESTIMATE. |

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

ISSUE CODE: A PRELIMINARY, B DESIGN, C MAT'L T.O., D MAT'L PURC., E BIDS, F CONST'N

SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM AUXILIARY WATER DISTRIBUTION

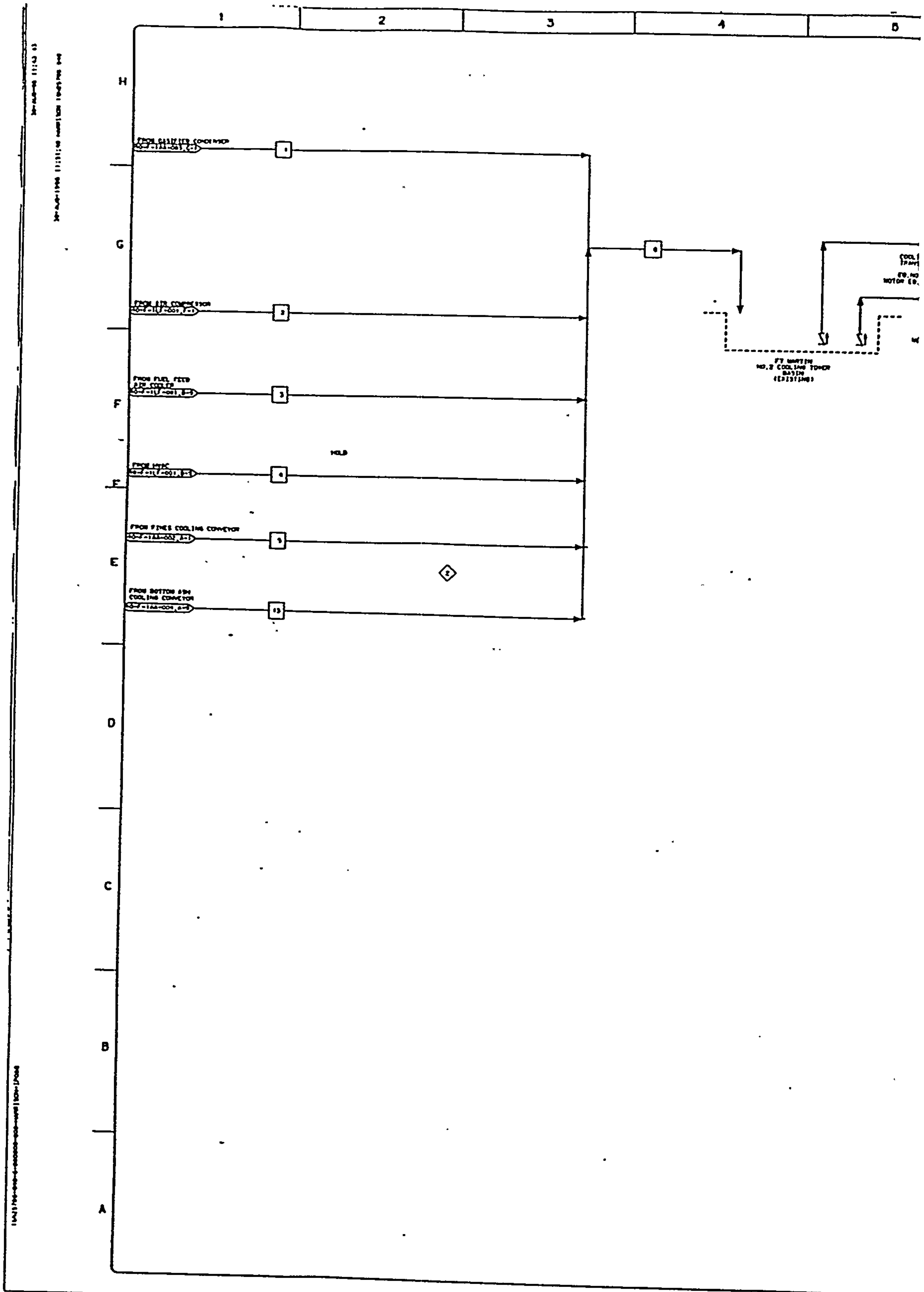
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER 16N25706-40-F-1KY-001



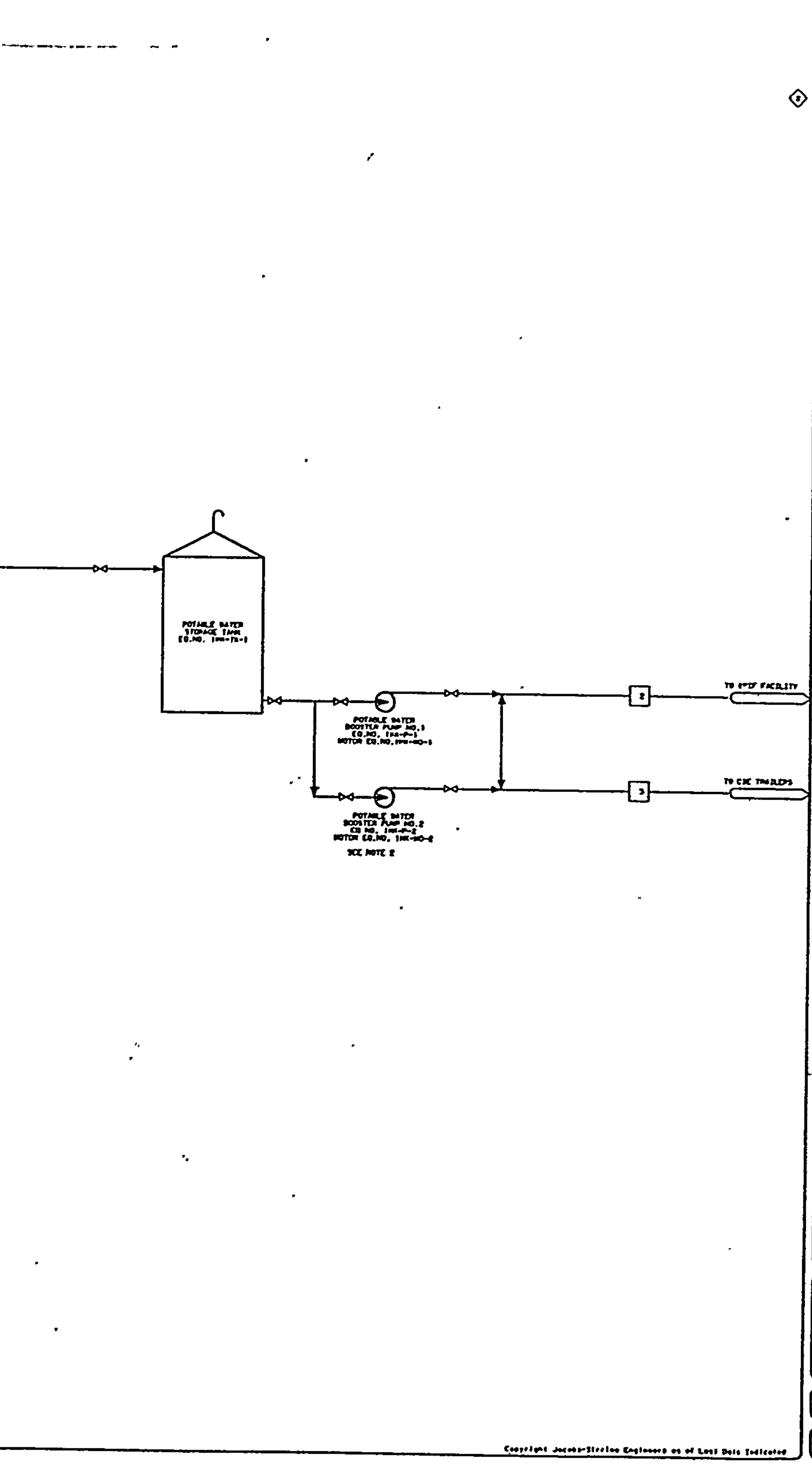
| (cut off) | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COMBINED COOLING WATER RETURN | | | COMBINED COOLING WATER SUPPLY | | | COOLING WATER TO AIR COMPRESSOR | | | COOLING WATER TO FUEL FEED AIR COOLER | | | COOLING WATER TO GASIFIER CONDENSER | | |
| Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| HOLD | HOLD | 100 | 150 | HOLD | 100 | 150 | 500 | 100 | 150 | 50 | 100 | 150 | HOLD | 100 | 150 |
| | | | | | | | | | | | | | | | |
| HOLD | HOLD | 30 | HOLD | HOLD | 30 | HOLD | 185 | 40 | 85 | 35 | 40 | 85 | HOLD | 40 | 85 |
| HOLD | HOLD | 30 | HOLD | HOLD | 30 | HOLD | HOLD | 40 | 85 | 10 | 40 | 85 | HOLD | 40 | 85 |

351




| LINE NUMBER | — | 1 | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | CW RETURN FROM GASIFIER COND | | | CW RETURN AIR COMPRESSOR | | | CW FROM FUEL FEED AIR COOLER | | | COOLING WATER FROM HVAC | | | COOLING WAT[ER] FROM FINES CO[NVEYOR] | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG |
| MAXIMUM DESIGN | HOLD | 100 | HOLD | 500 | 100 | 150 | 50 | 100 | 150 | HOLD | 100 | HOLD | HOLD | 100 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 30 | 105 | 185 | 30 | 105 | 35 | 30 | 105 | HOLD | 30 | HOLD | HOLD | 30 |
| MINIMUM OPERATING | HOLD | 30 | 105 | HOLD | 30 | 105 | 10 | 30 | 105 | HOLD | 30 | HOLD | HOLD | 30 |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION. | COOLING WATER TO HVAC | | | COOLING WATER TO FINES CONVEYOR | | | COOLING WATER FROM ASH CONVEYOR | | | COOLING WATER TO ASH CONVEYOR | | | | |
| UNITS | GPM | PSIG | Deg F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | | |
| MAXIMUM DESIGN | HOLD | 100 | HOLD | HOLD | 100 | HOLD | HOLD | 100 | HOLD | HOLD | 100 | HOLD | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 40 | 85 | HOLD | 40 | 85 | HOLD | 40 | HOLD | HOLD | 30 | HOLD | | |
| MINIMUM OPERATING | HOLD | 40 | 85 | HOLD | 40 | 85 | HOLD | 40 | HOLD | HOLD | 30 | HOLD | | |
| REVISION DATE | | | | | | | | | | | | | | |




NOTES

2. POTABLE WATER BOOSTER PUMPS OPERATE INTERMITTENT

| REV. NO. | CODE | DATE | DESCRIPTION |
|---|---|---|---|
| 2 | B | | REVISED PROCESS DESIGN ISSUED AS REV. 1 |
| 1 | A | | REVISED PER DEPARTMENT OF ENERGY COMMENTS ISSUED FOR DESIGN |
| 0 | A | | MOVED POTABLE WATER FROM DWG. |

