W.A. PARISH POST-COMBUSTION CO_2 CAPTURE AND SEQUESTRATION PROJECT

Topical Report

Final Public Design Report

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Prepared by

Petra Nova Parish Holdings LLC

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1 Acronyms and Abbreviations

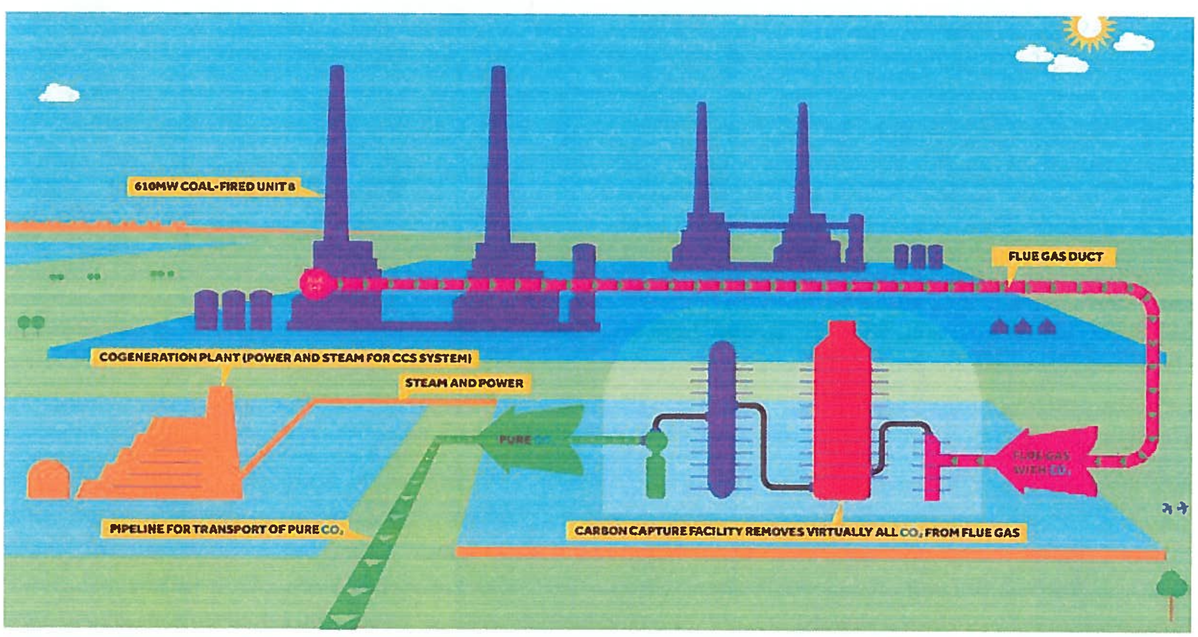
BEDD	Basic Engineering Design Data
BOP	balance of plant
CA	Cooperative Agreement
CEMS	Continuous Emissions Monitoring System
CCPI	Clean Coal Power Initiative
CCS	carbon capture system
CFD	Computational Fluid Dynamic
CO_2	carbon dioxide
COE	cost of electricity
cogen	cogeneration unit
CTG	Combustion Turbine Generator
Demin	Demineralized Water
DCS	distributed control system
DOE	Department of Energy
EIV	environmental information volume
EOR	enhanced oil recovery
EPC	Engineering, Procurement, and Construction
ERCOT	Electric Reliability Council of Texas
etc.	Etcetera
E&P	exploration and production
FD	forced draft
FE	Office of Fossil Energy
FEED	front-end engineering design
FGD	flue gas desulfurization
FNTP	full notice to proceed
GE	General Electric
gpm	gallons per minute
HAZOP	hazard and operability
HEC	Hilcorp Energy Company
HRB	heat recovery boiler
HSE	health, safety, and environmental
HSS	heat stable salt
HMB	Heat and Material Balance
IG	Integrally Geared
JBIC	Japan Bank for International Cooperation
JX	JX Nippon Oil & Gas Exploration EOR Limited
KEPCO	Kansai Electric Power Co., Inc.
KM CDR Process	Kansai Mitsubishi Carbon Dioxide Reduction Process
kW	kilowatt
LP	low pressure
MAP	Mitigation Action Plan
MEA	monoethanolamine
MCC	Motor Control Center
MHI	Mitsubishi Heavy Industries, Ltd.
MHIA	Mitsubishi Heavy Industries America, Inc.
MW	megawatt
MWe	megawatt equivalent
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NEXI	Nippon Export and Investment Insurance
NRG	NRG Energy, Inc.
O&M	operations and maintenance
P&ID	piping and instrumentation drawing/diagram
PDC	Power Distribution Center
Petra Nova	Petra Nova Parish Holdings LLC
PFD	process flow diagram
PLC	programmable logic control
PPE	personal protective equipment
psi	pounds per square inch
R&D	research and development
RAM	reliability, availability, maintainability
ROD	Record of Decision
Sargent & Lundy, L.L.C.	S&L
SoCo	Southern Company
SOPO	statement of project objectives
ss	suspended solid
SWPPP	storm water pollution prevention plan
TCEQ	Texas Commission on Environmental Quality
TCV	Texas Coastal Ventures, LLC
TEG	triethylene glycol
TIC	TIC - The Industrial Company
tpd	tons per day
tpy	tons per year
U.S.	United States
UPS/DC	Direct Current Uninterruptible Power Supply
VOC	volatile organic compound
WAP	W.A. Parish Electric Generating Station

2 Abstract

The Petra Nova Project is a commercial scale post-combustion carbon capture project that is being developed by a joint venture between NRG Energy, Inc. (NRG) and JX Nippon Oil and Gas Exploration EOR Limited (JX). The project is designed to separate and capture carbon dioxide (CO_2) from an existing coal-fired unit's flue gas slipstream at NRG's W.A. Parish Electric Generating Station (WAP) located southwest of Houston, Texas. The captured CO_2 will be transported and injected into the West Ranch oil field to boost oil production.

The project, which is partially funded by a grant from the United States (U.S.) Department of Energy (DOE) under the Clean Coal Power Initiative (CCPI) Round 3, will use the Kansai Mitsubishi Carbon Dioxide Recovery advanced amine-based CO_2 absorption technology (KM CDR Process®*) which was jointly developed by Mitsubishi Heavy Industries, Ltd. (MHI) and the Kansai Electric Power Co. Inc., to treat and capture at least 90 percent of the CO_2 from a 240-megawatt equivalent (MWe) flue gas slipstream off of Unit 8 at WAP. The project will capture approximately 5,000 tons of CO_2 per day (1.6 million tons of CO_2 per year) that would otherwise be emitted into the atmosphere, representing the largest commercial scale deployment of post-combustion CO_2 capture technology at a coal power plant to date.

The joint venture issued full notice to proceed (FNTP) in July 2014 and when complete, the project is expected to be the world's largest post-combustion carbon capture facility on an existing coal plant. The detailed engineering is sufficiently complete to prepare and issue the Final Public Design Report.



* KM CDR Process is a registered trademark of Mitsubishi Heavy Industries, Ltd., in Japan, the United States of America, European Union (CTM), Norway, Australia, and China.

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3.1 List of Figures and Tables

4 Introduction

The DOE's CCPI program is a multi-year initiative to foster more efficient advanced clean coal technologies for use in new and existing electric power generating facilities. The program, planned and managed by the DOE Office of Fossil Energy (FE) and implemented by the National Energy Technology Laboratory (NETL), is a private-public cost-sharing partnership that accelerates commercial deployment of advanced technologies to ensure reliability of an affordable electric supply while simultaneously protecting the environment.

As part of the implementation of the American Recovery and Reinvestment Act of 2009 (ARRA), the CCPI - Round 3 Funding Opportunity Announcement (FOA) was re-opened in June 2009 to seek coal-based projects that focused on the capture and sequestration (or beneficial use) of CO_2 emissions. Based on the requirements of the solicitation, NRG, with support from other stakeholders, submitted an application in August 2009 to build a 60MWe slip stream post-combustion carbon capture system at WAP. The captured product CO_2 would be beneficially used for enhanced oil recovery (EOR) in a nearby oilfield. The DOE and NRG reached agreement on a plan and entered into a Cooperative Agreement (CA) in May 2010, for up to $167 million in cost-shared funding, or about 50% of the total estimated project cost at that time.

Shortly after the CA was signed, NRG began the process of identifying candidate oilfields. The list of oilfields was refined and narrowed based on desirable geological characteristics and was further narrowed by commercial considerations and degree of interest in participating in such a project. During this process, NRG met with Hilcorp Energy Company (HEC) and, through their respective affiliates, entered into a 50/50 joint venture called Texas Coastal Ventures, LLC (TCV). TCV owns 100% of the working interests in the West Ranch oilfield in Jackson County, Texas, which is located approximately 80 miles southwest of WAP. TCV also owns 100% of the CO_2 pipeline which will transport the CO_2 from WAP to West Ranch.

Despite the technical feasibility of a 60MWe capture system, NRG concluded that a 60MWe project would not be economical. Oilfield simulation models showed that the low volume of CO_2 captured from a 60MWe system (approximately 20 MMscfd) injected into an oilfield, would not produce meaningful up front oil production following first injection. This was found to be true regardless of the size of the oilfield modeled. As a result, the DOE agreed to modify the CA to support a 240MWe Front End Engineering and Design (FEED) study. While the study was being conducted, NRG changed technology providers to MHIA since MHIA already had an operational demonstration capture plant successfully capturing CO_2 from coal-fired flue gas at a sufficient scale (25MWe). This had the added benefit of allowing prospective investors to witness performance and comprehend the prospect of scaling-up to 240MWe.

This larger, more capital intensive and higher risk innovation caused NRG to seek out additional participants and investors. These efforts led to JX, a Japanese company, looking for leading edge projects that could demonstrate successful CO_2-EOR. In May of 2013, JX purchased 50% of Petra Nova Parish Holdings (PNPH). JX not only brought much needed capital to help with the funding of the project, but as a world-class exploration and production (E&P) company, provided a wealth of experience in developing the EOR side of the project. JX also assisted in securing limited recourse financing from the Japan Bank for International Cooperation (JBIC) and Nippon Export and Investment Insurance (NEXI) for the project. The DOE again modified the CA in November 2013 to novate the agreement from NRG to the PNPH project entity to take into account the new project structure.

More recently, section 313 of the Consolidated Appropriations Act of 2016 directed the DOE to reallocate funds previously obligated to projects selected under solicitations for CCPI and FutureGen. Specifically, the law required that not less than $160 million be transferred from projects that did not secure funding to commence construction by January 2016 to projects that had secured construction funding by that date. Two CCPI projects met this criterion including the Petra Nova Project. Accordingly, $23 million was added to the overall project grant as a result of Section 313 of the FY2016 omnibus appropriation passed in December 2015. This brought the total grant amount to $190 million.

4.1 Objectives

The specific objectives for the CCS project are as follows:

- Demonstrate successful operation of an advanced amine post-combustion process to achieve 90% CO_2 capture efficiency of the selected size, up to 250MWe scale.
- Demonstrate technological advances aimed at lowering energy requirements of the carbon capture process.
- Demonstrate the concept of integrating a cogeneration (cogen) system into the carbon capture process to provide the energy requirements to operate the system in the form of steam and power.
- Establish the impact of CO_2 capture and sequestration operations on the Cost of Electricity (COE), and provide recommendations necessary for the demonstration technology to achieve a COE increase of less than 35%*.

The project is now in Phase 2 of its Three-Phase execution process. Phase 1 was to develop the project in sufficient detail to facilitate the decision-making process to progress to the next stage of project delivery (Phase 2). This was administered between March of 2010 and June of 2014. Phase 2, which is design, procurement, construction, and commissioning the fully integrated CO_2-EOR project (including CCS, Pipeline, and EOR infrastructure) began in July 2014 and will continue through December 2016. Phase 3 is the demonstration phase of the project whereby the integrated project becomes operational and reporting is conducted. This will take place from January 2017 through December 2019.

This report is based on developments that occurred during Phase 2. Phase 2 can be further subdivided into the following specific objectives:

- Engineer, Procure, Construct, Start-up and Commission a 240 MWe post combustion carbon capture and compression system with related Balance of Plant and facility interconnects on an existing coal-fired power plant.
- Engineer, Procure, Construct, Start-up and Commission a CO_2 Pipeline to transport the product CO_2 from the power plant to the EOR/sequestration site (The DOE Grant is not reimbursing these activities, just reporting on them for completeness).
- Engineer, Procure, Construct, Start-up and Commission the EOR infrastructure in the oil field (The DOE Grant is not reimbursing these activities, just reporting on them).
- Engineer, Procure, Construct, Start-up and Commission the CO_2 Monitoring Infrastructure and conduct baseline testing in advance of CO_2 injection.

* Petra Nova will not impact the COE because this project installed a standalone cogeneration system; however, the project can provide valuable information toward reducing the impact of CO_2 capture on COE when deployed differently.

With Phase 2 nearing completion, the Engineering team has assembled this Final Public Design Report specifically for the CCS and BOP portions of the project as a deliverable under the CA.

4.1.1 Final Public Design Report Objectives

The purpose of the Public Design Report is to consolidate for public use all available nonproprietary design information on the project. The following report includes an overview describing the technology and a summary of the mass and energy balances for the process. It also defines the overall process performance requirements and describes the evaluations and operating philosophies upon which those performance requirements are based. Also, a summary of design refinements during the execution phase is presented as well. Finally, a summary cost estimate of capital and estimated operating costs are included.

5 CO_2 Capture Process Overview and Description

MHI's CO_2 capture technology process, the KM CDR Process®, is similar in overall concept to other amine-based gas treating processes which have been utilized for many years in the natural gas, petrochemical, and refining industries, except that MHI has more recently adapted and scaled this process to recover CO_2 from low-pressure, oxygen-containing streams, such as power plant flue gas. It uses a proprietary high-performance solvent, KS-1™, for CO_2 absorption and desorption that was jointly developed by MHI and Kansai Electric Power Co., Inc. Their solvent performance is highly regarded, and the process has been adopted in many CO_2 capture plants in Japan and abroad, making MHI a leader in this industry. Below is a simplified process diagram and process description.

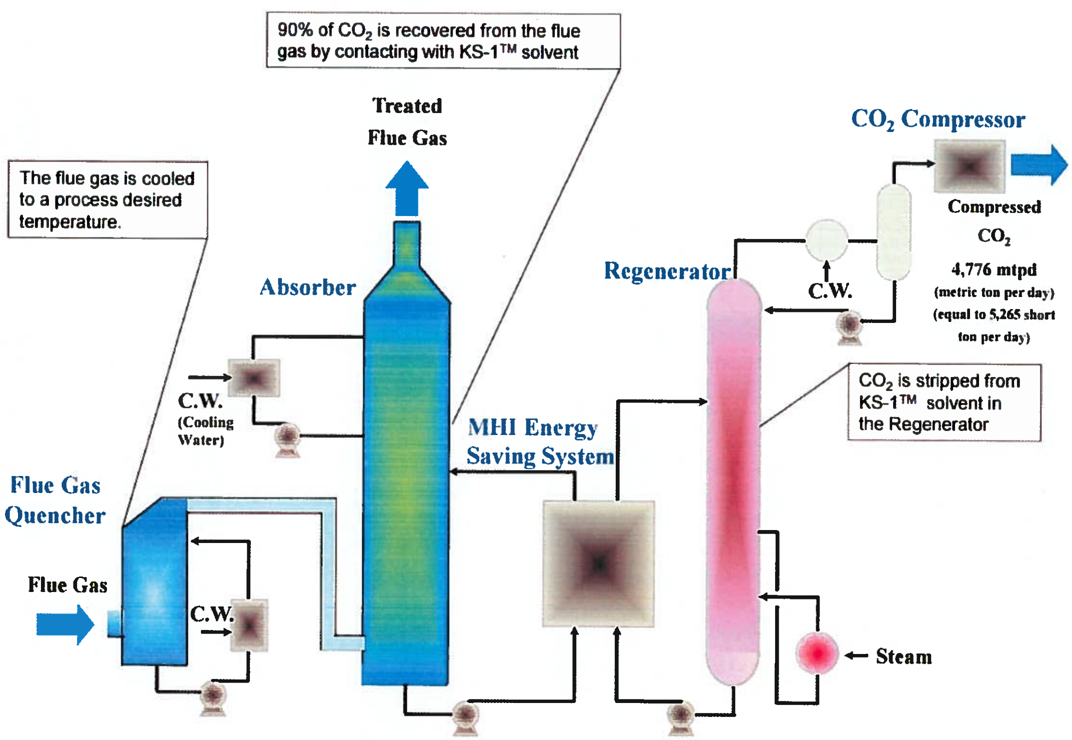

Figure 1. Simplified Process Flow Diagram (Generic)

The process consists of three main columns: a Quencher, where the flue gas is conditioned and prepared for the absorption process; an Absorber column, where CO_2 is absorbed into the amine-based solvent through a chemical reaction; and a Regenerator (or stripper) vessel, where the concentrated CO_2 is released and the original solvent is recovered and recycled back through the process. Each of these steps is further summarized below.

The flue gas is first routed to the Quencher for flue gas conditioning (i.e., cooling and trim acid gas removal). Certain constituents entrained in the flue gas, if not removed, would contaminate the solvent so the gas is scrubbed of these contaminating constituents in a deep polishing scrubber. The flue gas is then cooled from approximately 175°F to approximately 120°F because the absorption reaction is affected by the temperature of the flue gas (i.e., absorption of CO_2 in the solvent is an exothermic process that favors lower temperatures). This cooling process causes water to condense out of the wet flue gas.

The cooled and cleaned gas exits the top of the Quencher column where it is pulled through the blower. The blower located downstream of the cooler is used to pull the slipstream off of the host unit and overcome the pressure drop through the duct, Quencher and Absorber.

From the blower, the flue gas enters the bottom of the Absorber column and flows upward through the packed column beds where it comes into contact and chemically reacts with the solvent (loading the solvent with CO_2). Counter-current flow through multiple stages of structured packing maximizes contacting surface area and mass transfer rate of the CO_2 into the solvent. The CO_2-depleted gases are then cooled, washed and vented to the atmosphere.

The CO_2 "rich" solvent leaves the bottom of the Absorber and is routed through the cross heat exchanger, heating the solvent as it is pumped to the Regenerator. Wherein the Regenerator, the weakly bonded compound is reversed through the application of heat, in the form of process steam, to liberate the CO_2 and leave reusable solvent behind. The liberated CO_2 is sent to a compressor to compress the CO_2 up to the supercritical phase (resembling a liquid but still compressible) for pipeline transport. The CO_2 "lean" solvent is routed back to the Absorber, through the cross heat exchanger (the lean solvent is cooled by the rich solvent from the Absorber) to repeat the process. A portion of the cooled lean solvent is diverted through solvent filtration equipment to remove solution contaminants.

Some of the solvent is lost during the process for a variety of reasons including mechanical, vaporization, and degradation. Furthermore, some contaminants, such as heat stable salts (sulfates, nitrates, and oxalates of amine) and thermal/oxidation degradation products, cannot be removed in the solvent filtration package and must be removed through a periodic reclaiming operation. Fresh solvent is added to make up for these losses incurred in the process.

This process is energy intensive and requires heat in the form of steam to release the CO_2 from the solvent and power to run the equipment, including the very large CO_2 compressor. A cogeneration plant (combustion turbine with an HRB) was constructed to supply these utilities. Finally, a substantial amount of cooling is required (flue gas cooler, absorber cooling section, compressor, etc.) that is served with the construction of a new cooling tower.

5.1 Technology Readiness

Acid gas removal by amine-based chemical absorption has been used to separate CO_2 and other acid gases from natural gas, hydrogen, and other gas streams since the 1930s. Since the chemical reaction is so fundamental to the process, new and improved solvents with higher CO_2 absorption capacities, faster CO_2 absorption rates, high degradation resistance and low corrosiveness and energy use for regeneration are continuously under development. Through these comprehensive development efforts, the underlying chemistry (solvent reaction kinetics) is proven through simulation modeling work, laboratory experimentation, and bench-scale campaigns. How solvents react with the impurities in flue gas, including SO_x, NO_x, oxygen, and water, as well as trace amounts of metals, chlorides, and particulate matter have all been subjected to experimentation, modeled, and are well-understood. Therefore, before even considering investing significant resources into pilot test facilities, the chemistry has already been proven in laboratory and sophisticated modeling environments. The remaining challenges become the scale-up of process mechanics.

For the process mechanics, as summarized above, the gas stream contacts the solvent in tall columns known as absorbers (or scrubbers), in which turbulent flow through column fill, or "packing" material, promotes rapid CO_2 transfer from gas to liquid. Packed towers have been in use for more than 100 years, and the use of structured packing dates back to the 1960s. Column design and internal design components such as size, packing height, and column diameter are all used to manage the fluid dynamics of liquid distribution, liquid flow rate, liquid hold up, and packed bed pressure drop are some of the most critical aspects to column design. To provide the best possible scale-up data and to remove the technical risks associated with a large industrial CO_2 scrubbing unit, packing type, gas/liquid distributor qualities and their installation methods have to be compared to those in commercial use today. Transferring this technology from other industries and similar applications has made this transition easier. The advanced column designs developed for Flue Gas Desulfurization (FGD) air quality control systems are good reference points as to how technologies have been adapted and scaled-up for alternative applications.

MHI has been developing the KM CDR Process® in collaboration with the Kansai Electric Power Co., Inc. (KEPCO) for over twenty-five (25) years. MHI's initial vision was to develop a superior solvent to monoethanolamine (MEA) for CO_2 capture. This led to the development of a laboratory scale test program which evaluated more than 200 different solvents. MHI narrowed those solvents down to 20 and tested them at its first pilot plant at KEPCO's Nanko Power Plant in 1991. The pilot plant has a 2 tpd CO_2 capacity and is capable of evaluating the CO_2 capture performance of various solvents. The pilot plant test program resulted in the development and commercialization of the proprietary KS-1 solvent which is the advanced sterically hindered amine now used for CO_2 capture.

MHI has since deployed 11 commercial CO_2 capture plants ranging in capacity from 200 to 500 metric tons per day (tpd). Most of these commercial plants capture CO_2 from natural gas-fired flue gas to enhance urea production for the chemical and fertilizer industries. MHI's most recent plant built in Qatar captures CO_2 from natural gas-fired flue gas to enhance methanol production.

MHI has also tailored its KM CDR Process® to the unique challenges of coal-fired flue gas. In 2006, MHI completed several test programs on a test facility with a 10 tpd slip stream from the flue gas of a commercial 500MW coal-fired power plant in Matsushima, Japan. Long term operation of this plant verified the impact of coal-fired flue gas impurities on the KM CDR Process® and allowed MHI to develop solutions to these challenges.

Recently, along with Southern Company (SoCo), MHIA demonstrated the viability of this technology on a 25 MWe scale demonstration plant with a 500 tpd CO_2 capacity at Alabama Power's Plant Barry. From 2011 to 2014, approximately 200,000 tons of CO_2 were captured. Over the course of the program, the plant has provided invaluable information on the challenges of coal-fired post-combustion CO_2 capture. MHIA was able to successfully demonstrate key features of the technology including the stability of the KS-1^{TM} solvent, amine emissions reduction, heat integration, and automatic load following control. As a result of this testing, and the scientific, engineering and technical development work expended on the technology, MHI is ready to construct commercial CO_2 recovery plants >5,000 tons per day. At 240MWe, the column scale-up to handle the increased volume of flue gas from the Plant Barry reference project only requires about a three-fold (3x) increase. This is because the cross-sectional area design is proportional to the flue gas flow rate, so incremental increases in column diameter dramatically increases throughput and flow rate.

The Petra Nova Project illustrates the most recent development in MHI's process and, at a 240MWe scale, will demonstrate its scalability relative to other commercial or previously demonstrated technologies. When commissioned in 2016, the Petra Nova Project will be the largest integrated post-combustion project in the world. With the knowledge, experience and innovations developed by projects like these, carbon capture could be deployed on a larger and broader scale-- not only on power plants but also within other energy intensive industries.

5.2 Design Approach

The design approach followed a typical development sequence and associated design reviews starting with a design basis document, development and review of process flow diagrams (PFDs) and heat and material balances. This led to the preparation of piping and instrumentation diagrams (P&IDs), equipment specifications, data sheets and plot plans, three-dimensional (3D) modeling and other detailed design activities. Also, as is customary in the petrochemical industry, the project team carried out a Hazard and Operability Study (HAZOP) which is a method of assessing and evaluating potential hazards to employees or equipment common in the process industry. A HAZOP analysis provides a full review of a process system and systematically questions every part of it to establish how deviations from the design intention might arise and cause system instability. The team documented the cause and consequence of each process fault condition and revealed all of the available layers of protection during this process.

5.2.1 General Arrangement

The design effort within a brownfield congested site was a significant undertaking. The CO_2 capture plant was designed to process a portion of WAP Unit 8's coal combusted flue gas to provide the capture capacity equivalent to a 240MW unit. The preference is to process flue gas downstream of an installed FGD system because SO_2 in the flue gas has an adverse effect on the amine absorption process*. Therefore, if the 240MWe slipstream could be taken from Unit 8 downstream of the existing wet FGD, the need for a new limestone scrubber, reagent preparation, and disposal system would be eliminated. Even with this approach, a polishing sodium scrubber within the KM CDR Process® would still be required as the vintage FGD on Unit 8 was designed to be only 82% efficient which does not achieve outlet concentrations at the levels necessary to minimize solvent contamination.

*SO_2 is a stronger acid than CO_2, making it the preferred reaction which reduces the amine's ability to react with the CO_2. Moreover, this reaction contaminates the solvent because the reaction with SO_2 cannot be reversed in the regeneration process.

With Unit 8 selected, the host unit interconnection ductwork take-off point was evaluated. Several locations were considered for the duct interconnection to the complicated existing host unit configuration. The existing FGD system consists of three parallel absorber vessels with an overhead bypass gas duct that contains unscrubbed flue gas that mixes with the scrubbed gas in the stack breaching duct to maintain thermal buoyancy up the Unit 8 stack. This bypass gas renders the scrubber system only 82% efficient which could introduce undesirable levels of SO_2 into the carbon capture system if the take-off point is not optimal. In addition, removing nearly 35% of the flue gas from the existing ductwork leads to a new flow condition that required evaluation. Through various iterations of Computational Fluid Dynamic (CFD) modeling, it was determined that the bottom of the Unit 8 stack breeching duct is the optimum take-off location for the CCS flue gas supply duct. Unit 8 stack buoyancy modeling accounting for the CCS flue gas supply was also performed to determine the CCS operating load range in relation to the Unit 8 operating load range.

Next, the team needed to evaluate where to locate the CCS on the congested site. Based on the existing site constraints and general footprint requirements of the MHI process, the optimal location for the CCS was identified to be just west of, and behind, the Unit 7 baghouse. This space was the largest area adjacent to Unit 8 that required the least amount of facility relocation/disruption. The site was occupied by a warehouse that would have to be relocated but was otherwise reasonably open for a brownfield retrofit.

With the takeoff point selected, the team evaluated the long run of ductwork, (approximately 800 feet), required for the transfer of flue gas from Unit 8 to the CCS area. The flue gas is fully saturated when extracted from Unit 8, and the ductwork needed to be corrosion-resistant. Alloy-clad carbon steel duct and fiber-reinforced plastic (FRP) duct types were investigated, and FRP was determined to be the best solution for this project.

In addition to locating the CCS process, the team needed to locate Balance of Plant (BOP) equipment to service the CCS. The following systems are needed:

- Combustion Turbine Generator (CTG)/Heat Recovery Boiler (HRB) cogeneration system;
- Cooling Tower;
- Water Treatment Facilities (Demineralized Water or "Demin", Waste Water Treatment);
- BOP Piperack;
- Integration of existing facility site services (i.e. raw water, potable water, firewater, ammonia, etc.); and
- Treated Waste Water Discharge (permitted) via new outfall on Smither's Lake.

All of the components needed for the integration of the BOP systems are commercially-available and well-proven technologies. Previous study work determined the type and location of the cogeneration system. A wide array of combinations capable of producing the range of steam required, including various configurations of frame machines, aero-derivatives, micro turbines, and package boilers to flexibly serve the unique parasitic energy needs of CCS were explored. The prime mover of the cogeneration facility was identified to be a General Electric (GE) 7EA combustion turbine.

The Combustion Turbine was installed in 2013 in simple cycle peaking configuration outside of the Grant. This provided a critical piece of infrastructure and offered a near-term source of revenue as a power provider to the grid in advance of carbon capture integration.

The other system components, Cooling Tower, Water Treatment Facilities, and associated interconnections (between the islands as well as existing site facilities), were identified and laid out in a prudent and best fit arrangement. To minimize the large diameter cooling water piping runs, the cooling tower was eventually sited within the CCS island, as this was the ultimate location of all cooling water consumption. Figure 2 illustrates the BOP and CCS general arrangement of the systems at WAP. Appendix 7.3 shows the final plot plan of the related CCS and BOP facilities.

Figure 2. Site Arrangement

With the host unit and general arrangement determined, numerous design considerations were made throughout the engineering effort to facilitate and optimize the integration of the process with the existing facility. Prudent decision-making around these specifics, redundancy philosophy, metallurgy selection, and other value engineering exercises are further detailed below.

5.2.2 CCS Design

The engineering and design services for carbon capture were performed by MHI's engineering teams covering the complete spectrum of piping, mechanical, civil, structural, electrical, instrumentation, and process disciplines. Comprehensive design reviews (Design Basis, PFD, HMBs, P&ID, Layout, 3D modeling, HAZOP) provided the necessary confidence that the design satisfied the performance and engineering requirements, established compatibility between major components and battery limits, and allowed the project to assess risk areas with the design.

The Basic Engineering and Design Data (BEDD) document provided the basis for the design. This document included the following information:

- Codes and Standards that served as a basis for design;
- Flue Gas Feed characteristics;
- CO_2 Purity Requirements;
- Ambient Site Conditions; and
- Make up water characteristics.

