Appendix C – BB Power Report

BABCOCK BORSIG POWER, INC.

PRELIMINARY ENGINEERING STUDY FOR FEASIBILITY OF MODULAR BIO-GASIFIER HOT PRODUCER GAS INJECTION INTO PULVERIZED COAL FIRED FLAT WALL FURNACE

FOR:

NEXANT INC.

AT

WESTERN KENTUCKY ENERGY
REID PLANT
SEBREE POWER COMPLEX
SEBREE, KENTUCKY

BBP CONTRACT No. 200756
Original Contract Riley Stoker Corp. B2502

Date Issued: 31 May 2001

PRELIMINARY ENGINEERING STUDY FOR FEASIBILITY OF MODULAR BIO-GASIFIER HOT PRODUCER GAS INJECTION INTO PULVERIZED COAL FIRED FLAT WALL FURNACE

FOR
NEXANT INC.
AT

WESTERN KENTUCKY ENERGY
REID PLANT
SEBREE POWER COMPLEX
SEBREE, KENTUCKY

BBP CONTRACT NO. 200756
Original Contract Riley Stoker Corp. B2501

DATE ISSUED: 31 May 2001

Prepared By:

Frank Zone, Jr., P.E. 25 May 01
Sr. Staff Engineer
Boiler Design

Prepared By:

Richard J. Dube, P.E.
Sr. Consultant
Fuel Burning

Approved By:

Brian Vitalis 29 MAY 2001
Manager
Boiler Design

BABCOCK BORSIG POWER

May 31, 2001

NEXANT, Inc.
45 Fremont Street, 7th Floor
San Francisco, CA 94105-2210

Attn: Mr. Babul Patel

Subject: Phase 1 Engineering Study for Feasibility of Modular Bio-Gasifier Hot Producer Gas Injection into Pulverized Coal Fired Flat Wall Furnace
At Western Kentucky Energy, Reid Plant
Sebree Power Complex, Sebree, Kentucky
NEXANT, Inc. PO #0104-NEX-133
Original Contract Riley Stoker Corp, B2502
DB Riley Contract 200756

Dear Babul,

Thank you for using Babcock Borsig Power's engineering services; attached please find three copies of engineering's report that provides NEXANT assistance and recommendations in determining feasible locations, size, and number of penetrations required to flow syn gas into a pressurized type furnace.

As mentioned in today's conversation, once you have reviewed the report, call me a day ahead of time and I will set up a teleconference with engineering (Frank and Dick) to answer any questions that you may have.

Thank you for the opportunity to be of service to you, BBP looks forward to perhaps working with NEXANT on Phase 2 of this project.

Sincerely,

Babcock Borsig Power, Inc.

Elaine Strzelewicz

Elaine K. Strzelewicz
Job Manager, Field Engineering and Services Department

CC: K. Davis, P. Knight/1, J. Scott/1, E. Vega/1

Babcock Borsig Power, Inc.
Energy Systems and Services Division

Mailing Address:
Post Office Box 15040
Worcester, MA 01615-0040

Shipping Address:
5 Neponset Street
Worcester, MA 01606

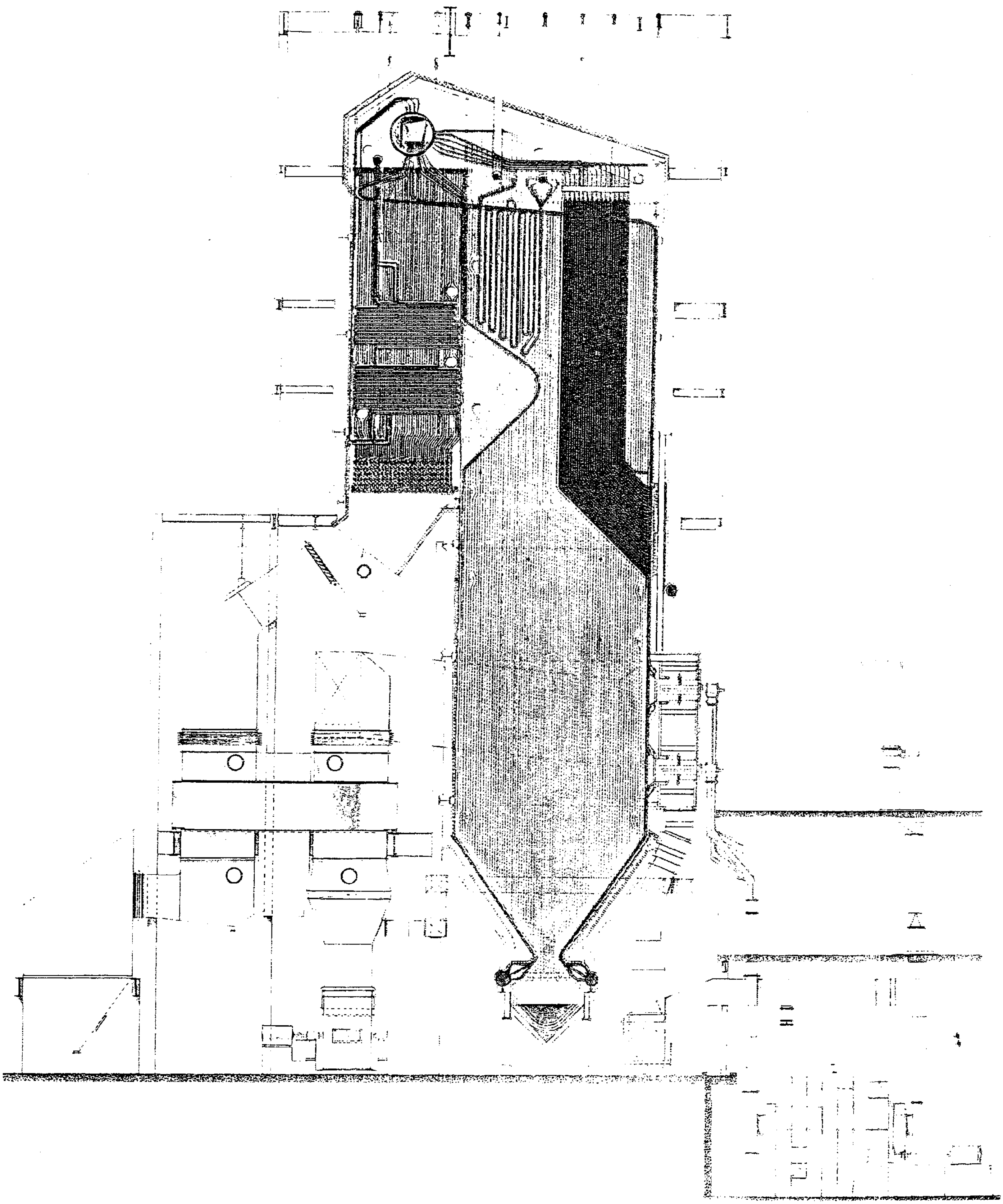
Telephone: (508) 852-7100
Fax: (508) 852-7548
www.bbpwr.com

BABCOCK BORSIG POWER, INC.

Nexant Inc.
WKE Reid Plant
BBP Contract 200756
DISTRIBUTION LIST

Nexant, Inc.

K. Davis
R. Dube
P. Knight
T. Martinko
J. Scott
E. Strzelewicz
E. Vega
B. Vitalis
F. Zone
Extra (3 Copies)



BIG RIVERS RURAL ELECTRIC COOPERATIVE CORP.

SEBREE, KENTUCKY

690,000 lbs/hr—1475 psig design—1300 psig operating—955F

Burns & McDonnell Engineering Co., Consulting Engineers

BABCOCK BORSIG POWER, INC.
Nexant Inc.
WKE Reid Plant
BBP Contract 200756

TABLE OF CONTENTS

BABCOCK BORSIG POWER, INC.
Nexant Inc.
WKE Reid Plant
BBP Contract 200756

LIST OF TABLES

LIST OF FIGURES

BABCOCK BORSIG POWER, INC.
Nexant Inc.
WKE Reid Plant
BBP Contract 200756

1.0 INTRODUCTION AND BACKGROUND

1.1 Introduction

NEXANT, Inc. and its partners, Western Kentucky Energy and Primenergy, are working with DOE-NETL to develop a biomass cofiring project at the Western Kentucky Energy Reid Plant located near Henderson, Kentucky. The cofiring project is a proposal for the installation of modular bio-gasifier(s) adjacent to the existing boiler and injecting the hot producer gas from the gasifier into the boiler. As part of phase 1, Nexant is seeking assistance in modeling the expected boiler operation post gasifier(s) installation. The specific tasks for BBP (subcontractor scope of work) as a part of phase 1 are as follows:

- Determine feasible locations for boiler penetration(s) to minimize the impact on existing boiler equipment
- Size the penetrations
- Determine pressure requirements at the penetrations
- Provide preliminary recommendations on required stiffening/strengthening at the boiler penetrations.