ISSUE CODE: A PRELIMINARY; B DESIGN; D BIDS

SEAL

SIGNATURE

DATE

DATE 04-21-93

JOB NO. 25706

JE

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

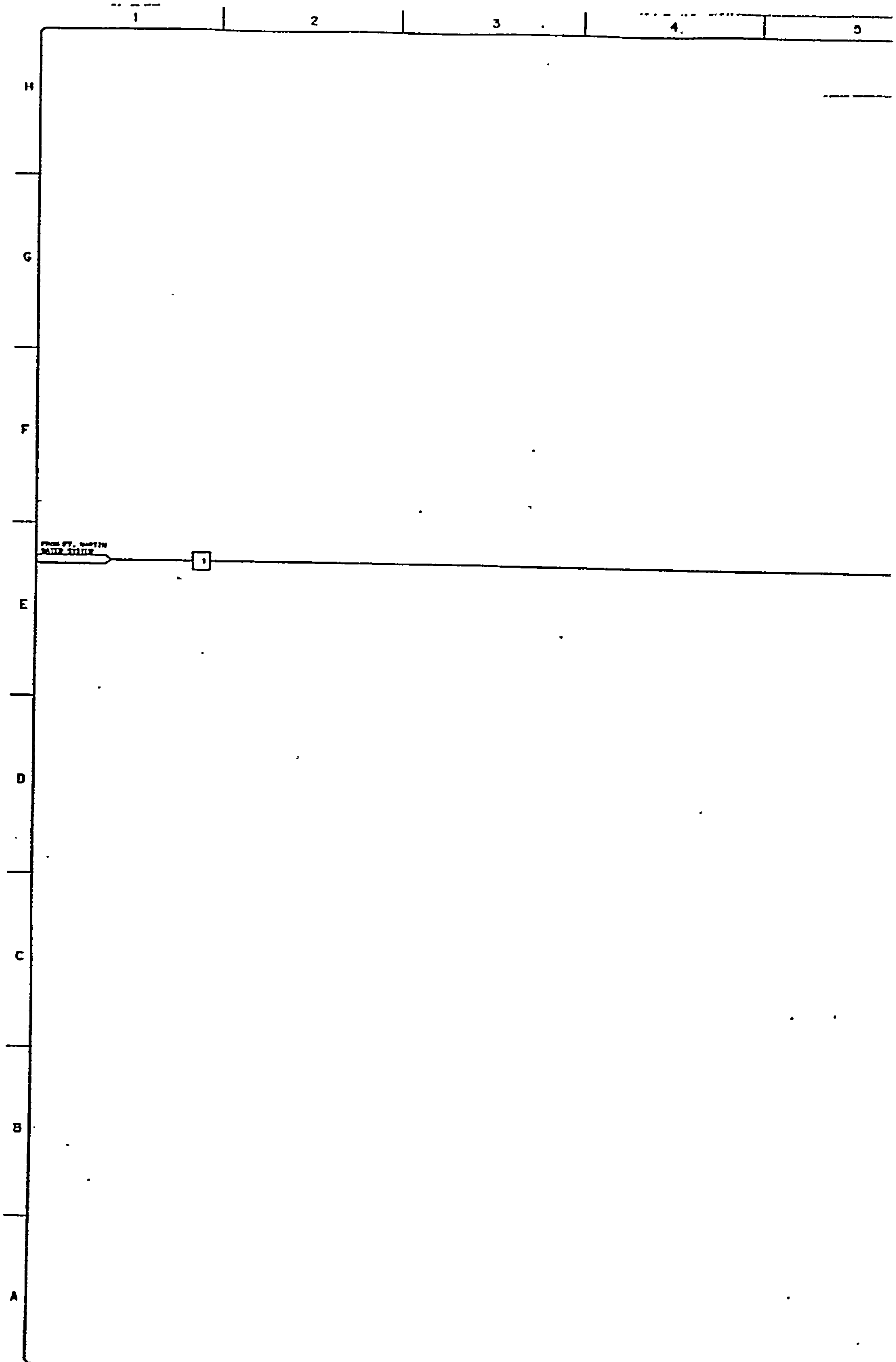
# FLOW DIAGRAM POTABLE WATER SYSTEM

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1KK-001

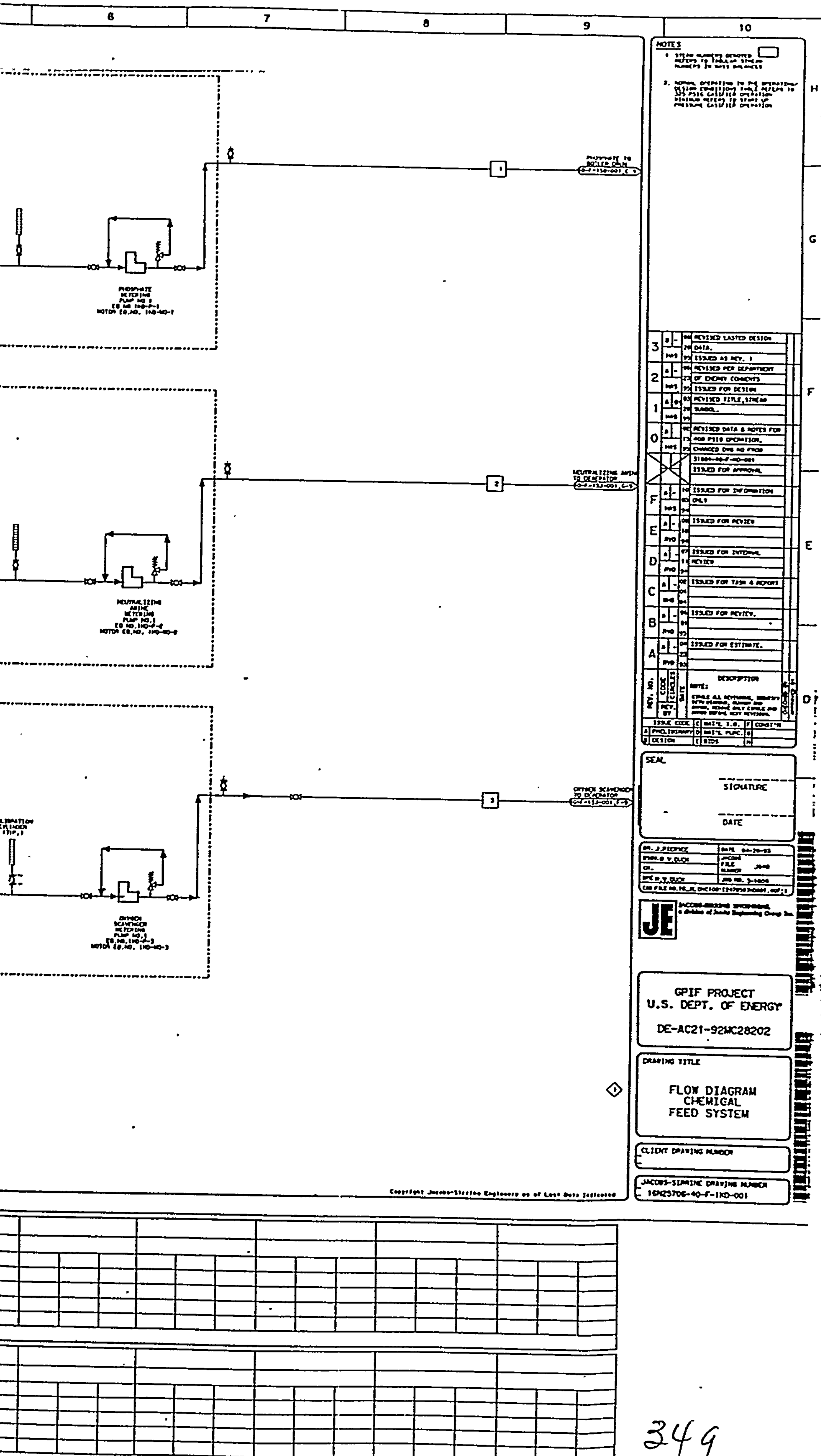


350



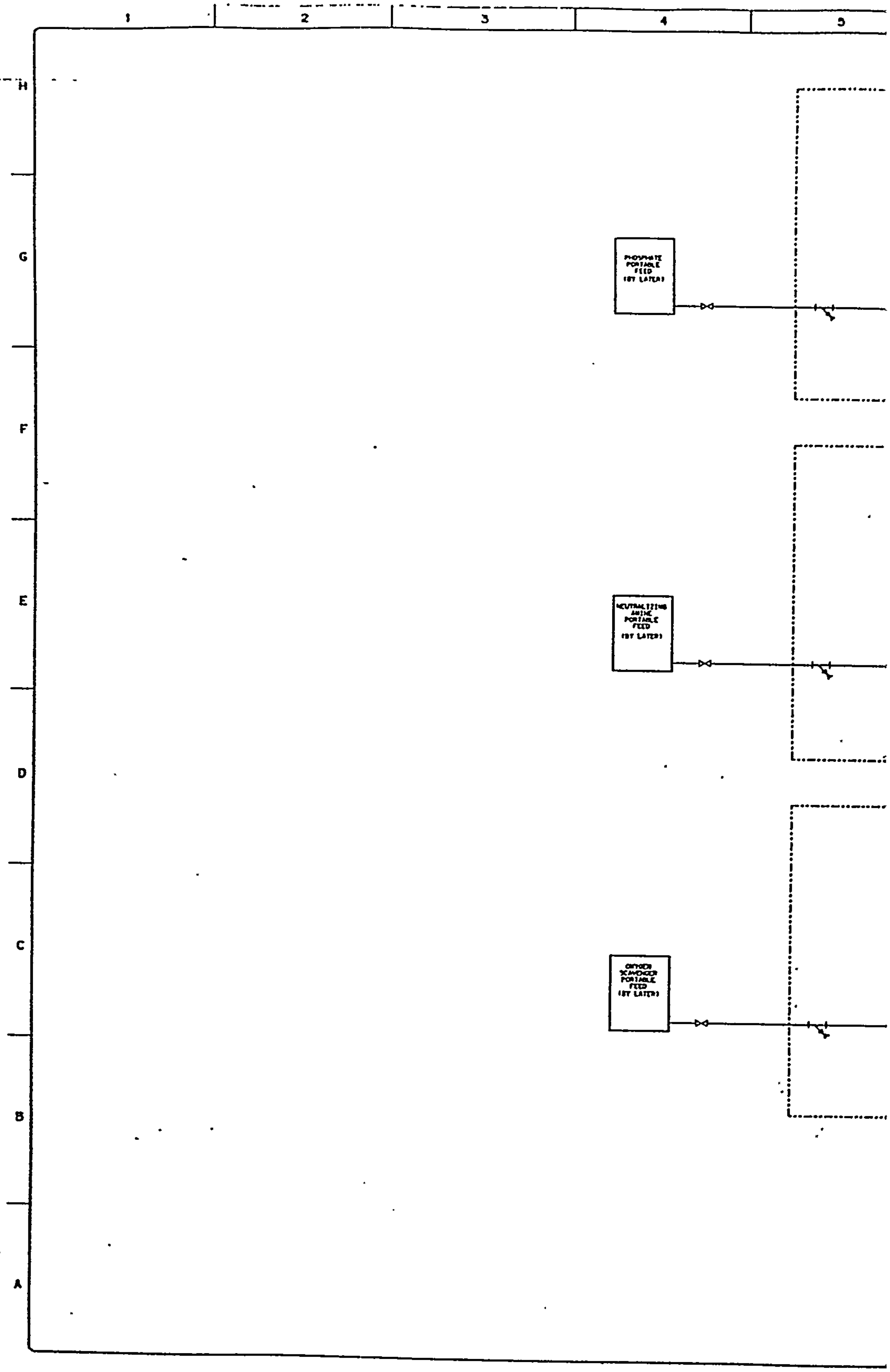

| LINE NUMBER | 1 | | | 2 | | | 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | POT. WATER FROM FT MARTIN | | | PW TO CPIF | | | PW TO TRAILERS | | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| MAXIMUM DESIGN | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | |
| NORMAL OPERATING | 1 | 150 | 55 | 65 | 30 | AMB | HOLD | 30 | AMB |
| MINIMUM OPERATING | 1 | 150 | 55 | 65 | 30 | AMB | HOLD | 30 | AMB |
| REVISION DATE | | | | | | | | | |

| LINE NUMBER | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | |
| UNITS | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | |
| REVISION DATE | | | | | | | | | |



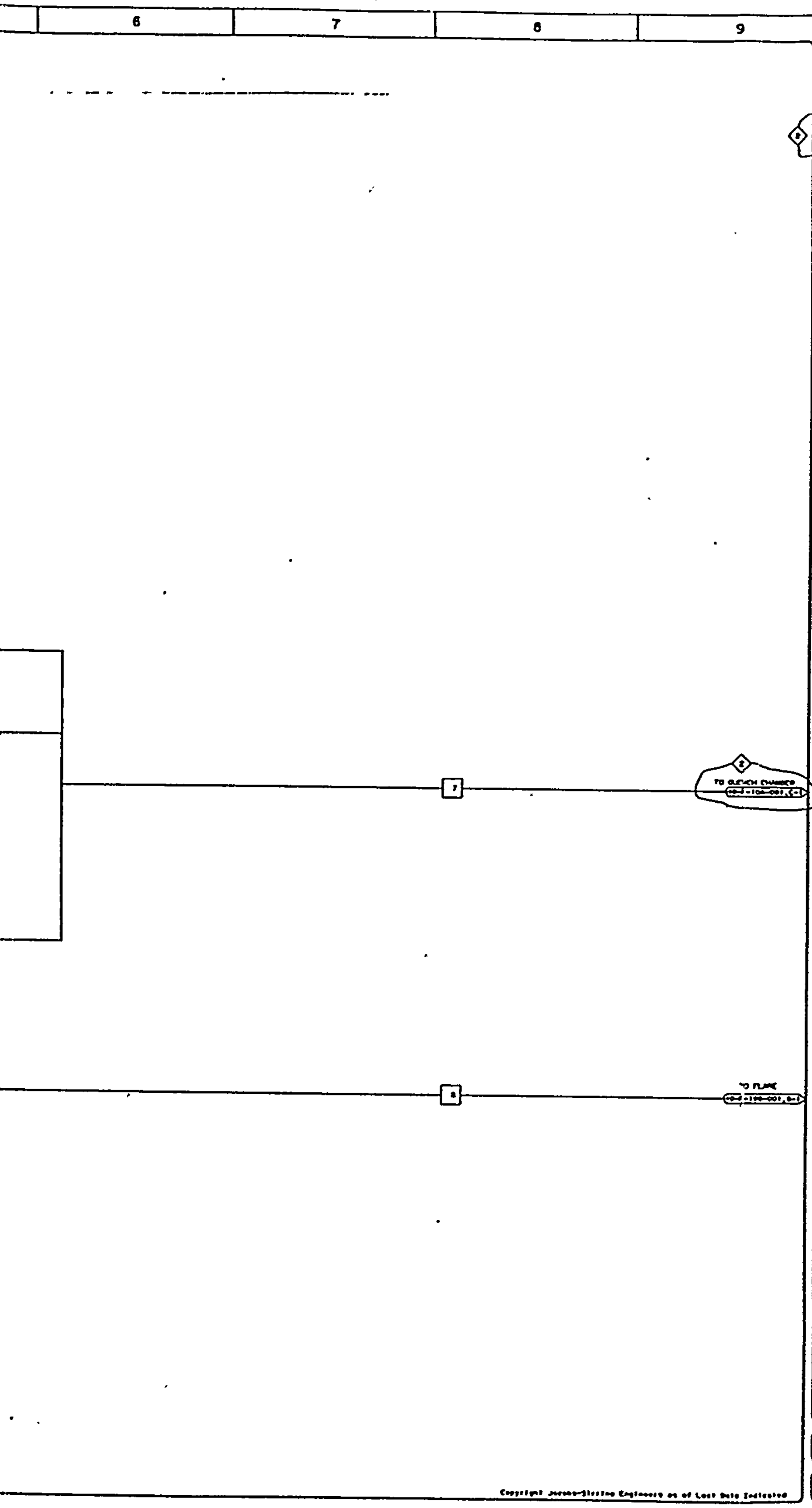
6
7
8
9
10
NOTES
SIGNATURE
DATE
SEAL
GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202
DRAWING TITLE
FLOW DIAGRAM
CHEMICAL
FEED SYSTEM
CLIENT DRAWING NUMBER
JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1XD-001


349




| LINE NUMBER | 1 | | | 2 | | | 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | PHOSP. | | | NEUT. AMINE | | | OXYG. SCVNG. | | |
| UNITS | GPH | PSIG | Deg.F | GPH | PSIG | Deg.F | GPH | PSIG | Deg.F |
| MAXIMUM DESIGN | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | |
| NORMAL OPERATING | LATER | 425 | 75 | LATER | 5 | 75 | LATER | 5 | 75 |
| MINIMUM OPERATING | LATER | 425 | 60 | LATER | 5 | 60 | LATER | 5 | 60 |
| REVISION DATE | | | | | | | | | |

| LINE NUMBER | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | |
| UNITS | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | |
| REVISION DATE | | | | | | | | | |




NOTES

1. STREAM NUMBERS DENOTED REFERS TO TABULAR STREAM NUMBERS IN MASS BALANCES.
2. [illegible]
3. [illegible]

| REV. NO. | CODE | REV. BY | DATE | DESCRIPTION |
|---|---|---|---|---|
| 2 | B | MHS | 95 | ADDED NOTE 3, REVISED OFFPAGE CONNECTORS, ADDED INSTRUMENTS |
| | | | | ISSUED AS REV. 1 |
| 1 | A | MHS | 95 | REVISED PER DEPARTMENT OF ENERGY COMMENTS ISSUED FOR DESIGN |
| 0 | A | MHS | 95 | REVISED PER 5/19/95 SCOPE REVIEW, ISSUED FOR COMMENTS |

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND APPROVE BEFORE NEXT REVISION.

| ISSUE CODE | | | | | |
|---|---|---|---|---|---|
| A | PRELIMINARY | D | MAT'L PURC. | G | |
| B | DESIGN | E | BIDS | H | |
| C | MAT'L T.O. | F | CONST'N | | |

SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
INCINERATOR

CLIENT DRAWING NUMBER

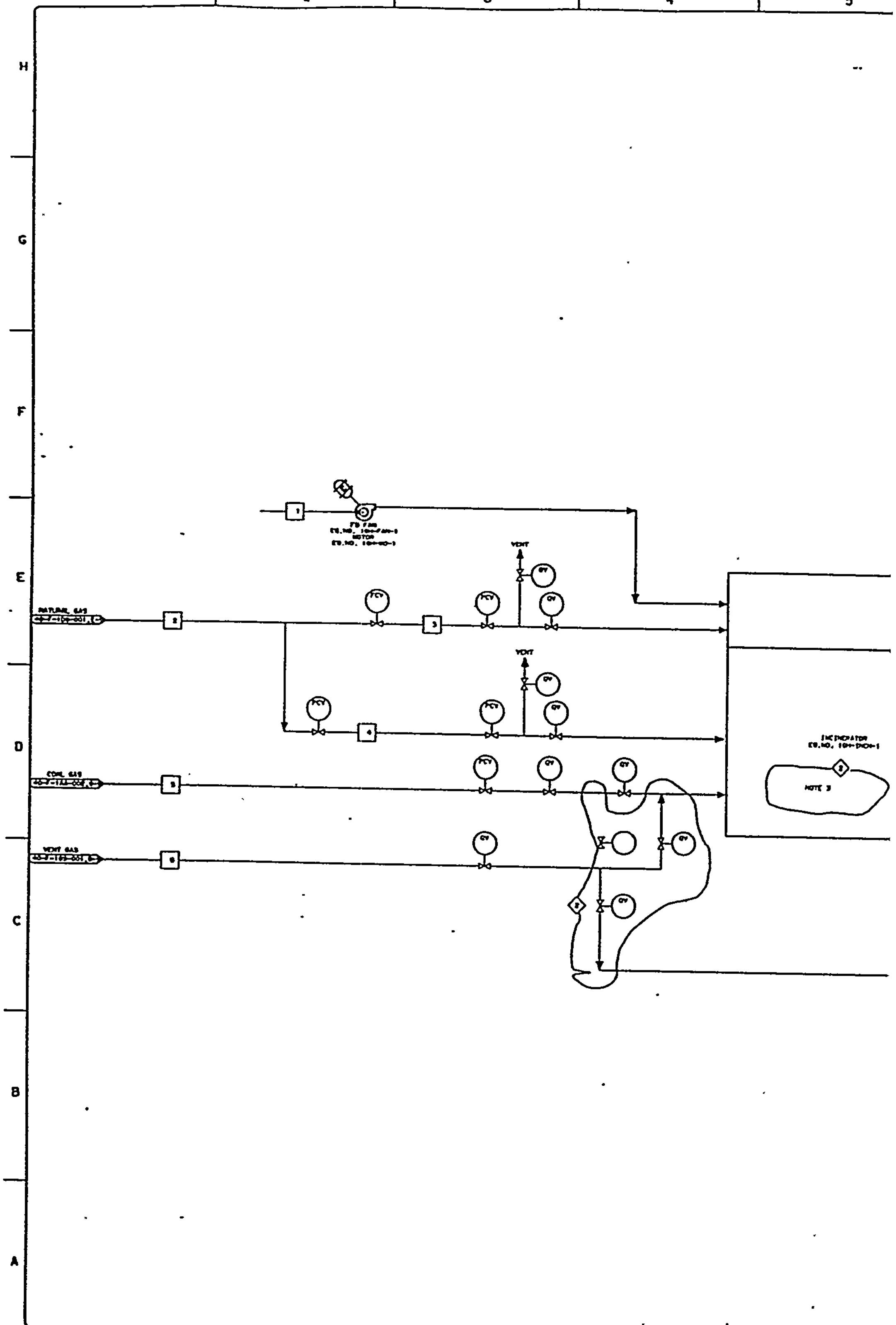
JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-104-001



| 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|
| VENT GAS | | | FLUE GAS | | | COAL GAS BLEED | | |
| PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| (SEE MASS BALANCE) | | | (BY VENDOR) | | | (SEE MASS BALANCE) | | |
| (SEE MASS BALANCE) | | | (BY VENDOR) | | | (SEE MASS BALANCE) | | |