The BEDD did not include detailed technical design requirements, which were prepared as separate discipline-specific documents that governed the technical teams' design. A non-confidential version of the BEDD document can be found in the Appendix to this report.

From there, the PFDs indicating the general flow of plant processes and equipment illustrating the pressures and compositions of major streams were developed. A simplified view of the PFD is shown in Figure 3 on the next page.

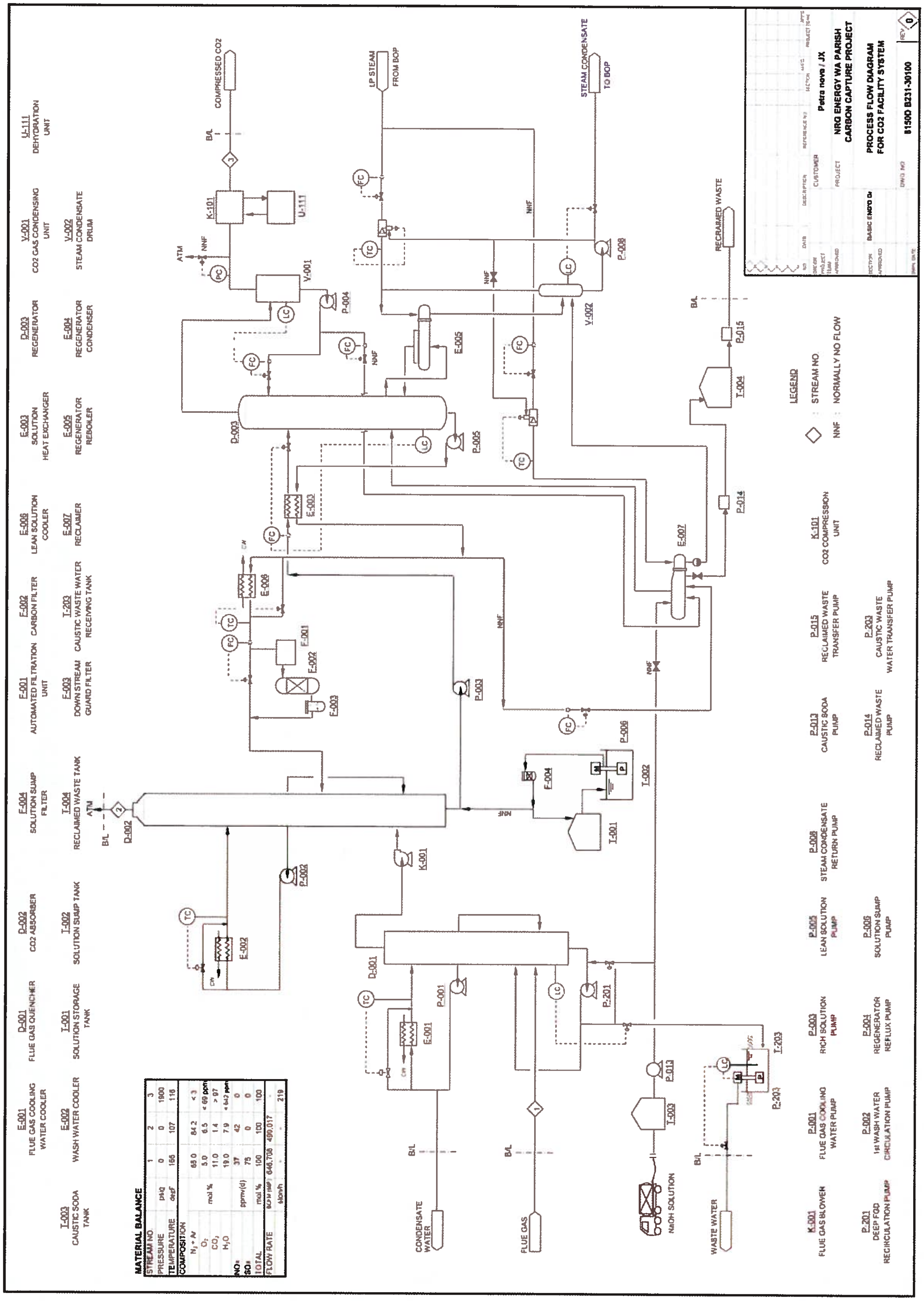

Figure 3. Simplified Process Flow Diagram

As previously described above and worth summarizing again here, there are three main sections of the process: gas conditioning, CO_2 absorption, and stripping sections. Before starting the absorption process, flue gas is treated and conditioned in a combined cooling section (to reach an optimal temperature) and purified, chiefly to remove SO_2 which is a cause of solvent degradation. Once treated, the flue gas is sent to an absorber tower, in which CO_2 reacts with the solvent, while the cleaned flue gas is released into the atmosphere. The separation of CO_2 is caused by a chemical reaction that creates a chemical compound in which CO_2 is loosely bound. The CO_2-loaded solvent is then sent to a stripper section where it is heated, releasing pure CO_2 and regenerating the solvent. While CO_2 is dried, compressed, and transported in a dense phase to the EOR site, the regenerated solvent is sent back to the absorber tower for additional capture, after being cooled by the CO_2-loaded solution exiting the absorber tower in a heat exchanger. Each of these sections and their design attributes are further described below.

5.2.2.1 Quencher

The Quencher removes SO_2 and other contaminants that may remain in the flue gas stream from Unit 8 in accordance with the inlet gas specifications. The Quencher is a rectangular tower with packing to ensure high liquid to gas contact. The Quencher has two primary functions: (i) flue gas cooling and (ii) SO_2 and other contaminant removal.

The bottom section, the trim FGD section, reduces the concentration of SO_2 in the flue gas before entering the CO_2 Absorber. The Trim FGD Section utilizes packing as the medium for liquid-gas contact between the flue gas and the Sodium Hydroxide (Na_2SO_4) solution. The pH is controlled by adding 50 weight percent (wt%) caustic soda to the Quencher from the caustic soda tanks by using a trim FGD caustic make-up pump. A portion of the solution continuously discharges to a caustic wastewater receiving tank at a constant flow rate. The caustic wastewater will be pumped to an interface connection for treatment in the BOP.

The section in the top of the Quencher column cools the flue gas so that the CO_2 removal efficiency can be increased within the CO_2 Absorber. Flue gas cooling is through direct contact saturation on the surface of the structured packing. The cooling water is circulated within the Quencher via a pump and heat is removed via an external heat exchanger (Flue Gas Water Cooler). The condensate will be characterized to determine its long term use. As the flue gas exits the top of the Quencher column, it is routed through the Flue Gas Blower to provide the draft through the system.

5.2.2.2 Absorber

The CO_2 Absorber column is a rectangular tower with structured packing and liquid distributors. The CO_2 Absorber is designed to efficiently remove CO_2 from the flue gas stream. The CO_2 Absorber is primarily comprised of two main sections: (i) the CO_2 absorption section in the lower part of the column and (ii) the treated flue gas washing section in the upper portion of the column. The CO_2 Absorber will utilize structured packing in order to reduce the pressure drop of flue gas inside the tower.

The absorption consists of packing and liquid distributor manifolds such that when the flue gas moves upward through the packing, the CO_2 lean solvent contacts the flue gas on the surface of the packing and absorbs 90% of the CO_2 in the flue gas stream. A single pump removes the rich solvent from the bottom of the CO_2 Absorber and transfers the fluid to the Regenerator. Plate and frame heat exchangers are utilized to heat the rich solvent as it is transferred to the Regenerator.

The upper portion of the CO_2 Absorber column is designed to maintain water balance and recover amine solvent vapor prior to exiting the vessel. The flue gas cooling system consists of a single pump circulating water from the bottom of the chimney tray through the plate and frame cooler and returning the cooled water to the top of the packing to cool and wash the treated flue gas. The washing section recycles water from the bottom of the chimney tray to the top of the packing through distributors to further recover amine within the flue gas. A demister is installed at the outlet of the washing section to recover amine mist from the treated flue gas. The chimney outlet was designed with a continuous emissions monitoring (CEMs) system.

5.2.2.3 Regenerator

A cylindrical Regenerator pressure vessel was designed to include structured packing and liquid distributors for the purpose of removing the CO_2 from the rich solvent fluid by heating the amine solvent and liberating the CO_2. Although a true pressure vessel, this system operates at very low relative pressures (approximately 10 psi). Regenerative reboilers are designed to transfer heat from low pressure steam supplied by the HRB to the solvent solution in order to release the CO_2. The released CO_2 vapor will be cooled down by the CO_2 gas condensing unit.

5.2.2.4 CO_2 Compressor/Dehydration

Given the high flow volume, centrifugal compressors are typically employed in these applications. The physics to compress CO_2 in a centrifugal compressor is the same as that for any other gas; however, CO_2 has many unique characteristics compared to other gases that must be considered in the compressor design.

Centrifugal compressors generally can be split into two major types which are distinguished by their design, namely single-shaft (inline, between bearings) and multi-shaft integrally geared (IG). The team investigated the best solution from existing turbo machinery providers and concluded, based on economics, efficiency, and power consumption, that integrally geared turbo compressors incorporate the optimum design concept for CO_2 compression.

The CO_2 Compression System developed for this project is an 8-stage IG compressor split into a low pressure (LP) side and a high pressure (HP) side, along with a triethylene glycol (TEG) dehydration unit which is designed to remove moisture from the CO_2. The CO_2 Compressor package increases the dehydrated CO_2 pressure up to supercritical conditions for pipeline transport.

5.2.2.5 Solvent System

The solvent system is a closed-loop process that is designed to maintain solvent purity so that the chemical reaction and kinetics remain efficient. Multiple systems such as solvent filtration, solvent reclaiming, and solvent storage and make-up are designed to help maintain solvent integrity.

A filtration system was designed to remove particulates that may accumulate in the solvent. The filtration system will ensure that particulates do not accumulate within the solvent which could cause flooding, erosion and fouling of the system in the CO_2 Absorber, Regenerator, and heat exchangers. The filtration system takes a 10% side-stream of solvent from the circulation loop through a single booster pump which pulls the lean solvent and pumps it through two automated filtration unit, two carbon filters, and two downstream guard filters. The automated filtration unit removes dust and rust continuously and automatically through the use of cellulose as the filter medium. The carbon filters are designed to remove oil and soluble impurities, and the downstream guard filters are designed to catch any stray carbon from the carbon filters.

A solvent reclaiming system is designed to remove soluble solvent degradation products such as heat stable salts (HSS), soluble metals, and suspended solids (SS) from the lean solution. Heat stable salts form when trace compounds react with the amine to form a salt which cannot be regenerated (released from the amine) by the use of heat in the Regenerator. The Reclaimer is designed to operate as a simple batch distiller. The unit includes systems to control usage of reflux water and demin water and a caustic soda solution of 50% by weight of NaOH to assist in evaporation of solvent and breakdown of heat stable salts to release pure solvent.

A solvent storage and make-up system is provided to ensure solvent levels are maintained during normal operation. The system will consist of solvent storage tanks, a solution sump tank, a single solution sump pump and filter. The system is configured to allow clean solvent to be injected into the rich solution pump suction for make-up purposes, and act as a system drain collection point to support equipment draining during periodic maintenance.

5.2.2.6 CCS Electrical and Control Room

A power distribution center (PDC) and control room building with a distributed control system (DCS) and laboratory was included to power, control, and operate the CCS. 13.8KV is being fed from the BOP cogeneration unit to the CCS PDC building. The CCS PDC Building includes a Direct Current Uninterruptible Power Supply (UPS/DC) Switchgear and Motor Control Centers (MCCs) for medium and low voltage users within the CCS process island. The PDC was prefabricated to minimize field labor. The PDC also includes control/DCS room facilities, restrooms, and a break room. The facility control system includes the DCS, for the CCS Facility, BOP Systems, and also the DCS functions to provide supervisory control of the cogen plant. The building is climate controlled and includes fire detection and protection systems as appropriate for hazard monitoring. Finally, an adjacent laboratory is designed for the purpose of analyzing liquid and gas in the CCS facility to confirm operational plant conditions.

5.2.3 Balance of Plant (BOP) Design

TIC subcontracted engineering to the Kiewit family of companies and, along with Sargent and Lundy, L.L.C. (S&L), collectively developed the BOP engineering efforts. S&L had originally performed some of the early study work for the project and retained the Unit 8 ductwork integration portion of the project, while TIC assumed the rest of the non-CCS-specific related engineering. S&L was retained as the Owner's Engineer for the project.

All of the components necessary for the BOP systems and plant integration are commercially-available systems and technologies. The primary systems included in the BOP Scope of Work include:

- Energy (Power and Steam) Supply/Integration;
- Control Systems;
- Water Systems;
- Instrument Air/Plant Air;
- Flue Gas Interconnect;
- Pipe Corridors (Utilities Corridors);
- Plant Tie-ins; and
- Waste Streams.

5.2.3.1 Energy (Power and Steam) Supply/Integration

The CCS requires a large amount of low-quality steam which will be provided by a Cogen facility. Contractor will remove the existing Combustion Turbine Generator (CTG) exhaust stack and install a Heat Recovery Boiler (HRB) with duct burners. Contractor will engineer all interconnecting ductwork, supports, piping, water feed systems, fuel feed systems, chemical feed systems and electrical systems to integrate the HRB to the existing CTG. Upon completion of the interconnection, the exhaust gas from the CTG will be directed to the HRB to raise single pressure steam at the conditions needed by gas treatment process.

The HRB design includes environmental controls to minimize emissions of carbon monoxide (CO) and Nitrogen Oxides (NO_X) from the Cogen unit. As a part of this, TIC designed a 29% aqueous ammonia delivery system to the HRB to be used in the NO_X reduction system. The ammonia will be supplied from existing storage tanks at WAP.

For power, the CTG delivers electric power at 13.8kV which is stepped up to 138kV for delivery to the Electric Reliability Council of Texas (ERCOT) system. Following installation of the HRB, the Cogen Unit will provide electric power at 13.8 kV to the CCS project with surplus electric power sold to the local grid. A few electrical system upgrades were required to address the short-circuit capacity of the interconnected system. TIC worked with the Owner's team to design the appropriate electrical system upgrades so that the Cogen Unit may supply electric power to the CCS and the local grid. TIC has included a Current Limiting Reactor (CLR) in series with the connection to the auxiliary power system in order to reduce the short-circuit levels on the 13.8kV auxiliary system.

5.2.3.2 Control Systems

TIC and MHI jointly designed and integrated the existing GTG and new BOP and CCS control systems. TIC and MHI have designed the Cogen Unit distributed controls to be integrated into the CCS distributed control system (DCS). Operation of the BOP and CCS facilities will be performed from the CCS control room. TIC and MHI integrated an existing CTG PI historian and Owner supplied CCS/BOP PI historian with the new CCS DCS. A new DCS communication network was installed to supplement and integrate the existing CTG control network. The network will rely on fiber-optic-based communication and a decentralized remote I/O DCS architecture. Hard-wired emergency shutdown control functions are provided between the Cogen Unit control system and the CCS control room.

The CCS and BOP facilities incorporate stand-alone programmable logic control (PLC) as well. The following systems incorporate vendor programmed PLC controls:

- Water Treatment System;
- HRB Duct Burner Management System; and
- CO_2 Compressor System.

The PLC systems interface and communicate with the new CCS DCS via the new fiber-optic network. Control logic for the operation of the balance of the BOP/CCS facility is programed into the CCS DCS.

5.2.3.3 Water Systems

5.2.3.3.1 Cooling Water

A new fiberglass mechanical-draft cooling tower was designed by TIC to deliver cooling water to the CCS at the flow rates and temperatures required. TIC designed the cooling water system to have a maximum temperature rise of 14°F. The makeup water will be obtained from Smither's Lake owned by the Plant. TIC designed all equipment required for the cooling water system including makeup water system, clarifier, cooling tower, circulating water system pumps, piping and chemical injection systems. The clarifier includes a thickener system that will dewater sludge from the clarifier for disposal by vacuum truck. Blowdown from the cooling tower will be piped to a permitted discharge outfall at Smither's Lake.

5.2.3.3.2 Demineralized Water

The existing demineralized water treatment (DWT) system at WAP does not have the capacity to service the plant as well as the CCS. Accordingly, a new DWT system was designed for the project. The quality of the source water, from WAP's service water system, requires conditioning with the application of pressure filters, two-pass Reverse Osmosis (RO), and polishing ion exchangers (with offsite regeneration). The demineralized water system includes piping, demineralizer equipment, 100,000 gallon demineralized water storage tank, supply pumps, electrical and control systems. The demineralized water equipment, except the 100,000 gallon storage tank, is housed in a building. The building includes a PLC control room, HVAC, lighting, and fire protection.

5.2.3.4 Instrument Air/Plant Air

A compressed air system was supplied as part of the Peaker project; however this system needs to be expanded to handle the additional air demand required to support the new BOP and CCS processes. Accordingly, TIC added two additional air compressors with air dyers to meet instrument air requirements for the CCS and BOP systems.

5.2.3.5 Flue Gas Interconnect

A flue gas slipstream for the CCS process island will be taken from the transition ductwork in the breeching duct, just upstream of the Unit 8 chimney. S&L designed the flue gas ductwork, equipment and interconnection arrangement from the Unit 8 chimney to the CCS battery limit/Quencher intake. The Unit 8 tie-in was designed to be a Hastelloy-clad rectangular duct, which houses two guillotine isolation dampers. Downstream of the tie-in, a rectangular duct transitions to a 15 ft. diameter round Fiberglass Reinforced Plastic (FRP) duct to the CCS battery limit/Quencher intake. Considerations were made for solids to drop out due to carryover from the desulphurization system with drainage provided due to the saturated nature of the flue gas.

5.2.3.6 Pipe Corridors

TIC designed a utility corridor between the BOP island and the CCS battery limit. The utility systems included with this corridor include the following:

- Low Pressure Steam Line;
- Condensate Return Line;
- Wastewater/Sump Discharge Line;
- Instrument Air Line;
- Service Air Line;
- Demineralized Water line; and
- Electrical Cable Tray and Conduits.

5.2.3.7 Plant Tie-Ins

Various tie-ins to existing plant systems were considered and ultimately agreed upon under defined commercial arrangements where excess system capacity was available. Tie-ins to the existing plant systems include:

- Flue Gas (described above);
- Ammonia (Cogen SCR);
- Fire Water Loop;
- Service Water;
- Utility Water;
- Potable Water; and
- Fuel Gas (Cogen and Duct Burners).

5.2.4 Air Emissions and Waste Streams

5.2.4.1 BOP Air Emissions

Estimated annual air emissions from the CT/HRB equipment are as follows (and within the projects permitted limits):

- Nitrogen Oxides (NO_x) – 38 tons per year (TPY)
- Carbon Monoxide (CO) – 102 TPY
- Carbon Dioxide (CO_2) – 582,238 TPY
- Volatile Organic Compounds (VOC) – 13 TPY
- Ammonia (NH_3) – 34 TPY
- Total Suspended Particulates (TSP) – 72 TPY
- Particulate Matter 10 (PM_{10}) – 72 TPY
- Particulate Matter 2.5 ($PM_{2.5}$) – 72 TPY
- Sulfur Dioxide (SO_2) – 7 TPY
- Sulfuric Acid (H_2SO_4) – 2.5 TPY
- Nitrous Oxide (N_2O) – 11 TPY
- Methane (CH_4) – 11 TPY

Estimated annual air emissions from the Cooling Tower are as follows:

- Total Suspended Particulates (TSP) – 5 TPY
- Particulate Matter 10 (PM_{10}) – 2 TPY
- Particulate Matter 2.5 ($PM_{2.5}$) – 0.01 TPY

5.2.4.2 CCS Air Emissions

Estimated annual air emissions from the CCS Facility are mainly as follows (and within the projects permitted limits):

- VOC – 38 TPY
- NH_3 – 6 TPY
- CO_2 – 192,051 TPY

5.2.4.3 BOP Waste Streams

The BOP waste streams are summarized as follows:

- Cooling Tower – Cooling tower blow down will be discharged directly to Smithers Lake via the Texas Commission on Environmental Quality (TCEQ) Permitted Outfall.
- Plant Drains – Plant drains will be collected in an Oil-Water Separator and clean underflow will be discharged to Smithers Lake via the TCEQ Permitted Outfall. Oily waste from this system will be collected then trucked offsite for commercial treatment and disposal.
- Condensate Clarifier – The condensate clarifier underflow waste stream will be routed to the sludge thickener.
- Multi-media Filter – The multi-media filter reject waste stream will be routed to the sludge thickener.
- Reverse Osmosis – The reverse osmosis reject waste stream will be routed to the sludge thickener.
- Raw Water Clarifier – The raw water clarifier waste stream will be routed to the sludge thickener.
- Portable Clarifier – The portable water clarifier waste stream will be routed to the sludge thickener.
- Sludge Thickener – Thickener sludge will be produced from the previously mentioned waste streams. The sludge will be disposed of in an onsite landfill. Water from the sludge production will be recycled back to a system equalization tank for reuse.

5.2.4.4 CCS Waste Streams

The CCS waste streams are summarized as follows:

- Interconnecting Ductwork - There is a drain installed in the Unit 8 interconnecting ductwork near the tie in point to collect any water that is dropped out of the flue gas. This drain collects the water and routes it into an existing plant sump near the tie-in point. The FRP duct slopes continuously to the Carbon Capture Island, and will serve as a drainage system for the water that condenses out after the drain installed near the tie-in point.
- Quencher – There are two waste streams that are dealt with on the Quench tower: i) the polishing scrubber caustic wastewater stream and ii) the flue gas condensate water from the cooling step. The design assumptions used are considered conservative, and due to this, the estimated characterization of the waste stream requires treatment. The project team believes the actual waste stream will not be as estimated, so a temporary WWT treatment and characterization facility is included for the first year of operation. At the conclusion of this year, the streams will be well characterized and it is anticipated that both waste streams will be discharged as described below.
  - Caustic Wastewater – The caustic wastewater in the deep polishing scrubber may include metals from the flue gas and elevated amounts of TSS. If no treatment is required, this stream will be discharged directly to Smithers Lake via the TCEQ Permitted Outfall. The current water treatment design incorporates a portable Phys-Chem treatment system for this wastewater stream.
  - Flue Gas Condensate – When the flue gas is cooled in the cooling step of the Quench Tower, water is condensed out of the wet flue gas. This water is treated in a condensate clarifier system and then used as return to the cooling tower and also used to supplement the RO/Demin water system.

- CO_2 Dehydration Unit – The CO_2 Dehydration Unit waste stream will be collected then trucked off-site for commercial treatment and disposal. Characterization of this waste stream will be performed to determine if the waste stream can be treated and reused in the CCS process or discharged via the TCEQ Permitted Outfall.
- Reclaimer Waste – The operation of the capture process will result in the formation of degradation products due to the presence of impurities in the flue gas. These degradation products reduce solvent performance. To control the concentration of these degradation products, a slipstream of the solvent is periodically sent to a solvent reclaiming system. Thermal reclaiming in its simplest form is a kettle that boils off reusable vapors (i.e., solvent) and return them to the process while the heavier boiling point and non-volatile impurities (heat stable salts) with a small amounts of solvent precipitate out as a sludge for disposal. Thermal reclaiming waste is predicted to contain trace metals that are potentially hazardous (i.e. selenium, mercury from the coal) classifying this as a hazardous waste. This hazardous waste can either be treated in a hazardous waste landfill or fired in a hazardous waste incinerator. Either option requires the team to find a third party offsite waste treatment solution. MHIA has provided the team with some information regarding the reclaimer waste from Plant Barry, but Plant Barry combusts a different coal (Columbian vs. Powder River Basin) and WAP Unit 8 may have slightly different emission controls than Barry. So, although a lot is known about this waste, the specific characterization of this waste from the Petra Nova application will need to be fully understood prior to arranging long term offtake arrangement with third party waste handlers. Obtaining a better understanding of anticipated quantities that will be generated over time can only be better understood through operations. Accordingly, the team has identified potential waste handlers, but plan to use Phase 3 to firm up an arrangement based on waste characterization and quantities

5.2.5 Value Engineering

5.2.5.1 Site Optimization

Value engineering efforts continued throughout the engineering efforts. Previous design work cited the cooling tower in the BOP portion of the project as described previously. This required the long run of large diameter cooling water piping, at grade, between the cooling tower and process island equipment. Not only was this undesirable aesthetically, there are unique design challenges with supporting and anchoring large piping on sleepers at grade or in large racks. Most importantly however, there could be material capital savings with relocating the cooling tower closer to the process as the long, large, cooling water piping runs would be replaced with longer, but much smaller make-up and blowdown piping. This would not only reduce the material cost of the piping, but the structural steel requirements in the pipe rack would be reduced as well. Accordingly, the team relocated the cooling tower into the process island.

Another value engineering design change in the process was the elimination of the backup steam source in the event of a CTG outage. Originally the project design incorporated a forced draft (FD) fan and robust duct burner configuration in the HRB to produce half the steam requirement, allowing for the carbon capture facility to continue operating at reduced load when the CT was down. This way, a CTG outage would not cause the entire system to remain idle. However, this configuration created significant design challenges for the HRB vendors, added material cost to the project, and would only be necessary in isolated situations. Further evaluation indicates that in the unlikely event there are systemic unforeseen operational issues with the CTG, a packaged boiler could provide the interim steam requirements more economically than this configuration.

Furthermore, a package boiler configuration could be deferred and deployed if this operational challenge became a systemic issue during operations. For these reasons and others, the back up steam supply was eliminated.

Periodic 3D balance of plant and carbon capture facility reviews are undertaken with all project entities, including TIC, MHIA, Petra Nova and NRG to review current designs and to optimize operability and facility access. These meetings have resulted in better maintenance access to critical equipment and safe access for personnel during operation of equipment. Minor system improvements due to configuration changes have also been realized.

5.2.5.2 Water Usage

Although WAP has about a 19,000 acre-feet semi-artificial body of water within its boundaries (Smither's Lake), most power plants do not have this type of abundant water resource, and water is becoming a scarce and sensitive resource regardless. The significant amount of cooling water required for the operation of a CCS puts further pressure on water resources and will represent a significant barrier to implementation if not managed. The team value engineered the possibilities and cost implications of decreasing CCS's water consumption through various process design changes. Considerations included advanced cooling tower designs (hybrid), adjusting metallurgy, treatment, and cycles of concentration, looking at dry cooling systems and sources of makeup, among others. Through these efforts, the project team was able to reduce the summer average make-up rates of the process from the originally anticipated 5,200 gpm down to about 2,200 gpm. Annually, this equates to nearly 3,500 acre-feet less diversion from Smithers Lake.

In addition, during the initial and detailed design of the process, the project team focused on ways to reuse water when possible. The following is a list of design improvements that were made to increase water reuse:

- Implementing a temporary WWT system to characterize the flue gas condensate waste stream. If no treatment is necessary, this high gpm waste stream will be used as cooling tower and demin water system make up.
- Draining the ductwork into the flue gas quencher to reuse the water within the process

5.2.5.3 Health, Safety, Environmental (HSE)

Petra Nova and its contractors are closely aligned on their commitment to health, safety, and environmental excellence. A zero incident culture is the primary goal of this behavioral based program. A safe and healthful work environment, with communication of safety issues, utilization of safe work practices in addition to providing ongoing safety training for all personnel (including contractors) that support the project is the culture that is cultivated. All CCS project personnel (including contractors) are expected to adhere to the requirements of the project Safety Program which incorporates the industry best practices of Petra Nova, NRG, and TIC. The HSE program is comprehensive in its scope and addresses the following project activities:

- Aerial Lifts
- Barriers and Barricades
- Change Analysis
- Confined Space
- Contractor Safety
- Discipline
- Electrical Safety
- Emergency Response
- Evacuation/Trenching/ Shoring
- Fall Protection
- Hazard Identification/ Communication/Reporting
- Hazardous Hot Work
- Hazardous/Process Waste Containment and Disposal
- Hearing Protection
- Heat Stress Prevention
- Housekeeping
- Incident and Injury Reporting
- Incident Management
- Job Briefings/Safety Meetings
- Job Safety Analysis (JSA)
- Lockout/Tagout (LOTO)
- Employee Fatigue
- Equipment Operation Safety
- Medical Surveillance
- Mobile Crane Safety

- PPE Requirements
- Personal Protective Grounding
- Preventive Maintenance
- Process Safety
- Protective Clothing
- Spill Prevention
- Spill Containment
- Spill Cleanup and disposal
- Recognition Program
- Record Keeping
- Respiratory Protection Program
- Responsibility/Accountability
- Scaffold Safety
- Self-Inspection of Safety Equipment
- Tool and Equipment Safety

5.2.5.3.1 CO_2 Discharge Safety

The high pressure CO_2 piping system, which includes the CO_2 compressor and elevated portion of downstream discharge piping, was identified as a potential safety hazard to personnel should a significant CO_2 release occur on this section of piping during operation. Consultants were hired to perform an analysis evaluating the potential effects of a CO_2 release from an orifice in the aforementioned section of pressurized pipeline to determine the area in which a harmful concentration of CO_2 could occur during an accidental release. Eight scenarios were evaluated, covering two different release orifice sizes, two different wind speed conditions, and two different ambient temperatures. The results of the Trinity Consultants analysis will be used to determine where to add additional monitoring and Personal Protective Equipment (PPE) for personnel working in those potentially affected areas.

5.2.5.3.2 Environmental

The environmental impact mitigation action plan (MAP) from the National Environmental Policy Act (NEPA) Record of Decision (ROD) has been implemented on the carbon capture project. Mitigations measures such as dust suppression, speed limits, equipment inspections, stormwater pollution prevention plan (SWPPP), and spill prevention plans are in place and being monitored. The detail plan and mitigation measures are included as an appendix to this report and the plan is updated periodically as the project progresses through different phases. The Pipeline and Oil Field activities will be updated in their respective reporting sections as those areas proceed through construction. Specific design features in the permanent plant to support runoff control include improved water flow paths for rain water run-off, containment around specific process vessels and oil containing equipment to prevent in advertent spills are described in more detail below.