1.2 Background

The Western Kentucky Energy Reid Plant was designed by Riley Stoker Corporation under contract B-2502 (1962). It consists of one steam generating unit at a maximum continuous rating of 690,000 Lb/hr steam flow, 1300 psig outlet steam pressure, 955 °F outlet steam temperature, 440 °F feedwater temperature entering the economizer, while firing West Kentucky Bituminous coal. The boiler has two (2) Riley ball tube mills, eight (8) Riley type 60 flare burners, and one (1) Ljungstrom 25VIx48 air heater.

2.0 EXECUTIVE SUMMARY

2.1 Objectives

The objectives of this preliminary engineering study are as follows:

- Determine the size and number of penetrations required to flow ~~syn~~ producer gas into the furnace.
- Determine feasible locations for the penetrations in order to minimize the impact on existing boiler equipment.
- Determine the ~~syn~~ producer gas pressure requirements at the penetrations.
- Provide preliminary recommendations on required stiffening/strengthening at the penetrations.

2.2 Findings and Conclusions

- The overfire combustion chamber stream 11 ~~syn~~ producer gas flow is 73,837 ACFM at 2,400 °F. The selected velocity is 150 ft/sec and total required cross sectional flow area is 8.204 ft^2. The conclusion is that 4 penetrations of 19.5 inch inside diameter will satisfy the total flow cross sectional area requirement.

- The most feasible locations for the penetrations are on the lower sidewalls of the furnace.

- The syn gas pressure requirement for stream 11 at the penetration is 10.0 i.w.c.

- The furnace expansion at the location of the 4 proposed penetrations from ambient rest position to MCR condition is 4.25 inch downward at the bottom and 0.75 inch towards the side and front. Strengthening or stiffening for these expansions is not done, rather expansion joints are usually provided.

- The Nexant, Inc., proposed 38" OD syn gas transport piping (4 pipes) with an estimated 268 °F outside surface temperature will require personnel protection to meet OSHA requirements and appropriate plant cooling/ventilation.

2.3 Recommendations

- The penetration velocity of 150 ft/sec , suggested by Nexant, Inc., should be increased to provide for smaller inside diameter and smaller outside diameter. This of course will require increased syn gas pressure at the penetration.

- The recommended velocity is 300 ft/sec and the inside diameter is 14 inch, 4 penetrations. The required pressure at the penetration is 12.6 i.w.c.

- The bio-gasifier stream 11 piping from the overfire combustion chamber to the furnace penetration must have expansion joints to accommodate the thermal movements of the furnace and to isolate piping loads from the furnace. The piping must have outside insulation to meet OSHA requirement of 130 °F surface temperature.

- The selection of the penetration location on the lower sidewalls of the furnace was based upon space availability and practicality. A CFD flow model study should be done to investigate the flow of syn gas into the furnace during coal firing.

3.0 DISCUSSION

3.1 Description of Bio-Gasifier Process

The bio-gasifier process utilizes poultry litter as primary fuel in conjunction with air and pilot gas to produce syn gas and residual ash. The poultry litter is delivered (via truck), stored in fuel storage house, unloaded to fuel silos, discharged to sizing screen (with hammermill recycle back to sizing screen, sent to metering bin, thence to bucket elevator, through to rotary valve, then to infeed conveyor, then to gasifier. A fan supplies underfire air to the gasifier and bottom ash is removed from the gasifier via conveyor to an ash silo. Gasifier product gas is water quenched prior to transport to a ceramic fiber filter process. Ash is removed from the ceramic fiber filter bucket via bottom valves and sent to the ash conveyor of the gasifier. The product gas then flows via an induced draft fan to an overfire combustion chamber. Overfire air, via a forced draft fan , and pilot gas are fed to the combustion chamber to produce syn gas. The syn gas then flows to a syn gas burner chamber for combustion with pilot gas and air (via forced draft fan). The final product gas is intended for use in the boiler.

A schematic diagram of the poultry litter gasification process is shown in Figure 1.

The three streams considered to be of interest for utilization in the boiler are stream 8 (1381.8°F), stream 11 (2400°F), and stream 14 (2330.2°F) and the stream component flow rates are listed in Table 1.

Stream 8 is a gas mixture of carbon monoxide, carbon dioxide, hydrogen, water vapor, nitrogen, and sulfur dioxide. The mass flow rate is 41,505 Lb/hr and the volumetric flow rate is 37701 ACFM at 1381.8°F. Not included in the flow stream are amines (small amount) as a result of the gasification process. The sensible heat of stream 8 is 429 Btu/Lb.

Stream 11 is a gaseous mixture of carbon monoxide, carbon dioxide, hydrogen, water vapor, and nitrogen. The mass flow rate is 57,440 Lb/hr and the volumetric flow rate is 74,129 ACFM at 2400°F. The sensible heat of stream 11 is 760 Btu/Lb.

Stream 14 is a gaseous mixture of carbon dioxide, water vapor, nitrogen, and oxygen. The mass flow rate is 82,588 Lb/hr and the volumetric flow rate is 100,000 ACFM at 2330°F. The sensible heat of stream 14 is 693 Btu/Lb. Stream 14 has no chemical heat (i.e., HHV=0)

Stream 8 and stream 11 have chemical heating value of up to 100 Btu/Lb (HHV). There is no chemical heating value for stream 14 because the gaseous mixture is composed of oxygen and inerts.

The original background information from Nexant, Inc., noted that the syn gas for boiler utilization would have a heating value of 100 Btu/Scf and sensible heat value at 1000° F stream temperature as injected into the boilers.

The syn gas of stream 8 has amines (nitrosamines, etc.) and when injected into the furnace may produce NOx because of the bound nitrogen in this chemical species group.

The syn gas of stream 14 is basically inert and therefore has no chemical heating value. Elimination of the final bio gas process combustion chamber will reduce the size, cost, etc., of the process and therefore this stream would not be available. In essence, this stream would be similar to flue gas recirculation.

Stream 11 is the main choice of Nexant, Inc. and is a better choice than stream 14 because that the volumetric flow rate of stream 11 is much less (approximately 26 %) than the volumetric flow rate of stream 14.

However, the temperature of stream 11 is 70F° greater than stream 14 (i.e. 2400°F – 2330°F = 70F°) and higher temperatures place more limitations on material selection (metals and refractories/insulation) than do lower temperature flowing media.

Actually streams 11 and 14 are much higher in temperature than normally encountered in conventional boiler practice for external boilers connections. Conventionally external boiler convections seldom exceed 1000 °F. Such high temperatures present materials, insulation, and expansion difficulties.