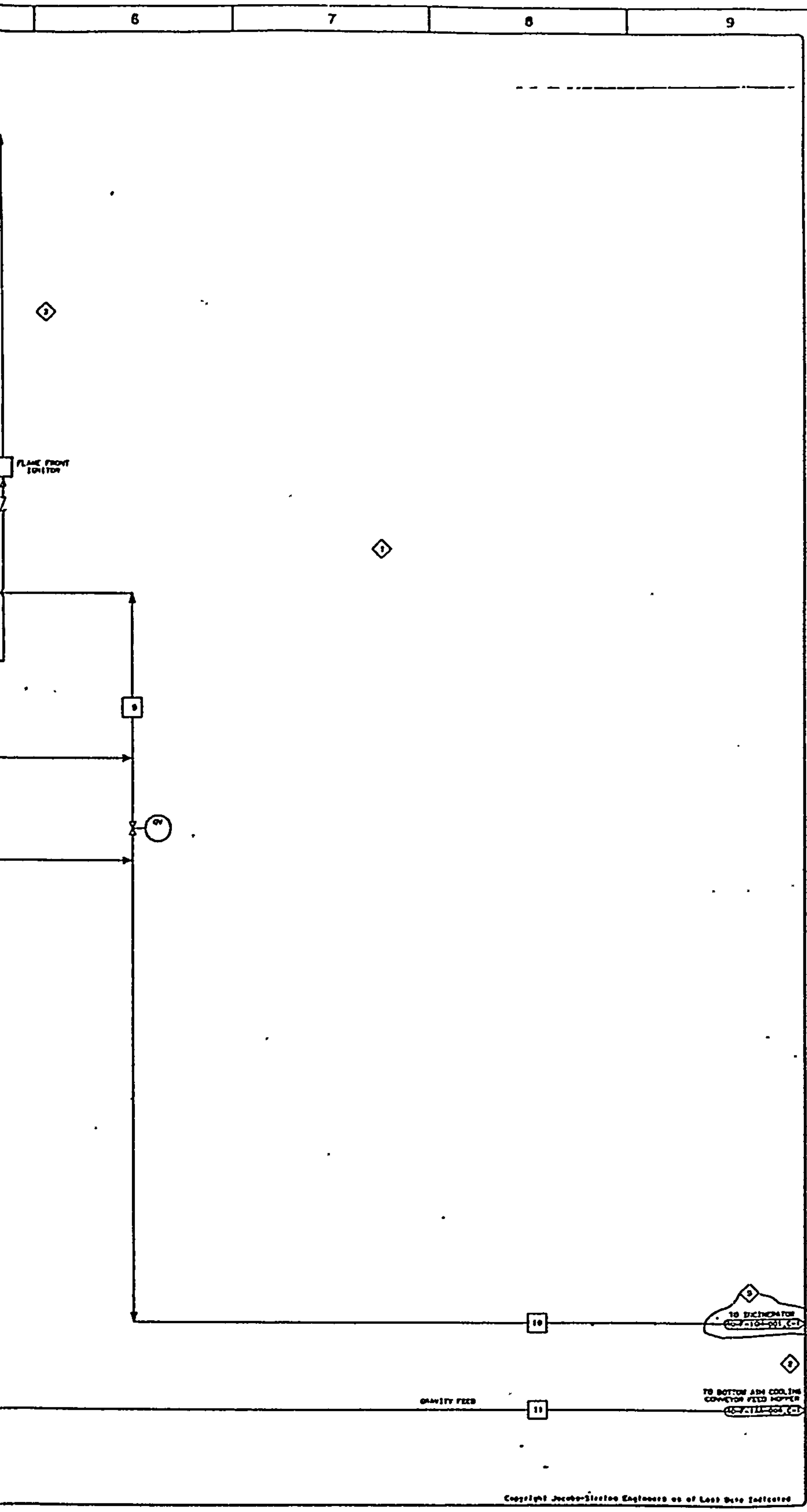
348

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | COMB. AIR | | | NATURAL GAS | | | ASSIST GAS | | | PILOT GAS | | | COAL GAS | | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | D |
| MAXIMUM DESIGN | | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | | |
| NORMAL OPERATING | (BY | VENDOR) | | (BY | VENDOR) | | (BY | VENDOR) | | (BY | VENDOR) | | (SEE | MASS BAL | A |
| MINIMUM OPERATING | (BY | VENDOR) | | (BY | VENDOR) | | (BY | VENDOR) | | (BY | VENDOR) | | (SEE | MASS BAL | A |
| REVISION DATE | | | | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | | |




| ...ED | 6 | | | 7 | | | 8 | | | ◇ 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GRATE LH | | | CYCLONE LH | | | NITROGEN | | | VENT TO FLARE | | | VENT TO INCINERATOR | | |
| Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| 1100 | HOLD | 420 | 750 | HOLD | 420 | 1100 | HOLD | 150 | 100 | HOLD | 150 | 750 | HOLD | 150 | 750 |
| | | | | | | | | | | | | | | | |
| 1100 | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | 2 | 50 | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD |
| 1100 | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | 2 | 50 | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD |

SEAL

SIGNATURE

DATE

DATE 04-21-93

JACOBS-SIRRINE ENGINEERING

a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

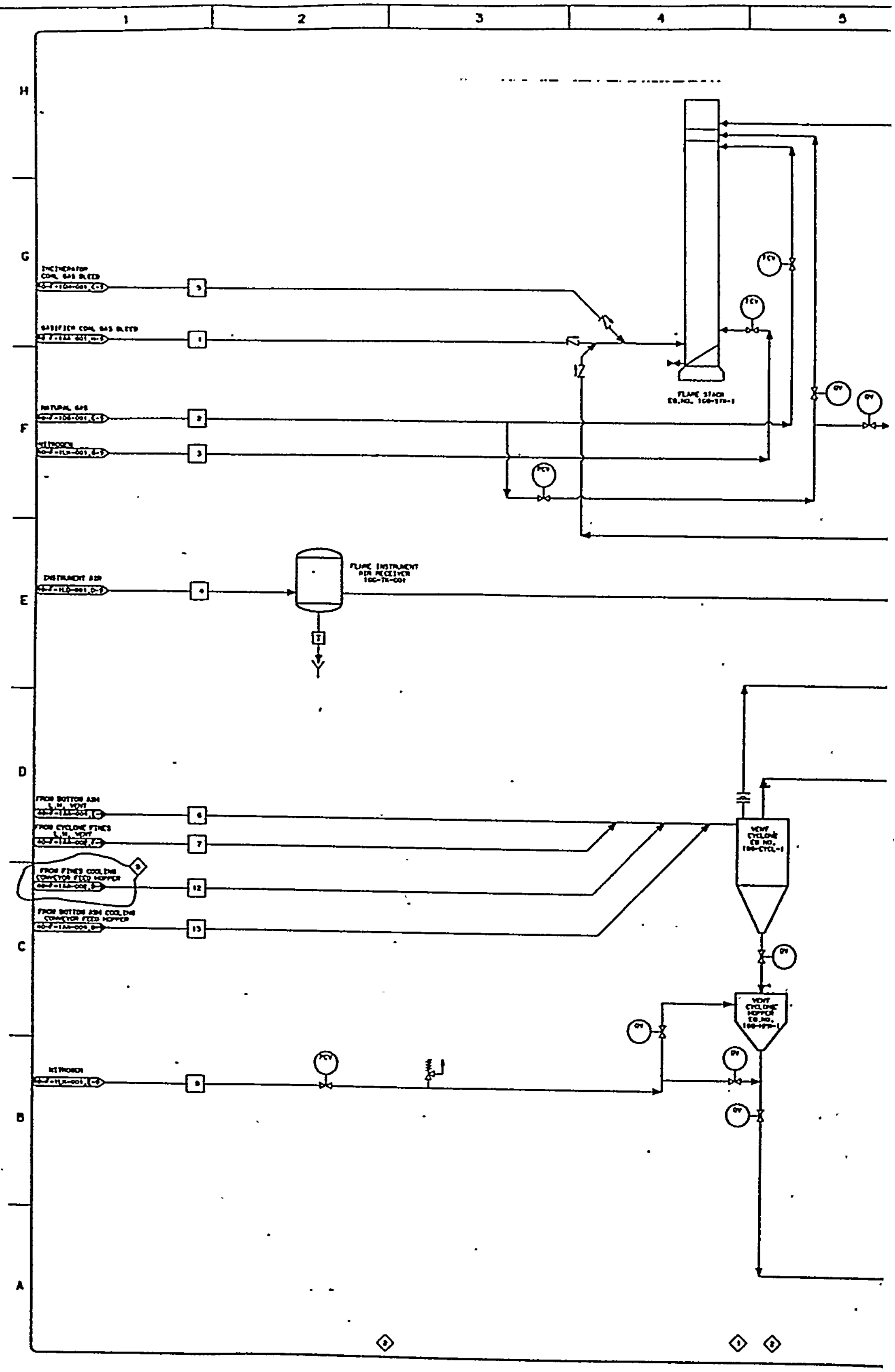
DRAWING TITLE

FLOW DIAGRAM
PROCESS VENT
DISTRIBUTION

CLIENT DRAWING NUMBER

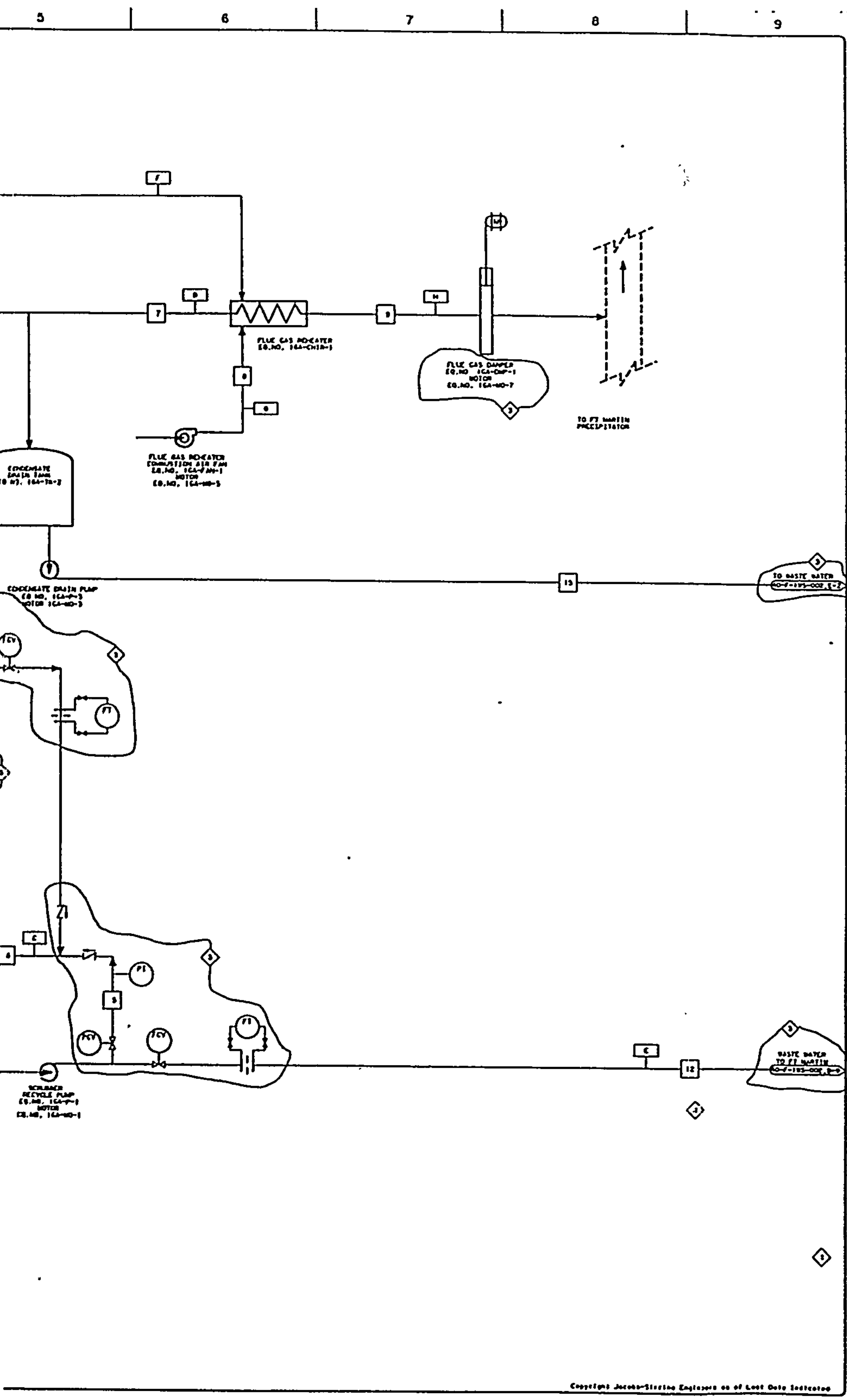
JACOBS-SIRRINE DRAWING NUMBER
16W25706-40-F-100-001

347




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | COAL GAS | | | NATURAL GAS | | | NITROGEN | | | INSTRUMENT AIR | | | COAL GAS BL | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | SCFM | PSIG | Deg.F | PPH | PSIG |
| MAXIMUM DESIGN | HOLD | 420 | 1150 | HOLD | 60 | | | 150 | 100 | | 150 | 125 | HOLD | HOLD |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | 0 | 40 | 60 | LATER | 30 | 50 | | 100 | 125 | HOLD | HOLD |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | 0 | 30 | 40 | LATER | 20 | 0 | | 100 | 125 | HOLD | HOLD |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | VENT ASH | | | | | | | | | | | | | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | | HOLD | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | | |



Copyright Jacobs-Sirrine Engineers as of Last Date Indicated

**NOTES**

1. STREAM NUMBERS DENOTED [box] REFERS TO TABULAR STREAM NUMBERS IN MASS BALANCES
2. NORMAL OPERATING IN THE OPERATING/DESIGN CONDITIONS TABLE REFERS TO 325 PSIG GASIFIER OPERATION. MINIMUM REFERS TO START UP PRESSURE GASIFIER OPERATION.

| REV. NO. | CODE | DATE | DESCRIPTION |
|---|---|---|---|
| 3 | | | CHANGED EQ NO. OF ID FAN DAMPER, ADDED INSTRUMENTS ISSUED AS REV. 3 |
| 2 | | | REVISED PER DEPARTMENT OF ENERGY COMMENTS. ISSUED FOR DESIGN |
| 1 | | | REVISED TITLE, STREAM SYMBOL, NO'S & EQ. NAMES ISSUED FOR APPROVAL |
| 0 | | | ISSUED FOR APPROVAL |

SEAL

SIGNATURE

DATE

JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
FLUE GAS
DESULFURIZATION
SYSTEM