5.2.5.4 Reliability, Availability, & Maintainability (RAM)

The design of the BOP and CCS Facilities incorporates a philosophy that minimizes the application of 100% redundancy while maintaining the ability to achieve high levels of reliability, availability, and maintainability (RAM). Consultants were hired to perform a RAM Analysis to independently evaluate the technical, process reliability, and spare parts provisioning risks associated with the project in order to increase confidence in the project's design and operational philosophy. The consultants concluded that it is extremely unlikely that the project will fail to operate. Furthermore, it is likely that the project will meet or exceed the minimum guaranteed CO_2 capture rate after an initial 'shake-out' period. The analysis shows that the project's expected mean capacity factor can achieve 85% levels with a well planned maintenance program and by having strategic spare parts and equipment available to minimize time to return to service.

5.2.5.5 Design Refinements

The considerable up front design work carried out during Phase 1 of the project minimized the number of changes in Phase 2. However, as with any major construction project, refinements were made along the way as the design evolution process proceeded, not only during the detailed engineering process, but also during construction. Many of the design refinements were a result of detailing the operational aspects that required additional features, while others were just insufficient scoping or discoveries along the way that required adjustment. Each of these categories and some particular items identified are summarized below. In all cases, these adjustments are to be expected and therefore were handled through project budgets and did not impact overall project schedule or budget.

5.2.5.5.1 Enhancements

There were a handful of items identified and deployed during Phase 2 that will improve the safety, operations, and maintenance of the project.

- CO_2 Monitoring – During the Phase 1 HAZOP review and described in section 5.2.5.3.1 above, it was not fully concluded how CO_2 leak detection would be specifically managed around the site including the number, type (continuous area monitors, leak detection, personnel portable monitors), and location (all areas, near high pressure, etc.) of such devices. Upon further examination during Phase 2 the project deployed a CO_2 detection system around the high pressure area with additional gas detectors at the control room as an enhancement.
- Combustion Turbine (CT) Control Logic Changes – The original design of the cogen controls and steam header pressure controls were not optimized to follow the CCS operation and the expected electrical dispatch requirements of ERCOT. During Phase 2 it became apparent that modifications to the steam header pressure control and combustion turbine dispatch process were needed to provide for smooth facility start-up and ramping. These modifications required control logic changes to allow for this flexibility.
- Absorber Elevator – Upon further investigation and understanding of how maintenance activities would be performed at various levels in the absorber column it was determined that this would best be handled through the use of a permanent elevator. The elevator installed for construction purposes was purchased with this in mind and is permanent.
- Access Walkways/Platforms/Ramps – Walkdowns of the nearly completed site and envisioning how operational "rounds" would be administered caused Petra Nova to install some additional access stairways and ramps throughout the site. Most notably is a stairway between the absorber column and the heat exchanger upper level which would have otherwise required someone to climb down from the one side to get to the other side.
- Area Site Improvements – Some impacts such as the tearing up of roads from re-routed truck traffic around the construction site as well as some improvements to existing facilities were funded to leave the Parish plant site impacted by the project in a better condition than it was prior to the project.
- Backup Power – There is a single source power feed into the project and in the event there is a 138kV outage or the line needs to be taken out, the entire project would lose power. Since power had to be brought in from another location to perform the construction activities, the team elected to pursue modifying and upgrading this system to provide an alternative backfeed in the event of an outage on the primary feed. Petra Nova utilized a great deal of the construction power system so that the modifications were minor when compared to installing a completely new system (if the construction system were removed).

There were other small-dollar changes made along the way such as various technical studies, additional instrumentation, additional pipe routing and metering for discharge streams, access/entry points, among other enhancements, but the abovementioned were the most significant from a dollar value or impact to the overall project.

5.2.5.5.2 Missed or Changed Scope

In addition to the enhancements, there were some true design changes due to discoveries along the way or because something wasn't scoped properly during the FEED study effort. The most significant are summarized here:

- Temporary Waste Water Treatment (WWT) Facility – As stated in Section 5.2.4.3 above, the blowdown stream from the quencher column needs to be fully characterized prior to determining treatment options. The technical assessments carried out prior to actual characterization show that this stream could have a broad range of outcomes and therefore the team decided to deploy a temporary WWT system prior to making an incorrect and possibly costly assumption. The temporary system set up and will be utilized for approximately the first year of commissioning and operation and was not part of the original scope.
- Fiberglass Reinforced Plastic (FRP) Ductwork Design Changes/Drains – The Unit 8 takeoff design was one of the least developed items during the FEED phase with a set of assumptions and allowances set aside for it. Various design refinements both on the FRP design itself, its interconnection into Unit 8 and drain configuration, that weren't sufficiently included in the base set of assumptions or budget allowances were made.
- CO_2 Bypass and Interconnection into the Pipeline – The valve configuration and piping interconnection into the Pipeline wasn't sufficiently defined in the FEED phase. The valve at the outlet of the CO_2 compressor wasn't designed to handle the pressure drop upon initial fill of the Pipeline and was reconfigured to deal with this.
- Transformer Firewall – The location of the demineralized (demin) water building was shifted slightly to stay off the existing gas line feeding the cogen. This shift pushed the building with a proximity to the step-up transformer that required a firewall between it and the building.
- Continuous Emissions Monitoring System (CEMS) Modifications – The plan was to reuse the existing CEMS installed on the CT in peaking configuration, however, additional modifications and measurements were necessary to support installation of the inlet bleed heat (IBH) system and the NOx measurement approach (differential method) were not originally planned.

These items were the most significant refinements documented on the project. Other, less significant, items included a few undocumented underground utilities, repairs to deficient facilities and other customary scope changes routinely experienced on brownfield retrofits. All changes and improvements were absorbed by the project budget and schedule.

5.2.6 Performance Summary

Below is a summary of project requirements for the CCS.

Capture Rate-

The capture plant will recover 90% of the CO_2 contained in the treated gas. At the design load, the KM CDR Process® plant would recover 5,265 short tpd (4,776 tonnes per day).

Energy Consumption-

Steam Consumption – 240 ton/hr

Power Consumption – BOP and Process Island combined requires nearly 40,000 kW of electrical power. The CO_2 compressor is approximately 50% of this load.

Water Consumption-

Cooling water requirement – The 240 MW carbon capture island requires approximately 130,000 gallons per minute (gpm) of circulating cooling water, with a maximum temperature rise of 14°F. A new mechanical-draft cooling tower is provided to meet these demands, with approximately 2,200 gpm of makeup water coming from Smither's Lake.

Demin – A new demineralized water system was constructed to supply system demands of about 16 gpm.

Service – Tie-in to existing plant system, but will consider upgrading one or more existing wells if its determined low cost incremental improvements are warranted. The need for well upgrades is still being confirmed.

Other - All the other water requirements are easily integrated with the existing site services.

Emissions & Effluents-

Air– The flue gas, mostly scrubbed of its CO_2, will exit the absorber column. Prior to commissioning and start-up, the air permit input parameters are being updated to capture final design parameters (emissions, emission points, emission locations, etc.). This is a standard process. As part of this effort the air dispersion model was updated and re-checked to confirm compliance.

Automated filtration unit – The dried cake in this filtration process contains solid filtered impurities, filter aid and residual moisture. The cake appears as a crumbly powder, free of airborne dust and can be easily handled. The normal way to get rid of this material is disposal in a hazardous waste landfill.

Reclaimer Waste – Over time, the KS-1™ solvent will accumulate contaminants from the gases being treated. A reclaimer has been installed to take periodic batches of solvent to remove these impurities from the solution. It does this by distilling the water and amine from the impurities leaving behind the degradation products.

Discharge Water – The total estimated normal flow of discharge water from the BOP/CCS Facilities (as described in Section 5.2.4 above) to the TCEQ Permitted Outfall on Smithers Lake is 915 gpm. This is based on a 24-hour average.

Storm water Run-Off – Storm water runoff from the BOP and CCS areas will be conveyed to catch basins using ditches and swales and then allowed to flow into the existing plant storm water system. Storm water collected in chemical storage areas and transformer pit drains will be contained, routed through an oil/water separator, and returned to the cooling tower. Storm water run-off and collection systems were designed and installed to accommodate the rainfall associated with a 100-year storm.

Spill Containment – Spill containment structures were provided for all chemical storage areas and skids. Containment designs were established on the basis that manual cleanup is possible. Spill containment at the chemical unloading areas is provided to contain small spills at hose connection points. The size of the spill containment area is designed in accordance with applicable codes and standards. Spill containment structures are designed to be chemically compatible with the material that is being contained. Manual discharge valves are provided for disposal of rainwater. Adequate spill containment is provided around equipment containing oil and/or equipped with deluge type fire protection. Different chemicals that produce harmful reactions when mixed together will be contained separately.

6 Cost

6.1 Capital Costs

The capital cost of the project is comprised of many components including labor costs, material and equipment pricing, construction management costs, commissioning and start-up costs, contingencies, mark-ups and overheads, as are customary on large construction projects. It is currently forecasted that the work completed during Phase 1 and Phase 2, as it relates to the CCS and BOP portions of the project, will total about $635M* with a +/-5% uncertainty band around that amount. Note that the cost of funds used during construction and financing fees are not included in this number. A further breakdown of the $635M in estimated cost is provided in Table 1 below. These categories correspond to the Plot Plan in Appendix 7.3 (note that Owner's Costs are general and are not a specific area on the Plot Plan).

Table 1. Capital Cost Breakdown

Category	Cost (Millions)
CCS	$255
CO_2 Compression/Dehydration	$60
Cogen	$150
Water Treatment	$35
Cooling Tower	$20
Flue Gas Tie-In	$15
Owner's Costs	$100
Total	**$635**

6.2 O&M Costs

The Operations and Maintenance (O&M) costs for the project are comprised of many components such as natural gas (partially offset by a small amount of power sales to the grid), labor, chemicals, routine and major maintenance, liquid and solid waste management, site services, and outside contract services. O&M costs are expected to fluctuate somewhat from year to year and are highly correlated to factors such as variations in the host coal-fired unit's operation, carbon capture system facility utilization and reliability, major maintenance schedules, underlying commodity costs (natural gas/chemicals/electric prices), and CO_2 demands at the oil field. Nevertheless, we expect that on average, over the life of the project, O&M costs will be around $35M per year.

7 Oil Field Response

There are several production stages during the life of a producing oil field. Initially, in the primary phase when a field is brought into production, oil flows naturally to the surface due to existing reservoir pressure. In the secondary phase, as reservoir pressure drops, water is typically injected to boost the pressure to displace the oil. Lastly, the remaining oil can be recovered by a variety of means such as CO_2 injection, natural gas miscible injection, and steam recovery in the final tertiary or EOR phase.

* Only CCS and BOP. Excludes Pipeline, Financing, and EOR costs.

To capture residual oil, the petroleum industry has spent decades and devoted billions of dollars for research and development of EOR technologies. One of the most promising technologies developed over the last 40 years was based on the use of CO_2 which, at high pressure and reservoir temperature, mixes with the oil to form a low viscosity, low surface tension fluid that can be more easily displaced. Additionally, CO_2 has the capability of invading zones not previously invaded by water, thereby releasing and reducing trapped oil. Since this aspect of the Project is very mature, DOE funding incentives were not available or applied to further promote or prove this element of the project. The grant funds are not being applied to CO_2-EOR operations. However, EOR is a related activity since it is needed to generate the revenues to help offset the costs of carbon capture.

Refurbishing mature oil fields to safely accept CO_2 injection requires a significant commitment of resources to modernize fields with up-to-date technology and address environmental and other concerns commonly found in legacy fields that may not otherwise be addressed. The end result is a better protected surrounding area as a result of CO_2-EOR operations than if the oilfield were to remain underutilized.

EOR operators traditionally design and execute CO_2 floods to minimize cost and maximize production so that the high cost of the CO_2 working fluid will not be inefficient. The CO_2 will be carefully managed by the operator through continuous monitoring of injection rates, production volumes and downhole pressures in the adjustment and refinement of their recovery strategy. These surveillance and monitoring methods are designed to help maximize lateral and vertical sweep efficiencies while minimizing residual oil saturation and gas production rates in order to optimize oil recovery and recycle utilization. As a result, incidents of CO_2 migration laterally or vertically away from the intended injection-production patterns in EOR operations are extremely rare.

To administer the flood, HEC plans to commence flooding operations starting within the deepest zone of the formation in the center of the field and working outward toward its flanks. As these initial patterns are produced, the wells will be recompleted (plugged back up to the next zone and re-perforated) to injection/production wells in the next zone in a similar fashion. The drilling campaign and topside facilities (additional test sites and central processing equipment) associated with this build-out will stay ahead of these efforts but are not fully in place at this time. As the field development plan progresses, the capital build-out program to drill additional wells, recomplete others, and add additional topside facilities (central processing and test sites) will be completed as needed.

Under this approach, the CO_2 is expected to boost production from around 500 barrels a day to about 15,000 barrels a day. Over the life of the flood, the West Ranch oilfield is currently estimated to hold approximately 60 million barrels of economically recoverable oil through CO_2-EOR.

8 Conclusion

Deploying clean energy technologies on a scale necessary to meet the nation's multifaceted energy imperative depends on achieving incremental advancements in existing technologies as well as the development and commercial deployment of next-generation, advanced energy technologies. Developing advanced post-combustion clean coal technologies for capturing CO_2 from existing coal-fired power plants can play a major role in the country's transition to a sustainable energy future, especially when coupled with CO_2-EOR. The risks associated with these first-of-kind projects coupled with an uncertain political and regulatory landscape motivates the government to support the acceleration and development of scaled demonstration projects in the pursuit of proving these technologies for further commercialization. The government's investment in the CCPI program and grant awarded to the Petra Nova project recognizes the importance of clean coal technologies to this Country's economy, energy security, and environment.

Big capital projects with multi-party involvement and first-of-a-scale technology are inherently risky. Enumerating risks, types of impact, associated probability and potential causes can help stakeholders make better decisions and complete projects according to plan. Petra Nova's upfront investment in development and project definition during Phase 1 considerably increased project predictability in terms of cost, scope, and schedule, reduced risks, and maximized the effectiveness of planning the execution. This planning combined with a the commercial structure and contract delivery approach which properly allocated risks to the party in the best position to control, manage, or absorb them motivated the tight integration and directional alignment of the solution-oriented project execution team. This alignment and outlook helped to minimize scope changes, enable efficient use of resources, mitigated risks, and should result in on-time, on-budget delivery of the Project at the end of 2016.

It is impossible to produce a perfect set of construction documents and identify all the challenges with a first-of-a-kind brownfield retrofit project even with significant upfront planning. Consequently, and as is customary with major retrofit projects, there were design changes, refinements, and improvements along the way. The single biggest change on this project was the least defined attribute during the development phase; the Unit 8 tie-in and interconnecting ductwork. Otherwise, the project management team succeeded to keep design changes to a controllable level that did not impact the project's overall schedule or budget.

The successful delivery of project will demonstrate that advanced CCS technologies do work which should lead to further deployment and help de-risk future projects. It also makes significant progress toward the relevant performance targets of the Energy Policy Act of 2005 including capture and sequestration at less than 35% increase to the COE. Cost is generally recognized as one of the main challenges to widespread global CCS adoption, and, with a capture cost of approximately $65/ton in this configuration, further improvements and breakthroughs are needed to bring down the cost to accelerate wider implementation. Nevertheless, the Petra Nova project is a huge step toward broader adoption and reflects how stakeholders in the regulatory, commercial, financial, and technical fields can work together to deliver a successfully integrated project. Unlocking the complex value chain and developing the structure and commercial arrangements that align sources of CO_2 with EOR field interests is a noteworthy accomplishment and something that can be modeled by future projects.

9 Appendices

9.1 Basic Engineering and Design Data (BEDD)

9.2 Process Flow Diagram (PFD)

9.3 Plot Plan

9.4 Water Balance

9.5 BOP Heat and Material Balance

9.6 High Level System Material Balance

9.7 Equipment List

9.8 Environmental Mitigation Action Plan

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BASIC ENGINEERING DESIGN DATA

UNLIMITED DUCUMENT

22 SHEETS WITH COVER

STATUS	☑ FOR DOE ☑ UNLIMITED ☐ PROTECTED ☐ LIMITED

REVISIONS

NO.	DATE	DESCRIPTION	REFERENCE	PREP'D	CHK'D	APP'D	APP'D
				DISCIPLINE			PROJECT

ORDER NO.	583110
PROJECT	PNC-EOR
APPROVED	
DISCIPLINE	Process Group
APPROVED	
CHECKED	
PREPARED	
DATE	03/16/2016

CUSTOMER: petra nova an NRG company; JX

PROJECT: PETRA NOVA WA PARISH CARBON CAPTURE PROJECT

MHI DRAWING NUMBER	REV.
8150D B 212 - 30100	0
CUSTOMER DRAWING NUMBER	REV.
-	-

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COST	
SCHEDULE	
BUSINESS	
PROCESS	E
MACHINE	
EQUIP.	
PIPING	
I&C	
ELECT.	
CIVIL	
CONST.	
VENDOR	
SITE	
TOTAL	0

SUMMARY OF REVISIONS							Doc No. : 8150D B212-30100
Cover Sheet		Item No.	Original		Revision		Reasons
Rev.	Date		Rev.	Description	Rev.	Description	
0	03/16/2016		0	Issued for DOE.			

CONTENTS

1. General

1.1. Project Description

(a)	Name of Client	Petra Nova CCS I LLC.
(b)	Order	583110
(c)	Name of Project	Petra Nova WA Parish Carbon Capture Project
(d)	Name of Product	Carbon Dioxide
(e)	Plant Capacity	5,265 stons/day
(f)	Plant Location	Thompsons, Texas
(g)	Scope	CO_2 Capture Unit CO_2 Compression Unit & Dehydration Unit

1.2. Unit of Measurement and Language

(a)	Unit of Measurement	English System
(b)	Language	English

1.3. Code and Standard

The following codes, standards, and specifications will be consulted to establish a basis for quality and safety in facility design and operation. Systems and equipment will be designed in accordance with the latest edition and addenda in effect at the date of contract execution where applicable, unless noted otherwise.

AASHTO	American Association of State Highway and Transportation Official
ABMA	American Boiler Manufacturers Association
ABMA	Anti-friction Bearing Manufacturers Association
ACI	American Concrete Institute
ACMA	Air Moving and Conditioning Association
AGMA	American Gear Manufacturers Association
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers

ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
CMAA	Crane Manufacturers Association of America
CTI	Cooling Tower Institute
DIN	German Industry Standards with prior approval of the Owner
EJMA	Expansion Joint Manufacturing Association
FM	Factory Mutual (Applicable sections will be referenced)
HEI	Heat Exchange Institute
HIS	Hydraulic Institute Standards
IBC	International Building Code
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society of North America
ISA	International Society of Automation
ISO	International Standards Organization
JIS	Japanese Industrial Standards with prior approval of the Owner
MBMA	Metal Building Manufacturers Association
MSS	Manufacturers Standardization Society of Valves and Fittings Industry
NACE	National Association of Corrosion Engineers
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PFI	Pipe Fabrication Institute
RMA	Rubber Manufacturers Association
SDI	Steel Deck Institute Standards
SFC	State Fire Code
SJI	Steel Joist Institute Standards
SMACCNA	Steel Metal & Air Conditioning Contractor National Association
SSPC	Society for Protective Coatings
TEMA	Tubular Exchanger Manufacturers Association

TIMA Thermal Insulation Manufacturers Association
UFC Uniform Fire Code
UL Underwriters Laboratories
UMC Uniform Mechanical Code
UPC Uniform Plumbing Code

Design specifications and construction of the Project will also be in accordance with all applicable local, state, and federal laws, including but not limited to those set forth below.

Americans with Disabilities Act

Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Clean Air Act and Amendments
Environmental Protection Agency Regulations
Federal Aviation Administration Regulations
Federal Energy Regulatory Commission Regulations
Federal Power Act
Noise Control Act of 1972
Occupational Safety and Health Act
Occupational Safety and Health Standards
Resource Conservation and Recovery Act (RCRA)
Safe Drinking Water Act
Solid Waste Disposal Act
Superfund Amendments and Reauthorization Act of 1988
Toxic Substances Control Act

In the event conflicts arise between the codes, standards of practice, specifications or manufacturer recommendations described herein and codes, laws, rules, decrees, regulations, standards, etc., of the locality where the equipment is to be installed, the more stringent code will apply. In the case of fire codes, NFPA 850 will be the governing fire code.

2. Flue Gas / Recovered CO_2 Data

2.1. Feed Definition

(a) Design condition (Full load condition)

Flue Gas Sources	Coal Fired Boiler	
	Design	Range
Flow Rate		
lb/hr	2,827,000 (*1)	2,800,000 -2,859,000
scfm	646,800	-
Nm^3/hr	1,023,900	-
Pressure, in.w.g	-3.1	-1 – -4
Temperature, °F	165	135 – 165
Composition, v/v %	Wet	
N_2	65.0	64.8 – 66.2
CO_2	11.0	10.9 – 11.2
O_2	5.0	4.9 – 5.0
H_2O	19.0	18.0 – 19.0
Composition, ppm vol wet	Wet	
SO_2	61	16 – 61
NO_X	30	23 – 30
HCl	2.2	0 – 2.2
HF	0.6	0 – 0.6
NH_3	1.3	0 – 1.3
H_2	0	0
Hydrocarbon (CH_4)	0	0
H_2S	0	0
S	0	0
Particulate Loading		
gr/acf wet	0.005	0.005
mg/Nm^3 wet	14.7	14.7
Mercury (*2) (*3)		
µg/Nm^3 wet	2.83	--

Note *1) Determined from CO2 capture requirement of 5,265 stons/day at 90% capture rate.

Note *2) To be measured by EPA 29 as total Hg.

Note *3) Mercury: 1.0 lb/TBtu (Reference)

(b) 50% Turn down condition

Flue Gas Sources	Coal Fired Boiler
	Design
Flow Rate	
lb/hr	1,529,471
scfm	348,359
Nm^3/hr	551,486
Pressure, in.w.g	-2.9
Temperature, °F	132
Composition, v/v %	Wet
N_2	66.90
CO_2	9.80
O_2	6.75
H_2O	16.54
Composition, ppm vol wet	Wet
SO_2	14.7
NO_X	30
HCl	2.2
HF	0.6
NH_3	1.3
H_2	0
Hydrocarbon (CH_4)	0
H_2S	0
S	0
Particulate Loading	
gr/acf wet	0.005
mg/Nm^3 wet	14.7
Mercury (*1) (*2)	
µg/Nm^3 wet	2.83

Note *1) To be measured by EPA 29 as total Hg.

Note *2) Mercury: 1.0 lb/TBtu (Reference)

2.2. Product Specifications

The CO_2 product from the CO_2 recovery plant shall keep the following specification.

(a) Capacity : 5,265 stons/day of CO_2 (100% dry)

4,776 mtons/day of CO_2 (100% dry)

(b) Quality Required

CO_2	> 97 mol% dry
N_2, H_2,	< 3 mol% dry
H_2S	< 10 ppm wt dry
O_2	< 50 ppm wt dry
H_2O	< 30 lb/MMscf
	< 642 ppm vol wet
Sulfur	< 35 ppm wt dry
Mercury	< 2 ppb wt dry
Hydrocarbons (CH_4)	< 5 mol% dry

(c) Pressure at the Upstream of PCV on Battery Limit: 1,900 psig

(d) Maximum Temperature at Battery Limit: 135°F

3. Turndown

Turn down ratio [%] 50

4. Site Conditions

4.1. Site Location

(a) Site Elevation [feet]	72.0 above mean sea level
(b) Atmospheric Pressure [psia]	14.69

4.2. Ambient Temperatures

4.2.1 Extreme Design Ambient Temperature

(a) Extreme High Dry bulb [°F]	105.7
(b) Extreme Low Dry bulb [°F]	9.9

4.2.2 Design Ambient Conditions for Basis of Performance Guarantees

(a) Dry bulb temperature [°F]	93
(b) Wet bulb temperature [°F]	77.3

4.3. Relative Humidity

(a) Max. [%]	100
(b) Min. [%]	20
(c) Design [%]	75

4.4. Precipitation

(a) Annual average rainfall [in]	45.81
(b) Maximum rainfall in 24 hours [in]	9.53
(c) Annual average snowfall [in]	0
(d) Maximum snowfall in 24 hours [in]	0

4.5. Wind

(a)	Basic Wind Speed (3-second gust) [mph]	110
(b)	Prevailing Wind Direction	SSE
(c)	Exposure	C
(d)	Importance Factor	1.15

4.6. Seismic Condition

(a)	0.2 second Acceleration	0.085
(b)	1.0 second Acceleration	0.034
(c)	Seismic Design Category	A
(d)	Occupancy Category:	III
(e)	Site Class	D

4.7. Geotechnical condition

Based on "TWEI Project No. 14.14.030 REPORT GEOTECHNICAL INVESTIGATION W.A PARISH CARBON CAPTURE PROJECT THOMPSONS, TEXAS".

5. Utility Condition at BOP Tie-in

5.1. Steam

	Type	LP Steam
(a)	Supply Pressure [psig]	
	Operation Range	95 - 105
(b)	Supply Temperature [°F]	
	Max.	380
	Nor.	340
	Min.	320
(c)	Mechanical Design Press. [psig]	170
(d)	Mechanical Design Temp. [°F]	395
(e)	Fouling Factor [ft^2h °F/ BTU]	0.00049

Condensate Return

(a)	Return Pressure [psig]	
	Min.	15
(b)	Mechanical Design Press. [psig]	30
(c)	Mechanical Design Temp. [°F]	310

5.2. Cooling Water

(a)	Supply Pressure [psig]	48 - 49 (*1)
(b)	Supply Temperature [°F] Max (Summer)	92 (*2)
(c)	Return Pressure [psig]	15 - 16
(d)	Return Temperature. [°F] Max	110
(e)	Mechanical Design Press. [psig]	95
(f)	Mechanical Design Temp. [°F]	150
(g)	Fouling Factor [ft^2h °F/ BTU]	0.00098

Parameter	UoM	Cooling Water
pH		7.8
Specific Conductivity	mmho	4176
TDS	ppm	2489
MO-Alkalinity, as $CaCO_3$	ppm	412
Ca Hardness, as $CaCO_3$	ppm	96
Mg Hardness, as $CaCO_4$	ppm	140
Iron	ppm	< 1
Copper	ppm	< 1
Zinc	ppm	< 1
Sodium	ppm	933
Potassium	ppm	31
Chloride	ppm	686
Sulfate	ppm	884
Nitrate	ppm	3.1
Silica	ppm	40.3
TSS	ppm	78.9

Note *1) Minimum requirement for CO2 recovery plant.

Note *2) A cooling water temperature of 92°F will cover 99% of the year.

5.3. Demineralized Water

(a) Supply Pressure [psig]

Min.		110

(b) Supply Temperature [°F]

Max.		105

(c) Mechanical Design Press. [psig]		150
(d) Mechanical Design Temp. [°F]		120

(f) Quality

pH	-	7
Sodium	mg/l	0.003
Chloride	mg/l	0.003
Iron	mg/l	0.00
Silica	mg/l	0.010
Specific Conductivity	uS/cm	0.100
TOC	ppb	0.100

5.4. Utility Water (Intermittent)

(a)	Supply Pressure [psig]	
	Max.	100
	Nor.	90 – 95
	Min.	60
(b)	Supply Temperature [°F]	
	Nor.	105
(c)	Mechanical Design Press. [psig]	150
(d)	Mechanical Design Temp. [°F]	120

5.5. RO 1st Pass water (during pre-commissioning) (*1)

(a)	Supply Pressure [psig]		
	Min.		110
(b)	Supply Temperature [°F]		
	Max.		105
(c)	Mechanical Design Press. [psig]		150
(d)	Mechanical Design Temp. [°F]		120
(f)	Quality		
	pH	-	6.5 – 7.5
	Alkalinity as CaCO3	mg/l	< 100
	Chloride	mg/l	< 30
	Iron	mg/l	< 5
	Calcium as CaCO3	mg/l	< 50
	Magnesium as CaCO3	mg/l	< 50
	TDS	mg/l	< 150
	TSS	mg/l	< 5

Note *1) Minimum requirement for CO2 recovery plant.

5.6. Caustic Soda

(a)	Supply Temperature [°F]	Ambient
(b)	Mechanical Design Temp. [°F]	125
(c)	Concentration [wt%]	50

5.7. Electric Power

The following electric supply shall be used for the design basis of motor specifications.

	Voltage [volt]	Phase [-]	Frequency [Hz]
More than 3500 hp :	13,200	3	60
250 to 3500 hp (Including 3,500 hp) :	4,000	3	60
¾ to 250 hp (Including 250 hp) :	460	3	60
Less than ¾ hp (Including ¾ hp) :	120	1	60

5.8. Potable Water (Intermittent)

(a)	Supply Pressure [psig]	
	Max.	115
	Min.	80
(b)	Supply Temperature [°F]	
	Nor.	100
(c)	Mechanical Design Press. [psig]	150
(d)	Mechanical Design Temp. [°F]	110

5.9. Fire Water (Intermittent)

(a) Supply Pressure [psig]

Nor. 125

(b) Supply Temperature [°F]

Nor. 85

(c) Mechanical Design Press. [psig] 175

(d) Mechanical Design Temp. [°F] 100

5.10. Air

(a) Type Instrument Air

(b) Supply Pressure [psig]

Max. 150

Min. 125

(c) Supply Temperature [°F]

Max. 115

(d) Dew Point [°F] Nor. -40

(e) Contamination of Oil Mist Oil free

(f) Mechanical Design

Press. [psig] 150

Temp. [°F] 115

6. Environmental Limitation

(a) Air Permit Item

From CO2 facility — VOC (*1)

(b) Noise Level (*2) — Maximum 85dBA @ a distance of five (5') feet above grade and three (3') feet from the equipment at full load operation

Note *1) Equipment Exceeding 85dbA Noise Level Guarantee.

The noise level of equipment in the following table exceeds the guaranteed noise level.