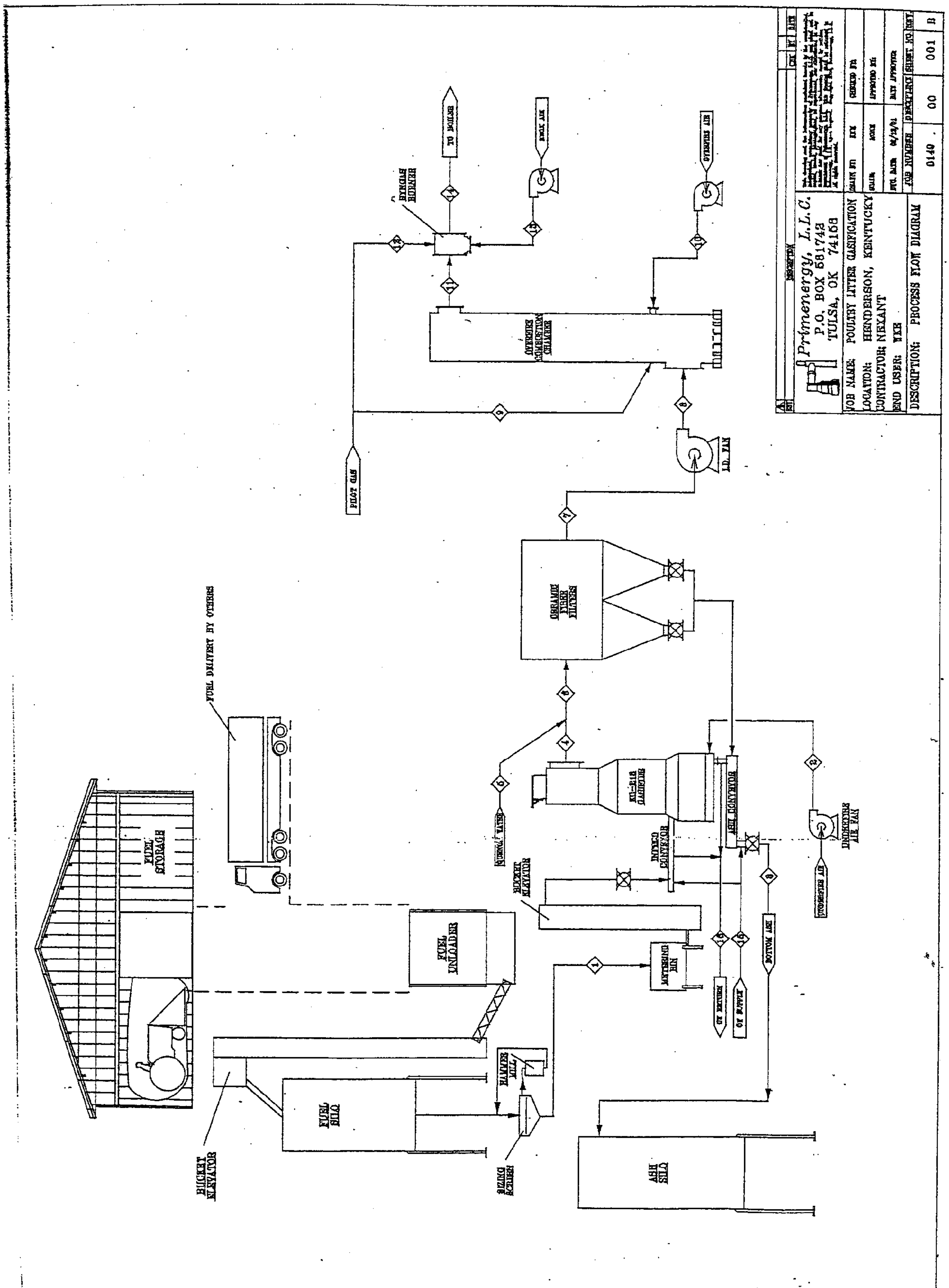


Figure 1
Poultry Litter Gasification
Process Schematic

Stream ID			1	2	3	4	8	9	10	11	12	13	14
Stream			GASIFIER	GASIFIER	GASIFIER	GASIFIER	ID	PILOT	OVERFIRE	OVERFIRE	PILOT	REOX	COMB
Name			FEED	COMB AIR	BOTTOM ASH	SYN GAS	FAN EXHAUST	GAS	COMB AIR	SYN GAS	GAS	COMB AIR	PROD TO BOILER
Pressure, "w.c.-g, or psig				20.0		3.0	8.0	(30.0)	13.0	7.0	(30.0)	13.0	6.0
Temperature, °F			77.00	80.0	300.0	1,550.0	1,381.8	77.0	80.0	2,400.0		80.0	2,330.2
Molecular Weight (Lb/Lbmole)				28.7	67.2	25.0	24.7	16.0	28.7	27.0	16.0	28.7	28.0
Component	**Formula**	**MW**	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h	Lb/h
Carbon	C	12.01	4,617.30		466.9								
Hydrogen	H	1.01	526.60										
Nitrogen	N	14.01	463.00										
Oxygen	O	16	3,416.10										
Sulfur	S	32.06	82.90										
Chlorine	Cl	35.45											
Fuel Gas	CH4	16.04						23.3			23.3		
Carbon Monoxide	CO	28.01				3,819.3	3,819.3			633.3			
Carbon Dioxide	CO2	44.01				9,206.7	9,206.7			14,276.2			15,335.0
Hydrogen	H2	2.02				421.0	421.0			200.4			
Water (v)	H20 (v)	18.02		267.1		5,411.6	6,575.7		157.0	8,756.2		244.6	10,843.7
Nitrogen	N2	28.01		20,853.3		21,316.3	21,316.3		12,257.5	33,573.7		19,098.9	52,672.6
Oxygen	O2	32		6,312.8					3,710.7			5,781.7	3,737.0
Sulfur Dioxide	SO2	64.06				165.7	165.7						
Hydrogen Chloride	HCl	36.46											
Ash	SiO2	60.08	3,494.00		3,960.9	69.9							
Lime	CaCO3	100.09											
Water (l)	H20 (l)	18.02	4,200.00										
TOTAL			16,800.0	27,433.2	4,427.8	40,410.3	41,504.6	23.3	16,125.1	57,439.8	23.3	25,125.3	82,588.3
AVAILABLE ENERGY VALUE (LHV-Hv), Btu/lb			4,051.50			953.9	928.7	21,502.0		229.0	21,502.0		
AVAILABLE ENERGY, MMBtu/h			68.10			38.5	38.5	0.5		13.2	0.5		
FLOW RATE, scfm (gpm)				6,049.9		10,242.9	10,644.2	9.2	3,556.1	13,478.1	9.2	5,541.0	18,642.4
FLOW RATE , acfm				6,282.6		39,592.7	37,701.1	9.5	3,692.9	74,129.3	8.1	5,754.1	100,030.5

Table 1
Gasifier Process Streams

3.2 Boiler Performance

Boiler heat and mass balance calculations were performed for original boiler performance conditions at 100 % load, stream 8 and coal at 100 % load, stream 11 and coal at 100 % load, and stream 14 and coal at 100 % load. The original boiler performance sheet is shown in the Appendix. The boiler conditions at 100 % load (MCR) are 640,000 Lb/hr steam flow, 955 °F outlet steam temperature, 1300 psig outlet steam pressure, 440 °F feedwater temperature, 343 °F stack temperature (undiluted), ambient air temperature 80 °F, and 22 % excess air (total). The boiler efficiencies are 86.55 % (original, coal only), 85.77 % (stream 8 and coal), 85.43 % (stream 11 and coal), and 85.82 % (stream 14 and coal).

The split of heat input by fuel is as follows: 100 % coal (original), 91% coal/9 % Syn Gas (coal and stream 8), 94% coal/6 % Syn Gas (coal and stream 11), and 94 % coal/6 % Syn Gas (coal and stream 14). The coal flows for comparison are 71,316 Lb/hr (original) 64,932 Lb/hr (stream 8), 67,218 Lb/hr (stream 11), and 66,943 Lb/hr (stream 14).

The EPRS heat release and the volumetric heat release are virtually the same for all cases. The furnace exit gas temperature (FEGT) is 1,870 °F (original), 1,861 °F (stream 8), 1,850 °F (stream 11), and

1,846 °F (stream 14) for a decrease of 9 °F, 20 °F. and 24 °F for stream 8,11, and 14, respectively. The change in furnace flue gas flow relative to original furnace flue gas flow is –0.2 % (stream 8), +2.6 % (stream 11), and +4.0 % (stream 14). These small changes in FEGT and furnace flue gas flows indicate the back pass (i.e. rear convection pass) of the boiler will perform similar to the original case and result in a similar stack temperature and therefore, yield the predicated boiler efficiencies. Therefore the boiler performance and efficiency is not expected to change for all four cases studied.

The furnace is a pressurized type and the pressure is +9.1 i.w.c. At 100 % MCR as per original contract design. The expected syn gas port pressure at the port exit plane of furnace entry is the sum of furnace pressure and one velocity pressure head of flowing syn gas as shown in Table 2 (i.e., 10.3 i.w.c. stream 8, 9.95 i.w.c. stream 11, and 10.0 i.w.c. stream 14). The calculated ACFM's of syn gas are 37,553 stream 8, 73,837 stream 11, and 99,635 stream 14. For the case of syn gas port velocity of 150 ft/sec (9,000 ft/min) and the selection of 4 ports, the syn gas port inside diameters are 14 inch (stream 8), 19.5 inch (stream 11), and 22.5 inch (stream 14).