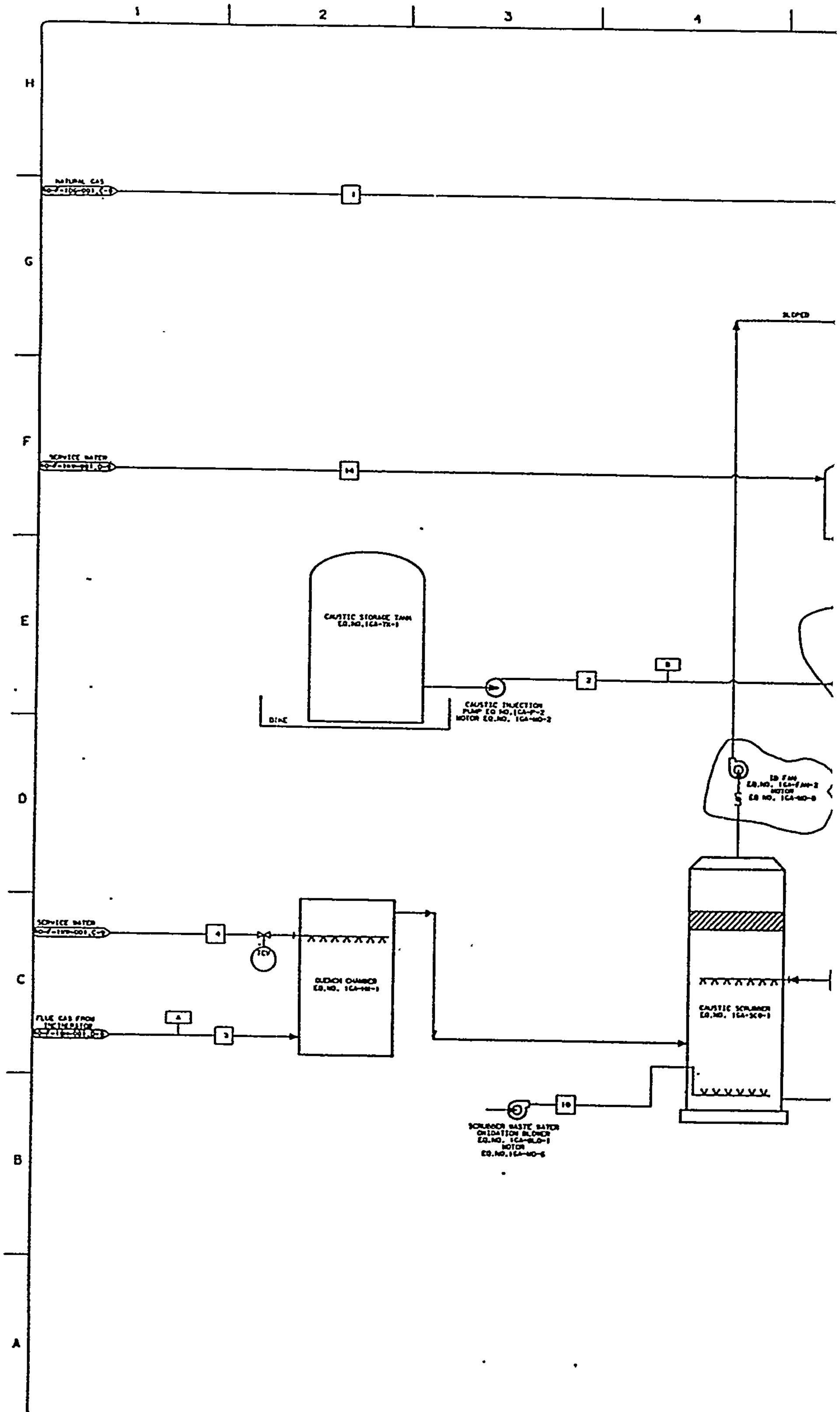
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1GA-001

| 5 | | | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCRUBBER WATER OUTLET | | | SCRUBBER RECIRCULATION | | | SCRUBBER FLUE GAS OUTLET | | | COMBUSTION AIR | | | FLUE GAS REHEATER OUTLET | | | OXIDATION BLOWER FLOW | | |
| GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 30.2 | 5 | 200 | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |

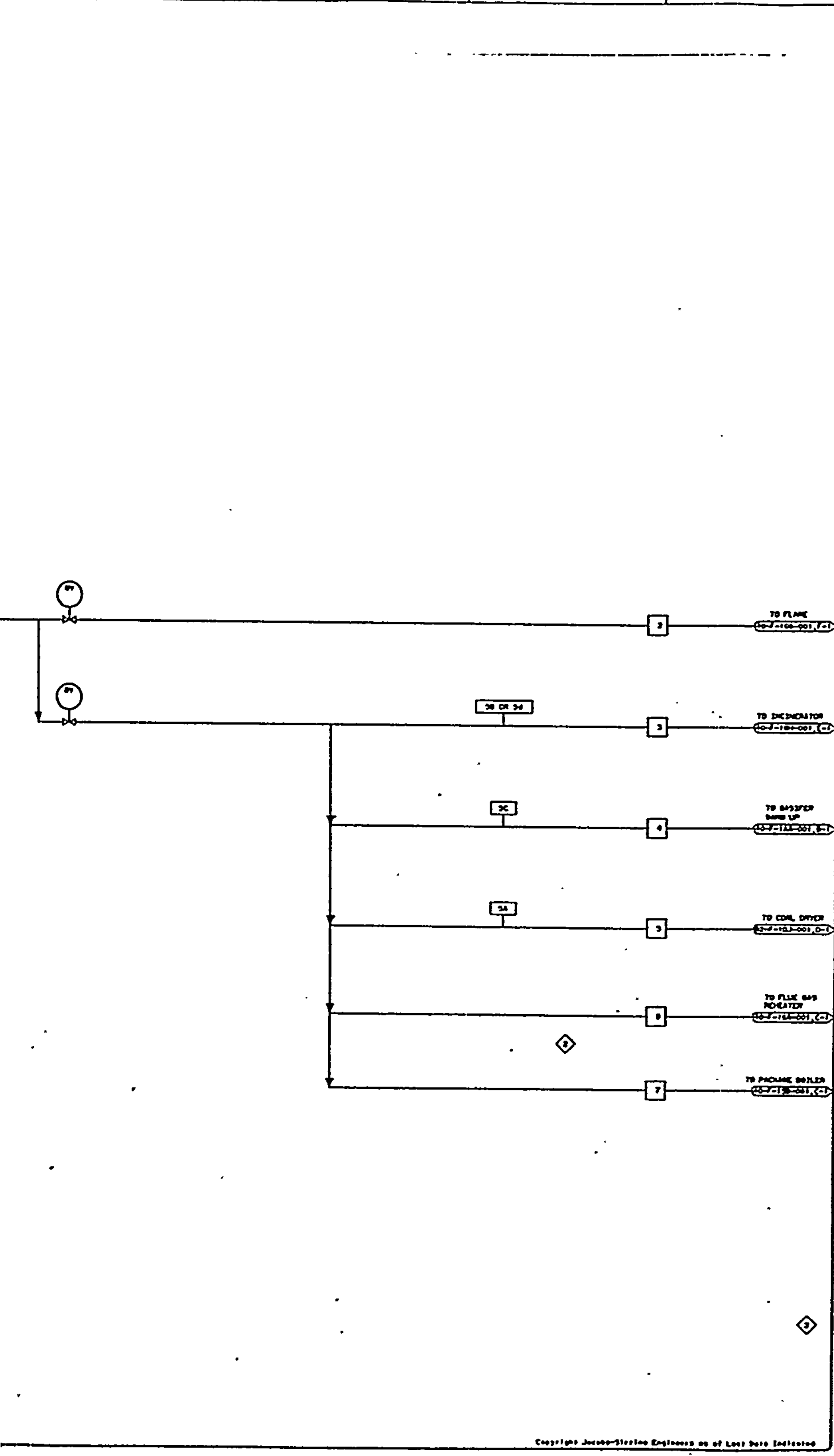
| 15 | | |
|---|---|---|
| CONDENSATE | | |
| GPM | PSIG | Deg.F |
| | | |
| | | |
| (SEE | MASS BAL | ANCE) |
| (SEE | MASS BAL | ANCE) |

346




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | NATURAL GAS | | | CAUSTIC | | | HRSG FLUE GAS | | | SERVICE WATER MAKEUP | | |
| UNITS | SCFM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F |
| MAXIMUM DESIGN | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | 1.5 | 2 | 60 | (SEE | MASS BAL | ANCE) | 31 | 80 | 60 |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | | | | (SEE | MASS BAL | ANCE) | | | |
| REVISION DATE | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | WASTE WATER | | | WASTE WATER | | | SERVICE WATER | | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| MAXIMUM DESIGN | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| MINIMUM OPERATING | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| REVISION DATE | | | | | | | | | | | | |




| 5 | | 6 | | | 7 | | |
|---|---|---|---|---|---|---|---|
| …AL GAS …L DRYER | | N.G. TO FLUE GAS REHEATER | | | NATURE GAS TO PACKAGE BOILER | | |
| PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F |
| 60 | 100 | | 60 | | | 60 | 100 |
| | | | | | | | |
| …SS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| …SS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |

SEAL

SIGNATURE

DATE

GPIF PROJECT
U.S. DEPT. OF ENERGY

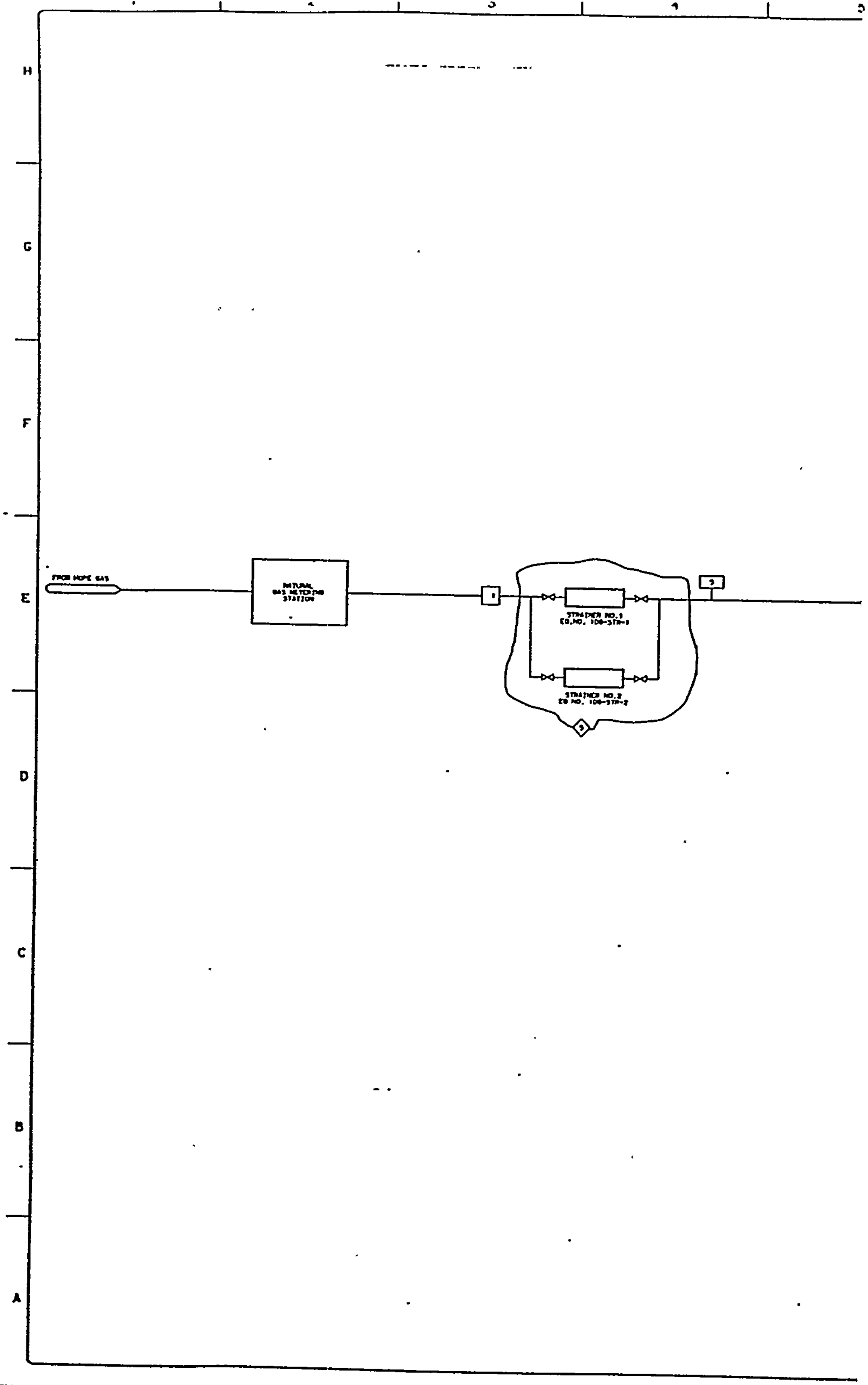
DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
NATURAL GAS
DISTRIBUTION

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16M25706-40-F-1DG-001

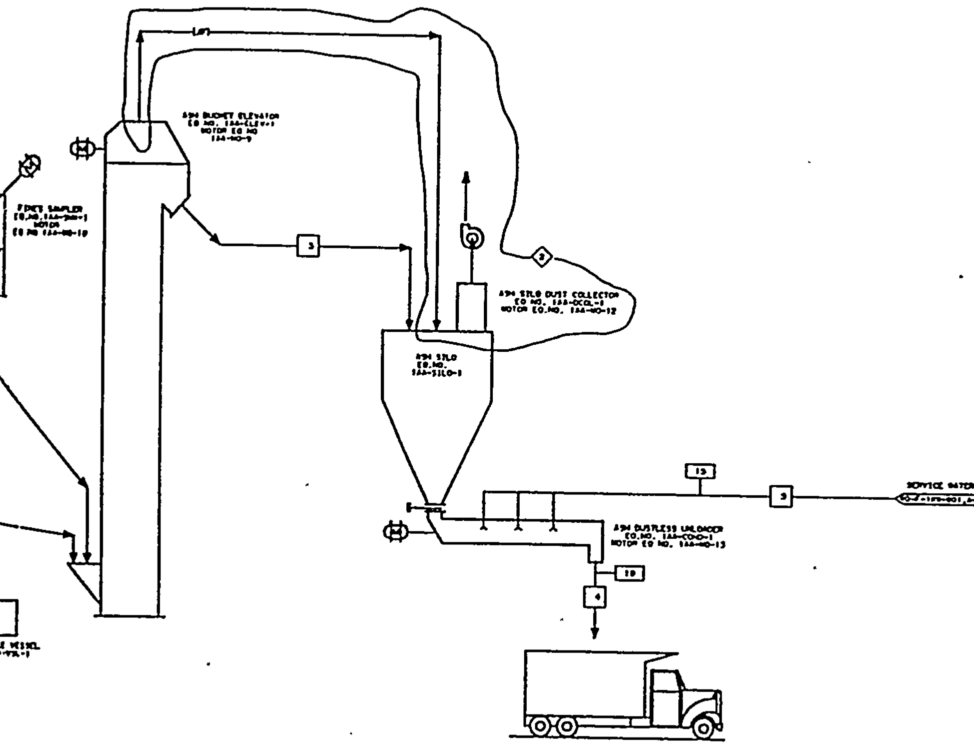



| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | NATURAL GAS SUPPLY | | | NATURAL GAS TO FLARE | | | NATURAL GAS TO INCINERATOR | | | NATURAL GAS TO GASIFIER | | | NATU TO CO | |
| UNITS | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | PSIG | Deg°F | PPH | |
| MAXIMUM DESIGN | 900 | 60 | 100 | | 60 | 100 | 420 | 60 | 100 | 100 | 60 | 100 | 170 | |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BALANCE) | | 0 | 30 | 60 | (SEE | MASS BALANCE) | | (SEE | MASS BALANCE) | | (SEE | MA |
| MINIMUM OPERATING | (SEE | MASS BALANCE) | | 0 | 20 | 40 | (SEE | MASS BALANCE) | | (SEE | MASS BALANCE) | | (SEE | MA |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | | |

5 6 7 8 9 10

NOTES




| REV. NO. | CODE | DATE | DESCRIPTION |
|---|---|---|---|
| 2 | B / MHS | 96 | UPDATED EQUIPMENT NAMES. ISSUED AS REV. 1 |
| 1 | A / MHS | 95 | REVISED PER DEPARTMENT OF ENERGY COMMENTS. ISSUED FOR DESIGN |
| 0 | A / MHS | 95 | REVISED PER 5/15/95 SCOPE REVISED, ISSUED FOR COMMENTS |