Item No.	Service
K-001	FLUE GAS BLOWER *1)
K-101	CO2 COMPRESSION UNIT *2)
	HRSG Steam Start UP Vents and Relief Valve Vents
	Cooling Tower Basin
	Cooling Tower Fan Deck
	HRSG Inlet Duct

Note *1) The noise insulation shall be provided for the casing of flue gas blower (K-001) and the blower suction and discharge duct in order to reduce the sound level around the blower.

*2) Noise mitigation measures shall be provided for CO2 compressor (K-101).

Noise insulation shall be provided for equipment and process piping in the unit.

7. Economic Evaluation Factor

(a) Electricity [US$/kWh]	0.045
(b) Steam [US$/kWh]	0.09
(c) Payback Period [year]	5

8. Design criteria

8.1. Design Plant life

Design Plant life [year] (*1) :30

Note *1) To be considered for equipment corrosion allowance of CS.

8.2. Flue gas monitoring

CEMS requirements at CO_2 absorber outlet : NOx, PM (filterable), CO, SO_2, CO_2 and Hg

8.3. Freezing protection

Freeze protection shall be provided for all piping systems smaller than 100 mm (4 inches), tubing, gages and instrumentation that contain fluids subject to freezing. All tubing requiring heat trace will be thermostatically controlled to prevent boil off of the sensing fluid.

Piping 6 inches and larger should be provided with provisions for draining to prevent freezing during periods where the carbon capture system is shutdown.

8.4. Minimum Metal Design Temperature

Minimum Metal Design Temperature : 9.9 °F

8.5. Electrical Area Classification

Unclassified

8.6. Chemical storage requirements

Chemical tank required capacity : 30 days of normal consumption

Solvent tank required capacity : dependent on transportation requirement

Vent and overflow : To be provided separately

8.7. Secondary Egress

Flue Gas Quencher : Not required

CO2 Absorber : Not require

8.8. Fouling Factor

The following fouling factor shall be used for the design of shell & tube type and plate type heat exchangers. The fouling factors except KS-1 Solution and KS-1 Solution for Reclaimer are same as specified in Tubular Exchanger Manufactures Association (TEMA).

Service	Fouling Factor [$ft^2h°F/BTU$]
LP. Steam	0.00049
Steam Condensate	0.00049
Cooling Water	0.00098
Process Condensate	0.00098
CO2	0.0010

8.9. Waste Water Tie-in Conditions with BOP

8.9.1. Dehydration Unit Waste Water

(a) Tie-in Pressure [psig] 43

(b) Tie-in Temperature [°F] 102

8.9.2. Area Sump Waste Water

(a) Tie-in Pressure [psig] 14

(b) Tie-in Temperature [°F] Ambient

8.9.3. Process Condensate Water

(a) Tie-in Pressure [psig] 26

(b) Tie-in Temperature [°F] 130

8.9.4. Caustic Waste Water

(a) Tie-in Pressure [psig] 25

(b) Tie-in Temperature [°F] 139

8.9.5. Sanitary Drainage

(a) Tie-in Pressure [psig] 18

(b) Tie-in Temperature [°F] Ambient

MITSUBISHI HEAVY INDUSTRIES AMERICA, INC.

PROCESS FLOW DIAGRAM

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REVISIONS

NO.	DATE	DESCRIPTION	REFERENCE	PREP'D (DISCIPLINE)	CHK'D (DISCIPLINE)	APP'D (DISCIPLINE)	APP'D (PROJECT)

ORDER NO.	583110
PROJECT	PNC-EOR
APPROVED	
DISCIPLINE	Process Group
APPROVED	
CHECKED	
PREPARED	
DATE	03/17/2016

CUSTOMER: petra nova an NRG company; JX

PROJECT: PETRA NOVA WA PARISH CARBON CAPTURE PROJECT

MHI DRAWING NUMBER	REV.
8150D B 230 - 30100	0

CUSTOMER DRAWING NUMBER	REV.
-	-

*Cover Only

DISTRIBUTION	
CUSTOMER	E
MHIA	E
TIC	E
PD	E
PM	E
APM	E
PE	E
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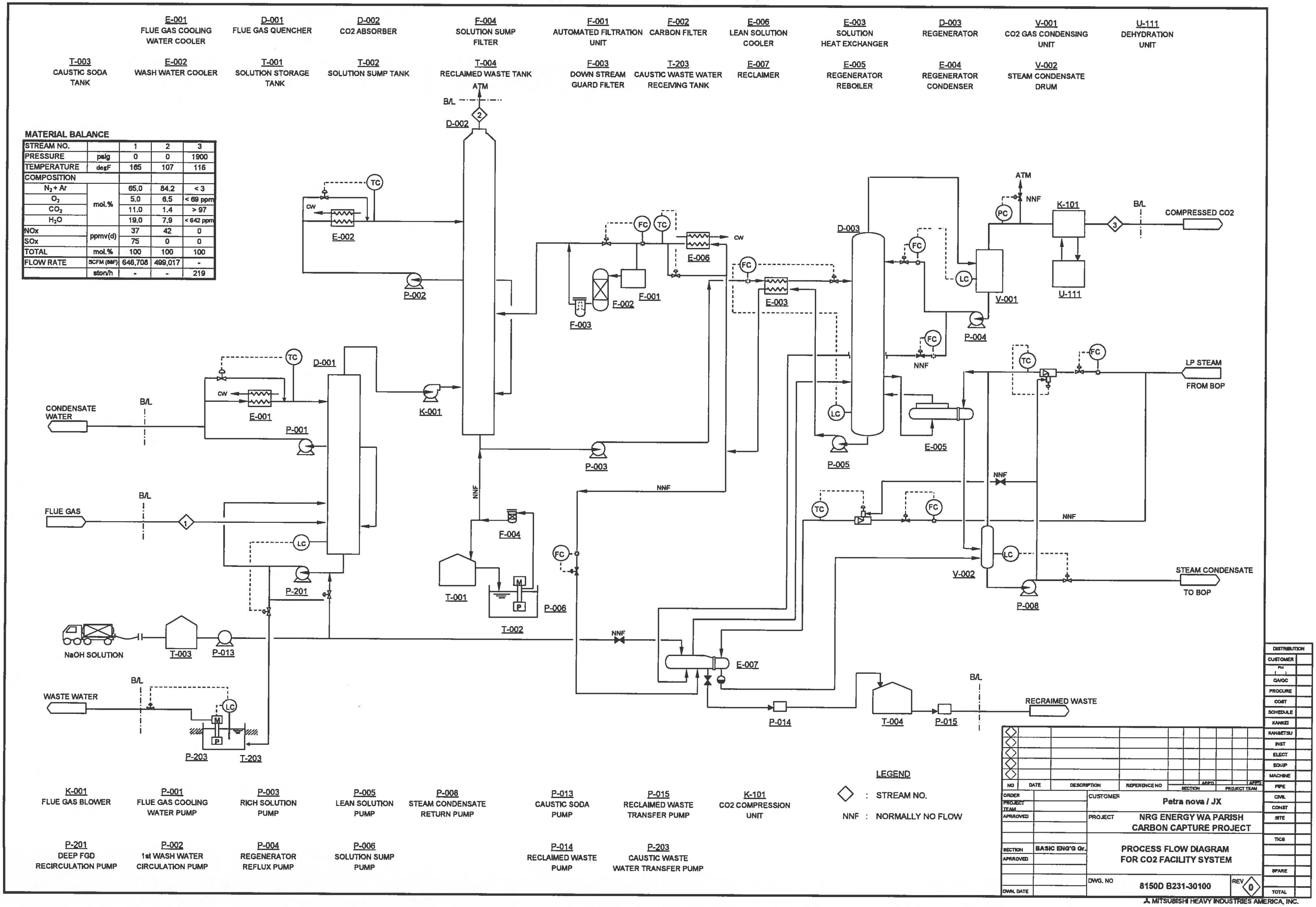
SUBCONT.	
LOGISTICS	
COST	
SCHEDULE	
BUSINESS	
PROCESS	E
MACHINE	
EQUIP.	
PIPING	
I&C	
ELECT.	
CIVIL	
CONST.	
VENDOR	
SITE	
TOTAL	0

SUMMARY OF REVISIONS

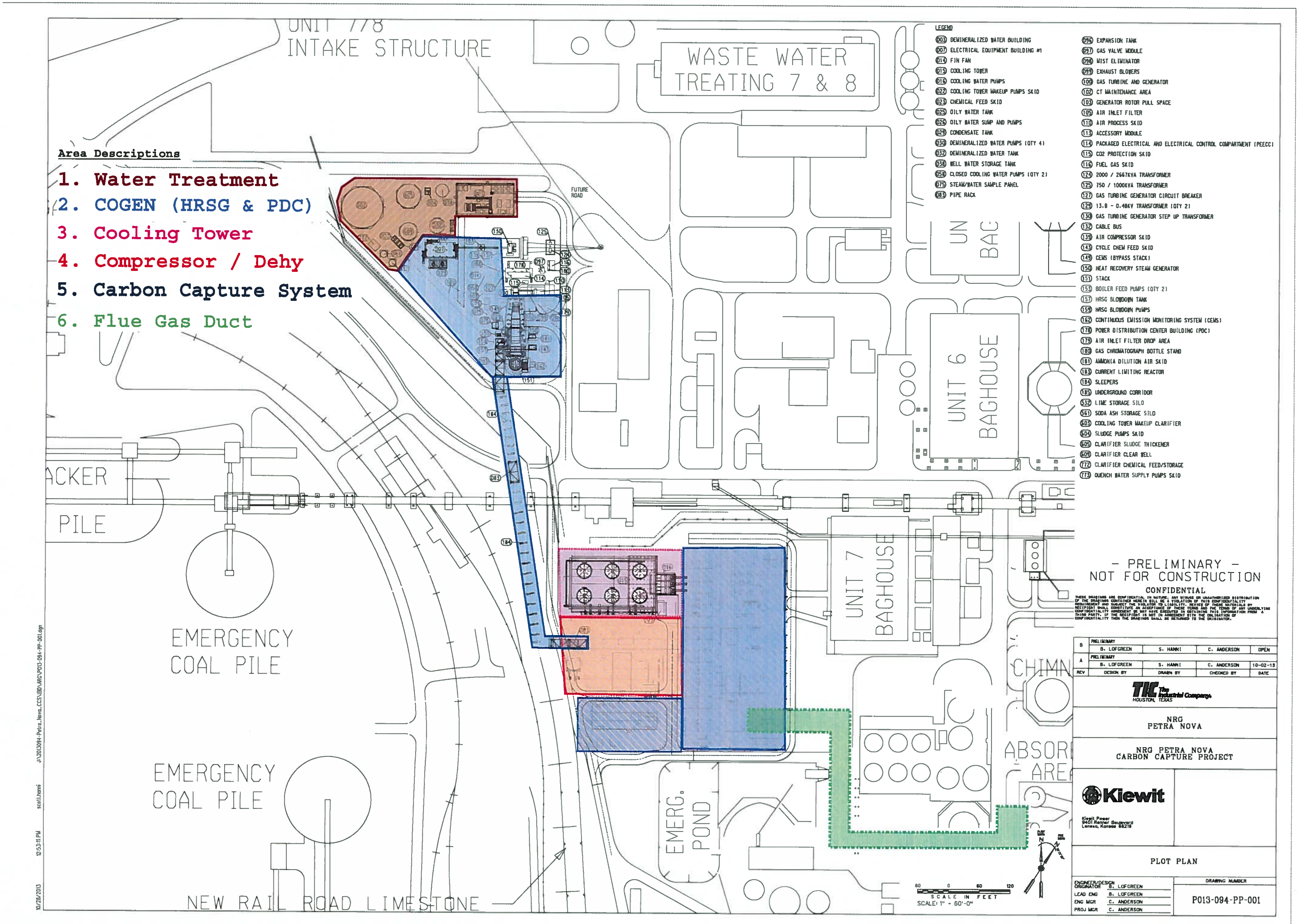
Doc No. : 8150D B230-30100

Cover Sheet		Item	Original		Revision		Reasons
Rev.	**Date**	No.	**Rev.**	**Description**	**Rev.**	**Description**	
0	03/17/2016		0	Issued for DOE.			



MATERIAL BALANCE

STREAM NO.		1	2	3
PRESSURE	psig	0	0	1900
TEMPERATURE	degF	165	107	116
COMPOSITION				
N_2 + Ar	mol.%	65.0	84.2	< 3
O_2		5.0	6.5	< 69 ppm
CO_2		11.0	1.4	> 97
H_2O		19.0	7.9	< 642 ppm
NOx	ppmv(d)	37	42	0
SOx		75	0	0
TOTAL	mol.%	100	100	100
FLOW RATE	SCFM (68F)	646,708	499,017	-
	ston/h	-	-	219


Area Descriptions
1. Water Treatment
2. COGEN (HRSG & PDC)
3. Cooling Tower
4. Compressor / Dehy
5. Carbon Capture System
6. Flue Gas Duct
UNIT 7/8
INTAKE STRUCTURE
WASTE WATER
TREATING 7 & 8
FUTURE ROAD
UNIT 6
BAGHOUSE
UNIT 7
BAGHOUSE
EMERGENCY
COAL PILE
EMERGENCY
COAL PILE
EMERG.
POND
ABSOR
AREA
CHIMN
PILE
NEW RAIL ROAD LIMESTONE
LEGEND
003 DEMINERALIZED WATER BUILDING
007 ELECTRICAL EQUIPMENT BUILDING #1
014 FIN FAN
015 COOLING TOWER
016 COOLING WATER PUMPS
022 COOLING TOWER MAKEUP PUMPS SKID
023 CHEMICAL FEED SKID
025 OILY WATER TANK
026 OILY WATER SUMP AND PUMPS
029 CONDENSATE TANK
030 DEMINERALIZED WATER PUMPS (QTY 4)
032 DEMINERALIZED WATER TANK
036 WELL WATER STORAGE TANK
058 CLOSED COOLING WATER PUMPS (QTY 2)
075 STEAM/WATER SAMPLE PANEL
083 PIPE RACK
096 EXPANSION TANK
097 GAS VALVE MODULE
098 MIST ELIMINATOR
099 EXHAUST BLOWERS
100 GAS TURBINE AND GENERATOR
102 CT MAINTENANCE AREA
103 GENERATOR ROTOR PULL SPACE
105 AIR INLET FILTER
110 AIR PROCESS SKID
113 ACCESSORY MODULE
114 PACKAGED ELECTRICAL AND ELECTRICAL CONTROL COMPARTMENT (PEECC)
115 CO2 PROTECTION SKID
116 FUEL GAS SKID
124 2000 / 2667KVA TRANSFORMER
125 750 / 1000KVA TRANSFORMER
127 GAS TURBINE GENERATOR CIRCUIT BREAKER
129 13.8 - 0.48KV TRANSFORMER (QTY 2)
130 GAS TURBINE GENERATOR STEP UP TRANSFORMER
132 CABLE BUS
139 AIR COMPRESSOR SKID
143 CYCLE CHEM FEED SKID
149 CEMS (BYPASS STACK)
150 HEAT RECOVERY STEAM GENERATOR
151 STACK
153 BOILER FEED PUMPS (QTY 2)
157 HRSG BLOWDOWN TANK
159 HRSG BLOWDOWN PUMPS
162 CONTINUOUS EMISSION MONITORING SYSTEM (CEMS)
178 POWER DISTRIBUTION CENTER BUILDING (PDC)
179 AIR INLET FILTER DROP AREA
180 GAS CHROMATOGRAPH BOTTLE STAND
181 AMMONIA DILUTION AIR SKID
183 CURRENT LIMITING REACTOR
184 SLEEPERS
185 UNDERGROUND CORRIDOR
532 LIME STORAGE SILO
561 SODA ASH STORAGE SILO
603 COOLING TOWER MAKEUP CLARIFIER
604 SLUDGE PUMPS SKID
605 CLARIFIER SLUDGE THICKENER
609 CLARIFIER CLEAR WELL
772 CLARIFIER CHEMICAL FEED/STORAGE
773 QUENCH WATER SUPPLY PUMPS SKID
- PRELIMINARY -
NOT FOR CONSTRUCTION
CONFIDENTIAL
B PRELIMINARY B. LOFGREEN S. HANNI C. ANDERSON OPEN
A PRELIMINARY B. LOFGREEN S. HANNI C. ANDERSON 10-02-13
REV DESIGN BY DRAWN BY CHECKED BY DATE
TIC The Industrial Company HOUSTON, TEXAS
NRG
PETRA NOVA
NRG PETRA NOVA
CARBON CAPTURE PROJECT
Kiewit
PLOT PLAN
ENGINEER/DESIGN ORIGINATOR B. LOFGREEN
LEAD ENG B. LOFGREEN
ENG MGR C. ANDERSON
PROJ MGR C. ANDERSON
DRAWING NUMBER
P013-094-PP-001
SCALE IN FEET
SCALE: 1" - 60'-0"
10/28/2013 12:53:11 PM

W.A. PARISH CARBON CAPTURE SEQUESTRATION (CCS) PROJECT

WATER-MASS BALANCE CALCULATION

CALCULATION NO.: WAP-CCS-M001

Prepared for

NRG Energy, Inc.

Date: July 30, 2014
Project No.: 12684-009
Issue: For Information, Rev. 3

Prepared by

Sargent & Lundy LLC

55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

ISSUE SUMMARY PAGE
& APPROVAL PAGE
WATER – MASS BALANCE CALCULATION
NRG ENERGY, INC.
PETRA NOVA

Purpose of Issue	Date	Pages Affected
For Information, Rev. 3	07-30-2014	All

This is to confirm that this Calculation has been prepared, reviewed and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0407, Calculations, which is part of our Quality Management System.

Current Revision Signatures:

PURPOSE	DATE	PREPARED	REVIEWED	APPROVED
For Information, Rev. 3	07-30-2014	M. Heermann Environmental	D. Martini Environmental	R. Smith Project Manager

CERTIFICATION PAGE

WATER – MASS BALANCE CALCULATION

NRG ENERGY, INC.
PETRA NOVA

I certify that this Calculation was prepared by me or under my direct supervision and that I am a registered professional engineer under the laws of the State of Texas.

This document is released for Information under the authority of Roger R. Smith, Texas P.E. #87358 on July 30, 2014.

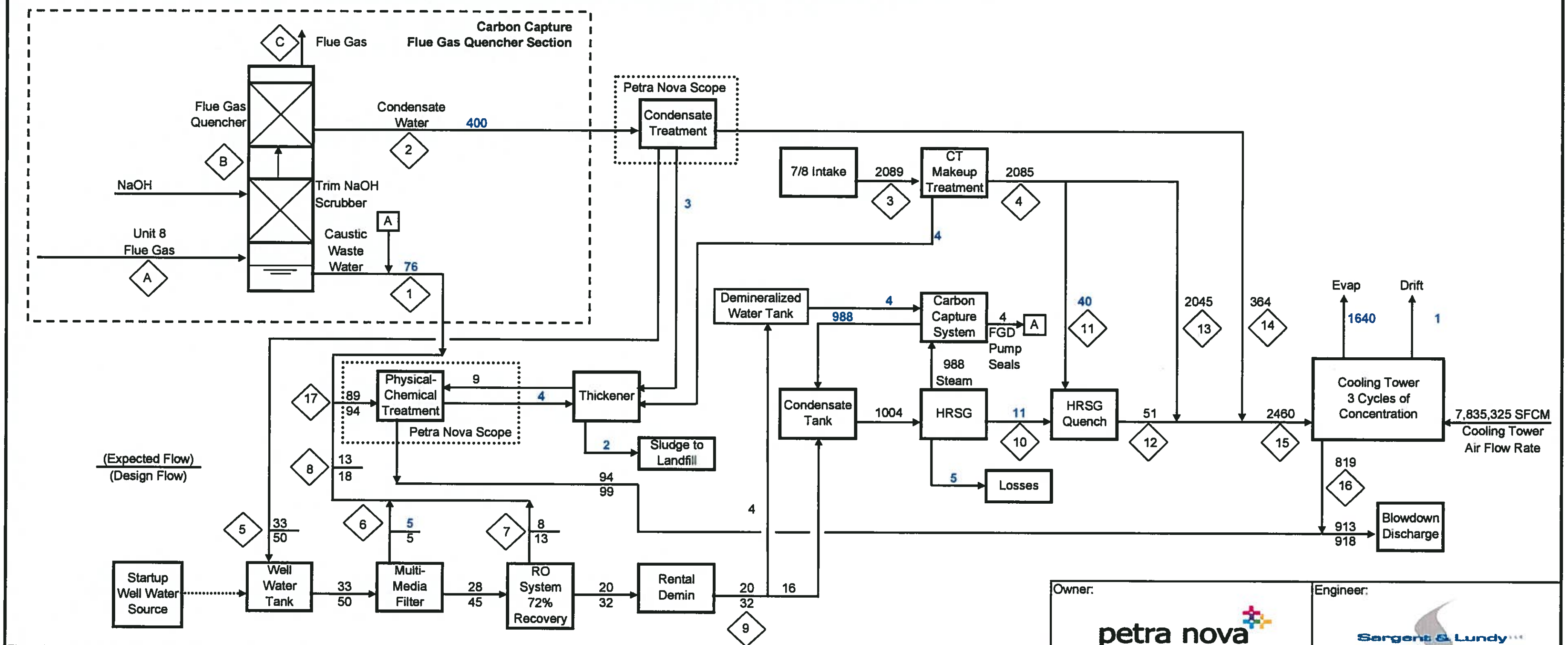
Sargent & Lundy LLC, Texas Registered Engineering Firm F-2202.

Certified By: ________________________ Date ______________

Seal:

STATE OF TEXAS
ROGER R. SMITH
87358
LICENSED
PROFESSIONAL ENGINEER

7/30/2014



Flows in 24-hr average GPM unless noted otherwise
Flows in **Bold** are entered values (see Notes for sources)

Drawing Release Record					
Rev	Date	Prepared	Reviewed	Approved	Purpose
0	29-May-14	M.Heermann	J. Penrose/ D. Martini	R. Smith	Client Comment
1	11-Jun-14	M.Heermann	D. Martini	R.Smith	Revised to include Additional Scope for Permit Requirements
2	25-Jul-14	M.Heermann	D. Martini	R.Smith	For Information
3	30-Jul-14	M.Heermann	D. Martini	R.Smith	Updated with New TSS Data

Project No: 12684-009

Owner: petra nova an NRG company

Engineer: Sargent & Lundy

Petra Nova

W.A. Parish Carbon Capture Project

WAP-CCS-M-001, Sheet 1

Waste Water Characterization - Water & Mass Balance

Stream Name / Stream Designation	Design Coal	Flue Gas (A)		Treated Flue Gas (B)		Quenched Flue Gas (C)	
Notes	1, 22	2, 3, 4, 5, 26		6			
Flow Rates		**646,708 SCFM** 827,857 ACFM	2,826,898 lb/hr	**653,934 SCFM** 523,833 SCFM-dry	2,847,169 lb/hr	**563,041 SCFM** 523,833 SCFM-dry	2,592,200 lb/hr
PARAMETERS							
Gas							
Pressure	N/A	**-3.1 in w.c.**				**-19.8 in w.c.**	
Temperature, °F	N/A	**165**		**140**		**101**	
SO_2	N/A	**75 ppm-dry**		**1.0 ppm-dry**		**1.0 ppm-dry**	
Particulate	N/A	**0.005 gr/acf**	34 lb/hr				
Moisture Carryover				**0.021 gr/scf(d)**	94 lb/hr	**0.000 gr/scf(d)**	0 lb/hr
Oxygen	N/A	**5.0 mol%-wet**				**5.7 mol%-wet**	
Water	N/A	**18 mol%**				**7.8 mol%-wet**	
CO_2	N/A	**11 mol%-wet**				**12.6 mol%-wet**	
Cations, ppm							
Calcium (Ca)	**194183**		6.7 lb/hr		0.02 lb/hr		0 lb/hr
Magnesium (Mg)	**40626**		1.4 lb/hr		0.003 lb/hr		0 lb/hr
Sodium (Na)	**16814**		1 lb/hr		0.734 lb/hr		0 lb/hr
Potassium (K)	**2883**		0.1 lb/hr		0.0002 lb/hr		0 lb/hr
Anions, ppm							
M-Alkalinity ($CaCO_3$)	N/A				0.015 lb/hr		
Chloride (Cl)	**150.00**		**7.9 lb/hr**		0.02 lb/hr		0 lb/hr
Sulfate (SO_4)	N/A				2 lb/hr		0 lb/hr
Phosphate (PO_4)	N/A						
Nitrate (NO_3)	N/A						
Fluoride (F)	**82.80**		**1.1 lb/hr**		0.003 lb/hr		0 lb/hr
Silica (SiO_2)	**336800**		12 lb/hr		0.03 lb/hr		0 lb/hr
Base							
Temperature, °F							
pH, std. units	N/A						
TDS, ppm	N/A						
TSS, ppm	N/A						
Trace, ppm							
Aluminum	**89637**		3.0 lb/hr		0.008 lb/hr		0 lb/hr
Antimony	**1.00**		0.00003 lb/hr				0 lb/hr
Arsenic	**1.70**		0.00006 lb/hr				0 lb/hr
Barium	**387.8**		0.01 lb/hr		0.00003 lb/hr		0 lb/hr
Beryllium	**2.30**		0.00008 lb/hr				0 lb/hr
Boron	**57.30**		0.002 lb/hr				0 lb/hr
Bromine	**20.00**		0.0007 lb/hr				0 lb/hr
Cadmium	**0.60**		0.00002 lb/hr				0 lb/hr
Chromium	**7.90**		0.0003 lb/hr				0 lb/hr
Cobalt	**2.63**		0.00009 lb/hr				0 lb/hr
Copper	**9.29**		0.0003 lb/hr				0 lb/hr
Iron	**69092**		2.3 lb/hr		0.006 lb/hr		0 lb/hr
Lead	**4.70**		0.0002 lb/hr				0 lb/hr
Manganese	**21.10**		0.0007 lb/hr				0 lb/hr
Mercury	**0.20**		**0.003 lb/hr**		**0.0020 lb/hr**		0 lb/hr
Nickel	**14.50**		0.0005 lb/hr				0 lb/hr
Selenium	**1.70**		0.00006 lb/hr				0 lb/hr
Strontium	**260.6**		0.009 lb/hr		0.00002 lb/hr		0 lb/hr
Titanium	**1.00**		0.00003 lb/hr				0 lb/hr
Uranium	**0.67**		0.00002 lb/hr				0 lb/hr
Vanadium	**25.20**		0.0009 lb/hr				0 lb/hr
Zinc	**16.35**		0.0006 lb/hr				0 lb/hr
Zirconium	**11.03**		0.0004 lb/hr				0 lb/hr

Stream Name / Stream Designation	Caustic Waste Water (1)		Condensate Water (2)		7/8 Intake Water (3)		Softened Water (4)	
Notes	8, 17, 23, 24		7, 9, 15		19, 27		19	
Flow Rates	76 gpm	38,002 lb/hr	400 gpm	200,000 lb/hr	2,089 gpm	1,045,496 lb/hr	2,085 gpm	1,043,494 lb/hr
Cations, ppm								
Calcium (Ca)	177	6.7 lb/hr	0.08	0.02 lb/hr	**95**	99 lb/hr	**23.8**	25 lb/hr
Magnesium (Mg)	37	1.4 lb/hr	0.02	0.003 lb/hr	**26.6**	28 lb/hr	**6.7**	7 lb/hr
Sodium (Na)	**7789**	295 lb/hr	4	0.734 lb/hr	**189.9**	199 lb/hr	**309.8**	323 lb/hr
Potassium (K)	3	0.10 lb/hr	0.001	0.0002 lb/hr	**11.3**	12 lb/hr	**11.3**	12 lb/hr
Anions, ppm								
M-Alkalinity ($CaCO_3$)	180	6.1 lb/hr	0.08	0.015 lb/hr	**149**	156 lb/hr	**149**	156 lb/hr
Chloride (Cl)	**250**	10 lb/hr	0.1	0.02 lb/hr	**251**	263 lb/hr	**251**	262 lb/hr
Sulfate (SO_4)	**16229**	617 lb/hr	8	2 lb/hr	**258**	270 lb/hr	**258**	270 lb/hr
Phosphate (PO_4)					**0.5**	1 lb/hr	**0.5**	1 lb/hr
Nitrate (NO_3)					**1.5**	2 lb/hr	**1.5**	2 lb/hr
Fluoride (F)	30.0	1 1 lb/hr	0.01	0.003 lb/hr				
Silica (SiO_2)	304	12 lb/hr	0.1	0.03 lb/hr	21	22 lb/hr	**19**	20 lb/hr
Base								
Temperature, °F	140							
pH, std. units	**6.5 - 7**		**4.5**		**8.1**			
TDS, ppm	25099	954 lb/hr	12	2 lb/hr	**1083**	1132 lb/hr	**950**	991 lb/hr
TSS, ppm	**950**	36 lb/hr	**150**	30 lb/hr	**71**	74 lb/hr	6 9	7 lb/hr
Trace, ppm								
Aluminum	80	3.0 lb/hr	0.04	0.008 lb/hr				
Antimony	0.001	0.00003 lb/hr	<0.001					
Arsenic	0.002	0.00006 lb/hr	<0.001					
Barium	0.3	0.01 lb/hr	<0.001	0.00003 lb/hr				
Beryllium	0.002	0.00008 lb/hr	<0.001					
Boron	0.05	0.002 lb/hr	<0.001					
Bromine	0.02	0.0007 lb/hr	<0.001					
Cadmium	0.0006	0.00002 lb/hr	<0.0001					
Chromium	0.007	0.0003 lb/hr	<0.001					
Cobalt	0.002	0.00009 lb/hr	<0.001					
Copper	0.008	0.0003 lb/hr	<0.001		**0.0557**	0.06 lb/hr	**0.017**	0.02 lb/hr
Iron	61	2.3 lb/hr	0.03	0.006 lb/hr	**0.42**	0.4 lb/hr	**0.21**	0.2 lb/hr
Lead	0.004	0.0002 lb/hr	<0.001					
Manganese	0.02	0.0007 lb/hr	<0.001		**0.05**	0.05 lb/hr	**0.03**	0.03 lb/hr
Mercury	0.02	0.0007 lb/hr	0.000002					
Nickel	0.01	0.0005 lb/hr	<0.001					
Selenium	0.002	0.00006 lb/hr	<0.001					
Strontium	0.2	0.009 lb/hr	<0.001	0.00002 lb/hr				
Titanium	0.001	0.00003 lb/hr	<0.001					
Uranium	<0.001	0.00002 lb/hr	<0.001					
Vanadium	0.02	0.0009 lb/hr	<0.001					
Zinc	0.01	0.0006 lb/hr	<0.001		**0.06**	0.06 lb/hr	**0.02**	0.02 lb/hr
Zirconium	0.01	0.0004 lb/hr	<0.001					