Item		Original	Stream 8	Stream 11	Stream 14
Boiler Load	%	100	100	100	100
Steam Flow	Lb/hr	690,000	690,000	690,000	690,000
Outlet Steam Temperature	°F	955	955	955	955
Outlet Steam Pressure	PSIG	1,300	1,300	1,300	1,300
FW Temperature	°F	440	440	440	440
Stack Temperature (Undiluated)	°F	343	343	343	343
Stack Temperature (Diluated)	°F	328	328	328	328
Ambient Air (R eference)	°F	80	80	80	80
Boiler Effeciency(With margin)	%	86.55	85.77	85.43	85.82
Excess Air	%	22	22	22	22
Coal Flow	Lb/hr	71,316	64,932	67,218	66,943
Syn Gas Flow	Lb/hr	0	41,505	57,440	82,588
Coal HHV	Btu/Ft	11,600	11,600	11,600	11,600
Syn Gas HHV	Btu/Ft^3	---	100	18	0
Syn Gas Sensible Heat	Btu/Lb	---	429.61	759.96	693.4
Syn Gas Temperature	°F	---	1381.8	2400	2330.2
Heat Input By Coal	%	100	91.048	94.253	93.868
Heat Input by Syn Gas	%	---	8.952	5.747	6.132
EPRS Hr	Btu/hr Ft^2	68,427	67,914	67,918	67,805
Vol Hr	Btu/hr Ft^3	14,517	14,647	14,705	14,437
Total Furnace Flue Gas	Lb/hr	810,244	808,729	831,546	843,148
FEGT	°F	1,870	1,861	1,850	1,846
Δ FEGT	°F	---	-9	-20	-24
Δ Furnace Flue Gas	%	---	-0.2	+2.6	+4.0
Furnace Pressure	i.w.c.	9.05	9.05	9.05	9.05
Syn Gas Pressure @ Port	i.w.c.	---	10.3	9.95	10
Total Syn Gas Flow	ACFM	---	37,553	73,837	99,635
Syn Gas Port Velocity	Ft/sec	---	150	150	150
No of Syn Gas Ports	---	---	4	4	4
Syn Gas Port Inside Diameter	Ft	---	1.152	1.616	1.88
Syn Gas Port Inside Diameter	In	---	14	19.5	22.5

Table 2
Boiler Performance

3.3 Syn Gas Penetration Size Requirements

The syn gas penetration size requirements are port size (inside diameter and outside diameter) and the number of ports for a total flow cross sectional area to satisfy the volumetric flow rate at specified temperatures at an assumed port velocity (i.e. inside diameter flowing velocity). A syn gas penetration sizing nomogram is shown in Figure 2. The entering arguments are flow ACFM, variable velocity (ft/sec), total flow area (ft^2), number of penetrations, and the result is penetration inside diameter.

The specific case of interest for Nexant, Inc., is stream 11 flowing 73,837 ACFM at 150 ft/sec and 2,400 °F. This results in a total penetration inside cross sectional area of 8.204 ft^2 and with 4 penetrations, the inside cross sectional area of each penetration is 2.051 ft^2 which converts to an inside diameter of 1.62 ft (i.e. 19.5 inch). However, at 300 ft/sec the inside diameter is 14 inch, which is less than 19.5 inch.

The outside diameter is determined by the thickness of the outside shell (pipe or tube), inside refractory lining, inside high temperature insulation, and outside low temperature insulation. At the 100 % load condition (MCR), the drum pressure is 1,366 psig and the drum saturation is 585 °F and the furnace wall tubes are slightly less than 585 °F on the insulated side. It is good boiler the tube/tube wall fin combination and selected metal attachment to the tube/tube wall fin for reasons of thermal expansion stress. Also it is BBP practice in design to meet all OSHA requirements of 130°F (maximum surface temperature) for pipes/tubes accesible to personnel. The method for estimating the heat loss per ft of pipe/tube length is to estimate inside film convective heat transfer coefficient, outside combined radiation and natural convection heat transfer coefficients , select insulating and refractory material thickness and internal conductivity, and perform the calculation for a series of concentric annuli with hot gas flowing on the inside and 80 °F ambient air on the outside.

BBP has performed these calculations and is basically in agreement with the method used by Nexant, Inc., i.e., a good first approximation to the overall pipe outside diameter is 38 inch for the 19.5 inch ID of stream 11 flowing 73,837 ACFM at 150 ft/sec at 2,400 °F.

For the 38 inch outside diameter Nexant, Inc. reports an outside surface temperature of 268 °F which exceeds OSHA requirements of 130 °F. If this design is to be used, special consideration to personnel protection and appropriate plant ventilation/cooling would be needed.

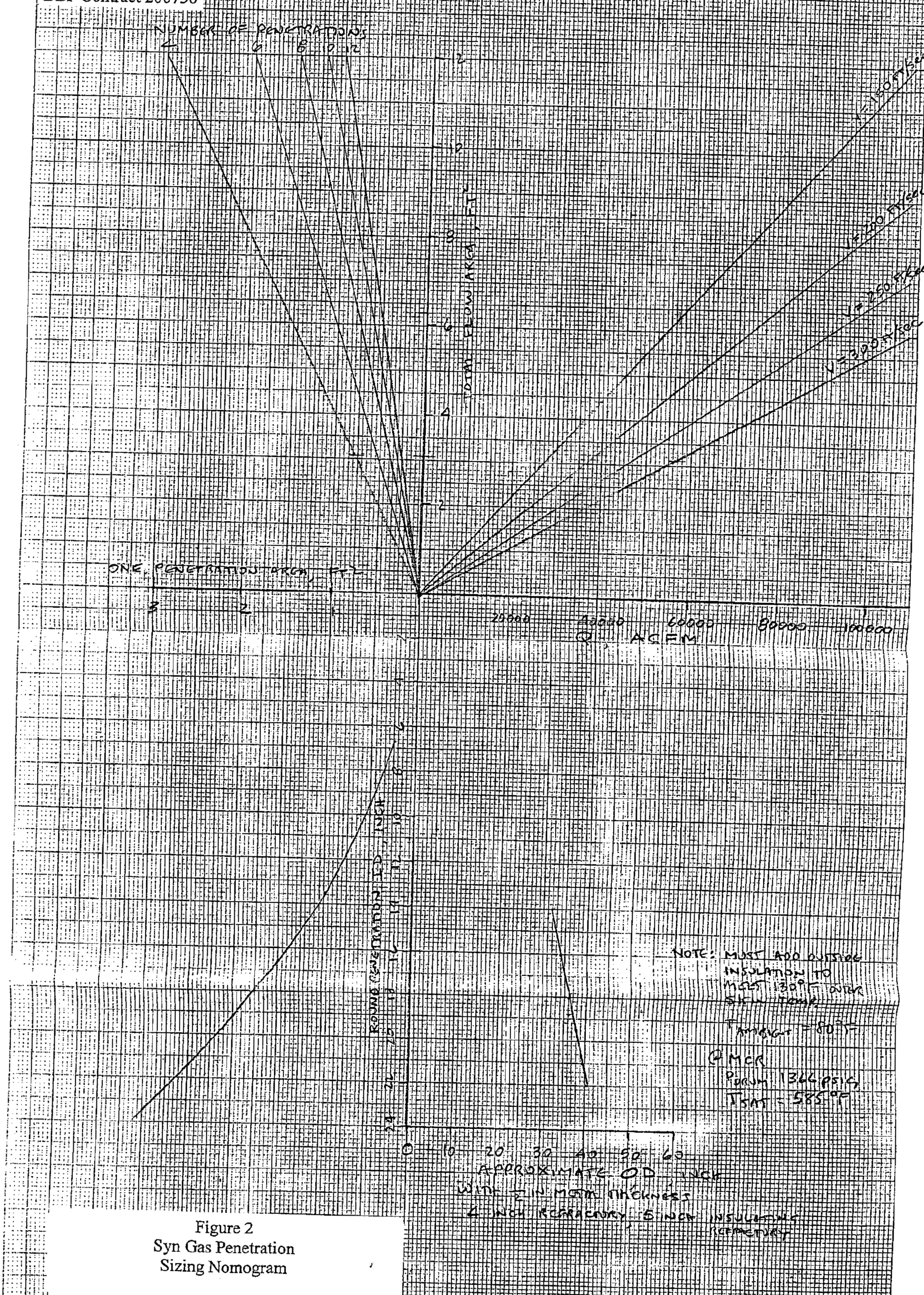


Figure 2
Syn Gas Penetration
Sizing Nomogram

FZ 10 MAY 01

3.4 Boiler Syn Gas Penetration Location

A boiler side elevation view is shown in the front of this report and should be referred to during this description of the penetration(s) locations. The rear convection pass of the boiler is located under the drum and above the air heater. The forced draft fan is located at ground level underneath the air heater. The Riley ball tube mills (2), pulverized coal transport pipes, coal silo(s), and raw coal transport pipes are located on the front side of the boiler as are the eight (8) Riley flare burners and windbox. Also located on the front wall above the top of the windbox is the supply header for the four(4) furnace water wall platens. There are two main downcomers , one on each side, from the drum to the bottom furnace water wall headers. These downcomers are 21 ½ inch pipes and the main centerline (vertical) is approximately 6 ft from the rear water wall tube centerline towards the front water wall.