ISSUE CODE: A PRELIMINARY, B DESIGN, C MAT'L T.O., D MAT'L PURC, E BIDS, F CONST'N

SEAL

SIGNATURE

DATE

DATE 5-24-95

JOB NO. 16N25706

JACOBS-SIRRINE ENGINEERING,
a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

FLOW DIAGRAM
SOLID WASTE DISPOSAL
SYSTEM

SUPERCEDES DRAWING
16N25706-40-F-1WS-001

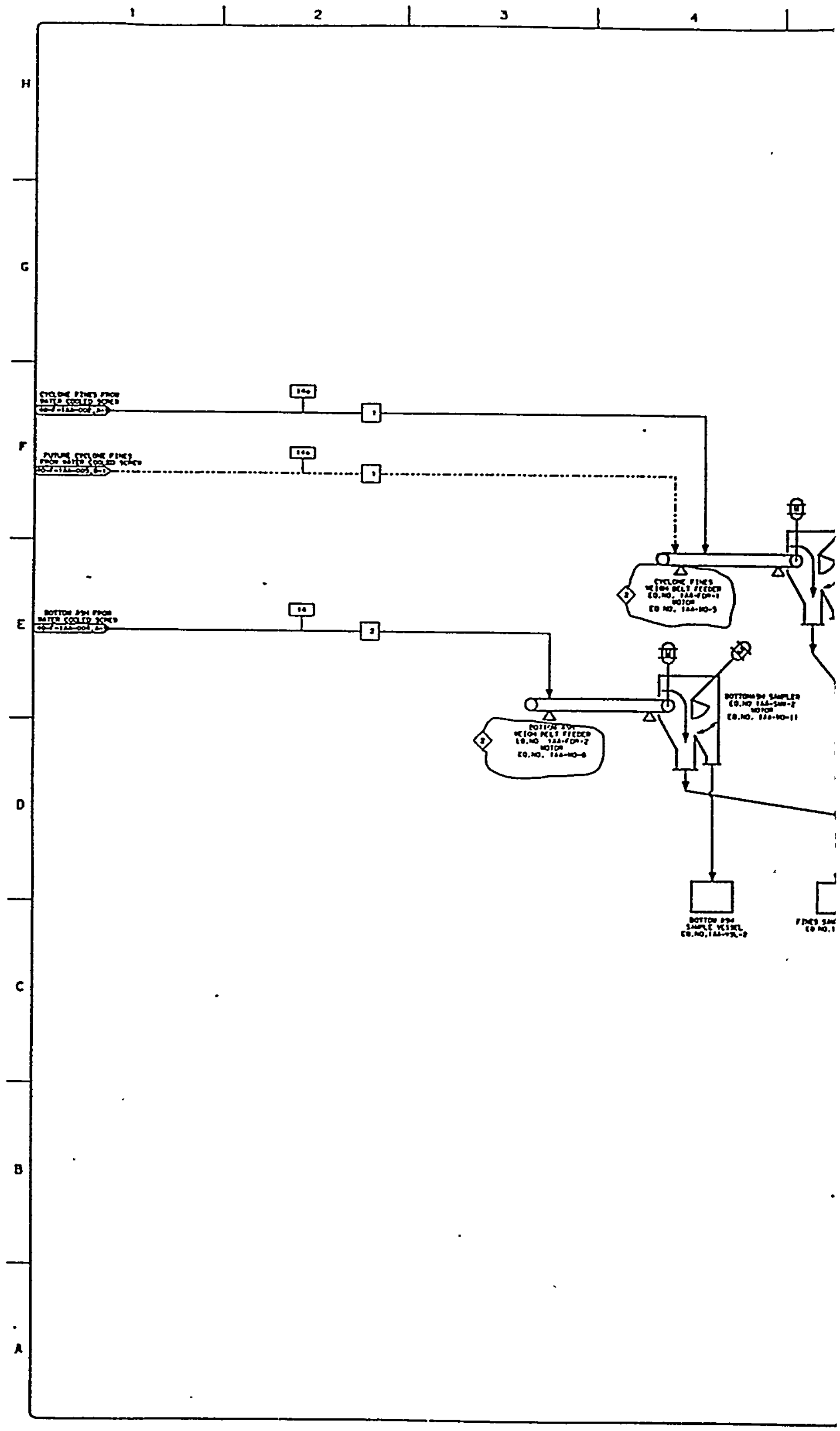
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1AA-005



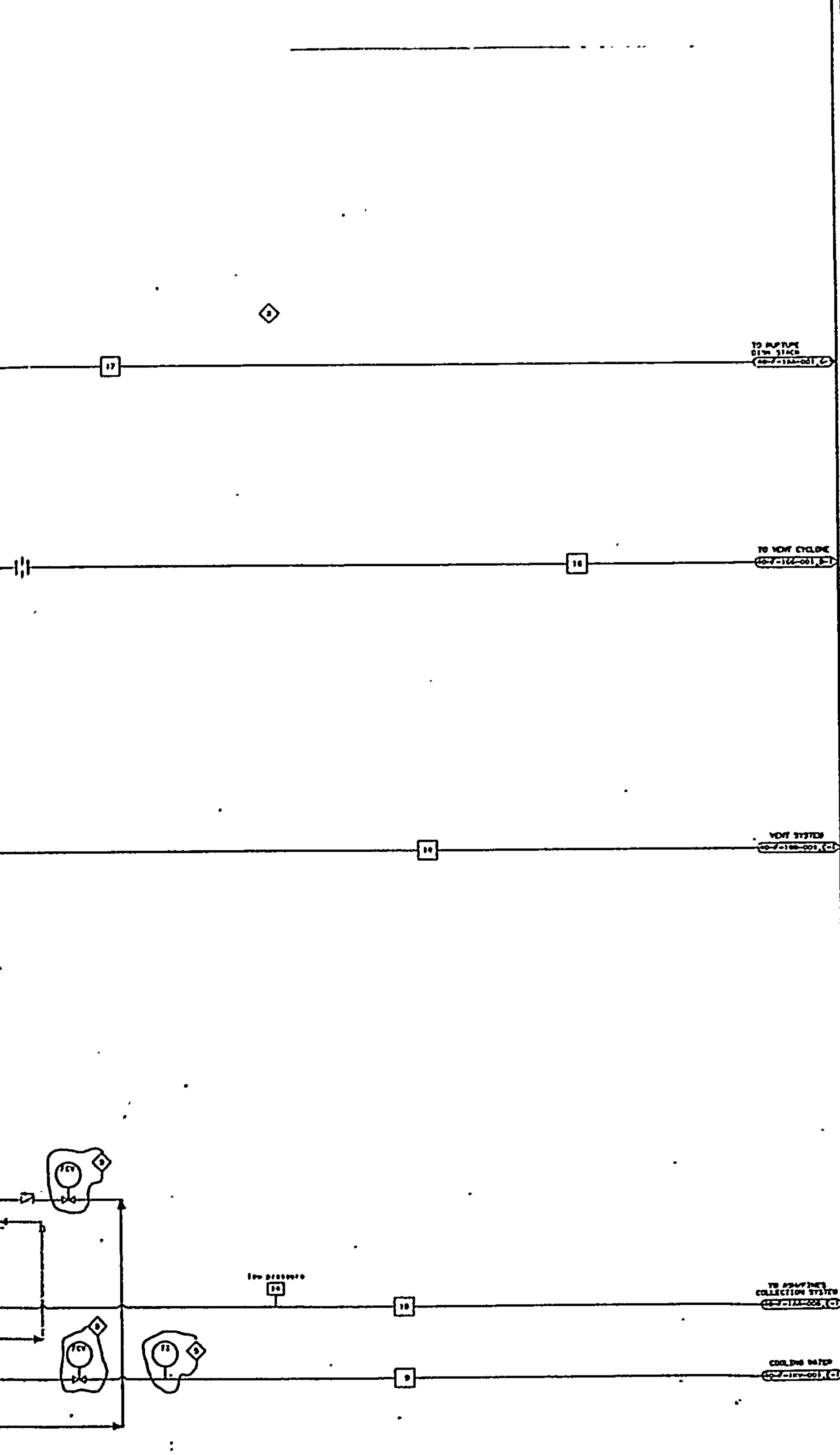
| 5 | | |
|---|---|---|
| SERVICE WATER | | |
| PSIG | Deg.F | |
| HOLD | 75 | |
| (SEE MASS BALANCE) | | |
| (SEE MASS BALANCE) | | |

344




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | CYCLONE FINES | | | BOTTOM ASH | | | BUCKET ELEVATOR DISCHARGE | | | CONDITIONED ASH TO FT MARTIN | | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| MAXIMUM DESIGN | 500 | 2 | 200 | 1000 | 10 | 750 | 1500 | ATM | HOLD | 1500 | ATM | HOLD |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) | HOLD | ATM | HOLD | (SEE | MASS BA | ANCE) |
| MINIMUM OPERATING | (SEE | MASS BA | ANCE) | (SEE | MASS BA | ANCE) | HOLD | ATM | HOLD | (SEE | MASS BA | ANCE) |
| REVISION DATE | | | | | | | | | | | | |

| LINE NUMBER | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | | | | | | | | | | | | |
| UNITS | | | | | | | | | | | | |
| MAXIMUM DESIGN | | | | | | | | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | |
| NORMAL OPERATING | | | | | | | | | | | | |
| MINIMUM OPERATING | | | | | | | | | | | | |
| REVISION DATE | | | | | | | | | | | | |






SEAL

SIGNATURE

DATE

DR. DATE 04-19-93

DSGN. H. B. STOKES

DPE H. B. STOKES

JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

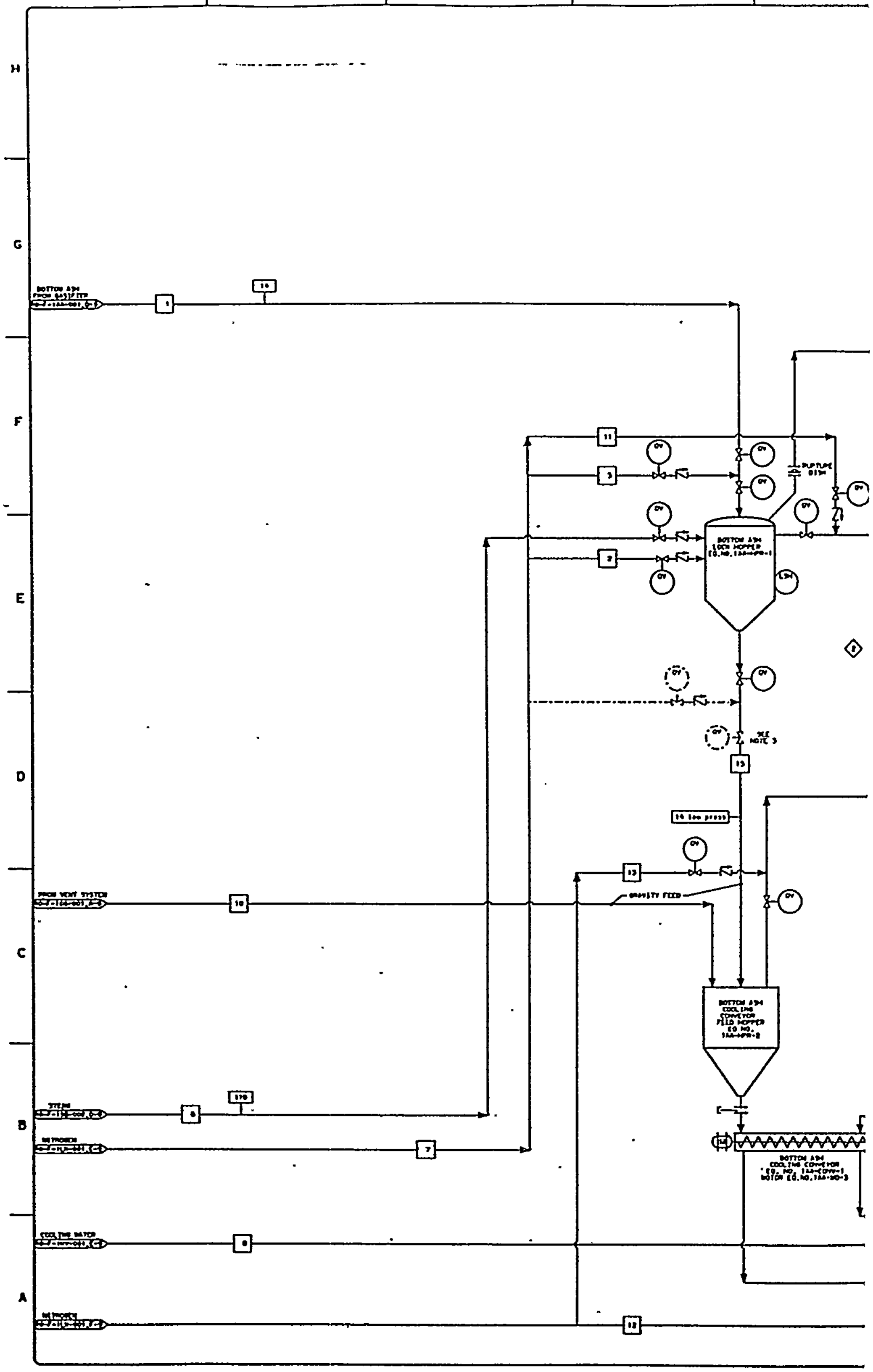
FLOW DIAGRAM
GASIFIER
ASH HANDLING

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16M25706-40-F-1AA-004

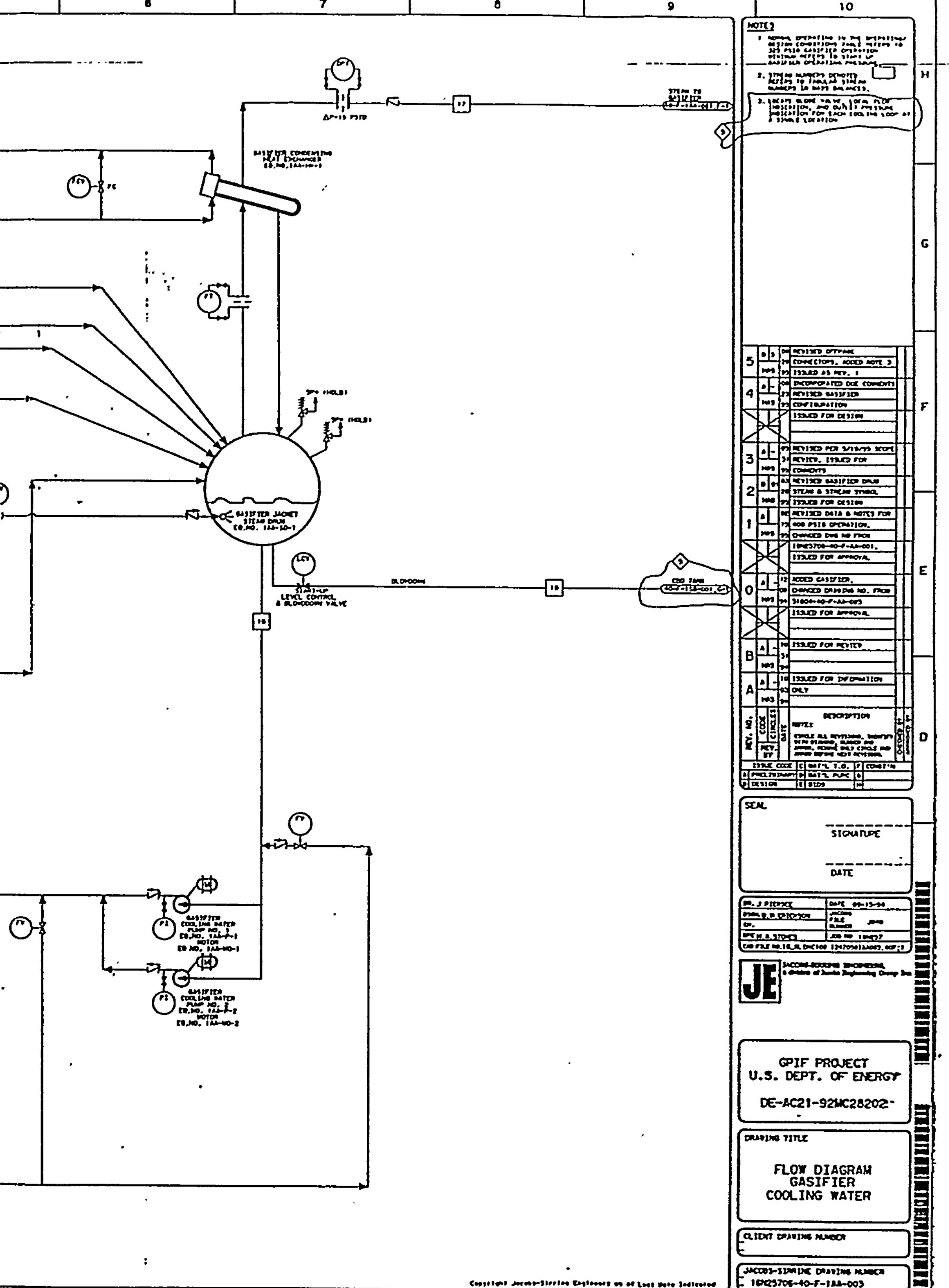
| 5 | | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | STEAM | | | NITROGEN | | | WATER | | | WATER | | | | | |
| | | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F |
| | | HOLD | 374 | 560 | HOLD | 374 | 465 | | HOLD | | | HOLD | | | | |
| | | | | | | | | | | | | | | | | |
| | | (SEE | MASS BAL | ANCE) | | (SEE PO8) | | | | | | | | | | |
| | | (SEE | MASS BAL | ANCE) | | (SEE PO8) | | | 0 | | | | | | | |

| 15 | | 16 | | | 17 | | | 18 | | | 19 | | | 20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH | | VENT | | | SAFETY VENT | | | ASH | | | | | | | | |
| SIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | | | | | | |
| 10 | 750 | HOLD | 420 | 750 | HOLD | 420 | 750 | 1000 | 10 | 750 | | | | | | |
| | | | | 750 | | | | | | | | | | | | |
| SS BAL | ANCE) | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | | | | | | | | | |
| SS BAL | ANCE) | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | | | | | | | | | |




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | ASH | | | NITROGEN | | | NITROGEN | | | | | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | | | |
| MAXIMUM DESIGN | 1000 | 420 | 750 | | 374 | 465 | | 374 | 465 | | | |
| MAXIMUM OPERATING | 1900 | 420 | 750 | | | | | | | | | |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | | SEE PDB | | | (SEE PDB | | | | |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | | SEE PDB | | | (SEE PDB | | | | |
| REVISION DATE | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | NITROGEN | | | NITROGEN | | | NITROGEN | | | VENT | | | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH |
| MAXIMUM DESIGN | HOLD | 374 | 465 | | 10 | 100 | HOLD | 10 | 100 | HOLD | 10 | 750 | 1000 |
| MAXIMUM OPERATING | | | | | | | | | | | | | |
| NORMAL OPERATING | ( | SEE PDB) | | | SEE PDB | | | SEE PDB | | HOLD | 2 | HOLD | (SEE |
| MINIMUM OPERATING | ( | SEE PDB) | | | SEE PDB | | | SEE PDB | | HOLD | 2 | HOLD | (SEE |
| REVISION DATE | | | | | | | | | | | | | |



SEAL

SIGNATURE

DATE

GPIF PROJECT
U.S. DEPT. OF ENERGY

DE-AC21-92MC28202

DRAWING TITLE

**FLOW DIAGRAM**
**GASIFIER**
**COOLING WATER**

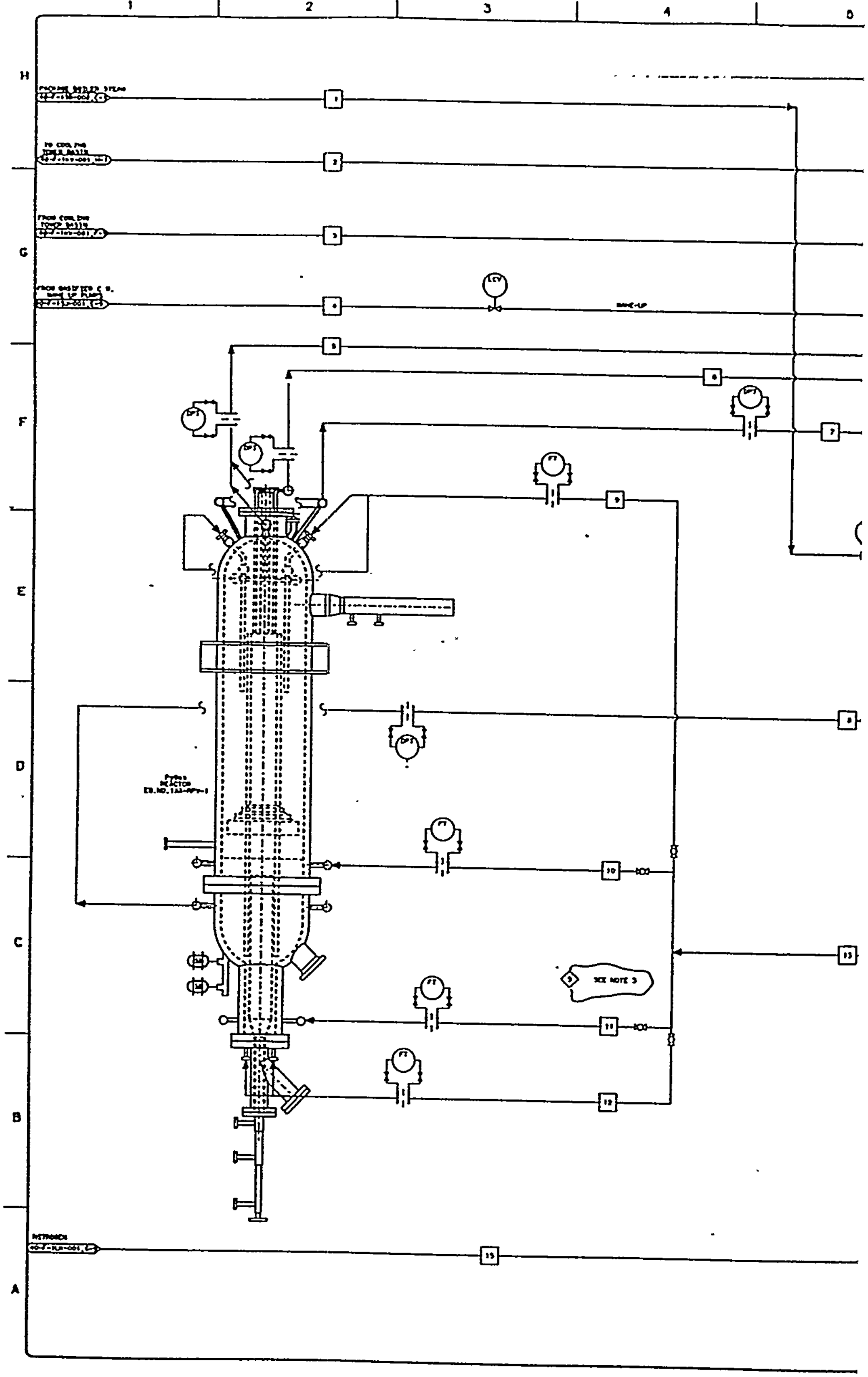
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16M25706-40-F-1AA-003

Copyright Jacobs-Sirrine Engineers as of Last Date Indicated

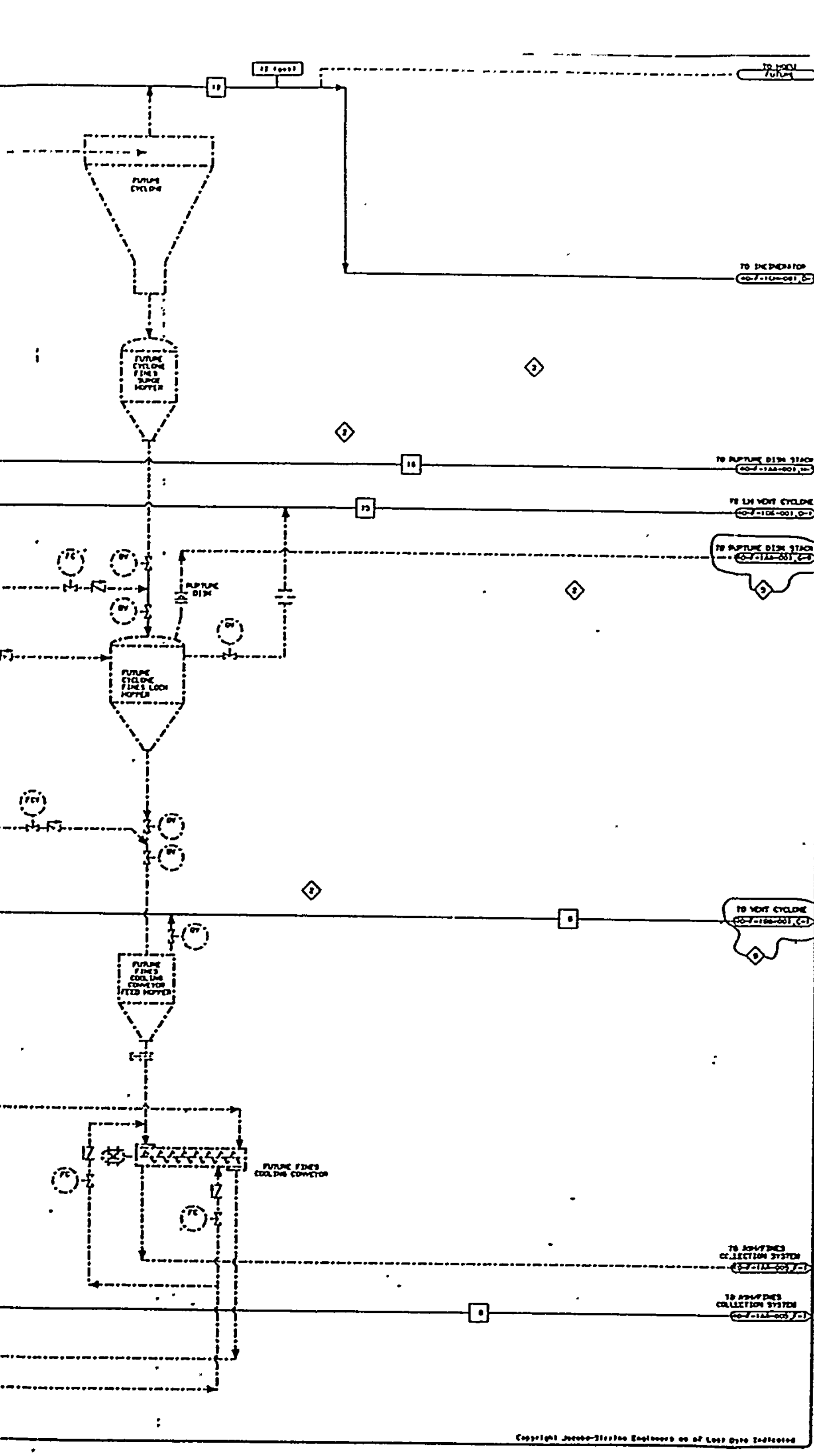
| | | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | STEAM / C.W. FROM PYROLYZER | | | STEAM / C.W. FROM UPPER JACKET | | | STEAM/CW FROM LOWER JACKET | | | SHROUD COOLING WATER | | | UPPER JACKET COOLING WATER | | |
| ...SIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| ...EY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY |
| | | | | | | | | | | | | | | | | |
| ...EY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY |
| ...EY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY |

| | | 16 | | | 17 | | | 18 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ...GEN | | COOLING WATER FROM DRUM | | | STEAM TO GASIFIER | | | BLOWDOWN | | | | | | | | |
| ...SIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg F | | | | | | |
| ...LD | HOLD | RILEY | RILEY | RILEY | HOLD | RILEY | RILEY | RILEY | RILEY | RILEY | | | | | | |
| | | | | | | | | | | | | | | | | |
| ...LD | HOLD | RILEY | RILEY | RILEY | 1000 | RILEY | RILEY | RILEY | RILEY | RILEY | | | | | | |
| ...LD | HOLD | RILEY | RILEY | RILEY | 500 | RILEY | RILEY | RILEY | RILEY | RILEY | | | | | | |




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | WARM UP STEAM | | | COOLING WATER FROM GAS.COND. | | | COOLING WATER TO GAS.COND. | | | F.W. TO DRUM | | | STEAM / ( FROM SH | |
| UNITS | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | P |
| MAXIMUM DESIGN | HOLD | 460 | 610 | HOLD | HOLD | HOLD | HOLD | HOLD | 90 | 1500 | HOLD | 227 | RILEY | RI |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | 0 | 420 | 600 | HOLD | HOLD | HOLD | HOLD | HOLD | 85 | 1000 | HOLD | 227 | RILEY | RI |
| MINIMUM OPERATING | 0 | · 420 | HOLD | HOLD | HOLD | HOLD | HOLD | HOLD | 60 | 500 | HOLD | 227 | RILEY | RI |
| REVISION DATE | | | | | | | | | | | | | | |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | LOWER JACKET COOLING WATER | | | PYROLYZER COOLING WATER | | | COOLING WATER TO GASIFIER | | | | | | NITR | |
| UNITS | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | P |
| MAXIMUM DESIGN | | | | | | | | | | | | | HOLD | HO |
| MAXIMUM OPERATING | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | | | | | |
| NORMAL OPERATING | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | | | | HOLD | HO |
| MINIMUM OPERATING | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | RILEY | | | | HOLD | HO |
| REVISION DATE | | | | | | | | | | | | | | |




| Rev. No. | Description |
|---|---|
| 5 | REVISED OFFPAGE CONNECTORS & INSTRUMENT ISSUED AS REV. 5 |
| 4 | REVISED PER DEPARTMENT OF ENERGY COMMENTS ISSUED FOR DESIGN |
| 3 | REVISED PER 3/15/95 SCOPE REVIEW. ISSUED FOR COMMENTS |
| 2 | REVISED FINES SAMPLE VALVES, STREAM SYMBOL, REMOVED STEAM & SERVICE |
| | RATED TO COAL GAS, ADDED RUP DISK LINES, REVISED TITLE, ISSUED FOR DESIGN |
| 1 | REVISED DATA & NOTES FOR 400 PSIG OPERATION, CHANGED DWG NO FROM |
| | 16M25706-40-F-AA-002, ADDED SECOND CYCLONE ISSUED FOR APPROVAL |
| 0 | CHANGED DRAWING NO. FROM 31006-40-F-AA-002 ISSUED FOR APPROVAL |
| F | ISSUED FOR INFORMATION ONLY |
| E | ISSUED FOR REVIEW |
| D | ISSUED FOR INTERNAL REVIEW |
| C | ISSUED FOR TASK 4 REPORT |
| B | ISSUED FOR REVIEW. |
| A | ISSUED FOR ESTIMATE. |

NOTES: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

ISSUE CODE: A PRELIMINARY; B DESIGN; C MAT'L I.O.; D MAT'L PURC.; E BIDS; F CONST'N

SEAL

SIGNATURE

DATE

JE — JACOBS-SIRRINE ENGINEERING, A division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE
FLOW DIAGRAM
GASIFIER
GAS CLEAN-UP
SYSTEM