Stream Name / Stream Designation	Process Condensate to Demineralized Water Makeup (5)		Multi-media Filter Backwash (6)		RO Reject (7)		Makeup Waste Water (8)	
Notes	10		14		13			
Flow Rates	33 gpm	16,513 lb/hr	5 gpm	2,502 lb/hr	13 gpm Design	6,505 lb/hr	18 gpm Design	9,007 lb/hr
Cations, ppm								
Calcium (Ca)	0.08	0.001377 lb/hr	0.08	0.00 lb/hr	0.18	0.001168 lb/hr	0	0.00 lb/hr
Magnesium (Mg)	0.02	0.00 lb/hr	0.02	0.000 lb/hr	0.04	0.00 lb/hr	0	0.00 lb/hr
Sodium (Na)	3.671	0.060618 lb/hr	3.67	0.009 lb/hr	7.91	0.0514337 lb/hr	7	0.06 lb/hr
Potassium (K)	0.001	0.00 lb/hr	0.00	0.0000 lb/hr	0.00	0.00 lb/hr	0.0	0.000 lb/hr
Anions, ppm								
M-Alkalinity ($CaCO_3$)	0	0.0 lb/hr	0.08	0.00 lb/hr	0.16	0.0 lb/hr	0	0.0 lb/hr
Chloride (Cl)	0.1	0.0 lb/hr	0.12	0.000 lb/hr	0.25	0.0 lb/hr	0	0.00 lb/hr
Sulfate (SO_4)	8	0.1 lb/hr	7.65	0.0 lb/hr	16.48	0.1 lb/hr	14	0.13 lb/hr
Phosphate (PO_4)	0	0.0 lb/hr	0.00	0.00 lb/hr	0.00	0.0 lb/hr	0	0.00 lb/hr
Nitrate (NO_3)								
Fluoride (F)	0.01	0.000 lb/hr	0.01	0.000035 lb/hr	0.03	0.0002 lb/hr	0.0	0.000 lb/hr
Silica (SiO_2)	0.1	0.0 lb/hr	0.1	0.00 lb/hr	0.31	0.00 lb/hr	0	0.002 lb/hr
Base								
Temperature, °F								
pH, std. units	4.5							
TDS, ppm	12	0.2 lb/hr	12	0.0 lb/hr	26	0.2 lb/hr	22	0 lb/hr
TSS, ppm	6 9	0.1 lb/hr	46	0.1 lb/hr	0	0.00 lb/hr	13	0.1 lb/hr
Trace, ppm								
Aluminum	0.04	0.0006 lb/hr	0.04	0.0001 lb/hr	0.08	0.0005 lb/hr	0.1	0.0006 lb/hr
Antimony	<0.001		<0.001		<0.001		<0.001	
Arsenic	<0.001		<0.001		<0.001		<0.001	
Barium	<0.001		<0.001		<0.001		<0.001	
Beryllium	<0.001		<0.001		<0.001		<0.001	
Boron	<0.001		<0.001		<0.001		<0.001	
Bromine	<0.001		<0.001		<0.001		<0.001	
Cadmium	<0.0001		<0.0001		<0.0001		<0.0001	
Chromium	<0.001		<0.001		<0.001		<0.001	
Cobalt	<0.001		<0.001		<0.001		<0.001	
Copper	<0.001		<0.001		<0.001		<0.001	
Iron	0.03	0.0005 lb/hr	0.03	0.00007 lb/hr	0.1	0.00041 lb/hr	0.05	0.00048 lb/hr
Lead	<0.001		<0.001		<0.001		<0.001	
Manganese	<0.001		<0.001		<0.001		<0.001	
Mercury	0.000002		0.000002		0.0001		0.000004	
Nickel	<0.001		<0.001		<0.001		<0.001	
Selenium	<0.001		<0.001		<0.001		<0.001	
Strontium	<0.001		0.00		<0.001		<0.001	
Titanium	<0.001		<0.001		<0.001		<0.001	
Uranium	<0.001		<0.001		<0.001		<0.001	
Vanadium	<0.001		0.001		<0.001		<0.001	
Zinc	<0.001		<0.001		<0.001		<0.001	
Zirconium	<0.001		<0.001		<0.001		<0.001	

Drawing Release Record

Rev	Date	Prepared	Reviewed	Approved	Purpose
0	29-May-14	M Heermann	J. Penrose/ D. Martini	R. Smith	Client Comment
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Parameters in **Bold** are entered values (see Notes for sources)

Project No: 12684-009

Owner:

Engineer:

Petra Nova

W.A. Parish Carbon Capture Project

WAP-CCS-M-001, Sheet 2

Waste Water Characterization - Water & Mass Balance

Stream Name	Demineralized Water		HRSG Blowdown		Quench Water		Quenched HRSG Blowdown		Clarified CT Makeup		Process Condensate to Cooling Tower		Combined CT Makeup		Cooling Tower Air Flow		Cooling Tower Blowdown		Feed to Physical Chemical Treatment	
Stream Designation	9		10		11		12		13		14		15				16		17	
Notes	10		11, 20														12, 16, 21			
Flow Rates	32 gpm	16,013 lb/hr	11 gpm	5,504 lb/hr	40 gpm	20,016 lb/hr	51 gpm	25,520 lb/hr	2,045 gpm	1,023,478 lb/hr	364 gpm	181,986 lb/hr	2,460 gpm	1,230,984 lb/hr	7,635,325 SCFM 8,206,548 ACFM	**19,270,000 lb/hr**	819 gpm	409,828 lb/hr	94 gpm Design	47,009 lb/hr
PARAMETERS																				
Gas																				
Pressure															**1.0 atm** **93 deg. F DB** Average Atmospheric Total Suspended Particulate **129.0 ug/m3**	3.8 lb/hr				
Temperature, °F																				
SO_2																				
Particulate																				
Moisture Carryover																				
Oxygen																				
Water																				
CO_2																				
Cations, ppm																				
Calcium (Ca)	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	24	0.5 lb/hr	19	0.5 lb/hr	24	24 lb/hr	0	0 lb/hr	20	25 lb/hr			61	25 lb/hr	143	7 lb/hr
Magnesium (Mg)	**0**	**0.00 lb/hr**	**0**	**0.00 lb/hr**	7	0.13 lb/hr	5	0.13 lb/hr	7	7 lb/hr	0	0.0 lb/hr	6	7 lb/hr			17	7 lb/hr	30	1.4 lb/hr
Sodium (Na)	**0.003**	**0.00005 lb/hr**	**0.009**	**0.00005 lb/hr**	310	6.2 lb/hr	243	6.2 lb/hr	310	317 lb/hr	4	1 lb/hr	263	324 lb/hr			790	324 lb/hr	6281	295 lb/hr
Potassium (K)	**0**	**0.00 lb/hr**	**0**	**0.00 lb/hr**	11	0.23 lb/hr	9	0.23 lb/hr	11	12 lb/hr	0.0	0.00 lb/hr	10	12 lb/hr			29	12 lb/hr	2	0.1 lb/hr
Anions, ppm																				
M-Alkalinity ($CaCO_3$)	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	149	3.0 lb/hr	117	3.0 lb/hr	149	153 lb/hr	0	0 lb/hr	127	156 lb/hr			100	41 lb/hr	100	6 lb/hr
Chloride (Cl)	**0.003**	**0.00005 lb/hr**	**0.009**	**0.00005 lb/hr**	251	5.0 lb/hr	197	5.0 lb/hr	251	257 lb/hr	0	0 lb/hr	213	262 lb/hr			639	262 lb/hr	202	10 lb/hr
Sulfate (SO_4)	**0.003**	**0.00005 lb/hr**	**0.009**	**0.00005 lb/hr**	258	5.2 lb/hr	203	5.2 lb/hr	258	264 lb/hr	8	1 lb/hr	220	271 lb/hr			931	381 lb/hr	13122	617 lb/hr
Phosphate (PO_4)	**0**	**0.0 lb/hr**	**4**	**0.02 lb/hr**	0.5	0.01 lb/hr	1.3	0.032 lb/hr	0.5	0.5 lb/hr	0.0	0.0 lb/hr	0.4	1 lb/hr			1.3	1 lb/hr	0.0	0 lb/hr
Nitrate (NO_3)	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	1.5	0.030 lb/hr	1	0.03 lb/hr	1.5	1.5 lb/hr			1	2 lb/hr			4	2 lb/hr	0.0	0 lb/hr
Fluoride (F)	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							0.01	0.00 lb/hr	0.00	0.00 lb/hr						
Silica (SiO_2)	**0.010**	**0.0002 lb/hr**	**0.03**	**0.0002 lb/hr**	19	0.39 lb/hr	15	0.39 lb/hr	19	20 lb/hr	0	0 lb/hr	16	20 lb/hr			49	20 lb/hr	245	12 lb/hr
Base																				
Temperature, °F																	**92**		128	
pH, std. units				**9.8**																
TDS, ppm	**0**	**0.0 lb/hr**	**4**	**0.02 lb/hr**	950	19.0 lb/hr	746	19.0 lb/hr	950	972 lb/hr	12	2 lb/hr	807	993 lb/hr			2801	1066 lb/hr	20294	954 lb/hr
TSS, ppm	**0**	**0.0 lb/hr**	**0**	**0.00 lb/hr**	6.9	0.14 lb/hr	5	0.14 lb/hr	6.9	7 lb/hr	6.9	1 lb/hr	6.9	9 lb/hr			**21**	9 lb/hr	770	36 lb/hr
Trace, ppm																				
Aluminum	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							0.04	0.007 lb/hr	0.006	0.007 lb/hr			0.02	0.007 lb/hr	65	3.0 lb/hr
Antimony	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		<0.001	0.00003 lb/hr
Arsenic	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.002	0.00006 lb/hr
Barium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001	0.00003 lb/hr	<0.001	0.00003 lb/hr			<0.001	0.00003 lb/hr	0.3	0.013 lb/hr
Beryllium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.002	0.00008 lb/hr
Boron	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.04	0.002 lb/hr
Bromine	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.02	0.0007 lb/hr
Cadmium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.0001		<0.0001				<0.0001		<0.0005	0.00002 lb/hr
Chromium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.006	0.0003 lb/hr
Cobalt	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.002	0.00009 lb/hr
Copper	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	0.017	0.0003 lb/hr	0.013	0.0003 lb/hr	0.017	0.02 lb/hr	<0.001		0.01	0.0 lb/hr			0.04	0.02 lb/hr	0.007	0.0003 lb/hr
Iron	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	0.21	0.004 lb/hr	0.16	0.004 lb/hr	0.21	0.21 lb/hr	0.03	0.005 lb/hr	0.2	0.2 lb/hr			0.5	0.2 lb/hr	50	2.3 lb/hr
Lead	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.004	0.0002 lb/hr
Manganese	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	0.03	0.0006 lb/hr	0.02	0.001 lb/hr	0.03	0.03 lb/hr	<0.001		0.025	0.03 lb/hr			0.08	0.03 lb/hr	0.02	0.0007 lb/hr
Mercury	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							0.000002		<0.000001				<0.000001		0.01	0.0007 lb/hr
Nickel	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.01	0.0005 lb/hr
Selenium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.002	0.00006 lb/hr
Strontium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001	0.00002 lb/hr	<0.001	0.00002 lb/hr			<0.001	0.00002 lb/hr	0.2	0.009 lb/hr
Titanium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		<0.001	0.00003 lb/hr
Uranium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		<0.001	0.00002 lb/hr
Vanadium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.02	0.0009 lb/hr
Zinc	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**	0.02	0.0004 lb/hr	0.01	0.0004 lb/hr	0.02	0.02 lb/hr	<0.001		0.01	0.0 lb/hr			0.04	0.02 lb/hr	0.01	0.0006 lb/hr
Zirconium	**0**	**0.0 lb/hr**	**0**	**0.0 lb/hr**							<0.001		<0.001				<0.001		0.01	0.0004 lb/hr

Drawing Release Record

Rev	Date	Prepared	Reviewed	Approved	Purpose
0	29-May-14	M Heermann	J. Penrose/ D. Martini	R. Smith	Client Comment
1	11-Jun-14	M Heermann	D. Martini	R Smith	Revised to include Additional Scope for Permit Requirements
2	25-Jul-14	M Heermann	D. Martini	R Smith	For Information
3	30-Jul-14	M Heermann	D. Martini	R Smith	Updated with New TSS Data

Parameters in **Bold** are entered values (see Notes for sources)

Project No 12684-009

Owner: petra nova an NRG company

Engineer: Sargent & Lundy

Petra Nova

W.A. Parish Carbon Capture Project

WAP-CCS-M-001, Sheet 3

Waste Water Characterization - Water & Mass Balance

Notes

1 Coal data from Buckskin Mine Typical Coal Quality analysis included in design basis e-mail (Klumpyan, J. 4/11/2011), for some trace metal concentrations see Note #22.

2 Flue gas characteristics from MHIA Basic Engineering Design Data, WAP-B212-00100, Table 2.1(a).

3 Mercury mass flow in flue gas calculated from regulatory limit/maximum allowance of 1.2 lb/TBtu per Mercury and Air Toxics Standards multiplied by 5999 MMBtu/hr and the ratio of the CCS Flue Gas mass flow rate to the Case 1B (fully-blended, high sulfur) mass flow rate. These values represent the maximum allowed condition, and are to be considered a worst-case estimate. Actual values are not available, as the plant is not yet operating. It is expected that actual emissions will be below the regulatory limit with some operating margin.

4 Flue gas flow to CCS from Mitsubishi Heavy Industries America drawing 8150-B231-00100.

5 Flue gas trace mass flow rates other than mercury and chlorine calculated from Buckskin Mine Typical Coal Quality assuming trace metals carried into the trim NaOH scrubber as particulate.

6 Treated flue gas particulate flow rate (gr/acf) from Petra Nova CCS Waste Water Treatment System Request for Information 03 19 14 - Responsel 04 01 14.xls, MHIA response #10

7 Condensate water flow rate from Mitsubishi Heavy Industries America (MHIA) drawing 8150-B231-00100.

8 Caustic waste water flow rate, sodium concentration, and sulfate concentration from MHIA drawing 8150-B231-00100. Alkalinity is added to balance the charge.

9 CCS steam condensate flow rate from MHIA drawing 8150-B231-00100.

10 CCS demineralized water demand from Kiewit Petra Nova - Water Balance - Flow Diagram

11 HRSG blowdown, losses, and quench water demand from Kiewit Petra Nova - Water Balance - Flow Diagram

12 Cooling tower evaporation and drift from Kiewit Petra Nova - Water Balance - Flow Diagram

13 RO system recovery (72%) and guaranteed maximum flow from Kiewit Petra Nova - Water Balance - Flow Diagram

14 Multi-media filter backwash from Kiewit Petra Nova - Water Balance - Flow Diagram

15 Condensate water total suspended solids (TSS) from Petra Nova CCS Waste Water Treatment System Request for Information 03 19 14 - Responsel 04 01 14.xls, MHIA response #2

16 Cooling tower blowdown sulfate concentration based on maintaining 100 ppm of alkalinity. The actual pH, and alkalinity and sulfate concentrations may be somewhat higher and lower depending on the actual treatment program selected.

17 Mercury in the flue gas is primarily in the gaseous phase (elemental); therefore, it is only minimally collected in the DEEP FGD and Quencher. This balance assumes that 25% of the gaseous mercury is partitioned to the liquid caustic waste water phase based on MHIA confidential carbon capture system demonstration test data. The collection efficiency per Takahito Yonekawa e-mail transmitted on 4/15/2014.

18 Mass balance concentrations calculated to be less than 1 ppb are designated with "<0.001 ppm". With the exception of Cadmium (<0.0001 ppm) and mercury (<0.000001 ppm)

19 Unit 7/8 Intake water quality (except TSS, see Note #27) and softened water quality from Kiewit Petra Nova - Water Balance - Flow Diagram.

20 HRSG blowdown quality estimated from Kiewit Petra Nova - Water Balance - Flow Diagram

21 Cooling tower blowdown TSS concentration based on an assumed 30 ppm limit minus margin for particulate matter (PM10) in the air entrained in the circulating water. PM10 entrainment estimated using maximum PM10 reading from EPA air quality monitors in the vicinity of Houston, TX (129 $\mu g/m^3$, measured at monitor #482011035 in 2012). Cooling tower air flow based on Kiewit Comment #5 on WAP-CCS-M001_KPE_Comment_Resolution.xls (8,206,548 ACFM @ 93 deg. F DB & 1 atm) converted to SCFM.

22 Coal Arsenic, Beryllium, Cadmium, Chlorine, Chromium, Fluorine, Lead, Manganese, Nickel, Selenium, and Vanadium concentrations from WA Parish Fuel Specification, Long Term Trace Element Concentration Final Limits. (J. Kessling E-mail, 5/7/2014) For all other coal data see Note #1.

23 Caustic Waste Water pH 6.5-7 per WAP-CCS-M001_MHIA_Comment_Resolution_20MAY2014, Comment #8

24 Caustic Waste Water suspended solids (TSS) and Chloride (Cl) from MHIA document, Trm FGD SS and Cl Balance Calculation.xls

25 Cooling tower blowdown temperature from Kiewit Comment #25 on WAP-CCS-M001_KPE_Comment_Resolution.xls, Maximum Cooling Tower Blowdown temperature will be same as maximum cooling tower cold water temperature, 92 deg F.

26 Flue gas fluoride concentration from S&L Calc # 2011-08687, attachment #9, 3 lb/hr mass flow and the ratio of the CCS Flue Gas mass flow rate to the Case 2B (fully-blended, high sulfur) mass flow rate.

27 Unit 7/8 Intake water total suspended solids concentration estimated from maximum value of weekly suspended solids sample data taken 3/12/2014 through 6/11/2014. (71 mg/L)

Owner: petra nova an NRG company

Engineer: Sargent & Lundy

Drawing Release Record

Rev	Date	Prepared	Reviewed	Approved	Purpose
0	29-May-14	M.Heermann	D. Martini	R. Smith	Client Comment
1	11-Jun-14	M.Heermann	D. Martini	R.Smith	Revised to include Additional Scope for Permit Requirements
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Project No: 12684-009

Petra Nova
W.A. Parish Carbon Capture Project

WAP-CCS-M-001, Sheet 4

Waste Water Characterization - Water & Mass Balance

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name	Units	Case C4-1	Case C4-2	Case C4-3	Case C4-4	Case C4-5	Case C4-6	Case C4-7	Case C4-8
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1054 F	Fired 1115 F	Fired 1186 F	Fired 1215 F
Process Steam		462.2 kpph	441.8 kpph	423.8 kpph	414.7 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-1	C4-2	C4-3	C4-4	C4-5	C4-6	C4-7	C4-8
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	97,376	86,208	73,953	70,266	97,376	86,208	73,953	70,266
Gross CTG Heat Rate (LHV)	Btu/kWh	10,317	10,497	10,828	10,955	10,317	10,497	10,828	10,955
Gross CTG Heat Rate (HHV)	Btu/kWh	11,441	11,641	12,008	12,150	11,441	11,641	12,008	12,150
CTG Heat Input (LHV)	MMBtu/h	1,004.59	904.93	800.73	769.80	1,004.59	904.93	800.73	769.80
CTG Heat Input (HHV)	MMBtu/h	1,114.09	1,003.57	888.01	853.71	1,114.09	1,003.57	888.01	853.71
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	58.70	79.66	98.28	107.74
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	65.10	88.35	109.00	119.49
Plant Heat Input (LHV)	MMBtu/h	1,004.59	904.93	800.73	769.80	1,063.29	984.59	899.02	877.54
Plant Heat Input (HHV)	MMBtu/h	1,114.09	1,003.57	888.01	853.71	1,179.19	1,091.91	997.01	973.19
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,993	1,941	1,885	1,867	2,015	1,971	1,922	1,907
Total Auxiliary Power/Losses, percent of gross		2.05%	2.25%	2.55%	2.66%	2.07%	2.29%	2.60%	2.71%
Net Plant Output w/ Step-Up Xfmr Losses	kW	95,383	84,267	72,068	68,399	95,361	84,237	72,031	68,359
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	10,532	10,739	11,111	11,254	11,150	11,688	12,481	12,837
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,680	11,909	12,322	12,481	12,365	12,962	13,841	14,236
Auxiliary Power Calculations									
Boiler Feed Pump	kW	172	165	158	155	194	194	194	194
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,572	1,565	1,558	1,555	1,594	1,594	1,594	1,594
Generator Step-up Transformer Losses	kW	390	345	296	281	390	345	296	281
Auxiliary Transformer Losses	kW	31	31	31	31	32	32	32	32
Subtotal Transformer Losses	kW	421	376	327	312	421	377	328	313
Total Auxiliary Power and Transformer Losses	kW	1,993	1,941	1,885	1,867	2,015	1,971	1,922	1,907
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	1,004.6	904.9	800.7	769.8	1,004.6	904.9	800.7	769.8
	Flow, lb/h	49,159	44,282	39,183	37,670	49,159	44,282	39,183	37,670
Fuel LHV	Btu/lb	20,435	20,436	20,436	20,436	20,435	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,654,491	2,428,454	2,200,103	2,128,748	2,654,491	2,428,454	2,200,103	2,128,748
	Pressure, in. H2O (prelimina	13.96	11.90	9.99	9.45	13.96	11.90	9.99	9.45
	Temperature, F	977.3	1,002.4	1,035.1	1,044.0	977.3	1,002.4	1,035.1	1,044.0

Case Name	Units	Case C4-9	Case C4-10	Case C4-11	Case C4-12	Case C4-13	Case C4-14	Case C4-15	Case C4-16
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1095 F	Fired 1160 F	Fired 1235 F	Fired 1268 F
Process Steam		439.2 kpph	420.0 kpph	401.4 kpph	392.3 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-9	C4-10	C4-11	C4-12	C4-13	C4-14	C4-15	C4-16
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	92,508	81,898	70,255	66,753	92,508	81,898	70,255	66,753
Gross CTG Heat Rate (LHV)	Btu/kWh	10,358	10,539	10,871	11,000	10,358	10,539	10,871	11,000
Gross CTG Heat Rate (HHV)	Btu/kWh	11,487	11,688	12,056	12,199	11,487	11,688	12,056	12,199
CTG Heat Input (LHV)	MMBtu/h	958.21	863.15	763.76	734.25	958.21	863.15	763.76	734.25
CTG Heat Input (HHV)	MMBtu/h	1,062.65	957.23	847.01	814.29	1,062.65	957.23	847.01	814.29
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	82.17	101.95	121.87	131.83
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	91.13	113.07	135.16	146.20
Plant Heat Input (LHV)	MMBtu/h	958.21	863.15	763.76	734.25	1,040.38	965.10	885.63	866.08
Plant Heat Input (HHV)	MMBtu/h	1,062.65	957.23	847.01	814.29	1,153.78	1,070.30	982.17	960.49
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,965	1,915	1,862	1,844	1,996	1,953	1,907	1,893
Total Auxiliary Power/Losses, percent of gross		2.12%	2.34%	2.65%	2.76%	2.16%	2.38%	2.71%	2.84%
Net Plant Output w/ Step-Up Xfmr Losses	kW	90,543	79,983	68,393	64,909	90,512	79,945	68,348	64,860
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	10,583	10,792	11,167	11,312	11,494	12,072	12,958	13,353
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,736	11,968	12,384	12,545	12,747	13,388	14,370	14,809
Auxiliary Power Calculations									
Boiler Feed Pump	kW	164	157	150	146	194	194	194	194
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,564	1,557	1,550	1,546	1,594	1,594	1,594	1,594
Generator Step-up Transformer Losses	kW	370	328	281	267	370	328	281	267
Auxiliary Transformer Losses	kW	31	31	31	31	32	32	32	32
Subtotal Transformer Losses	kW	401	359	312	298	402	359	313	299
Total Auxiliary Power and Transformer Losses	kW	1,965	1,915	1,862	1,844	1,996	1,953	1,907	1,893
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	958.2	863.1	763.8	734.3	958.2	863.1	763.8	734.3
	Flow, lb/h	46,889	42,238	37,374	35,930	46,889	42,238	37,374	35,930
Fuel LHV	Btu/lb	20,436	20,436	20,436	20,436	20,436	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,501,679	2,287,217	2,072,874	2,000,545	2,501,679	2,287,217	2,072,874	2,000,545
	Pressure, in. H2O (prelimina	12.54	10.68	8.98	8.45	12.54	10.68	8.98	8.45
	Temperature, F	981.5	1,007.6	1,037.7	1,047.5	981.5	1,007.6	1,037.7	1,047.5

Approved - Returned: 07/15/2014
88.15.04.004-IFR-HV-0001-001 - Packet 88.15.04.004-IFR-002 - WA Parish Carbon Capture Project - 2013094 - Received: 06/24/2014

Kiewit Power Engineers – NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-1	Case C4-2	Case C4-3	Case C4-4	Case C4-5	Case C4-6	Case C4-7	Case C4-8
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1054 F	Fired 1115 F	Fired 1186 F	Fired 1215 F
Process Steam		462.2 kpph	441.8 kpph	423.8 kpph	414.7 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-1	C4-2	C4-3	C4-4	C4-5	C4-6	C4-7	C4-8
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	3.24%	3.18%	3.09%	3.08%	3.24%	3.18%	3.09%	3.08%
	% vol H2O	6.31%	6.94%	8.35%	7.91%	6.31%	6.94%	8.35%	7.91%
	% vol N2	75.54%	75.00%	73.83%	74.17%	75.54%	75.00%	73.83%	74.17%
	% vol O2	14.01%	13.97%	13.84%	13.96%	14.01%	13.97%	13.84%	13.96%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	100%	100%	100%	100%	100%	100%	100%	100%
Generator Gross Output	kW	97,376	86,208	73,953	70,266	97,376	86,208	73,953	70,266
Gross Heat Rate	Btu/kWh (LHV)	10,317	10,497	10,828	10,955	10,317	10,497	10,828	10,955
Heat Recovery Steam Generator									
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	58.70	79.66	98.28	107.74
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	65.10	88.35	109.00	119.49
Inlet Temperature	Temperature, F	977.3	1,002.4	1,035.1	1,044.0	977.3	1,002.4	1,035.1	1,044.0
Exit Temperature	Temperature, F	977.3	1,002.4	1,035.1	1,044.0	1,054.2	1,115.2	1,186.0	1,214.8
Final LP Steam to Process	Flow, lb/h	462,192	441,790	423,845	414,696	520,006	520,005	520,005	520,005
	Pressure, psia	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
	Temperature, F	337.1	336.7	336.3	336.1	338.3	338.3	338.3	338.3
	Enthalpy, Btu/lb	1,191.8	1,191.6	1,191.4	1,191.2	1,192.5	1,192.5	1,192.5	1,192.5
HRSG LP Steam (at HRSG terminal point)	Flow, lb/h	462,192	441,790	423,845	414,696	520,006	520,005	520,005	520,005
	Pressure, psia	[redacted]							
	Temperature, F								
	Enthalpy, Btu/lb								
LPEV Drum Exit	Flow, lb/h	462,192	441,790	423,845	414,696	520,006	520,005	520,005	520,005
	Pressure, psia	[redacted]							
	Temperature, F								
	Enthalpy, Btu/lb								
LPEV Blowdown	Flow, lb/h	2,311	2,209	2,119	2,073	2,600	2,600	2,600	2,600
LP Pinch	dT, F	40.9	41.3	42.0	41.7	40.5	40.3	40.4	39.7
LP Approach	dT, F	13.2	16.1	19.6	20.7	23.7	30.9	38.7	41.9
Feedwater to LPEV	Flow, lb/h	464,503	443,998	425,964	416,770	522,606	522,605	522,605	522,605
	Pressure, psia	130.8	128.9	127.2	126.4	136.6	136.6	136.6	136.6
	Temperature, F	334.6	330.6	326.1	324.5	327.4	320.2	312.4	309.2
	Enthalpy, Btu/lb	305.7	301.5	296.8	295.1	298.3	290.7	282.7	279.4
Feedwater to LPEC (after LP FW CV, excluding static head requirement)	Flow, lb/h	464,503	443,998	425,964	416,770	522,606	522,605	522,605	522,605
	Pressure, psia	156.7	152.5	149.0	147.3	169.2	169.2	169.2	169.2
	Temperature, F	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0
	Enthalpy, Btu/lb	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
BFP Discharge	Flow, lb/h	464,503	443,998	425,964	416,770	522,606	522,605	522,605	522,605
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.7	189.7	189.7	189.6	189.7	189.7	189.7	189.7
	Enthalpy, Btu/lb	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
BFP Suction	Flow, lb/h	464,503	443,998	425,964	416,770	522,606	522,605	522,605	522,605
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.2	189.2	189.1	189.1	189.2	189.2	189.2	189.2
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	157.3	157.3	157.3	157.3
Stack Exit	Flow, lb/h	2,654,491	2,428,454	2,200,103	2,128,748	2,657,364	2,432,352	2,204,912	2,134,020
	Temperature, F	286.2	284.2	282.3	281.3	282.4	279.1	276.1	274.4
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.90%	0.90%	0.88%	0.89%
	% vol CO2	3.24%	3.18%	3.09%	3.08%	3.42%	3.45%	3.45%	3.49%
	% vol H2O	6.31%	6.94%	8.35%	7.91%	6.66%	7.45%	9.04%	8.69%
	% vol N2	75.54%	75.00%	73.83%	74.17%	75.40%	74.80%	73.57%	73.86%
	% vol O2	14.01%	13.97%	13.84%	13.96%	13.62%	13.40%	13.06%	13.07%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.567	28.493	28.330	28.377	28.545	28.461	28.288	28.329