The selected area for location of the penetrations is on the side walls, from elevation 452 ft 6 in to elevation 457 ft 6, and from the furnace side wall center to 7 ½ ft towards the front on each side wall. Therefore, the available area is 5 ft x 10 ft = 50 ft^2 on either side wall to locate 2 penetrations in each area for a total of 4 penetrations at elevation 455 ft. The penetration location is shown in the sketch of Figure 3.

Nexant Inc.
WKE Reid Plant
BBP Contract 200756

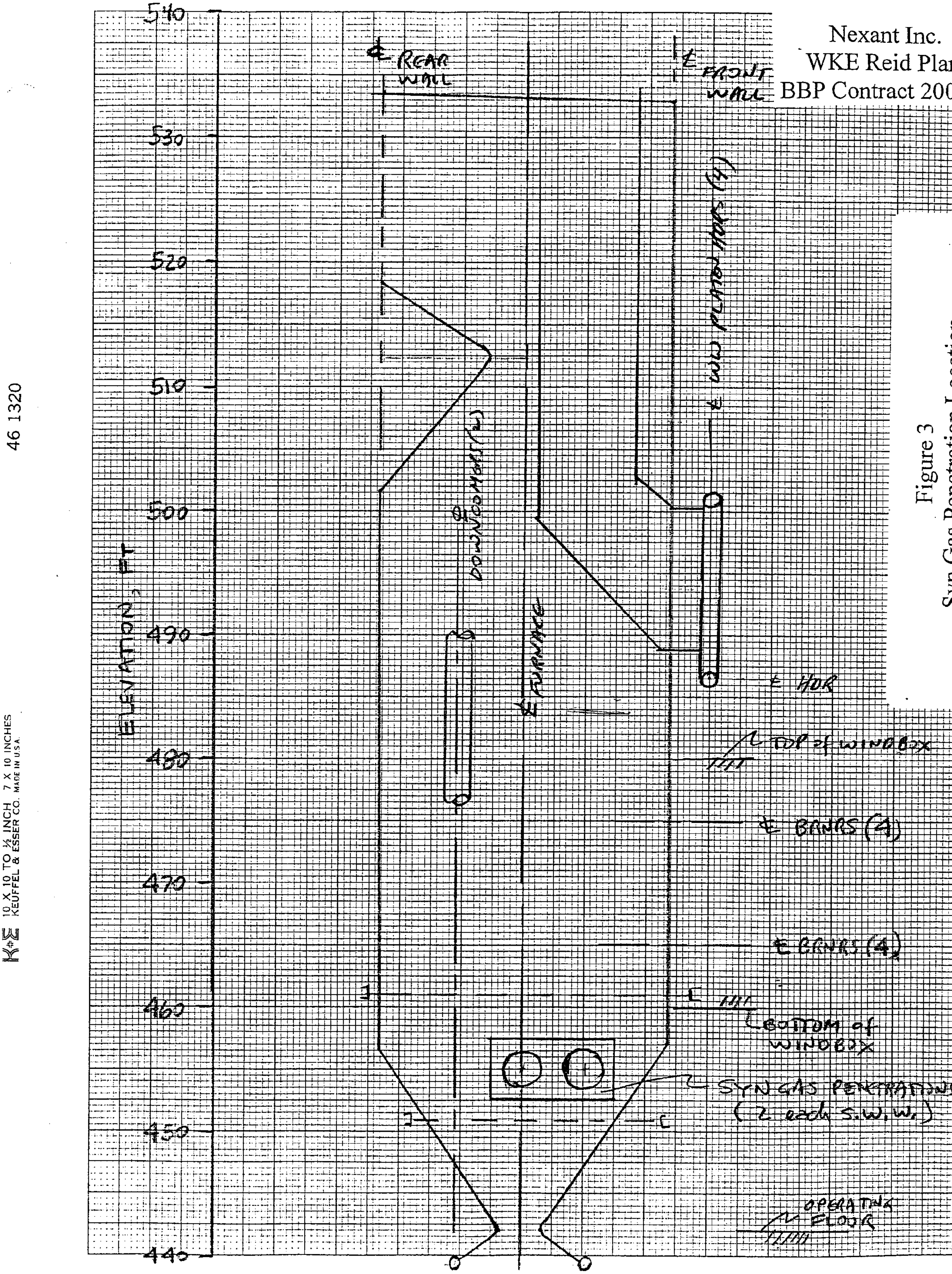


Figure 3
Syn Gas Penetration Location

3.5 Syn Gas Pressure Requirements

At 100 % load, the furnace design flue gas pressure is +9.05 i.w.c. and the syn gas penetration static pressure at the plane of injection into the furnace is 10.3 i.w.c. (stream 8), 10.0 i.w.c. (stream 11), and 10.0 i.w.c. (stream 14).

Presently, stream 11 is the item of interest by Nexant, Inc., and therefore the static pressure is 10.0 i.w.c. for a syn gas velocity of 150 ft/sec and volumetric flow rate of 73,837 ACFM utilizing a total of four (4) penetrations into the furnace. However, at 300 ft/sec the static pressure is 12.6 i.w.c. at the penetration.

3.6 Preliminary Recommendations on Required Stiffening/Strengthening at the Boiler Penetrations

The drum centerline is at elevation 543 ft 6 in and the centerline of the furnace waterwall headers is at elevation 439 ft 0 in. The vertical expansion of the furnace is 5 inch downward at elevation 439 ft 0 in. The expected expansion at elevation 455 ft 0 in elevation is 4¼ inch downward.

The horizontal expansion from the boiler rear wall to the furnace front water wall is 1 1/8 inch. The horizontal expansion to the left and to the right about the centerline of the furnace is ¾ inch at the left side water wall and ¾ inch at the right side water wall. The approximate expansion at the centerline locations of the penetrations on the furnace side water walls are ¾ inch outward and ¾ inch towards front of furnace.

The syn gas piping must have expansion joints to accommodate the boiler/furnace expansions expected at the location of the penetrations. By locating the expansion joints close to the furnace, piping loads are not transferred to furnace walls. Waterwall penetrations would likely be similar to standard boiler openings whereby bent tubes and scallop plates form a rigid structure on the furnace wall.

4.0 APPENDICES

4.1 Original Boiler Performance

2502

surized Unit

BIG RIVERS RURAL ELECTRIC COOPERATIVE CORP.
SEBREE, KENTUCKY

PB-3920
Sheet 1 of 2

Predicted performance data - One steam generating unit, 690,000 lbs. of steam per hour maximum continuous capacity; 1300 psig operating pressure; variable feed water; steam temperature 955 F.
Fuel - Coal, West Kentucky Bituminous; Moist. 10.0; V.M. 34.9; F.C. 43.1; Ash 12.0; 11,600 Btu per pound as fired. C 61.6; O 7.2; S 3.2; N 1.3; H 4.7; softening temperature ash 2254 F; grindability 60 Hardgrove.

				MCR ↓	4 Hour Peak	4 Hour Peak: Top Htr Out
1.	Pounds of steam per hour act. evap.	172,500	345,000	690,000	760,000	760,000
2.	Feed water temperature, F.	320	370	440	450	385
3.	K Btu in steam above F. W. temp.	197,078	384,333	724,797	789,815	843,995
4.	Temp. of gases leaving furnace, F.	1,560	1,660	1,870	1,900	1,930
5.	CO_2 in boiler exit gases	14.0	14.7	14.9	14.9	14.9
6.	% excess air in boiler exit gases	30	24	22	22	22
7.	Temp. of gases entering economizer, F.	660	725	845	870	890
8.	Temp. of economizer exit gases, F.	540	625	755	780	785
9.	Temp. of water entering economizer, F.	320	370	440	450	385
10.	Temp. of water leaving economizer, F.	361	403	466	476	419
11.	Water pressure drop thru economizer, psi	1	3	10	12	12
12.	Temp. of air heater exit gases, F. (Uncorrected)	259	284	329	342	347
	Temp. of air heater exit gases, F. (Corrected)	243	270	315	328	334
14.	Temp. of air entering heater, F.	141	116	80	80	80
15.	Temp. of air (ambient), F.	80	80	80	80	80
16.	Temp. of air leaving heater, F.	478	526	593	607	607
17.	Total steam temperature leaving superheater, F.	894	936	955	955	955
18.	Steam pressure drop thru superheater and control, psi	4	17	66	80	80
19.	Boiler drum pressure, psig	1,304	1,317	1,366	1,380	1,380
20.	Pressure drop thru economizer	0.15	0.45	1.50	1.80	2.05
21.	Pressure drop thru superheater	0.20	0.60	2.05	2.45	2.80
22.	Pressure drop thru dust collector	0.15	0.65	2.50	3.00	3.45
23.	Pressure drop thru steam coil	0.05	0.15	0.55	0.65	0.75
24.	Pressure drop thru air heater (gas side)	0.35	1.00	3.00	3.55	4.00
25.	Pressure drop thru air heater (air side)	0.25	0.65	2.05	2.45	2.75
26.	Pressure drop thru ducts and dampers (Including air measurement)	0.15	0.45	1.55	1.85	2.10
27.	Pressure drop thru firing equipment	0.20	0.65	2.30	2.75	3.10
28.	Total static pressure at fan (inches w.g.)	1.50	4.60	15.50	18.50	21.00