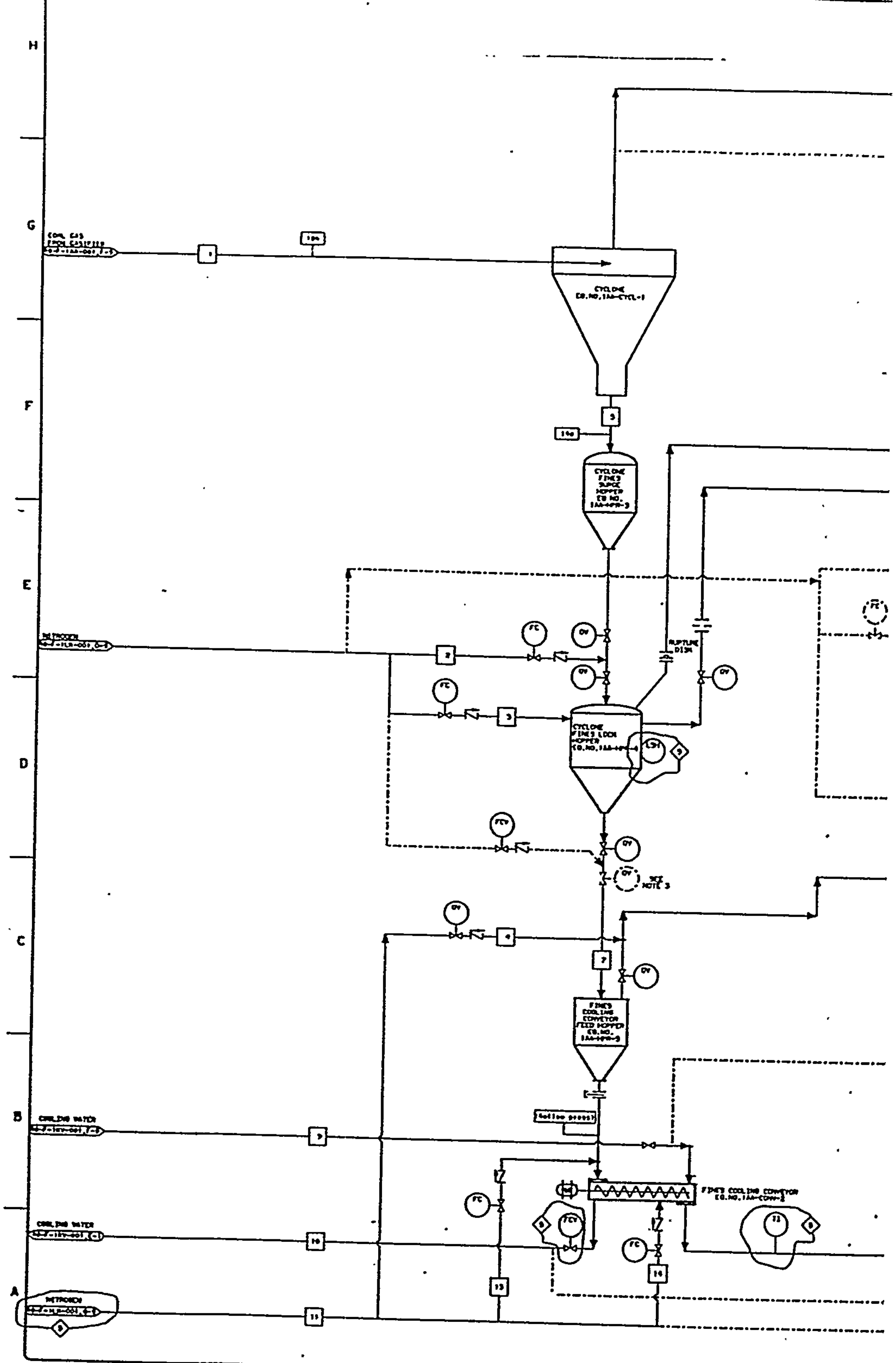
CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16M25706-40-F-1AA-002



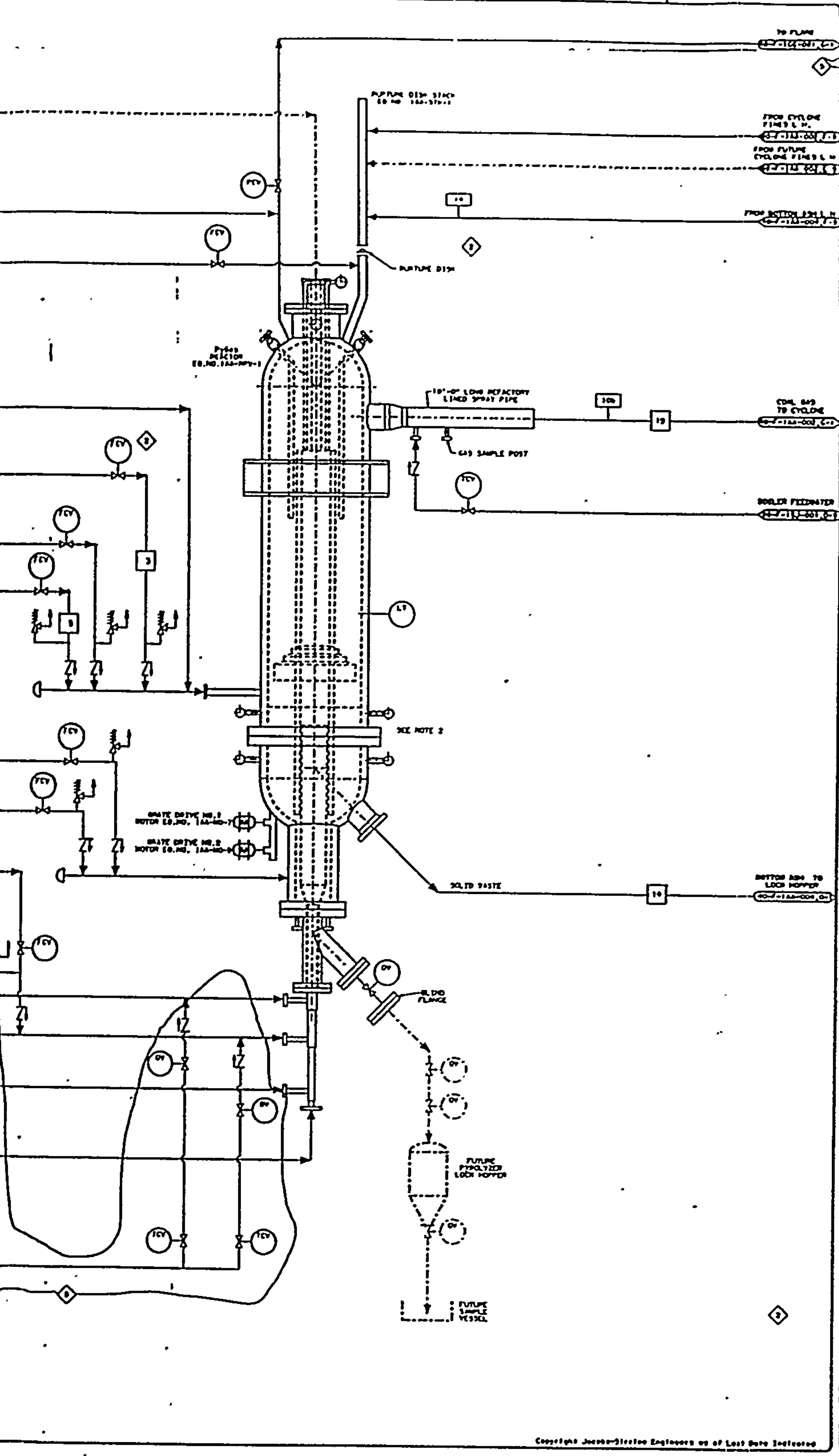
| 5 | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HOPPER VENT | | | FINES | | | FINES | | | COOLING WATER | | | COOLING WATER | | |
| Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F | GPM | PSIG | Deg.F |
| 1100 | HOLD | 10 | 1100 | | | | 500 | 2 | 200 | | | | | | |
| | | | | | | | | | | | HOLD | | | HOLD | |
| ANCE) | HOLD | 2 | HOLD | (SEE | MASS BA | LANCE) | (SEE | MASS BA | LANCE) | | | | | | |
| ANCE) | HOLD | 2 | HOLD | (SEE | MASS BA | LANCE) | (SEE | MASS BA | LANCE) | | | | | | |

| 15 | 16 | | | 17 | | | 18 | | | 19 | | | 20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NT | SAFETY VENT | | | | | | | | | | | | | | |
| Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | GPM | PSIG | Deg.F |
| 1100 | HOLD | 420 | 1100 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| HOLD | HOLD | HOLD | HOLD | | | | | | | | | | | | |
| HOLD | HOLD | HOLD | HOLD | | | | | | | | | | | | |




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | COAL GAS | | | N2 | | | N2 | | | N2 | | | FINE | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PS |
| MAXIMUM DESIGN | 20,320 | 420 | 1100 | HOLD | 374 | 465 | HOLD | 374 | 465 | HOLD | 10 | 100 | 500 | 42 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | (SEE MASS BALANCE) | | | | (SEE PDB) | | | (SEE PDB) | | | | | | |
| MINIMUM OPERATING | (SEE MASS BALANCE) | | | | (SEE PDB) | | | (SEE PDB) | | HOLD | 2 | 50 | (SEE | MASS |
| REVISION DATE | | | | | | | | | | HOLD | 2 | 50 | (SEE | MASS |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | N2 | | | COAL GAS | | | N2 | | | N2 | | | LH V | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSI |
| MAXIMUM DESIGN | HOLD | 10 | 100 | 19,970 | 420 | 1100 | HOLD | 10 | 100 | | 10 | 100 | HOLD | 42 |
| MAXIMUM OPERATING | | | | | | | | | | | | | | |
| NORMAL OPERATING | HOLD | 2 | 50 | (SEE MASS BALANCE) | | | | (SEE PDB) | | | (SEE PDB) | | HOLD | HOL |
| MINIMUM OPERATING | HOLD | 2 | 50 | (SEE MASS BALANCE) | | | | (SEE PDB) | | | (SEE PDB) | | HOLD | HOL |
| REVISION DATE | | | | | | | | | | | | | | |




SEAL

SIGNATURE

DATE

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE

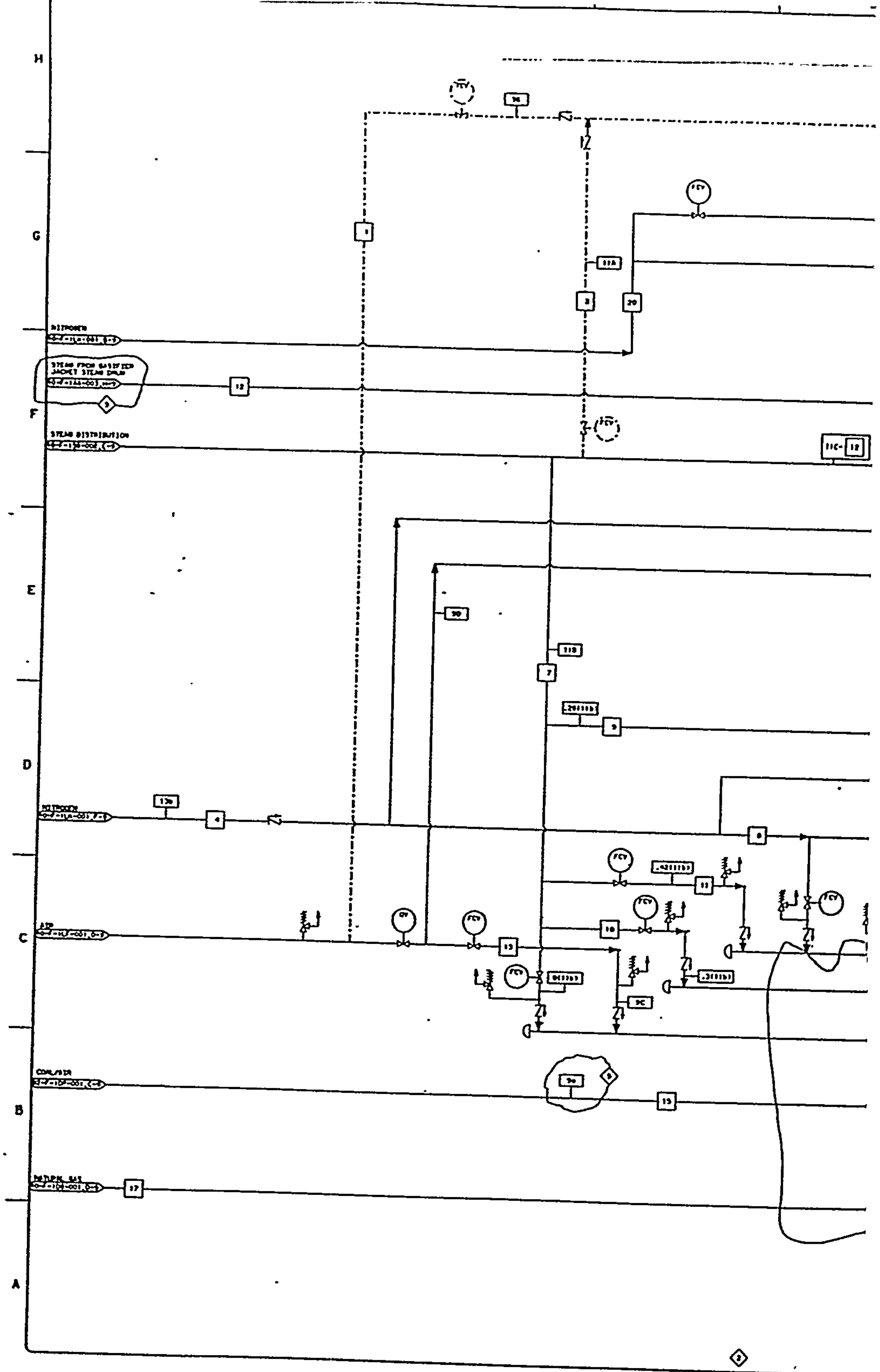
FLOW DIAGRAM
GASIFIER
SYSYEM

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-F-1AA-001

| 5 | | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GRATE | | | | | STEAM TO PYROLYZER | | | N2 TO PYROLYZER | | | SWEEPING STEAM TO CONE | | | STEAM TO PYROLYZER CONE | | |
| IG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| 74 | 410 | | | | 700 | 374 | 600 | | | | 700 | 374 | 600 | 700 | 374 | 600 |
| | | | | | | | | | HOLD | | | | | | | |
| BAL | ANCE) | | | | (SEE | MASS BAL | ANCE) | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |
| BAL | ANCE) | | | | (SEE | MASS BAL | ANCE) | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) |

| 15 | | 16 | | | 17 | | | 18 | | | 19 | | | 20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AIR | | | | | NATURAL GAS | | | | | | COAL GAS | | | | | |
| IG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F |
| 14 | 150 | | | | HOLD | 60 | Amb | | | | 20320 | 420 | 1100 | HOLD | 420 | 100 |
| 74 | 150 | | | | | | | | | | | | | | | |
| BAL | ANCE) | | | | HOLD | RILEY | Amb | | | | (SEE | MASS BAL | ANCE) | HOLD | 325 | 50 |
| BAL | ANCE) | | | | HOLD | RILEY | Amb | | | | (SEE | MASS BAL | ANCE) | HOLD | HOLD | 50 |




| LINE NUMBER | 1 | | | 2 | | | 3 | | | 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | AIR TO GASIFIER TOP | | | STEAM TO GASIFIER TOP | | | STEAM TO GRATE | | | N2 TO GASIFIER | | | AIR TO | |
| UNITS | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | P |
| MAXIMUM DESIGN | FUTURE | 374 | 410 | FUTURE | 374 | 600 | FUTURE | 374 | 600 | | | | | |
| MAXIMUM OPERATING | | | | | | | | | | | | | 7000 | 3 |
| NORMAL OPERATING | FUTURE | FUTURE | FUTURE | FUTURE | FUTURE | FUTURE | | | | | HOLD | | | |
| MINIMUM OPERATING | FUTURE | FUTURE | FUTURE | FUTURE | FUTURE | FUTURE | (SEE | MASS BAL | ANCE) | 0 | | | (SEE | MAS |
| REVISION DATE | | | | FUTURE | FUTURE | FUTURE | (SEE | MASS BAL | ANCE) | 0 | | | (SEE | MAS |

| LINE NUMBER | 11 | | | 12 | | | 13 | | | 14 | | | 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION: | STEAM TO PYROLYZER | | | STEAM FROM GASIFIER STEAM DRUM | | | AIR TO PYROLYZER | | | GRATE ASH | | | COAL/ | |
| UNITS | PPH | PSIG | Deg F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | PSIG | Deg.F | PPH | P |
| MAXIMUM DESIGN | 700 | 374 | 600 | 1000 | HOLD | HOLD | 4500 | 374 | 410 | 1000 | 420 | 750 | 8000 | 4 |
| MAXIMUM OPERATING | | | | | | | | | | | | | 8000 | 3 |
| NORMAL OPERATING | (SEE | MASS BAL | ANCE) | 1 | HOLD | HOLD | (SEE | MASS BAL | ANCE) | | | | | |
| MINIMUM OPERATING | (SEE | MASS BAL | ANCE) | 5 | HOLD | HOLD | (SEE | MASS BAL | ANCE) | (SEE | MASS BAL | ANCE) | (SEE | MAS |
| REVISION DATE | | | | | | | | | | (SEE | MASS BAL | ANCE) | (SEE | MASS |