Case Name		Case C4-9	Case C4-10	Case C4-11	Case C4-12	Case C4-13	Case C4-14	Case C4-15	Case C4-16
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG	1x95% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1095 F	Fired 1160 F	Fired 1235 F	Fired 1268 F
Process Steam		439.2 kpph	420.0 kpph	401.4 kpph	392.3 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG									
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-9	C4-10	C4-11	C4-12	C4-13	C4-14	C4-15	C4-16
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%
	% vol CO2	3.28%	3.22%	3.13%	3.12%	3.28%	3.22%	3.13%	3.12%
	% vol H2O	6.38%	7.02%	8.42%	7.99%	6.38%	7.02%	8.42%	7.99%
	% vol N2	75.51%	74.97%	73.81%	74.14%	75.51%	74.97%	73.81%	74.14%
	% vol O2	13.92%	13.89%	13.76%	13.86%	13.92%	13.89%	13.76%	13.86%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	95%	95%	95%	95%	95%	95%	95%	95%
Generator Gross Output	kW	92,508	81,898	70,255	66,753	92,508	81,898	70,255	66,753
Gross Heat Rate	Btu/kWh (LHV)	10,358	10,539	10,871	11,000	10,358	10,539	10,871	11,000
Heat Recovery Steam Generator									
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	82.17	101.95	121.87	131.83
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	91.13	113.07	135.16	146.20
Inlet Temperature	Temperature, F	981.5	1,007.6	1,037.7	1,047.5	981.5	1,007.6	1,037.7	1,047.5
Exit Temperature	Temperature, F	981.5	1,007.6	1,037.7	1,047.5	1,095.1	1,160.0	1,235.2	1,268.5
Final LP Steam to Process	Flow, lb/h	439,185	420,043	401,422	392,275	520,005	520,004	520,001	520,004
	Pressure, psia	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
	Temperature, F	336.6	336.2	335.8	335.7	338.3	338.3	338.3	338.3
	Enthalpy, Btu/lb	1,191.5	1,191.3	1,191.1	1,191.0	1,192.5	1,192.5	1,192.5	1,192.5
HRSG LP Steam (at HRSG terminal point)	Flow, lb/h	439,185	420,043	401,422	392,275	520,005	520,004	520,001	520,004
	Pressure, psia								
	Temperature, F								
	Enthalpy, Btu/lb								
LPEV Drum Exit	Flow, lb/h	439,185	420,043	401,422	392,275	520,005	520,004	520,001	520,004
	Pressure, psia								
	Temperature, F								
	Enthalpy, Btu/lb								
LPEV Blowdown	Flow, lb/h	2,196	2,100	2,007	1,961	2,600	2,600	2,600	2,600
LP Pinch	dT, F	41.0	41.4	42.1	41.8	40.2	39.9	39.8	38.9
LP Approach	dT, F	13.5	16.5	19.7	20.9	28.7	36.1	44.8	49.0
Feedwater to LPEV	Flow, lb/h	441,381	422,143	403,429	394,236	522,605	522,604	522,601	522,604
	Pressure, psia	128.7	126.9	125.2	124.4	136.6	136.6	136.6	136.6
	Temperature, F	333.1	329.0	324.8	323.1	322.5	315.0	306.3	302.1
	Enthalpy, Btu/lb	304.1	299.9	295.5	293.7	293.1	285.4	276.4	272.0
Feedwater to LPEC (after LP FW CV, excluding static head requirement)	Flow, lb/h	441,381	422,143	403,429	394,236	522,605	522,604	522,601	522,604
	Pressure, psia	152.0	148.3	144.8	143.1	169.2	169.2	169.2	169.2
	Temperature, F	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0
	Enthalpy, Btu/lb	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
BFP Discharge	Flow, lb/h	441,381	422,143	403,429	394,236	522,605	522,604	522,601	522,604
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.7	189.7	189.6	189.6	189.7	189.7	189.7	189.7
	Enthalpy, Btu/lb	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
BFP Suction	Flow, lb/h	441,381	422,143	403,429	394,236	522,605	522,604	522,601	522,604
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.2	189.1	189.1	189.1	189.2	189.2	189.2	189.2
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	157.3	157.3	157.3	157.3
Stack Exit	Flow, lb/h	2,501,679	2,287,217	2,072,874	2,000,545	2,505,700	2,292,206	2,078,837	2,006,996
	Temperature, F	285.3	283.3	281.6	280.6	280.0	276.7	274.9	274.1
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.88%	0.89%	0.90%	0.90%	0.88%	0.88%
	% vol CO2	3.28%	3.22%	3.13%	3.12%	3.55%	3.59%	3.60%	3.66%
	% vol H2O	6.38%	7.02%	8.42%	7.99%	6.90%	7.71%	9.33%	9.01%
	% vol N2	75.51%	74.97%	73.81%	74.14%	75.31%	74.70%	73.45%	73.74%
	% vol O2	13.92%	13.89%	13.76%	13.86%	13.34%	13.11%	12.73%	12.71%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.562	28.488	28.326	28.372	28.530	28.445	28.270	28.309

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-17	Case C4-18	Case C4-19	Case C4-20	Case C4-21	Case C4-22	Case C4-23	Case C4-24
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1134 F	Fired 1204 F	Fired 1284 F	Fired 1304 F
Process Steam		427.0 kpph	407.6 kpph	388.3 kpph	378.3 kpph	520.0 kpph	520.0 kpph	520.0 kpph	511.9 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-17	C4-18	C4-19	C4-20	C4-21	C4-22	C4-23	C4-24
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	87,639	77,587	66,558	63,240	87,639	77,587	66,558	63,240
Gross CTG Heat Rate (LHV)	Btu/kWh	10,407	10,589	10,923	11,052	10,407	10,589	10,923	11,052
Gross CTG Heat Rate (HHV)	Btu/kWh	11,542	11,743	12,113	12,256	11,542	11,743	12,113	12,256
CTG Heat Input (LHV)	MMBtu/h	912.07	821.59	726.99	698.90	912.07	821.59	726.99	698.90
CTG Heat Input (HHV)	MMBtu/h	1,011.49	911.14	806.23	775.08	1,011.49	911.14	806.23	775.08
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	94.72	114.81	136.02	138.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	105.05	127.33	150.84	153.04
Plant Heat Input (LHV)	MMBtu/h	912.07	821.59	726.99	698.90	1,006.80	936.41	863.00	836.90
Plant Heat Input (HHV)	MMBtu/h	1,011.49	911.14	806.23	775.08	1,116.54	1,038.47	957.07	928.13
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,941	1,893	1,842	1,825	1,976	1,936	1,892	1,876
Total Auxiliary Power/Losses, percent of gross		2.21%	2.44%	2.77%	2.89%	2.25%	2.50%	2.84%	2.97%
Net Plant Output w/ Step-Up Xfmr Losses	kW	85,698	75,694	64,716	61,415	85,663	75,651	64,666	61,364
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	10,643	10,854	11,234	11,380	11,753	12,378	13,346	13,638
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,803	12,037	12,458	12,620	13,034	13,727	14,800	15,125
Auxiliary Power Calculations									
Boiler Feed Pump	kW	159	152	145	141	194	194	194	191
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,559	1,552	1,545	1,541	1,594	1,594	1,594	1,591
Generator Step-up Transformer Losses	kW	351	310	266	253	351	310	266	253
Auxiliary Transformer Losses	kW	31	31	31	31	32	32	32	32
Subtotal Transformer Losses	kW	382	341	297	284	382	342	298	285
Total Auxiliary Power and Transformer Losses	kW	1,941	1,893	1,842	1,825	1,976	1,936	1,892	1,876
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	912.1	821.6	727.0	698.9	912.1	821.6	727.0	698.9
	Flow, lb/h	44,632	40,204	35,575	34,200	44,632	40,204	35,575	34,200
Fuel LHV	Btu/lb	20,435	20,436	20,435	20,436	20,435	20,436	20,435	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,372,037	2,163,694	1,961,132	1,891,204	2,372,037	2,163,694	1,961,132	1,891,204
	Pressure, in. H2O (prelimina	11.40	9.67	8.12	7.64	11.40	9.67	8.12	7.64
	Temperature, F	996.9	1,024.0	1,052.4	1,060.9	996.9	1,024.0	1,052.4	1,060.9

Case Name		Case C4-25	Case C4-26	Case C4-27	Case C4-28	Case C4-29	Case C4-30	Case C4-31	Case C4-32
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1172 F	Fired 1245 F	Fired 1309 F	Fired 1326 F
Process Steam		416.6 kpph	396.4 kpph	376.3 kpph	366.5 kpph	520.0 kpph	520.0 kpph	509.9 kpph	500.1 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-25	C4-26	C4-27	C4-28	C4-29	C4-30	C4-31	C4-32
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	82,770	73,277	62,860	59,726	82,770	73,277	62,860	59,726
Gross CTG Heat Rate (LHV)	Btu/kWh	10,562	10,747	11,085	11,216	10,562	10,747	11,085	11,216
Gross CTG Heat Rate (HHV)	Btu/kWh	11,714	11,918	12,294	12,439	11,714	11,918	12,294	12,439
CTG Heat Input (LHV)	MMBtu/h	874.24	787.51	696.83	669.91	874.24	787.51	696.83	669.91
CTG Heat Input (HHV)	MMBtu/h	969.53	873.35	772.79	742.93	969.53	873.35	772.79	742.93
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	105.52	127.46	138.00	138.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	117.02	141.35	153.04	153.04
Plant Heat Input (LHV)	MMBtu/h	874.24	787.51	696.83	669.91	979.76	914.97	834.83	807.91
Plant Heat Input (HHV)	MMBtu/h	969.53	873.35	772.79	742.93	1,086.55	1,014.70	925.83	895.97
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,918	1,872	1,823	1,806	1,957	1,919	1,873	1,857
Total Auxiliary Power/Losses, percent of gross		2.32%	2.55%	2.90%	3.02%	2.36%	2.62%	2.98%	3.11%
Net Plant Output w/ Step-Up Xfmr Losses	kW	80,852	71,405	61,037	57,920	80,813	71,358	60,987	57,869
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	10,813	11,029	11,417	11,566	12,124	12,822	13,689	13,961
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,991	12,231	12,661	12,827	13,445	14,220	15,181	15,483
Auxiliary Power Calculations									
Boiler Feed Pump	kW	155	148	140	137	194	194	190	187
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,555	1,548	1,540	1,537	1,594	1,594	1,590	1,587
Generator Step-up Transformer Losses	kW	331	293	251	239	331	293	251	239
Auxiliary Transformer Losses	kW	31	31	31	31	32	32	32	32
Subtotal Transformer Losses	kW	362	324	282	270	363	325	283	271
Total Auxiliary Power and Transformer Losses	kW	1,918	1,872	1,823	1,806	1,957	1,919	1,873	1,857
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	874.2	787.5	696.8	669.9	874.2	787.5	696.8	669.9
	Flow, lb/h	42,780	38,536	34,099	32,782	42,780	38,536	34,099	32,782
Fuel LHV	Btu/lb	20,436	20,436	20,436	20,436	20,436	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,258,143	2,065,398	1,870,511	1,804,637	2,258,143	2,065,398	1,870,511	1,804,637
	Pressure, in. H2O (prelimina	10.43	8.89	7.46	7.02	10.43	8.89	7.46	7.02
	Temperature, F	1,012.3	1,036.1	1,063.2	1,071.3	1,012.3	1,036.1	1,063.2	1,071.3

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-17	Case C4-18	Case C4-19	Case C4-20	Case C4-21	Case C4-22	Case C4-23	Case C4-24	Case C4-25	Case C4-26	Case C4-27	Case C4-28	Case C4-29	Case C4-30	Case C4-31	Case C4-32
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x90% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG	1x85% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1134 F	Fired 1204 F	Fired 1284 F	Fired 1304 F	Unfired	Unfired	Unfired	Unfired	Fired 1172 F	Fired 1245 F	Fired 1309 F	Fired 1326 F
Process Steam		427.0 kpph	407.6 kpph	388.3 kpph	378.3 kpph	520.0 kpph	520.0 kpph	520.0 kpph	511.9 kpph	416.6 kpph	396.4 kpph	376.3 kpph	366.5 kpph	520.0 kpph	520.0 kpph	509.9 kpph	500.1 kpph
Condensate Temperature to HRSG		[redacted]															
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-17	C4-18	C4-19	C4-20	C4-21	C4-22	C4-23	C4-24	C4-25	C4-26	C4-27	C4-28	C4-29	C4-30	C4-31	C4-32
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%
	% vol CO2	3.29%	3.24%	3.15%	3.14%	3.29%	3.24%	3.15%	3.14%	3.31%	3.25%	3.16%	3.16%	3.31%	3.25%	3.16%	3.16%
	% vol H2O	6.41%	7.05%	8.46%	8.03%	6.41%	7.05%	8.46%	8.03%	6.45%	7.08%	8.49%	8.06%	6.45%	7.08%	8.49%	8.06%
	% vol N2	75.50%	74.96%	73.79%	74.12%	75.50%	74.96%	73.79%	74.12%	75.48%	74.95%	73.78%	74.11%	75.48%	74.95%	73.78%	74.11%
	% vol O2	13.90%	13.85%	13.72%	13.81%	13.90%	13.85%	13.72%	13.81%	13.85%	13.82%	13.69%	13.79%	13.85%	13.82%	13.69%	13.79%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	90%	90%	90%	90%	90%	90%	90%	90%	85%	85%	85%	85%	85%	85%	85%	85%
Generator Gross Output	kW	87,639	77,587	66,558	63,240	87,639	77,587	66,558	63,240	82,770	73,277	62,860	59,726	82,770	73,277	62,860	59,726
Gross Heat Rate	Btu/kWh (LHV)	10,407	10,589	10,923	11,052	10,407	10,589	10,923	11,052	10,562	10,747	11,085	11,216	10,562	10,747	11,085	11,216
Heat Recovery Steam Generator																	
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	94.72	114.81	136.02	138.00	0.00	0.00	0.00	0.00	105.52	127.46	138.00	138.00
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	105.05	127.33	150.84	153.04	0.00	0.00	0.00	0.00	117.02	141.35	153.04	153.04
Inlet Temperature	Temperature, F	996.9	1,024.0	1,052.4	1,060.9	996.9	1,024.0	1,052.4	1,060.9	1,012.3	1,036.1	1,063.2	1,071.3	1,012.3	1,036.1	1,063.2	1,071.3
Exit Temperature	Temperature, F	996.9	1,024.0	1,052.4	1,060.9	1,134.4	1,204.3	1,283.9	1,304.3	1,012.3	1,036.1	1,063.2	1,071.3	1,172.3	1,244.7	1,308.5	1,325.7
Final LP Steam to Process	Flow, lb/h	427,012	407,640	388,261	378,288	520,005	520,005	520,004	511,933	416,597	396,409	376,294	366,528	520,005	520,005	509,923	500,149
	Pressure, psia	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
	Temperature, F	336.4	336.0	335.6	335.4	338.3	338.3	338.3	338.1	336.1	335.7	335.3	335.1	338.3	338.3	338.1	337.9
	Enthalpy, Btu/lb	1,191.4	1,191.2	1,190.9	1,190.8	1,192.5	1,192.5	1,192.5	1,192.4	1,191.3	1,191.0	1,190.8	1,190.7	1,192.5	1,192.5	1,192.4	1,192.3
HRSG LP Steam	Flow, lb/h	427,012	407,640	388,261	378,288	520,005	520,005	520,004	511,933	416,597	396,409	376,294	366,528	520,005	520,005	509,923	500,149
(at HRSG terminal point)	Pressure, psia	[redacted]															
	Temperature, F																
	Enthalpy, Btu/lb																
LPEV Drum Exit	Flow, lb/h	427,012	407,640	388,261	378,288	520,005	520,005	520,004	511,933	416,597	396,409	376,294	366,528	520,005	520,005	509,923	500,149
	Pressure, psia	[redacted]															
	Temperature, F																
	Enthalpy, Btu/lb																
LPEV Blowdown	Flow, lb/h	2,135	2,038	1,941	1,891	2,600	2,600	2,600	2,560	2,083	1,982	1,881	1,833	2,600	2,600	2,550	2,501
LP Pinch	dT, F	41.0	41.3	42.1	41.7	39.8	39.3	39.0	38.3	41.0	41.3	42.0	41.6	39.3	38.7	38.6	38.0
LP Approach	dT, F	15.3	18.4	21.3	22.3	33.3	40.9	50.5	52.4	17.2	19.7	22.4	23.4	37.6	46.8	52.6	54.1
Feedwater to LPEV	Flow, lb/h	429,147	409,678	390,202	380,179	522,605	522,605	522,604	514,492	418,680	398,391	378,176	368,361	522,605	522,605	512,473	502,650
	Pressure, psia	127.5	125.8	124.1	123.2	136.6	136.6	136.6	135.7	126.6	124.8	123.0	122.2	136.6	136.6	135.5	134.6
	Temperature, F	330.5	326.4	322.5	321.0	317.8	310.2	300.6	298.3	328.1	324.5	320.7	319.2	313.5	304.3	297.9	295.9
	Enthalpy, Btu/lb	301.5	297.2	293.1	291.5	288.3	280.4	270.5	268.1	298.9	295.1	291.2	289.7	283.8	274.3	267.7	265.6
Feedwater to LPEC	Flow, lb/h	429,147	409,678	390,202	380,179	522,605	522,605	522,604	514,492	418,680	398,391	378,176	368,361	522,605	522,605	512,473	502,650
(after LP FW CV, excluding static head requirement)	Pressure, psia	149.6	145.9	142.4	140.6	169.2	169.2	169.2	167.4	147.6	143.8	140.2	138.5	169.2	169.2	166.9	164.8
	Temperature, F	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0
	Enthalpy, Btu/lb	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.3	158.4	158.4	158.4	158.4
BFP Discharge	Flow, lb/h	429,147	409,678	390,202	380,179	522,605	522,605	522,604	514,492	418,680	398,391	378,176	368,361	522,605	522,605	512,473	502,650
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.7	189.6	189.6	189.6	189.7	189.7	189.7	189.7	189.6	189.6	189.6	189.6	189.7	189.7	189.7	189.7
	Enthalpy, Btu/lb	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.3	158.4	158.4	158.4	158.4
BFP Suction	Flow, lb/h	429,147	409,678	390,202	380,179	522,605	522,605	522,604	514,492	418,680	398,391	378,176	368,361	522,605	522,605	512,473	502,650
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.1	189.1	189.1	189.1	189.2	189.2	189.2	189.2	189.1	189.1	189.1	189.1	189.2	189.2	189.2	189.2
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	157.3	157.3	157.3	157.2	157.2	157.2	157.2	157.2	157.3	157.3	157.2	157.2
Stack Exit	Flow, lb/h	2,372,037	2,163,694	1,961,132	1,891,204	2,376,673	2,169,312	1,967,787	1,897,957	2,258,143	2,065,398	1,870,511	1,804,637	2,263,306	2,071,635	1,877,264	1,811,390
	Temperature, F	283.9	282.0	280.4	279.4	277.8	274.5	273.7	272.5	282.6	280.9	279.5	278.6	275.8	274.6	272.6	271.5
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.88%	0.89%	0.90%	0.89%	0.88%	0.88%	0.91%	0.90%	0.88%	0.89%	0.90%	0.89%	0.88%	0.88%
	% vol CO2	3.29%	3.24%	3.15%	3.14%	3.62%	3.67%	3.71%	3.73%	3.31%	3.25%	3.16%	3.16%	3.69%	3.76%	3.78%	3.78%
	% vol H2O	6.41%	7.05%	8.46%	8.03%	7.04%	7.88%	9.53%	9.16%	6.45%	7.08%	8.49%	8.06%	7.18%	8.04%	9.62%	9.24%
	% vol N2	75.50%	74.96%	73.79%	74.12%	75.25%	74.63%	73.38%	73.68%	75.48%	74.95%	73.78%	74.11%	75.19%	74.57%	73.34%	73.65%
	% vol O2	13.90%	13.85%	13.72%	13.81%	13.19%	12.92%	12.51%	12.54%	13.85%	13.82%	13.69%	13.79%	13.03%	12.74%	12.40%	12.45%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.561	28.486	28.323	28.370	28.522	28.435	28.258	28.300	28.558	28.484	28.322	28.368	28.513	28.425	28.252	28.295

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-33	Case C4-34	Case C4-35	Case C4-36	Case C4-37	Case C4-38	Case C4-39	Case C4-40
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1208 F	Fired 1283 F	Fired 1329 F	Fired 1346 F
Process Steam		406.4 kpph	385.0 kpph	363.4 kpph	354.1 kpph	520.0 kpph	518.8 kpph	497.0 kpph	487.8 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-33	C4-34	C4-35	C4-36	C4-37	C4-38	C4-39	C4-40
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	77,901	68,966	59,162	56,213	77,901	68,966	59,162	56,213
Gross CTG Heat Rate (LHV)	Btu/kWh	10,735	10,923	11,267	11,400	10,735	10,923	11,267	11,400
Gross CTG Heat Rate (HHV)	Btu/kWh	11,905	12,114	12,495	12,643	11,905	12,114	12,495	12,643
CTG Heat Input (LHV)	MMBtu/h	836.29	753.32	666.58	640.83	836.29	753.32	666.58	640.83
CTG Heat Input (HHV)	MMBtu/h	927.44	835.43	739.24	710.68	927.44	835.43	739.24	710.68
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	116.10	138.00	138.00	138.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	128.75	153.04	153.04	153.04
Plant Heat Input (LHV)	MMBtu/h	836.29	753.32	666.58	640.83	952.38	891.32	804.58	778.83
Plant Heat Input (HHV)	MMBtu/h	927.44	835.43	739.24	710.68	1,056.19	988.48	892.28	863.72
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,894	1,850	1,803	1,788	1,937	1,901	1,854	1,838
Total Auxiliary Power/Losses, percent of gross		2.43%	2.68%	3.05%	3.18%	2.49%	2.76%	3.13%	3.27%
Net Plant Output w/ Step-Up Xfmr Losses	kW	76,007	67,116	57,359	54,425	75,964	67,065	57,308	54,375
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,003	11,224	11,621	11,775	12,537	13,290	14,040	14,323
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,202	12,448	12,888	13,058	13,904	14,739	15,570	15,885
Auxiliary Power Calculations									
Boiler Feed Pump	kW	152	144	136	132	194	193	185	182
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,552	1,544	1,536	1,532	1,594	1,593	1,585	1,582
Generator Step-up Transformer Losses	kW	312	276	237	225	312	276	237	225
Auxiliary Transformer Losses	kW	31	31	31	31	32	32	32	32
Subtotal Transformer Losses	kW	343	307	267	255	343	308	268	256
Total Auxiliary Power and Transformer Losses	kW	1,894	1,850	1,803	1,788	1,937	1,901	1,854	1,838
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	836.3	753.3	666.6	640.8	836.3	753.3	666.6	640.8
	Flow, lb/h	40,923	36,863	32,619	31,359	40,923	36,863	32,619	31,359
Fuel LHV	Btu/lb	20,436	20,436	20,436	20,435	20,436	20,436	20,436	20,435
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,160,399	1,972,608	1,781,749	1,721,978	2,160,399	1,972,608	1,781,749	1,721,978
	Pressure, in. H2O (prelimina	9.63	8.19	6.84	6.45	9.63	8.19	6.84	6.45
	Temperature, F	1,024.9	1,047.3	1,072.6	1,079.9	1,024.9	1,047.3	1,072.6	1,079.9

Case Name		Case C4-41	Case C4-42	Case C4-43	Case C4-44	Case C4-45	Case C4-46	Case C4-47	Case C4-48
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1248 F	Fired 1302 F	Fired 1349 F	Fired 1364 F
Process Steam		395.0 kpph	375.3 kpph	353.9 kpph	344.6 kpph	520.0 kpph	509.0 kpph	487.5 kpph	478.2 kpph
Condensate Temperature to HRSG									
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-41	C4-42	C4-43	C4-44	C4-45	C4-46	C4-47	C4-48
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	73,032	64,656	55,465	52,700	73,032	64,656	55,465	52,700
Gross CTG Heat Rate (LHV)	Btu/kWh	10,833	11,023	11,370	11,504	10,833	11,023	11,370	11,504
Gross CTG Heat Rate (HHV)	Btu/kWh	12,014	12,224	12,609	12,758	12,014	12,224	12,609	12,758
CTG Heat Input (LHV)	MMBtu/h	791.19	712.70	630.64	606.28	791.19	712.70	630.64	606.28
CTG Heat Input (HHV)	MMBtu/h	877.43	790.39	699.38	672.36	877.43	790.39	699.38	672.36
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	128.95	138.00	138.00	138.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	143.00	153.04	153.04	153.04
Plant Heat Input (LHV)	MMBtu/h	791.19	712.70	630.64	606.28	920.14	850.70	768.64	744.28
Plant Heat Input (HHV)	MMBtu/h	877.43	790.39	699.38	672.36	1,020.43	943.43	852.42	825.40
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,870	1,829	1,784	1,770	1,918	1,880	1,835	1,821
Total Auxiliary Power/Losses, percent of gross		2.56%	2.83%	3.22%	3.36%	2.63%	2.91%	3.31%	3.46%
Net Plant Output w/ Step-Up Xfmr Losses	kW	71,162	62,827	53,681	50,930	71,114	62,776	53,630	50,879
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,118	11,344	11,748	11,904	12,939	13,551	14,332	14,628
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,330	12,580	13,028	13,202	14,349	15,028	15,895	16,223
Auxiliary Power Calculations									
Boiler Feed Pump	kW	147	140	132	129	194	190	182	178
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,547	1,540	1,532	1,529	1,594	1,590	1,582	1,578
Generator Step-up Transformer Losses	kW	292	259	222	211	292	259	222	211
Auxiliary Transformer Losses	kW	31	31	31	31	32	32	32	32
Subtotal Transformer Losses	kW	323	289	252	241	324	290	253	242
Total Auxiliary Power and Transformer Losses	kW	1,870	1,829	1,784	1,770	1,918	1,880	1,835	1,821
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	791.2	712.7	630.6	606.3	791.2	712.7	630.6	606.3
	Flow, lb/h	38,717	34,876	30,860	29,668	38,717	34,876	30,860	29,668
Fuel LHV	Btu/lb	20,436	20,436	20,436	20,436	20,436	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,064,761	1,894,370	1,712,810	1,656,338	2,064,761	1,894,370	1,712,810	1,656,338
	Pressure, in. H2O (prelimina	8.88	7.61	6.37	6.01	8.88	7.61	6.37	6.01
	Temperature, F	1,036.1	1,057.6	1,082.0	1,088.5	1,036.1	1,057.6	1,082.0	1,088.5

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
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1997 Steam Tables