↑

RILEY STOKER CORPORATION
WORCESTER, MASSACHUSETTS
8-29-62 D.G.W.

jt

Pressurized Unit

BIG RIVERS RURAL ELECTRIC COOPERATIVE CORP.
SEBREE, KENTUCKY

					4 Hour Peak	4 Hour Peak Top Htr Out
	Pounds of steam per hour act. evap.	172,500	345,000	690,000	760,000	760,000
29.	Pounds of fuel per hour	19,030	37,350	71,900	78,620	84,210
30.	Pounds of air per hour ent. air heater	239,900	419,100	763,500	831,700	888,600
31.	Pounds of air per hour lvg. air heater	200,600	375,700	711,700	778,200	833,600
32.	Pounds of air per hour for combustion	211,200	395,500	749,200	819,200	877,500
33.	Pounds of gas per hour ent. air heater	228,000	428,400	812,500	888,400	951,600
34.	Pounds of gas per hour lvg. air heater	267,300	471,800	864,300	941,900	1,006,600
35.	Overall efficiency complete unit	89.3	88.7	86.9	86.6	86.4
36.	Heat release in furnace, Btu/cu.ft./hr.	4,400	8,600	16,600	18,200	19,400
37.	Heat release in furnace, Btu/sq.ft. E.P.R.S./hour	18,100	35,800	69,900	76,600	82,000
38.	Number of burners in operation	8	8	8	8	8

HEAT BALANCE

39.	Dry flue gas loss at exit	2.85	3.84	5.53	5.80	5.98
40.	Loss due to hydrogen and fuel moisture	4.78	4.92	5.19	5.21	5.22
41.	Loss due to moisture in air	0.07	0.09	0.13	0.14	0.15
42.	Loss due to radiation	1.00	0.50	0.25	0.23	0.23
43.	Loss due unburned combustibles	0.50	0.45	0.50	0.52	0.52
	Manufacturer's margin	1.50	1.50	1.50	1.50	1.50
45.	Total losses	10.70	11.30	13.10	13.40	13.60
46.	Efficiencies of complete unit	89.3	88.7	86.9	86.6	86.4

NOTE: Steam temperature control 760,000#/hr down to 456,000#/hr. (By spray).
Efficiencies based above air temperature entering air heater.

The unit consists of R-36 W.W. boiler, H.S. 4245 sq.ft.; plus projected water walls, H.S. 11,690 sq.ft.; Total H.S. 15,935 sq.ft.; economizer, H.S. 5100 sq.ft.; Ljungstrom 25VIX48 air heater, H.S. 82,400 sq.ft.; superheater for 955 F.; 2 Riley Ball Tube Mills, 8 #4A Riley burners; furnace volume 50,250 cu.ft.; Drawing LP-1098 & A & B.

RILEY STOKER CORPORATION
WORCESTER, MASSACHUSETTS
8-29-62 D.G.W.

jt

4.2 Communications

ELAINE STRZELEWICZ
04/24/2001 03:56 PM

To: Frank Zone/Riley/US@Riley
cc: Richard Dube/Riley/US@Riley
Subject: Poultry Litter Gasification - PFD

FYI.

---------------------- Forwarded by Elaine Strzelewicz/Riley/US on 04/24/2001 03:55 PM ---------------------------

"Babul Patel" <bpatel@nexant.com> on 04/24/2001 02:58:56 PM

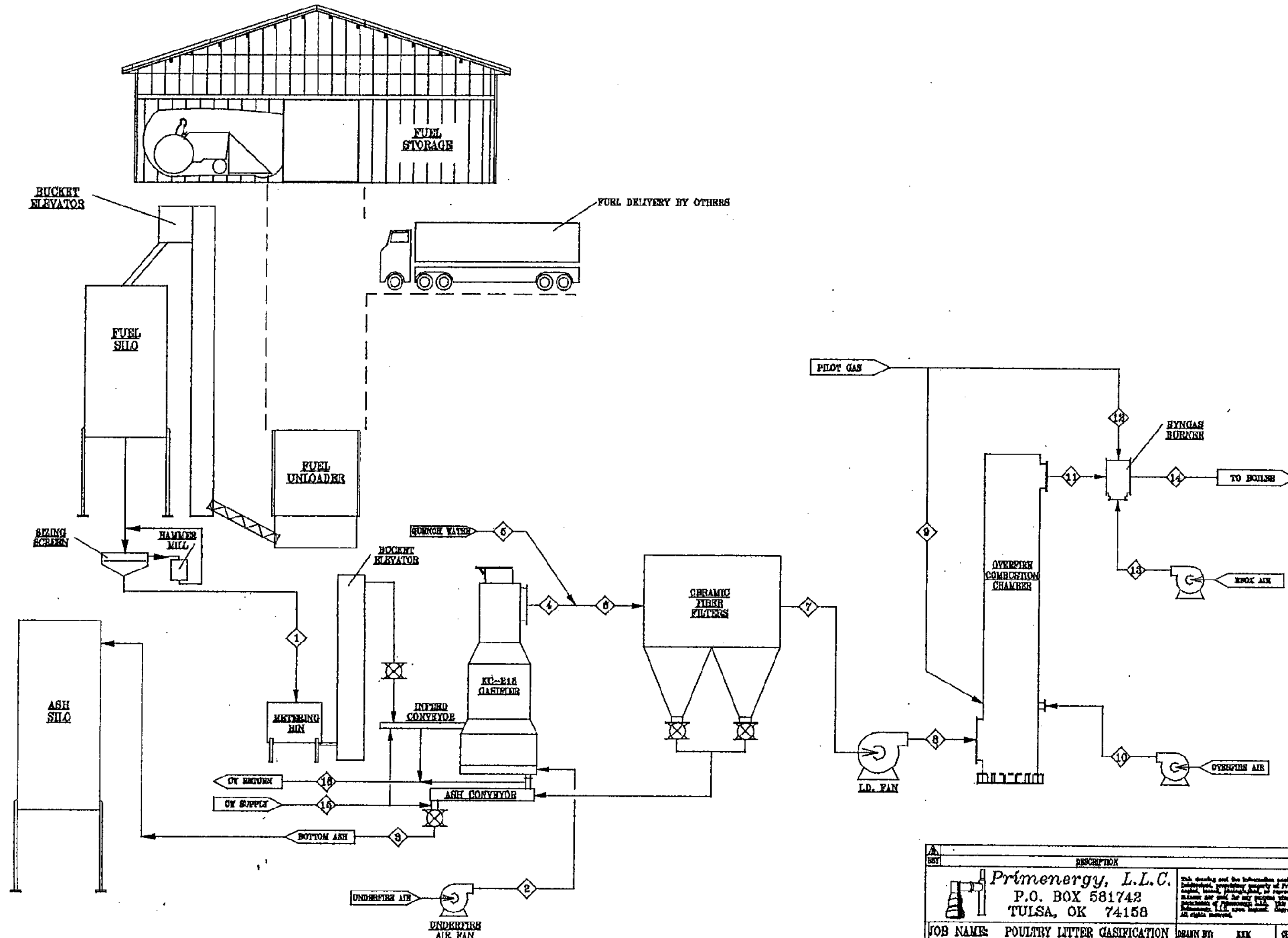
To: "Ellen Strzelewicz" <estrzelewicz@bbpwr.com>
cc:
Subject: Poultry Litter Gasification - PFD

Ellen/ Frank:

Here is the PFD - in MS Word format. The stream numbers correspond to the stream numbers identified in the Excel spread sheet.
As Frank mentioned in our Telecom, we do not have to inject the gases into the boiler @ 2250 Deg F. After the producer gas is filtered through the Hot Gas Filter and boosted to a pressure of 6" WG by an ID fan, we can directly send to the boiler, if appropriate.