# GRAM LEGEND

## VALVE BODY SYMBOLS

- GLOBE VALVE
- GATE VALVE
- BALL VALVE
- PLUG VALVE
- BUTTERFLY VALVE
- CHECK VALVE
- STOP CHECK NON-RETURN VALVE
- SAFETY OR RELIEF VALVE
- THREE-WAY VALVE RIGHT CLOSED

MISCELLANEOUS

- ARC VALVE

## PROCESS VARIABLE

| | FIRST LETTER | | SUCCEEDING LETTER | | |
|---|---|---|---|---|---|
| | MEASURED OR INITIATING VARIABLE | MODIFIER | READOUT OR PASSIVE FUNCTION | OUTPUT FUNCTION | MODIFIER |
| A | ANALYSIS | | ALARM | | |
| B | BURNER FLAME | | USER'S CHOICE | USER'S CHOICE | USER'S CHOICE |
| C | CONDUCTIVITY | | | CONTROL | CLOSED |
| D | DENSITY (MASS) OR SPECIFIC GRAVITY | DIFFERENTIAL | | | |
| E | VOLTAGE (EMF) | | ELEMENT | | |
| F | FLOW RATE | RATIO (FRACTION) | | | |
| G | GAGING (DIMENSIONAL) | | GLASS | | |
| H | HAND (MANUALLY INITIATED) | | | | HIGH |
| I | CURRENT (ELECTRICAL) | | INDICATE | | |
| J | POWER | SCAN | | | |
| K | TIME OR TIME SCHEDULE | | | CONTROL STATION | |
| L | LEVEL | | LIGHT (PILOT) | | LOW |
| M | MOISTURE OR HUMIDITY | | | | MIDDLE |
| N | USER'S CHOICE | | USER'S CHOICE | USER'S CHOICE | USER'S CHOICE |
| O | USER'S CHOICE | | ORIFICE (RESTRICTION) | | OPEN |
| P | PRESSURE OR VACUUM | | POINT (TEST) CONNECTION | | |
| Q | QUANITY OR EVENT | INTERGRATE OR TOTALIZE | | | |
| R | RADIOACTIVITY | | RECORD OR PRINT | | |
| S | SPEED OR FREQUENCY | SAFETY | | SWITCH | |
| T | TEMPERATURE | | | TRANSMIT | |
| U | MULTIVARIABLE | | MULTIFUNCTION | MULTIFUNCTION | MULTIFUNCTION |
| V | VISCOSITY OR VIBRATION | | | VALVE, DAMPER OR LOUVER | |
| W | WEIGHT OR FORCE | | WELL | | |
| X | UNCLASSIFIED | | UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED |
| Y | USER'S CHOICE | | | RELAY OR COMPUTE | |
| Z | POSITION | | | DRIVE, ACTUATE OR UNCLASSIFIED FINAL CONTROL ELEMENT | |

## SYSTEM IDENTIFIER

| IDENTIFIER | NUMBER OF DRAWING |
|---|---|
| AA - GASIFIER SYSTEM & GASIFIER SUB SYSTEMS | 5 |
| DG - NATURE GAS SYSTEM | 1 |
| DH - COAL RECEIVING & STORAGE SYSTEM | 1 |
| DJ - COAL AND LIMESTONE PREPARATION SYSTEM | 1 |
| DP - COAL AND LIMESTONE FEED SYSTEM | 1 |
| GA - FLUE GAS DESULFURIZATION SYSTEM | 1 |
| ~~GG - PROCESS VENT SYSTEM~~ | 1 |
| GH - INCINERATOR | 1 |
| ~~GK - CONDENSATE AND FEEDWATER CHEMISTRY CONTROL SYSTEM~~ | 1 |
| KK - POTABLE WATER DISTRIBUTION SYSTEM | 1 |
| KV - AUXILIARY COOLING WATER SYSTEM | 1 |
| KW - SERVICE WATER SYSTEM | 1 |
| LD - INSTRUMENT AIR SUPPLY SYSTEM | 1 |
| LE - LEGEND SHEET | 1 |
| LF - PROCESS AIR SYSTEM | 1 |
| ~~LN - NITROGEN SYSTEM~~ | 1 |
| MI - YARD FACILITIES | 0 |
| SB - MAIN STEAM SYSTEM | 2 |
| SJ - FEEDWATER SYSTEM | 2 |
| WS - WASTE MANAGEMENT SYSTEM | 2 |
| TOTAL DRAWINGS | 25 |

## EQUIPMENT IDENTIFIER

AGT - AGITATOR
ACU - AIR CONDITIONING UNIT
AHU - AIR HANDLING UNIT
PSI - AIR COMMON
AL - AIR LOCK
BLO - BLOWER
BLR - BOILER
BRN - BURNER
CAB - CABINET
CHT - CHUTE
CHTR- COMBUSTION HEATER
CLF - CLASSIFIER
CYCL- CLCLONE
CMP - COMPRESSOR
COND- CONDITIONER
CONV- CONVEYOR
CLR - COOLER
CRSH- CRUSHER
DMP - DAMPER
DEA - DEAERATOR
DG - DIESEL GENERATOR
DRY - DRYER
DUCT- DUCT
DCOL- DUST COLLECTOR
EDR - EDUCTOR, EJECTOR
EHTR- ELECTRIC UNIT HEATER
ELEV- ELEVATOR
HPR - HOPPER
FAN - FAN
FAR - FLAME ARRESTER
FDR - FEEDER
FLT - FILTER
HX - HEAT EXCHANGER
HOI - HOIST
HPR - HOPPER
INCN- INCINERATOR
LDR - LOADER
LH - LAB HOOD
LV - LOUVER
MO - MOTOR
MCC - MOTOR CONTROL CENTER
NZL - NOZZLE
P - PUMP
RPV - REACTOR
RL - ROTARY VALVE
RCV - RECEIVER
RPD - RUPTURE DISK
SMX - SAMPLER
SCG - SCRUBBER
SEP - SEPERATOR
SIL - SILENCER
SILO- SILO
STK - STACK
SD - STEAM DRUM
STR - STRAINER
HVSW- SWITCHS HIGH VOLTAGE
TK - TANK
TARP- TARPAULIN
XFRM- TRANSFORMER
UPS - UNINTERRUPTABLE POWER SUPPLY
VAP - VAPORIZOR
VSL - VESSEL

## FLOW INSTRUMENTS

- FLOW DEVICE*

## LEVEL INSTRUMENTS

- LEVEL INSTRUMENT*

## LOCAL GAUGES

- (SEE PROCESS VARIABLE TABLE FOR INSTRUMENT DESCRIPTION)

## FINAL CONTROL ELEMENTS

- CONTROL VALVE*
- CONTROL VALVE MOTOR OPERATED

* PROCESS VARIABLE TABLE ... VARIABLE DESCRIPTION

- FLOW STREAM SYMBOLS
- DRAWING REVISION SYMBOLS

| REV. NO. | CODE | CIRCLES | DATE | DESCRIPTION |
|---|---|---|---|---|
| 3 | B | 3 | 08 | UPDATED EQUIPMENT & |
| | | | 28 | SYSTEM INDENTIFIER |
| | HAS | | 95 | ISSUED AS REV. 1 |
| 2 | B | 02 | 03 | CHANGE DRAWING NO. FROM |
| | | | 28 | 16N25706-40-L-001 |
| | HAS | | 95 | REVISED SYSTEM IDENIFIER |
| 1 | A | - | 02 | REVISED EQ. IDENTIFIER |
| | | | 15 | ADDED EQ. & VALVE SYMBOLS |
| | HAS | | 95 | ISSUED FOR APPROVAL |
| 0 | A | 02 | 12 | REVISED:EQUIP. SYMBOLS |
| | | | 08 | & SYSTEM IDENTIFIERS |
| | HAS | | 94 | ADDED: EQUIP. INDENTIFIER |
| | | | | CHANGED DRAWING NO. FROM |
| | | | | 31604-40-L-ILE-001 |
| | | | | ISSUED FOR APPROVAL |
| A | A | - | 09 | ISSUED FOR DOE REVIEW |
| | | | 08 | |
| | HAS | | 94 | |

REV. BY — CHECKED BY — APPROVED BY

NOTE: CIRCLE ALL REVISIONS, IDENTIFY WITH DIAMOND, NUMBER AND ARROW. REMOVE ONLY CIRCLE AND ARROW BEFORE NEXT REVISION.

| ISSUE CODE | | | |
|---|---|---|---|
| A PRELIMINARY | C MAT'L T.O. | F CONST'N | |
| B DESIGN | D MAT'L PURC. | G | |
| | E BIDS | H | |

SEAL

SIGNATURE

DATE

| | |
|---|---|
| DR. D.W. LEDBETTER | DATE 09-07-94 |
| DSGN. R.V. DUCK | JACOBS FILE NUMBER |
| CK. | |
| DPE H.A. STOKES | JOB NO. 25706 |
| CAD FILE NO. 16_M_DKC100:12470SOM,E001.40L;1 | |

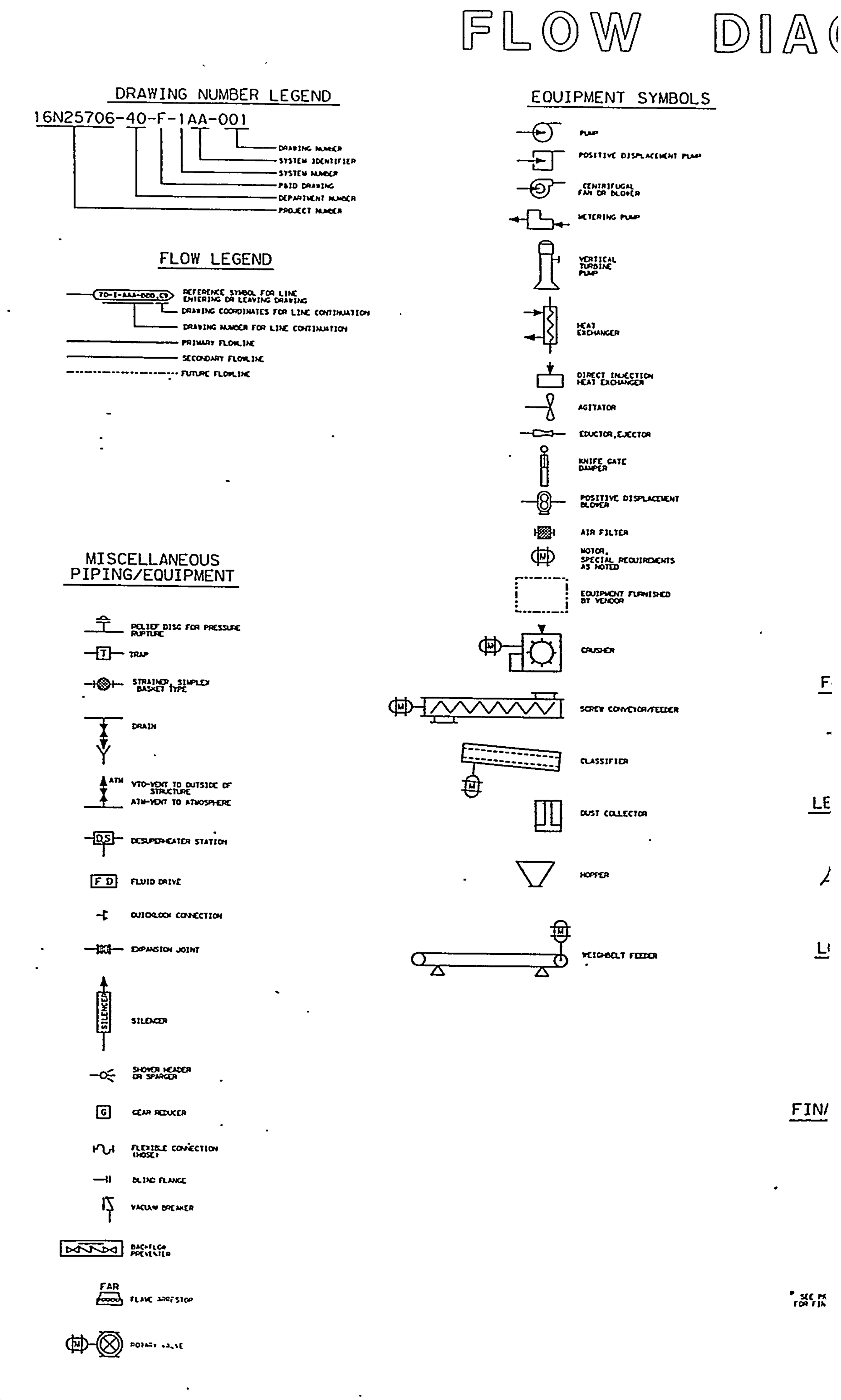
JACOBS-SIRRINE ENGINEERS, a division of Jacobs Engineering Group Inc.

GPIF PROJECT
U.S. DEPT. OF ENERGY
DE-AC21-92MC28202

DRAWING TITLE
FLOW DIAGRAM LEGEND

CLIENT DRAWING NUMBER

JACOBS-SIRRINE DRAWING NUMBER
16N25706-40-LE-001


FLOW DIA
DRAWING NUMBER LEGEND
16N25706-40-F-1AA-001
DRAWING NUMBER
SYSTEM IDENTIFIER
SYSTEM NUMBER
P&ID DRAWING
DEPARTMENT NUMBER
PROJECT NUMBER
FLOW LEGEND
70-I-AAA-000,C9
REFERENCE SYMBOL FOR LINE ENTERING OR LEAVING DRAWING
DRAWING COORDINATES FOR LINE CONTINUATION
DRAWING NUMBER FOR LINE CONTINUATION
PRIMARY FLOWLINE
SECONDARY FLOWLINE
FUTURE FLOWLINE
MISCELLANEOUS PIPING/EQUIPMENT
RELIEF DISC FOR PRESSURE RUPTURE
T
TRAP
STRAINER, SIMPLEX BASKET TYPE
DRAIN
ATM
VTO-VENT TO OUTSIDE OF STRUCTURE
ATM-VENT TO ATMOSPHERE
DS
DESUPERHEATER STATION
F D
FLUID DRIVE
QUICKLOCK CONNECTION
EXPANSION JOINT
SILENCER
SILENCER
SHOWER HEADER OR SPARGER
G
GEAR REDUCER
FLEXIBLE CONNECTION (HOSE)
BLIND FLANGE
VACUUM BREAKER
BACKFLOW PREVENTER
FAR
EQUIPMENT SYMBOLS
PUMP
POSITIVE DISPLACEMENT PUMP
CENTRIFUGAL FAN OR BLOWER
METERING PUMP
VERTICAL TURBINE PUMP
HEAT EXCHANGER
DIRECT INJECTION HEAT EXCHANGER
AGITATOR
EDUCTOR,EJECTOR
KNIFE GATE DAMPER
POSITIVE DISPLACEMENT BLOWER
AIR FILTER
M
MOTOR, SPECIAL REQUIREMENTS AS NOTED
EQUIPMENT FURNISHED BY VENDOR
CRUSHER
SCREW CONVEYOR/FEEDER
CLASSIFIER
DUST COLLECTOR
HOPPER
WEIGHBELT FEEDER
FIN