Case Name		Case C4-33	Case C4-34	Case C4-35	Case C4-36	Case C4-37	Case C4-38	Case C4-39	Case C4-40	Case C4-41	Case C4-42	Case C4-43	Case C4-44	Case C4-45	Case C4-46	Case C4-47	Case C4-48
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x80% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG	1x75% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1208 F	Fired 1283 F	Fired 1329 F	Fired 1346 F	Unfired	Unfired	Unfired	Unfired	Fired 1248 F	Fired 1302 F	Fired 1349 F	Fired 1364 F
Process Steam		406.4 kpph	385.0 kpph	363.4 kpph	354.1 kpph	520.0 kpph	518.8 kpph	497.0 kpph	487.8 kpph	395.0 kpph	375.3 kpph	353.9 kpph	344.6 kpph	520.0 kpph	509.0 kpph	487.5 kpph	478.2 kpph
Condensate Temperature to HRSG		[redacted]															
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-33	C4-34	C4-35	C4-36	C4-37	C4-38	C4-39	C4-40	C4-41	C4-42	C4-43	C4-44	C4-45	C4-46	C4-47	C4-48
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%	0.91%	0.90%	0.88%	0.89%
	% vol CO2	3.31%	3.26%	3.17%	3.16%	3.31%	3.26%	3.17%	3.16%	3.28%	3.21%	3.13%	3.11%	3.28%	3.21%	3.13%	3.11%
	% vol H2O	6.45%	7.09%	8.51%	8.07%	6.45%	7.09%	8.51%	8.07%	6.39%	7.00%	8.42%	7.98%	6.39%	7.00%	8.42%	7.98%
	% vol N2	75.48%	74.95%	73.77%	74.11%	75.48%	74.95%	73.77%	74.11%	75.51%	74.98%	73.81%	74.14%	75.51%	74.98%	73.81%	74.14%
	% vol O2	13.85%	13.81%	13.66%	13.77%	13.85%	13.81%	13.66%	13.77%	13.92%	13.91%	13.76%	13.88%	13.92%	13.91%	13.76%	13.88%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	80%	80%	80%	80%	80%	80%	80%	80%	75%	75%	75%	75%	75%	75%	75%	75%
Generator Gross Output	kW	77,901	68,966	59,162	56,213	77,901	68,966	59,162	56,213	73,032	64,656	55,465	52,700	73,032	64,656	55,465	52,700
Gross Heat Rate	Btu/kWh (LHV)	10,735	10,923	11,267	11,400	10,735	10,923	11,267	11,400	10,833	11,023	11,370	11,504	10,833	11,023	11,370	11,504
Heat Recovery Steam Generator																	
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	116.10	138.00	138.00	138.00	0.00	0.00	0.00	0.00	128.95	138.00	138.00	138.00
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	128.75	153.04	153.04	153.04	0.00	0.00	0.00	0.00	143.00	153.04	153.04	153.04
Inlet Temperature	Temperature, F	1,024.9	1,047.3	1,072.6	1,079.9	1,024.9	1,047.3	1,072.6	1,079.9	1,036.1	1,057.6	1,082.0	1,088.5	1,036.1	1,057.6	1,082.0	1,088.5
Exit Temperature	Temperature, F	1,024.9	1,047.3	1,072.6	1,079.9	1,208.1	1,282.7	1,329.4	1,345.8	1,036.1	1,057.6	1,082.0	1,088.5	1,248.1	1,302.3	1,348.6	1,364.4
Final LP Steam to Process	Flow, lb/h	406,393	385,047	363,424	354,137	520,004	518,790	497,045	487,751	394,954	375,272	353,878	344,608	520,005	508,978	487,473	478,206
	Pressure, psia	[redacted]															
	Temperature, F																
	Enthalpy, Btu/lb																
HRSG LP Steam (at HRSG terminal point)	Flow, lb/h	406,393	385,047	363,424	354,137	520,004	518,790	497,045	487,751	394,954	375,272	353,878	344,608	520,005	508,978	487,473	478,206
	Pressure, psia	[redacted]															
	Temperature, F																
	Enthalpy, Btu/lb																
LPEV Drum Exit	Flow, lb/h	406,393	385,047	363,424	354,137	520,004	518,790	497,045	487,751	394,954	375,272	353,878	344,608	520,005	508,978	487,473	478,206
	Pressure, psia	125.7	123.8	122.0	121.2	136.6	136.4	134.3	133.3	124.7	123.0	121.2	120.4	136.6	135.4	133.3	132.4
	Temperature, F	344.7	343.6	342.5	342.0	351.1	351.0	349.8	349.3	344.1	343.1	342.0	341.5	351.1	350.5	349.3	348.7
	Enthalpy, Btu/lb	1,191.5	1,191.3	1,191.0	1,190.9	1,192.9	1,192.9	1,192.7	1,192.5	1,191.4	1,191.2	1,190.9	1,190.8	1,192.9	1,192.8	1,192.5	1,192.4
LPEV Blowdown	Flow, lb/h	2,032	1,925	1,817	1,771	2,600	2,584	2,485	2,439	1,975	1,876	1,769	1,723	2,600	2,545	2,437	2,391
LP Pinch	dT, F	40.9	41.2	42.0	41.6	38.8	38.1	38.3	37.6	40.8	41.0	41.8	41.4	38.1	37.6	37.8	37.2
LP Approach	dT, F	18.6	21.0	23.4	24.2	41.5	50.6	54.3	55.7	19.9	22.1	24.4	25.2	47.3	52.3	55.9	57.1
Feedwater to LPEV	Flow, lb/h	408,425	386,972	365,241	355,907	522,604	521,384	499,531	490,189	396,929	377,148	355,648	346,331	522,605	511,523	489,910	480,597
	Pressure, psia	125.7	123.8	122.0	121.2	136.6	136.4	134.3	133.3	124.7	123.0	121.2	120.4	136.6	135.4	133.3	132.4
	Temperature, F	326.1	322.6	319.1	317.8	309.6	300.4	295.5	293.6	324.2	321.0	317.6	316.4	303.8	298.2	293.4	291.6
	Enthalpy, Btu/lb	296.8	293.2	289.6	288.2	279.8	270.3	265.3	263.3	294.9	291.5	288.0	286.7	273.8	268.0	263.1	261.2
Feedwater to LPEC (after LP FW CV, excluding static head requirement)	Flow, lb/h	408,425	386,972	365,241	355,907	522,604	521,384	499,531	490,189	396,929	377,148	355,648	346,331	522,605	511,523	489,910	480,597
	Pressure, psia	145.7	141.8	138.0	136.4	169.2	168.9	164.1	162.1	143.6	140.0	136.4	134.9	169.2	166.7	162.0	160.0
	Temperature, F	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0
	Enthalpy, Btu/lb	158.4	158.4	158.3	158.3	158.4	158.4	158.4	158.4	158.4	158.3	158.3	158.3	158.4	158.4	158.4	158.4
BFP Discharge	Flow, lb/h	408,425	386,972	365,241	355,907	522,604	521,384	499,531	490,189	396,929	377,148	355,648	346,331	522,605	511,523	489,910	480,597
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.6	189.6	189.6	189.6	189.7	189.7	189.7	189.7	189.6	189.6	189.6	189.6	189.7	189.7	189.7	189.7
	Enthalpy, Btu/lb	158.4	158.4	158.3	158.3	158.4	158.4	158.4	158.4	158.4	158.3	158.3	158.3	158.4	158.4	158.4	158.4
BFP Suction	Flow, lb/h	408,425	386,972	365,241	355,907	522,604	521,384	499,531	490,189	396,929	377,148	355,648	346,331	522,605	511,523	489,910	480,597
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.1	189.1	189.1	189.1	189.2	189.2	189.2	189.2	189.1	189.1	189.1	189.1	189.2	189.2	189.2	189.2
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	157.3	157.3	157.2	157.2	157.2	157.2	157.2	157.2	157.3	157.2	157.2	157.2
Stack Exit	Flow, lb/h	2,160,399	1,972,608	1,781,749	1,721,978	2,166,080	1,979,361	1,788,502	1,728,730	2,064,761	1,894,370	1,712,810	1,656,338	2,071,071	1,901,123	1,719,563	1,663,091
	Temperature, F	281.6	279.9	278.7	277.8	274.0	273.0	271.5	270.5	280.5	279.0	277.9	277.1	274.1	272.0	270.5	269.5
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.88%	0.89%	0.90%	0.89%	0.88%	0.88%	0.91%	0.90%	0.88%	0.89%	0.90%	0.89%	0.88%	0.88%
	% vol CO2	3.31%	3.26%	3.17%	3.16%	3.75%	3.83%	3.80%	3.81%	3.28%	3.21%	3.13%	3.11%	3.79%	3.80%	3.78%	3.79%
	% vol H2O	6.45%	7.09%	8.51%	8.07%	7.29%	8.18%	9.70%	9.31%	6.39%	7.00%	8.42%	7.98%	7.37%	8.13%	9.66%	9.26%
	% vol N2	75.48%	74.95%	73.77%	74.11%	75.15%	74.52%	73.31%	73.62%	75.51%	74.98%	73.81%	74.14%	75.12%	74.54%	73.32%	73.64%
	% vol O2	13.85%	13.81%	13.66%	13.77%	12.90%	12.58%	12.31%	12.37%	13.92%	13.91%	13.76%	13.88%	12.82%	12.63%	12.36%	12.42%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.558	28.484	28.320	28.367	28.506	28.416	28.247	28.291	28.562	28.489	28.326	28.373	28.501	28.419	28.250	28.294

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-49	Case C4-50	Case C4-51	Case C4-52	Case C4-53	Case C4-54	Case C4-55	Case C4-56
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x70% CTG	1x70% CTG	1x70% CTG	1x70% CTG	1x65% CTG	1x65% CTG	1x65% CTG	1x65% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired
Process Steam		386.8 kpph	365.8 kpph	345.5 kpph	334.8 kpph	378.3 kpph	357.1 kpph	337.5 kpph	325.1 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-49	C4-50	C4-51	C4-52	C4-53	C4-54	C4-55	C4-56
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	68,163	60,346	51,767	49,186	63,295	56,035	48,069	45,673
Gross CTG Heat Rate (LHV)	Btu/kWh	10,948	11,140	11,490	11,626	11,133	11,327	11,684	11,822
Gross CTG Heat Rate (HHV)	Btu/kWh	12,141	12,354	12,743	12,893	12,346	12,562	12,958	13,111
CTG Heat Input (LHV)	MMBtu/h	746.26	672.22	594.82	571.84	704.63	634.73	561.64	539.95
CTG Heat Input (HHV)	MMBtu/h	827.60	745.50	659.66	634.17	781.44	703.92	622.86	598.80
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plant Heat Input (LHV)	MMBtu/h	746.26	672.22	594.82	571.84	704.63	634.73	561.64	539.95
Plant Heat Input (HHV)	MMBtu/h	827.60	745.50	659.66	634.17	781.44	703.92	622.86	598.80
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,848	1,809	1,766	1,752	1,825	1,788	1,749	1,734
Total Auxiliary Power/Losses, percent of gross		2.71%	3.00%	3.41%	3.56%	2.88%	3.19%	3.64%	3.80%
Net Plant Output w/ Step-Up Xfmr Losses	kW	66,315	58,537	50,001	47,434	61,470	54,247	46,320	43,939
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,253	11,484	11,896	12,055	11,463	11,701	12,125	12,289
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,480	12,736	13,193	13,369	12,713	12,976	13,447	13,628
Auxiliary Power Calculations									
Boiler Feed Pump	kW	144	136	129	125	141	133	126	121
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,544	1,536	1,529	1,525	1,541	1,533	1,526	1,521
Generator Step-up Transformer Losses	kW	273	241	207	197	253	224	192	183
Auxiliary Transformer Losses	kW	31	31	31	30	31	31	31	30
Subtotal Transformer Losses	kW	304	272	238	227	284	255	223	213
Total Auxiliary Power and Transformer Losses	kW	1,848	1,809	1,766	1,752	1,825	1,788	1,749	1,734
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	746.3	672.2	594.8	571.8	704.6	634.7	561.6	539.9
	Flow, lb/h	36,518	32,895	29,107	27,983	34,481	31,060	27,484	26,422
Fuel LHV	Btu/lb	20,435	20,436	20,436	20,436	20,436	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	1,990,439	1,819,969	1,652,416	1,595,225	1,918,059	1,754,627	1,596,076	1,539,678
	Pressure, in. H2O (prelimina	8.31	7.08	5.97	5.62	7.78	6.63	5.61	5.27
	Temperature, F	1,047.3	1,068.0	1,091.0	1,095.2	1,057.7	1,077.3	1,099.6	1,099.8

Case Name		Case C4-57	Case C4-58	Case C4-59	Case C4-60	Case C4-61	Case C4-62	Case C4-63	Case C4-64
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x60% CTG	1x60% CTG	1x60% CTG	1x60% CTG	1x55% CTG	1x55% CTG	1x55% CTG	1x55% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired
Process Steam		371.1 kpph	350.5 kpph	325.8 kpph	314.3 kpph	364.3 kpph	343.6 kpph	314.3 kpph	303.6 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-57	C4-58	C4-59	C4-60	C4-61	C4-62	C4-63	C4-64
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	58,426	51,725	44,372	42,160	53,557	47,414	40,674	38,646
Gross CTG Heat Rate (LHV)	Btu/kWh	11,349	11,547	11,911	12,051	11,627	11,830	12,203	12,347
Gross CTG Heat Rate (HHV)	Btu/kWh	12,586	12,806	13,209	13,365	12,884	13,120	13,533	13,692
CTG Heat Input (LHV)	MMBtu/h	663.05	597.27	528.50	508.08	622.69	560.92	496.33	477.15
CTG Heat Input (HHV)	MMBtu/h	735.32	662.38	586.11	563.46	690.56	622.06	550.43	529.16
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plant Heat Input (LHV)	MMBtu/h	663.05	597.27	528.50	508.08	622.69	560.92	496.33	477.15
Plant Heat Input (HHV)	MMBtu/h	735.32	662.38	586.11	563.46	690.56	622.06	550.43	529.16
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,803	1,768	1,729	1,716	1,781	1,748	1,710	1,698
Total Auxiliary Power/Losses, percent of gross		3.09%	3.42%	3.90%	4.07%	3.33%	3.69%	4.20%	4.39%
Net Plant Output w/ Step-Up Xfmr Losses	kW	56,623	49,957	42,643	40,444	51,776	45,666	38,964	36,948
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,710	11,956	12,394	12,563	12,027	12,283	12,738	12,914
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,986	13,259	13,745	13,932	13,338	13,622	14,127	14,322
Auxiliary Power Calculations									
Boiler Feed Pump	kW	138	131	121	117	136	128	117	113
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,538	1,531	1,521	1,517	1,536	1,528	1,517	1,513
Generator Step-up Transformer Losses	kW	234	207	177	169	214	190	163	155
Auxiliary Transformer Losses	kW	31	31	30	30	31	31	30	30
Subtotal Transformer Losses	kW	264	238	208	199	245	220	193	185
Total Auxiliary Power and Transformer Losses	kW	1,803	1,768	1,729	1,716	1,781	1,748	1,710	1,698
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	663.1	597.3	528.5	508.1	622.7	560.9	496.3	477.2
	Flow, lb/h	32,446	29,227	25,862	24,863	30,471	27,448	24,288	23,349
Fuel LHV	Btu/lb	20,436	20,436	20,436	20,435	20,436	20,435	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	1,858,327	1,702,090	1,540,675	1,489,047	1,801,976	1,649,553	1,486,822	1,439,235
	Pressure, in. H2O (prelimina	7.35	6.28	5.26	4.97	6.95	5.93	4.94	4.67
	Temperature, F	1,067.1	1,086.4	1,100.0	1,100.0	1,076.4	1,095.4	1,100.0	1,100.0

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-49	Case C4-50	Case C4-51	Case C4-52	Case C4-53	Case C4-54	Case C4-55	Case C4-56
Ambient Conditions		9.9F/80%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x70% CTG	1x70% CTG	1x70% CTG	1x70% CTG	1x65% CTG	1x65% CTG	1x65% CTG	1x65% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired
Process Steam		386.8 kpph	365.8 kpph	345.5 kpph	334.8 kpph	378.3 kpph	357.1 kpph	337.5 kpph	325.1 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-49	C4-50	C4-51	C4-52	C4-53	C4-54	C4-55	C4-56
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	3.21%	3.15%	3.06%	3.05%	3.15%	3.09%	2.99%	2.99%
	% vol H2O	6.25%	6.89%	8.29%	7.86%	6.13%	6.77%	8.16%	7.73%
	% vol N2	75.56%	75.03%	73.86%	74.19%	75.61%	75.07%	73.91%	74.24%
	% vol O2	14.07%	14.03%	13.91%	14.01%	14.21%	14.17%	14.05%	14.15%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	70%	70%	70%	70%	65%	65%	65%	65%
Generator Gross Output	kW	68,163	60,346	51,767	49,186	63,295	56,035	48,069	45,673
Gross Heat Rate	Btu/kWh (LHV)	10,948	11,140	11,490	11,626	11,133	11,327	11,684	11,822
Heat Recovery Steam Generator									
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Temperature	Temperature, F	1,047.3	1,068.0	1,081.0	1,095.2	1,057.7	1,077.3	1,099.6	1,099.8
Exit Temperature	Temperature, F	1,047.3	1,068.0	1,081.0	1,095.2	1,057.7	1,077.3	1,099.6	1,099.8
Final LP Steam to Process	Flow, lb/h	386,842	365,762	345,497	334,842	378,275	357,073	337,475	325,054
	Pressure, psia	[redacted]							
	Temperature, F								
	Enthalpy, Btu/lb								
HRSG LP Steam (at HRSG terminal point)	Flow, lb/h	386,842	365,762	345,497	334,842	378,275	357,073	337,475	325,054
	Pressure, psia	[redacted]							
	Temperature, F								
	Enthalpy, Btu/lb								
LPEV Drum Exit	Flow, lb/h	386,842	365,762	345,497	334,842	378,275	357,073	337,475	325,054
	Pressure, psia	123.9	122.1	120.5	119.6	123.2	121.4	119.8	118.9
	Temperature, F	343.7	342.6	341.6	341.0	343.3	342.2	341.2	340.6
	Enthalpy, Btu/lb	1,191.3	1,191.0	1,190.8	1,190.7	1,191.2	1,190.9	1,190.7	1,190.6
LPEV Blowdown	Flow, lb/h	1,934	1,829	1,727	1,674	1,891	1,785	1,687	1,625
LP Pinch	dT, F	40.6	40.9	41.6	41.3	40.4	40.7	41.4	41.1
LP Approach	dT, F	21.2	23.3	25.4	25.9	22.4	24.3	26.3	26.3
Feedwater to LPEV	Flow, lb/h	388,776	367,591	347,225	336,516	380,167	358,859	339,162	326,679
	Pressure, psia	123.9	122.1	120.5	119.6	123.2	121.4	119.8	118.9
	Temperature, F	322.5	319.3	316.2	315.2	320.8	317.8	314.8	314.3
	Enthalpy, Btu/lb	293.1	289.8	286.5	285.5	291.4	288.3	285.2	284.6
Feedwater to LPEC	Flow, lb/h	388,776	367,591	347,225	336,516	380,167	358,859	339,162	326,679
(after LP FW CV, excluding static head requirement)	Pressure, psia	142.1	138.4	135.0	133.3	140.6	136.9	133.7	131.7
	Temperature, F	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0
	Enthalpy, Btu/lb	158.4	158.3	158.3	158.3	158.4	158.3	158.3	158.3
BFP Discharge	Flow, lb/h	388,776	367,591	347,225	336,516	380,167	358,859	339,162	326,679
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.6	189.6	189.6	189.6	189.6	189.6	189.6	189.6
	Enthalpy, Btu/lb	158.4	158.3	158.3	158.3	158.4	158.3	158.3	158.3
BFP Suction	Flow, lb/h	388,776	367,591	347,225	336,516	380,167	358,859	339,162	326,679
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.1	189.1	189.1	189.1	189.1	189.1	189.1	189.1
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.2
Stack Exit	Flow, lb/h	1,990,439	1,819,969	1,652,416	1,595,225	1,918,059	1,754,627	1,596,076	1,539,678
	Temperature, F	279.5	278.1	277.1	276.4	278.6	277.3	276.4	275.9
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	3.21%	3.15%	3.06%	3.05%	3.15%	3.09%	2.99%	2.99%
	% vol H2O	6.25%	6.89%	8.29%	7.86%	6.13%	6.77%	8.16%	7.73%
	% vol N2	75.56%	75.03%	73.86%	74.19%	75.61%	75.07%	73.91%	74.24%
	% vol O2	14.07%	14.03%	13.91%	14.01%	14.21%	14.17%	14.05%	14.15%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.571	28.496	28.334	28.380	28.578	28.504	28.342	28.388

Case Name		Case C4-57	Case C4-58	Case C4-59	Case C4-60	Case C4-61	Case C4-62	Case C4-63	Case C4-64
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x60% CTG	1x60% CTG	1x60% CTG	1x60% CTG	1x55% CTG	1x55% CTG	1x55% CTG	1x55% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired
Process Steam		371.1 kpph	350.5 kpph	325.8 kpph	314.3 kpph	364.3 kpph	343.6 kpph	314.3 kpph	303.6 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-57	C4-58	C4-59	C4-60	C4-61	C4-62	C4-63	C4-64
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	3.06%	3.00%	2.92%	2.91%	2.96%	2.91%	2.84%	2.83%
	% vol H2O	5.96%	6.59%	8.02%	7.58%	5.78%	6.42%	7.88%	7.43%
	% vol N2	75.68%	75.14%	73.96%	74.30%	75.75%	75.21%	74.02%	74.36%
	% vol O2	14.40%	14.37%	14.21%	14.32%	14.60%	14.56%	14.38%	14.50%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	60%	60%	60%	60%	55%	55%	55%	55%
Generator Gross Output	kW	58,426	51,725	44,372	42,160	53,557	47,414	40,674	38,646
Gross Heat Rate	Btu/kWh (LHV)	11,349	11,547	11,911	12,051	11,627	11,830	12,203	12,347
Heat Recovery Steam Generator									
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Temperature	Temperature, F	1,067.1	1,086.4	1,100.0	1,100.0	1,076.4	1,095.5	1,100.0	1,100.0
Exit Temperature	Temperature, F	1,067.1	1,086.4	1,100.0	1,100.0	1,076.4	1,095.5	1,100.0	1,100.0
Final LP Steam to Process	Flow, lb/h	371,101	350,494	325,809	314,299	364,262	343,637	314,280	303,624
	Pressure, psia	[redacted]							
	Temperature, F								
	Enthalpy, Btu/lb								
HRSG LP Steam (at HRSG terminal point)	Flow, lb/h	371,101	350,494	325,809	314,299	364,262	343,637	314,280	303,624
	Pressure, psia	[redacted]							
	Temperature, F								
	Enthalpy, Btu/lb								
LPEV Drum Exit	Flow, lb/h	371,101	350,494	325,809	314,299	364,262	343,637	314,280	303,624
	Pressure, psia	122.6	120.9	118.9	118.0	122.0	120.3	118.0	117.2
	Temperature, F	342.9	341.8	340.6	340.0	342.5	341.5	340.0	339.5
	Enthalpy, Btu/lb	1,191.1	1,190.9	1,190.6	1,190.5	1,191.0	1,190.8	1,190.5	1,190.3
LPEV Blowdown	Flow, lb/h	1,856	1,752	1,629	1,571	1,821	1,718	1,571	1,518
LP Pinch	dT, F	40.2	40.4	41.3	41.0	39.9	40.2	41.2	40.9
LP Approach	dT, F	23.5	25.4	26.3	26.2	24.6	26.4	26.1	26.1
Feedwater to LPEV	Flow, lb/h	372,957	352,246	327,438	315,871	366,084	345,355	315,851	305,142
	Pressure, psia	122.6	120.9	118.9	118.0	122.0	120.3	118.0	117.2
	Temperature, F	319.4	316.5	314.3	313.8	318.0	315.1	313.9	313.4
	Enthalpy, Btu/lb	289.9	286.8	284.6	284.1	288.4	285.4	284.2	283.7
Feedwater to LPEC	Flow, lb/h	372,957	352,246	327,438	315,871	366,084	345,355	315,851	305,142
(after LP FW CV, excluding static head requirement)	Pressure, psia	139.3	135.8	131.8	130.1	138.1	134.7	130.1	128.5
	Temperature, F	190.0	190.0	190.0	190.0	190.0	190.0	190.0	190.0
	Enthalpy, Btu/lb	158.3	158.3	158.3	158.3	158.3	158.3	158.3	158.3
BFP Discharge	Flow, lb/h	372,957	352,246	327,438	315,871	366,084	345,355	315,851	305,142
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.6	189.6	189.6	189.6	189.6	189.6	189.6	189.6
	Enthalpy, Btu/lb	158.3	158.3	158.3	158.3	158.3	158.3	158.3	158.3
BFP Suction	Flow, lb/h	372,957	352,246	327,438	315,871	366,084	345,355	315,851	305,142
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.1	189.1	189.1	189.1	189.1	189.1	189.1	189.1
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.2
Stack Exit	Flow, lb/h	1,858,327	1,702,090	1,540,675	1,489,047	1,801,976	1,649,553	1,486,822	1,439,235
	Temperature, F	277.8	276.5	276.0	275.6	277.0	275.8	275.7	275.3
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	3.06%	3.00%	2.92%	2.91%	2.96%	2.91%	2.84%	2.83%
	% vol H2O	5.96%	6.59%	8.02%	7.58%	5.78%	6.42%	7.88%	7.43%
	% vol N2	75.68%	75.14%	73.96%	74.30%	75.75%	75.21%	74.02%	74.36%
	% vol O2	14.40%	14.37%	14.21%	14.32%	14.60%	14.56%	14.38%	14.50%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.589	28.514	28.350	28.397	28.600	28.525	28.359	28.407

Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-65	Case C4-66	Case C4-67	Case C4-68	Case C4-101	Case C4-102	Case C4-103	Case C4-104
Ambient Conditions Number of CTG/HRSG Units Operating HRSG Firing/DB Exit Temperature		9.9F/60%RH 1x50% CTG Unfired	50.0F/75%RH 1x50% CTG Unfired	93.0F/50%RH 1x50% CTG Unfired	105.7F/28%RH 1x50% CTG Unfired	9.9F/60%RH 1x100% CTG Fired 1056 F	50.0F/75%RH 1x100% CTG Fired 1118 F	93.0F/50%RH 1x100% CTG Fired 1189 F	105.7F/28%RH 1x100% CTG Fired 1218 F
Process Steam		357.4 kpph	334.0 kpph	306.6 kpph	295.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID GateCycle Case ID Atmospheric Pressure Fuel Type		1WAPA4 C4-65 14.690 psia Natural Gas	1WAPA4 C4-66 14.690 psia Natural Gas	1WAPA4 C4-67 14.690 psia Natural Gas	1WAPA4 C4-68 14.690 psia Natural Gas	1WAPA4 C4-101 14.690 psia Natural Gas	1WAPA4 C4-102 14.690 psia Natural Gas	1WAPA4 C4-103 14.690 psia Natural Gas	1WAPA4 C4-104 14.690 psia Natural Gas
CTG Model CTG Performance Reference HRSG Performance Reference		GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	48,688	43,104	36,976	35,133	97,376	86,208	73,953	70,266
Gross CTG Heat Rate (LHV)	Btu/kWh	11,961	12,170	12,554	12,702	10,317	10,497	10,828	10,955
Gross CTG Heat Rate (HHV)	Btu/kWh	13,265	13,497	13,922	14,086	11,441	11,641	12,008	12,150
CTG Heat Input (LHV)	MMBtu/h	582.36	524.59	464.19	446.25	1,004.59	904.93	800.73	769.80
CTG Heat Input (HHV)	MMBtu/h	645.84	581.77	514.78	494.89	1,114.09	1,003.57	888.01	853.71
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	60.36	81.51	100.34	109.87
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	66.94	90.40	111.28	121.85
Plant Heat Input (LHV)	MMBtu/h	582.36	524.59	464.19	446.25	1,064.95	986.44	901.07	879.67
Plant Heat Input (HHV)	MMBtu/h	645.84	581.77	514.78	494.89	1,181.03	1,093.97	999.29	975.55
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	1,759	1,727	1,693	1,681	2,015	1,970	1,921	1,906
Total Auxiliary Power/Losses, percent of gross		3.61%	4.01%	4.58%	4.78%	2.07%	2.29%	2.60%	2.71%
Net Plant Output w/ Step-Up Xfmr Losses	kW	46,929	41,377	35,283	33,452	95,361	84,238	72,032	68,360
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,409	12,678	13,156	13,340	11,168	11,710	12,509	12,868
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	13,762	14,060	14,590	14,794	12,385	12,987	13,873	14,271
Auxiliary Power Calculations									
Boiler Feed Pump	kW	133	125	114	110	193	193	193	193
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,533	1,525	1,514	1,510	1,593	1,593	1,593	1,593
Generator Step-up Transformer Losses	kW	195	172	148	141	390	345	296	281
Auxiliary Transformer Losses	kW	31	30	30	30	32	32	32	32
Subtotal Transformer Losses	kW	225	203	178	171	421	377	328	313
Total Auxiliary Power and Transformer Losses	kW	1,759	1,727	1,693	1,681	2,015	1,970	1,921	1,906
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	582.4	524.6	464.2	446.3	1,004.6	904.9	800.7	769.8
	Flow, lb/h	28,498	25,671	22,715	21,837	49,159	44,282	39,183	37,670
Fuel LHV	Btu/lb	20,435	20,436	20,436	20,436	20,435	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	1,747,011	1,597,016	1,452,023	1,399,726	2,654,491	2,428,454	2,200,103	2,128,748
	Pressure, in. H2O (prelimina	6.57	5.60	4.73	4.44	13.96	11.90	9.99	9.45
	Temperature, F	1,085.7	1,098.9	1,100.0	1,100.0	977.3	1,002.4	1,035.1	1,044.0

Case Name		Case C4-105	Case C4-106	Case C4-107	Case C4-108	Case C4-109	Case C4-110	Case C4-111	Case C4-112
Ambient Conditions Number of CTG/HRSG Units Operating HRSG Firing/DB Exit Temperature		9.9F/60%RH 1x100% CTG Fired 1052 F	50.0F/75%RH 1x100% CTG Fired 1113 F	93.0F/50%RH 1x100% CTG Fired 1183 F	105.7F/28%RH 1x100% CTG Fired 1212 F	9.9F/60%RH 1x100% CTG Fired 1050 F	50.0F/75%RH 1x100% CTG Fired 1110 F	93.0F/50%RH 1x100% CTG Fired 1180 F	105.7F/28%RH 1x100% CTG Fired 1208 F
Process Steam		520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG		[redacted]							
GateCycle Model ID GateCycle Case ID Atmospheric Pressure Fuel Type		1WAPA4 C4-105 14.690 psia Natural Gas	1WAPA4 C4-106 14.690 psia Natural Gas	1WAPA4 C4-107 14.690 psia Natural Gas	1WAPA4 C4-108 14.690 psia Natural Gas	1WAPA4 C4-109 14.690 psia Natural Gas	1WAPA4 C4-110 14.690 psia Natural Gas	1WAPA4 C4-111 14.690 psia Natural Gas	1WAPA4 C4-112 14.690 psia Natural Gas
CTG Model CTG Performance Reference HRSG Performance Reference		GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201	GE 7EA/BH IBH Curves N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary									
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1
Gross CTG Output	kW	97,376	86,208	73,953	70,266	97,376	86,208	73,953	70,266
Gross CTG Heat Rate (LHV)	Btu/kWh	10,317	10,497	10,828	10,955	10,317	10,497	10,828	10,955
Gross CTG Heat Rate (HHV)	Btu/kWh	11,441	11,641	12,008	12,150	11,441	11,641	12,008	12,150
CTG Heat Input (LHV)	MMBtu/h	1,004.59	904.93	800.73	769.80	1,004.59	904.93	800.73	769.80
CTG Heat Input (HHV)	MMBtu/h	1,114.09	1,003.57	888.01	853.71	1,114.09	1,003.57	888.01	853.71
Duct Burner Heat Input (LHV)	MMBtu/h	57.20	77.99	96.43	105.82	55.52	76.13	94.36	103.67
Duct Burner Heat Input (HHV)	MMBtu/h	63.43	86.49	106.94	117.35	61.58	84.42	104.64	114.97
Plant Heat Input (LHV)	MMBtu/h	1,061.79	982.92	897.16	875.62	1,060.12	981.06	895.09	873.47
Plant Heat Input (HHV)	MMBtu/h	1,177.53	1,090.06	994.95	971.06	1,175.67	1,087.99	992.65	968.68
Calculations Based on High-Side of Generator Step-Up Transformers									
Total Auxiliary Power/Losses	kW	2,016	1,971	1,922	1,908	2,017	1,972	1,923	1,908
Total Auxiliary Power/Losses, percent of gross		2.07%	2.29%	2.60%	2.72%	2.07%	2.29%	2.60%	2.72%
Net Plant Output w/ Step-Up Xfmr Losses	kW	95,360	84,237	72,031	68,358	95,359	84,236	72,030	68,358
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	11,134	11,669	12,455	12,809	11,117	11,647	12,427	12,778
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,348	12,940	13,813	14,205	12,329	12,916	13,781	14,171
Auxiliary Power Calculations									
Boiler Feed Pump	kW	195	195	195	195	195	195	195	195
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,595	1,595	1,595	1,595	1,595	1,595	1,595	1,595
Generator Step-up Transformer Losses	kW	390	345	296	281	390	345	296	281
Auxiliary Transformer Losses	kW	32	32	32	32	32	32	32	32
Subtotal Transformer Losses	kW	421	377	328	313	421	377	328	313
Total Auxiliary Power and Transformer Losses	kW	2,016	1,971	1,922	1,908	2,017	1,972	1,923	1,908
Combustion Turbine Generator									
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	1,004.6	904.9	800.7	769.8	1,004.6	904.9	800.7	769.8
	Flow, lb/h	49,159	44,282	39,183	37,670	49,159	44,282	39,183	37,670
Fuel LHV	Btu/lb	20,435	20,436	20,436	20,436	20,435	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	2,654,491	2,428,454	2,200,103	2,128,748	2,654,491	2,428,454	2,200,103	2,128,748
	Pressure, in. H2O (prelimina	13.96	11.90	9.99	9.45	13.96	11.90	9.99	9.45
	Temperature, F	977.3	1,002.4	1,035.1	1,044.0	977.3	1,002.4	1,035.1	1,044.0