Babul Patel
Nexant Inc.
bpatel@nexant.com
Ph: (415)-768-1200
Fax: (415)-768-3580

- PFD.doc



REV	DESCRIPTION	CHK	BY	DATE

Primenergy, L.L.C.
P.O. BOX 581742
TULSA, OK 74158

JOB NAME: POULTRY LITTER GASIFICATION
LOCATION: HENDERSON, KENTUCKY
CONTRACTOR: NEXANT
END USER: WKE
DESCRIPTION: PROCESS FLOW DIAGRAM

DRAWN BY:	KKK	CHECKED BY:
SCALE:	NONE	APPROVED BY:
DWG. DATE:	08/13/01	DATE APPROVED:

JOB NUMBER	DISCIPLINE	SHEET NO.	REV.
0149	00	001	B

ELAINE STRZELEWICZ
04/24/2001 03:58 PM

To: Frank Zone/Riley/US@Riley, Richard Dube/Riley/US@Riley
cc:
Subject: Western Kentucky Poultry Litter Biomass Gasification Project

FYI. Frank, I provided you copies of this data this afternoon.

---------------------- Forwarded by Elaine Strzelewicz/Riley/US on 04/24/2001 03:56 PM ---------------------------

"Babul Patel" <bpatel@nexant.com> on 04/24/2001 12:47:50 PM

To: "Ellen Strzelewicz" <estrzelewicz@bbpwr.com>
cc:
Subject: Western Kentucky Poultry Litter Biomass Gasification Project

Ellen:

Here are two files - one Excel - contains some Reid plant operating data, and expected gas composition, flow rate, temperature and pressure. The second is a word file that contains site specific information and the Riley Boiler Specifications. Let me know if you will need additional information.

Thanks

Babul Patel
Nexant Inc.
bpatel@nexant.com
Ph: (415)-768-1200
Fax: (415)-768-3580

- Reid Plant Data.xls
- ReidSite_data.doc

CASE I: 8.4 TPH POULTRY LI

Stream ID			1	2	3
Stream Name			GASIFIER FEED	GASIFIER COMB AIR	GASIFIER BOTTOM ASH
Pressure, "w.c.-g, or (psig)			----	20.0	----
Temperature, °F			77.0	80.0	300.0
Molecular Weight (lb/lbmole)			---	28.7	67.2
Component	Formula	MW	lb/h	lb/h	lb/h
Carbon	C	12.01	4,617.3		466.9
Hydrogen	H	1.01	526.6		
Nitrogen	N	14.01	463.0		
Oxygen	O	16.00	3,416.1		
Sulfur	S	32.06	82.9		
Chlorine	Cl	35.45	-		
Fuel Gas	CH4	16.04			
Carbon Monoxide	CO	28.01			
Carbon Dioxide	CO2	44.01			
Hydrogen	H2	2.02			
Water (v)	H2O (v)	18.02		267.1	
Nitrogen	N2	28.01		20,853.3	
Oxygen	O2	32.00		6,312.8	
Sulfur Dioxide	SO2	64.06			
Hydrogen Chloride	HCl	36.46			
Ash	SiO2	60.08	3,494.0		3,960.9
Lime	CaCO3	100.09			
Water (l)	H2O (l)	18.02	4,200.0		
TOTAL			16,800.0	27,433.2	4,427.8
AVAILABLE ENERGY VALUE (LHV-Hv), Btu/lb			4,051.5		
AVAILABLE ENERGY, MMBtu/h			68.1		-
FLOW RATE, scfm (gpm)				6,049.9	
FLOW RATE, acfm				6,282.6	

TTER

4 GASIFIER SYNGAS	8 ID FAN EXHAUST	9 PILOT GAS	10 OVERFIRE COMB AIR	11 OVERFIRE SYNGAS	12 PILOT GAS	13 REOX COMB AIR
(0.3)	8.0	(30.0)	13.0	7.0	(30.0)	13.0
1,550.0	1,381.8	77.0	80.0	2,400.0		80.0
25.0	24.7	16.0	28.7	27.0	16.0	28.7
lb/h	lb/h	lb/h	lb/h	lb/h	lb/h	lb/h
		23.3			23.3	
3,819.3	3,819.3			633.3		
9,206.7	9,206.7			14,276.2		
421.0	421.0			200.4		
5,411.6	6,575.7		157.0	8,756.2		244.6
21,316.3	21,316.3		12,257.5	33,573.7		19,098.9
			3,710.7			5,781.7
165.7	165.7					
-						
69.9						
40,410.3	41,504.6	23.3	16,125.1	57,439.8	23.3	25,125.3
953.9	928.7	21,502.0		229.0	21,502.0	
38.5	38.5	0.5		13.2	0.5	
10,242.9	10,644.2	9.2	3,556.1	13,478.1	9.2	5,541.0
39,592.7	37,701.1	9.5	3,692.9	74,129.3	8.1	5,754.1

14 COMB PROD TO BOILER
6.0
2,330.2
28.0
lb/h
15,335.0
10,843.7
52,672.6
3,737.0
82,588.3
18,642.4
100,030.5

Site Specific Data

Henderson, KY Area Meteorological Data
Latitude: 37:45:00 N, Longitude: 87:30:00 W, Elevation: 387 Ft.

Element	Annual Mean	Annual Minimum	Annual Maximum	Units
Avg. Temperature	56.9	-20.	113.	Deg F
Avg. Ambient Pressure				IN Hg
Avg. Relative Humidity	72	55		% RH
Avg. Wind Speed	70[1]		74[2]	MPH (UBC)
Annual Precipitation	44.8	28.25	71.01	IN
Maximum One Day			6.33	IN
Annual Snow Fall	16.1			IN
Maximum One Day			39.5	IN
Seismic Zone	1[3]			UBC -1997

Ref: National Climatic Data Center

1. Per Uniform Building Code mean design wind speed.
2. From NOAA wind gust over 5 seconds (1930-1996 data).
3. A micro earthquake occurred at 3:04:26 AM (CDT) on Saturday, August 26, 2000.
The magnitude 2.5 event occurred 28 km (18 miles) ENE (61 degrees) of 20 Evansville.
The hypocentral depth is 5 km (3 miles). (Ref. – USGS website)
Indiana-Illinois-Kentucky border point is classified as Seismic Zone 2A. (UBC – 1997 Fig. 16-2)

Site Specific Data

Boiler Specifications:

REID PLANT
Location Henderson, KY
WKE Contract B2502

GENERAL INFORMATION	
RILEY Boiler Contract No.	B2502
RILEY Boiler Serial No.	3456
Year Built	1964
RILEY Fuel Burning Contract No.	TM6833.
Engineers Burns and McDonnell Co., Kansas City, MO	
Maximum Continuous Capacity	690,000 lbs. Steam /hr
Peak capacity	760,9000 lbs. Steam/hr.
Type of Furnace Operation -	Pressurized
Drum Design Pressure	1475 psig
Economizer design Pressure	1525 psig.
Operating Pressure at Superheater Outlet	1300 psig
Steam, Temperature at Superheater Outlet	955°F
Furnace Volume	50,250 cu. ft.
Heat Release (At 690,000-lbs./hr. capacity when burning coal.)	16,600 Btu/cu. ft/hr.
Heat Release (At 760,000-lbs./hr. capacity for four hrs)	19,400 Btu/cu. ft./hr.
Heating Surfaces (Per Manufacturer's Stamping Sheet)	
Boiler	4,020 sq. ft.
Water Walls	12,100 sq. ft.
Superheater	32, 330 sq. ft.
Economizer	4,200 sq. ft.
Air Heater	82,400 sq. ft.
Approximate Water Capacity to Normal Water Level	500,788 lbs. ~62,599 gals
Approximate Water Capacity for Hydrostatic Test	827,253 lbs. ~103,407gals

RILEY *Stoker Corporation*
WORCESTER, MASSACHUSETTS

Site Specific Data

Reid Plant Coal Analysis

Coal	Average	Minimum	Maximum	Units	Source
As Burned Coal (LHV)	11,986	11,422	12,296	Btu/lb.	Reid Plant Data (Y 2000)
Moisture	8.6	7.5	10.8	%	
Ash	10.6	8.6	12.2	%	
S	2.6	2.3	2.8	%	▼

Poultry Liter Analysis

Poultry Litter	Average	Minimum	Maximum	Units	Source
Sample #					Date:
LHV				Btu/lb.	
Moisture				%	
Ash				%	
Volatile				%	
fixed Carbon				%	
Sulfur				%	
Hydrogen				%	
Nitrogen				%	
Chlorine				%	
Phosphorus (P)				%	
Potassium (K)				%	
Sodium (Na)				%	

Reid Plant Environmental Emission Limit

Pollutant	PPM	lbs./MBtu	Tones/Quarter	Tones/Year
CO				
NOx				
SOx				
Particulates				
Metals				
Hg				
Heat Input (MBtu/hr)				

ELAINE STRZELEWICZ
05/03/2001 08:30 AM

To: Frank Zone/Riley/US@Riley, Richard Dube/Riley/US@Riley
cc: Enrique Vega/Riley/US@Riley
Subject: WKE - Poultry Litter

Frank, based on our conversation with Babul, please see the following.

---------------------- Forwarded by Elaine Strzelewicz/Riley/US on 05/03/2001 08:20 AM ---------------------------

"Babul Patel" <bpatel@nexant.com> on 05/02/2001 07:20:14 PM

To: "Ellen Strzelewicz" <estrzelewicz@bbpwr.com>
cc:
Subject: WKE - Poultry Litter

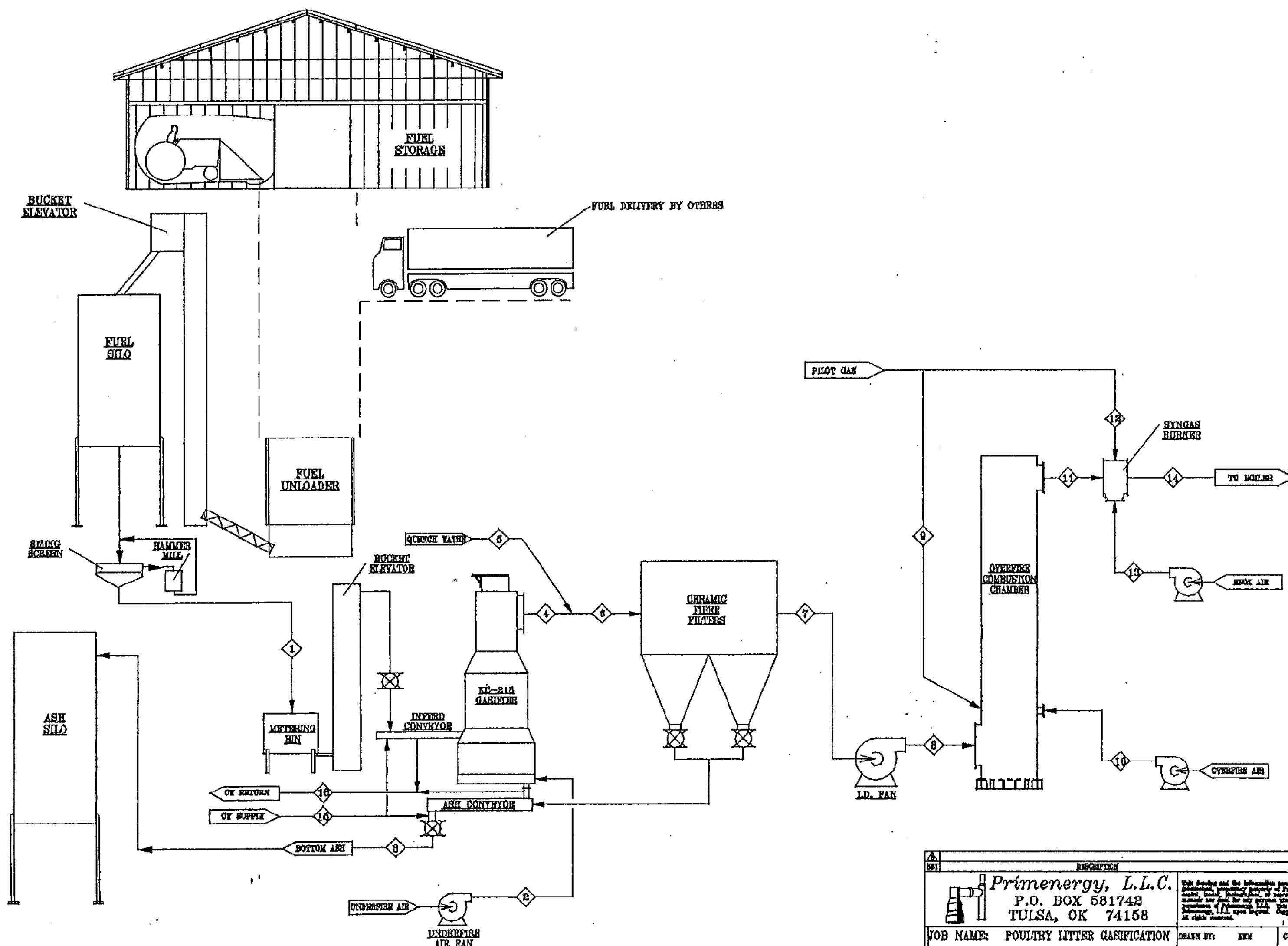
After our phone conversation, I talked to our experts and gasifier vendor. The reason for over fire burner in the gasifier design is to handle NOx.

Unfortunately, poultry litter contains considerable bound nitrogen, which comes out of the gasifier as ammonia, methyl amine, NOx, etc. The gasification temperature is not sufficient to reduce these bound nitrogen compounds to N2. If oxidized directly, as it would be in the boiler, a large portion of these will convert to NOx. The result will be very high NOx emissions.
By utilizing the over fire, we provide a high temperature, reducing atmosphere, which reduces these bound nitrogen compounds to N2. This was the basis for our design. We are looking into cooling the gas before ID fan, but the over fire burner will be after ID fan. The ReOX burner can be eliminated. I am attaching the PFD that was basis for our Material and Energy Balance.

Please pass this information to Frank and Dick Doubey. Give me a call if you think this will be a problem.

Babul Patel
Nexant Inc.
bpatel@nexant.com
Ph: (415)-768-1200
Fax: (415)-768-3580

- PFD.doc



Primenergy, L.L.C.
P.O. BOX 581742
TULSA, OK 74158

JOB NAME: POULTRY LITTER GASIFICATION
LOCATION: HENDERSON, KENTUCKY
CONTRACTOR: NEXANT
END USER: WKE
DESCRIPTION: PROCESS FLOW DIAGRAM

DWG. DATE: 08/13/01

JOB NUMBER	DISCIPLINE	SHEET NO.	REV.
0149	00	001	B

ELAINE STRZELEWICZ
05/16/2001 11:23 AM

To: bpatel@nexant.com
cc: Frank Zone/Riley/US@Riley, Richard Dube/Riley/US@Riley
Subject: FW: Boiler Entry

BAbul, Frank needs thermal conductivity values of insulation and refractory for the pipe inside lining in order to perform his calculation.

---------------------- Forwarded by Elaine Strzelewicz/Riley/US on 05/16/2001 11:19 AM ---------------------------

"Babul Patel" <bpatel@nexant.com> on 05/15/2001 07:32:49 PM

To: "Ellen Strzelewicz" <estrzelewicz@bbpwr.com>
cc:
Subject: FW: Boiler Entry

Ellen:

I had discussion with Frank and Dick about the boiler penetrations. I passed their questions and concerns to Primenergy, and I got following response. I have also left messages with refractory engineer from the past to seek his advise.
I am checking Kevin's' calculations, but 4 ~38" penetrations along the side of the boiler do not look out of the ordinary. The overfire chamber is a refractory lined vessel with approx. 6' ID that will be sitting on the ground approximately 15' from the boiler house. We will have to figure out how to route 4 large pipes from there into the boiler. Ideally, we would like to have the cooled gas at 1000 deg F going into the boiler, but due to NOx issue, we have to burn the gas outside.

Hope, this helps. If Frank and Dick have questions, please call.

Babul Patel
Nexant Inc.
bpatel@nexant.com
Ph: (415)-768-1200
Fax: (415)-768-3580

-----Original Message-----
From: Kevin McQuigg [mailto:kmcquigg@primenergy.com]
Sent: Tuesday, May 15, 2001 12:57 PM
To: Babul Patel (E-mail)
Cc: W.N. (Bill) Scott
Subject: Boiler Entry

Babul,

I am presently working on the calculations, including the flue gas to air heat exchanger downstream of the hot gas filters. As it turns out, the air preheat makes only a small difference on the gas flows.