Kiewit Power Engineers – NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-65	Case C4-66	Case C4-67	Case C4-68	Case C4-101	Case C4-102	Case C4-103	Case C4-104	Case C4-105	Case C4-106	Case C4-107	Case C4-108	Case C4-109	Case C4-110	Case C4-111	Case C4-112
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG	1x100% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Fired 1056 F	Fired 1118 F	Fired 1189 F	Fired 1218 F	Fired 1052 F	Fired 1113 F	Fired 1183 F	Fired 1212 F	Fired 1050 F	Fired 1110 F	Fired 1180 F	Fired 1208 F
Process Steam		357.4 kpph	334.0 kpph	306.6 kpph	295.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph	520.0 kpph
Condensate Temperature to HRSG		[redacted]															
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-65	C4-66	C4-67	C4-68	C4-101	C4-102	C4-103	C4-104	C4-105	C4-106	C4-107	C4-108	C4-109	C4-110	C4-111	C4-112
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	2.86%	2.81%	2.72%	2.72%	3.24%	3.18%	3.09%	3.08%	3.24%	3.18%	3.09%	3.08%	3.24%	3.18%	3.09%	3.08%
	% vol H2O	5.58%	6.23%	7.65%	7.23%	6.31%	6.94%	8.35%	7.91%	6.31%	6.94%	8.35%	7.91%	6.31%	6.94%	8.35%	7.91%
	% vol N2	75.82%	75.28%	74.11%	74.44%	75.54%	75.00%	73.83%	74.17%	75.54%	75.00%	73.83%	74.17%	75.54%	75.00%	73.83%	74.17%
	% vol O2	14.82%	14.77%	14.63%	14.72%	14.01%	13.97%	13.84%	13.96%	14.01%	13.97%	13.84%	13.96%	14.01%	13.97%	13.84%	13.96%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	50%	50%	50%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Generator Gross Output	kW	48,688	43,104	36,976	35,133	97,376	86,208	73,953	70,266	97,376	86,208	73,953	70,266	97,376	86,208	73,953	70,266
Gross Heat Rate	Btu/kWh (LHV)	11,961	12,170	12,554	12,702	10,317	10,497	10,828	10,955	10,317	10,497	10,828	10,955	10,317	10,497	10,828	10,955
Heat Recovery Steam Generator																	
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	60.36	81.51	100.34	109.87	57.20	77.89	96.43	105.82	55.52	76.13	94.36	103.67
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	66.94	90.40	111.28	121.85	63.43	86.49	106.94	117.35	61.58	84.42	104.64	114.97
Inlet Temperature	Temperature, F	1,085.7	1,098.9	1,100.0	1,100.0	977.3	1,002.4	1,035.1	1,044.0	977.3	1,002.4	1,035.1	1,044.0	977.3	1,002.4	1,035.1	1,044.0
Exit Temperature	Temperature, F	1,085.7	1,098.9	1,100.0	1,100.0	1,056.4	1,117.8	1,189.1	1,218.1	1,052.2	1,112.9	1,183.2	1,211.8	1,050.1	1,110.3	1,180.0	1,208.5
Final LP Steam to Process	Flow, lb/h	357,427	333,996	306,608	295,029	520,005	520,005	520,005	520,004	520,006	520,005	520,005	520,005	520,006	520,006	520,005	520,006
	Pressure, psia	[redacted]															
	Temperature, F																
	Enthalpy, Btu/lb																
HRSG LP Steam (at HRSG terminal point)	Flow, lb/h	357,427	333,996	306,608	295,029	520,005	520,005	520,005	520,004	520,006	520,005	520,005	520,005	520,006	520,006	520,005	520,006
	Pressure, psia	[redacted]															
	Temperature, F																
	Enthalpy, Btu/lb																
LPEV Drum Exit	Flow, lb/h	357,427	333,996	306,608	295,029	520,005	520,005	520,005	520,004	520,006	520,005	520,005	520,005	520,006	520,006	520,005	520,006
	Pressure, psia	121.5	119.6	117.5	116.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6
	Temperature, F	342.2	341.0	339.7	339.1	351.1	351.1	351.1	351.1	351.1	351.1	351.1	351.1	351.1	351.1	351.1	351.1
	Enthalpy, Btu/lb	1,190.9	1,190.7	1,190.4	1,190.2	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9	1,192.9
LPEV Blowdown	Flow, lb/h	1,787	1,670	1,533	1,475	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600
LP Pinch	dT, F	39.7	40.0	41.0	40.8	40.5	40.3	40.4	39.6	40.5	40.4	40.5	39.7	40.5	40.4	40.5	39.8
LP Approach	dT, F	25.6	26.7	26.1	26.1	26.7	34.3	42.4	45.8	20.9	27.9	35.3	38.3	17.9	24.5	31.5	34.4
Feedwater to LPEV	Flow, lb/h	359,214	335,686	308,141	296,504	522,605	522,605	522,605	522,604	522,606	522,605	522,605	522,605	522,606	522,606	522,605	522,606
	Pressure, psia	121.5	119.6	117.5	116.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6	136.6
	Temperature, F	316.5	314.3	313.5	313.0	324.4	316.8	308.7	305.3	330.2	323.2	315.9	312.8	333.2	326.6	319.6	316.7
	Enthalpy, Btu/lb	286.9	284.6	283.8	283.3	295.1	287.2	278.8	275.4	301.1	293.9	286.2	283.0	304.2	297.4	290.2	287.1
Feedwater to LPEC (after LP FW CV, excluding static head requirement)	Flow, lb/h	359,214	335,686	308,141	296,504	522,605	522,605	522,605	522,604	522,606	522,605	522,605	522,605	522,606	522,606	522,605	522,606
	Pressure, psia	137.0	133.1	128.9	127.2	169.2	169.2	169.2	169.2	169.2	169.2	169.2	169.2	169.2	169.2	169.2	169.2
	Temperature, F	190.0	190.0	190.0	190.0	180.0	180.0	180.0	180.0	199.0	199.0	199.0	199.0	209.0	209.0	209.0	209.0
	Enthalpy, Btu/lb	158.3	158.3	158.3	158.3	148.4	148.4	148.4	148.4	167.5	167.5	167.5	167.5	177.5	177.5	177.5	177.5
BFP Discharge	Flow, lb/h	359,214	335,686	308,141	296,504	522,605	522,605	522,605	522,604	522,606	522,605	522,605	522,605	522,606	522,606	522,605	522,606
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	189.6	189.6	189.6	189.6	179.7	179.7	179.7	179.7	198.7	198.7	198.7	198.7	208.7	208.7	208.7	208.7
	Enthalpy, Btu/lb	158.3	158.3	158.3	158.3	148.4	148.4	148.4	148.4	167.5	167.5	167.5	167.5	177.5	177.5	177.5	177.5
BFP Suction	Flow, lb/h	359,214	335,666	308,141	296,504	522,605	522,605	522,605	522,604	522,606	522,605	522,605	522,605	522,606	522,606	522,605	522,606
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	189.1	189.1	189.1	189.1	179.2	179.2	179.2	179.2	198.2	198.2	198.2	198.2	208.2	208.2	208.2	208.2
	Enthalpy, Btu/lb	157.2	157.2	157.2	157.2	147.2	147.2	147.2	147.2	166.3	166.3	166.3	166.3	176.3	176.3	176.3	176.3
Stack Exit	Flow, lb/h	1,747,011	1,597,016	1,452,023	1,399,726	2,657,445	2,432,443	2,205,013	2,134,124	2,657,290	2,432,271	2,204,822	2,133,926	2,657,208	2,432,179	2,204,720	2,133,821
	Temperature, F	276.2	275.3	275.4	275.0	277.0	273.5	270.3	268.6	287.3	284.1	281.3	279.7	292.7	289.7	287.0	285.5
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.90%	0.90%	0.88%	0.89%	0.90%	0.90%	0.88%	0.89%	0.90%	0.90%	0.88%	0.89%
	% vol CO2	2.86%	2.81%	2.72%	2.72%	3.43%	3.46%	3.46%	3.50%	3.42%	3.44%	3.45%	3.48%	3.41%	3.44%	3.44%	3.47%
	% vol H2O	5.58%	6.23%	7.65%	7.23%	6.67%	7.46%	9.06%	8.71%	6.65%	7.44%	9.03%	8.68%	6.64%	7.43%	9.01%	8.66%
	% vol N2	75.82%	75.28%	74.11%	74.44%	75.40%	74.80%	73.56%	73.86%	75.40%	74.81%	73.57%	73.87%	75.41%	74.81%	73.58%	73.88%
	% vol O2	14.82%	14.77%	14.63%	14.72%	13.60%	13.38%	13.04%	13.05%	13.63%	13.41%	13.07%	13.09%	13.64%	13.42%	13.09%	13.10%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.612	28.537	28.373	28.419	28.545	28.460	28.287	28.328	28.546	28.462	28.288	28.330	28.547	28.463	28.289	28.331

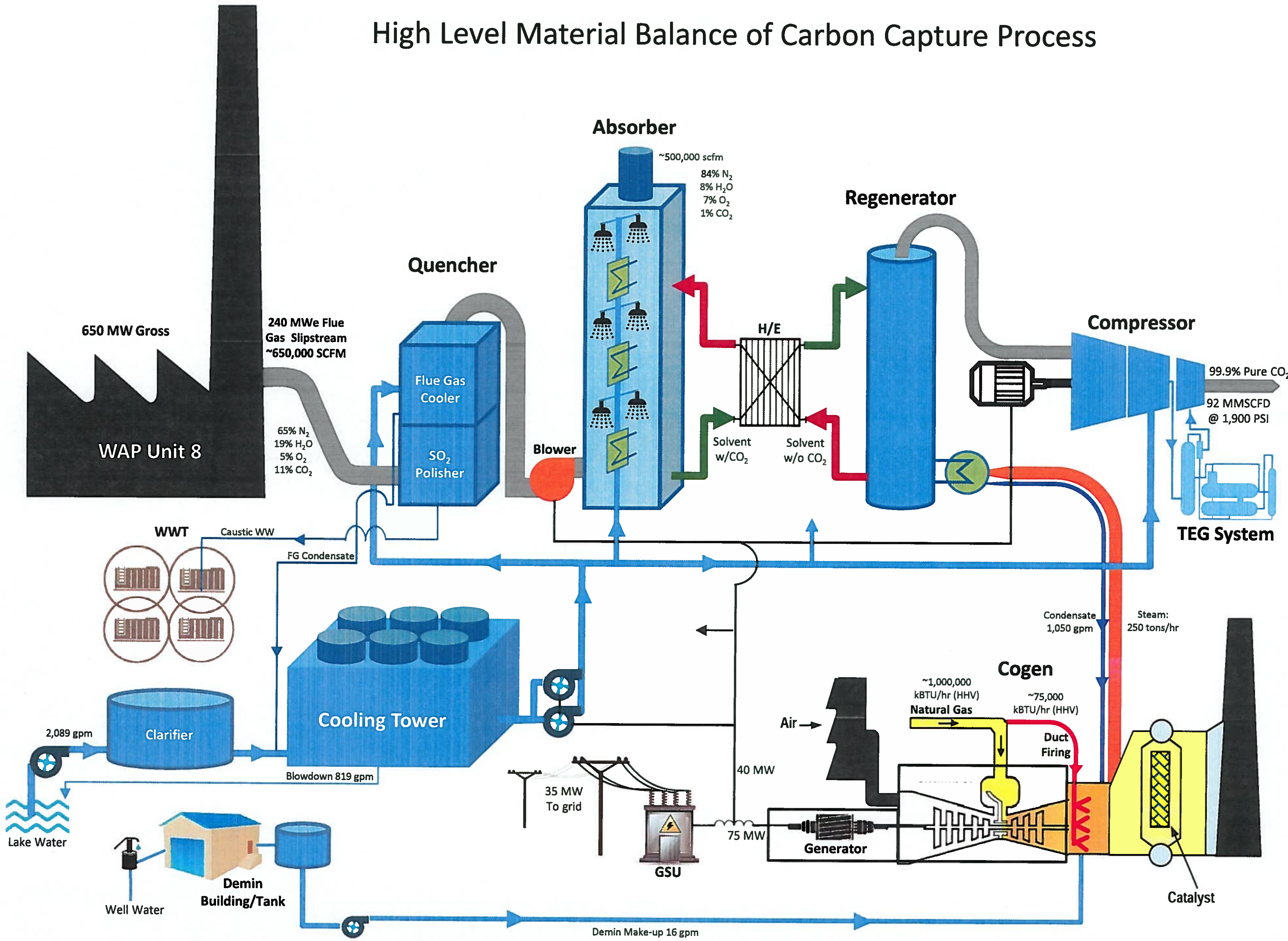
Kiewit Power Engineers – NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-113	Case C4-114	Case C4-115	Case C4-116	Case C4-117	Case C4-118	Case C4-119	Case C4-120	Case C4-121	Case C4-122	Case C4-123	Case C4-124
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired
Process Steam		356.2 kpph	332.8 kpph	305.5 kpph	294.0 kpph	358.5 kpph	335.0 kpph	307.6 kpph	296.0 kpph	359.8 kpph	336.2 kpph	308.7 kpph	297.0 kpph
Condensate Temperature to HRSG		[redacted]											
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-113	C4-114	C4-115	C4-116	C4-117	C4-118	C4-119	C4-120	C4-121	C4-122	C4-123	C4-124
Atmospheric Pressure		14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia	14.690 psia
Fuel Type		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
CTG Model		GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH	GE 7EA/IBH
CTG Performance Reference		IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves	IBH Curves
HRSG Performance Reference		N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201	N/E Rev. A 4/7/201
Run Date		17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14	17-Jun-14
Performance Summary													
Number of CTG/HRSG Units Operating		1	1	1	1	1	1	1	1	1	1	1	1
Gross CTG Output	kW	48,688	43,104	36,976	35,133	48,688	43,104	36,976	35,133	48,688	43,104	36,976	35,133
Gross CTG Heat Rate (LHV)	Btu/kWh	11,961	12,170	12,554	12,702	11,961	12,170	12,554	12,702	11,961	12,170	12,554	12,702
Gross CTG Heat Rate (HHV)	Btu/kWh	13,265	13,497	13,922	14,086	13,265	13,497	13,922	14,086	13,265	13,497	13,922	14,086
CTG Heat Input (LHV)	MMBtu/h	582.36	524.59	464.19	446.25	582.36	524.59	464.19	446.25	582.36	524.59	464.19	446.25
CTG Heat Input (HHV)	MMBtu/h	645.84	581.77	514.78	494.89	645.84	581.77	514.78	494.89	645.84	581.77	514.78	494.89
Duct Burner Heat Input (LHV)	MMBtu/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Duct Burner Heat Input (HHV)	MMBtu/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plant Heat Input (LHV)	MMBtu/h	582.36	524.59	464.19	446.25	582.36	524.59	464.19	446.25	582.36	524.59	464.19	446.25
Plant Heat Input (HHV)	MMBtu/h	645.84	581.77	514.78	494.89	645.84	581.77	514.78	494.89	645.84	581.77	514.78	494.89
Calculations Based on High-Side of Generator Step-Up Transformers													
Total Auxiliary Power/Losses	kW	1,758	1,727	1,692	1,680	1,760	1,728	1,693	1,681	1,761	1,729	1,694	1,682
Total Auxiliary Power/Losses, percent of gross		3.61%	4.01%	4.58%	4.78%	3.61%	4.01%	4.58%	4.78%	3.62%	4.01%	4.58%	4.79%
Net Plant Output w/ Step-Up Xfmr Losses	kW	46,930	41,377	35,284	33,453	46,928	41,376	35,283	33,452	46,927	41,375	35,282	33,451
Net Plant Heat Rate (LHV) w/ Step-Up Xfmr Losses	Btu/kWh	12,409	12,678	13,156	13,340	12,410	12,679	13,156	13,340	12,410	12,679	13,156	13,340
Net Plant Heat Rate (HHV) w/ Step-Up Xfmr Losses	Btu/kWh	13,762	14,060	14,589	14,794	13,762	14,061	14,590	14,794	13,763	14,061	14,590	14,795
Auxiliary Power Calculations													
Boiler Feed Pump	kW	132	124	114	109	134	125	115	111	135	126	116	112
CTG Auxiliaries	kW	400	400	400	400	400	400	400	400	400	400	400	400
Fuel Gas Compressors	kW	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	kW	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal Balance-of-Plant Auxiliary Power	kW	1,532	1,524	1,514	1,509	1,534	1,525	1,515	1,511	1,535	1,526	1,516	1,512
Generator Step-up Transformer Losses	kW	195	172	148	141	195	172	148	141	195	172	148	141
Auxiliary Transformer Losses	kW	31	30	30	30	31	31	30	30	31	31	30	30
Subtotal Transformer Losses	kW	225	203	178	171	225	203	178	171	225	203	178	171
Total Auxiliary Power and Transformer Losses	kW	1,758	1,727	1,692	1,680	1,760	1,728	1,693	1,681	1,761	1,729	1,694	1,682
Combustion Turbine Generator													
Ambient Conditions	Pressure, psia	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690	14.690
	Temperature, F	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7	9.9	50.0	93.0	105.7
	Relative Humidity	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%	60.0%	75.0%	49.7%	28.0%
	WBT, F	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3	7.8	46.1	77.3	77.3
Fuel Flow	Fuel Type	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
	HC, MMBtu/h (LHV)	582.4	524.6	464.2	446.3	582.4	524.6	464.2	446.3	582.4	524.6	464.2	446.3
	Flow, lb/h	28,498	25,671	22,715	21,837	28,498	25,671	22,715	21,837	28,498	25,671	22,715	21,837
Fuel LHV	Btu/lb	20,435	20,436	20,436	20,436	20,435	20,436	20,436	20,436	20,435	20,436	20,436	20,436
Fuel HHV	Btu/lb	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663	22,663
Fuel Gas Temperature	Temperature, F	60	60	60	60	60	60	60	60	60	60	60	60
CTG Exhaust Flow	Flow, lb/h	1,747,011	1,597,016	1,452,023	1,399,726	1,747,011	1,597,016	1,452,023	1,399,726	1,747,011	1,597,016	1,452,023	1,399,726
	Pressure, in. H2O (prelimina	6.57	5.60	4.73	4.44	6.57	5.60	4.73	4.44	6.57	5.60	4.73	4.44
	Temperature, F	1,085.7	1,098.9	1,100.0	1,100.0	1,085.7	1,098.9	1,100.0	1,100.0	1,085.7	1,098.9	1,100.0	1,100.0

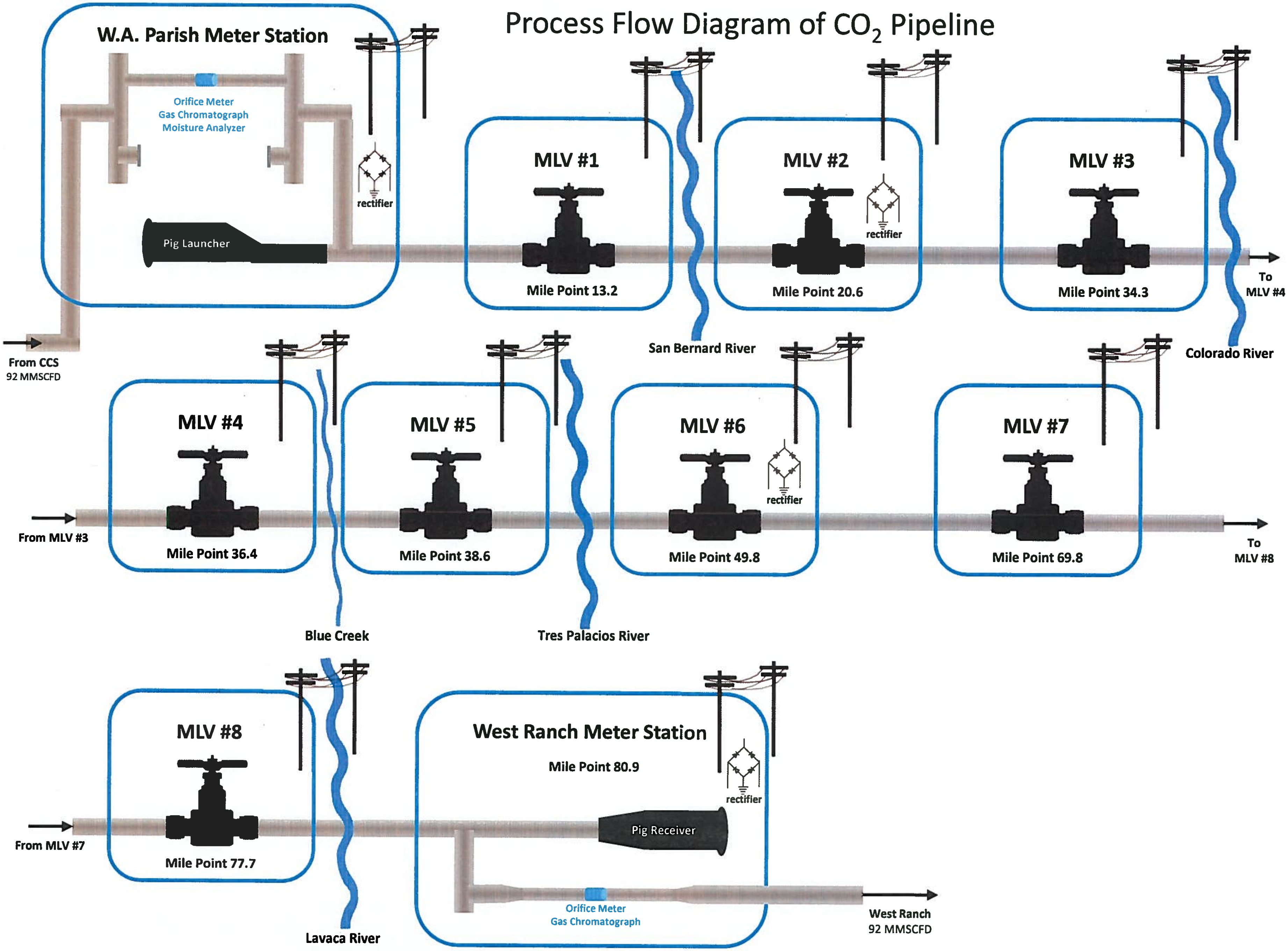
Kiewit Power Engineers -- NRG W.A. Parish
1x7EA + HRSG Cogeneration
Rev. A Issued for Review
Model Revision: GC561-06172014-1 BJScrivner
1997 Steam Tables

Case Name		Case C4-113	Case C4-114	Case C4-115	Case C4-116	Case C4-117	Case C4-118	Case C4-119	Case C4-120	Case C4-121	Case C4-122	Case C4-123	Case C4-124
Ambient Conditions		9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH	9.9F/60%RH	50.0F/75%RH	93.0F/50%RH	105.7F/28%RH
Number of CTG/HRSG Units Operating		1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG	1x50% CTG
HRSG Firing/DB Exit Temperature		Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired	Unfired
Process Steam		356.2 kpph	332.8 kpph	305.5 kpph	294.0 kpph	358.5 kpph	335.0 kpph	307.6 kpph	296.0 kpph	359.8 kpph	336.2 kpph	308.7 kpph	297.0 kpph
Condensate Temperature to HRSG		[redacted]											
GateCycle Model ID		1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4	1WAPA4
GateCycle Case ID		C4-113	C4-114	C4-115	C4-116	C4-117	C4-118	C4-119	C4-120	C4-121	C4-122	C4-123	C4-124
CTG Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	2.86%	2.81%	2.72%	2.72%	2.86%	2.81%	2.72%	2.72%	2.86%	2.81%	2.72%	2.72%
	% vol H2O	5.58%	6.23%	7.65%	7.23%	5.58%	6.23%	7.65%	7.23%	5.58%	6.23%	7.65%	7.23%
	% vol N2	75.82%	75.28%	74.11%	74.44%	75.82%	75.28%	74.11%	74.44%	75.82%	75.28%	74.11%	74.44%
	% vol O2	14.82%	14.77%	14.63%	14.72%	14.82%	14.77%	14.63%	14.72%	14.82%	14.77%	14.63%	14.72%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
CTG Load	% of Base Load	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Generator Gross Output	kW	48,688	43,104	36,976	35,133	48,688	43,104	36,976	35,133	48,688	43,104	36,976	35,133
Gross Heat Rate	Btu/kWh (LHV)	11,961	12,170	12,554	12,702	11,961	12,170	12,554	12,702	11,961	12,170	12,554	12,702
Heat Recovery Steam Generator													
Duct Burner	HC, MMBtu/h (LHV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	HC, MMBtu/h (HHV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Temperature	Temperature, F	1,085.7	1,098.9	1,100.0	1,100.0	1,085.7	1,098.9	1,100.0	1,100.0	1,085.7	1,098.9	1,100.0	1,100.0
Exit Temperature	Temperature, F	1,085.7	1,098.9	1,100.0	1,100.0	1,085.7	1,098.9	1,100.0	1,100.0	1,085.7	1,098.9	1,100.0	1,100.0
Final LP Steam to Process	Flow, lb/h	356,227	332,846	305,542	294,003	358,521	335,045	307,580	295,965	359,761	336,235	308,682	297,025
	Pressure, psia	[redacted]											
	Temperature, F												
	Enthalpy, Btu/lb												
HRSG LP Steam	Flow, lb/h	356,227	332,846	305,542	294,003	358,521	335,045	307,580	295,965	359,761	336,235	308,682	297,025
(at HRSG terminal point)	Pressure, psia	[redacted]											
	Temperature, F												
	Enthalpy, Btu/lb												
LPEV Drum Exit	Flow, lb/h	356,227	332,846	305,542	294,003	358,521	335,045	307,580	295,965	359,761	336,235	308,682	297,025
	Pressure, psia	121.4	119.5	117.4	116.5	121.5	119.6	117.5	116.7	121.6	119.7	117.6	116.8
	Temperature, F	342.1	340.9	339.6	339.1	342.2	341.0	339.7	339.2	342.3	341.1	339.8	339.2
	Enthalpy, Btu/lb	1,190.9	1,190.7	1,190.4	1,190.2	1,191.0	1,190.7	1,190.4	1,190.2	1,191.0	1,190.7	1,190.4	1,190.3
LPEV Blowdown	Flow, lb/h	1,781	1,664	1,528	1,470	1,793	1,675	1,538	1,480	1,799	1,681	1,543	1,485
LP Pinch	dT, F	39.7	40.0	41.1	40.8	39.7	40.0	41.0	40.8	39.7	40.0	41.0	40.8
LP Approach	dT, F	28.6	29.7	29.2	29.1	23.0	23.9	23.3	23.3	20.0	20.9	20.2	20.2
Feedwater to LPEV	Flow, lb/h	358,008	334,510	307,069	295,473	360,314	336,721	309,118	297,444	361,560	337,916	310,226	298,510
	Pressure, psia	121.4	119.5	117.4	116.5	121.5	119.6	117.5	116.7	121.6	119.7	117.6	116.8
	Temperature, F	313.5	311.2	310.4	309.9	319.3	317.1	316.4	315.9	322.3	320.2	319.5	319.0
	Enthalpy, Btu/lb	283.8	281.4	280.6	280.1	289.7	287.5	286.7	286.2	292.9	290.7	290.0	289.5
Feedwater to LPEC	Flow, lb/h	358,008	334,510	307,069	295,473	360,314	336,721	309,118	297,444	361,560	337,916	310,226	298,510
(after LP FW CV, excluding static head requirement)	Pressure, psia	136.8	133.0	128.8	127.1	137.2	133.3	129.1	127.4	137.4	133.5	129.2	127.5
	Temperature, F	180.0	180.0	180.0	180.0	199.0	199.0	199.0	199.0	209.0	209.0	209.0	209.0
	Enthalpy, Btu/lb	148.3	148.3	148.3	148.3	167.4	167.4	167.4	167.4	177.4	177.4	177.4	177.4
BFP Discharge	Flow, lb/h	358,008	334,510	307,069	295,473	360,314	336,721	309,118	297,444	361,560	337,916	310,226	298,510
	Pressure, psia	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
	Temperature, F	179.6	179.6	179.6	179.6	198.6	198.6	198.6	198.6	208.6	208.6	208.6	208.6
	Enthalpy, Btu/lb	148.3	148.3	148.3	148.3	167.4	167.4	167.4	167.4	177.4	177.4	177.4	177.4
BFP Suction	Flow, lb/h	358,008	334,510	307,069	295,473	360,314	336,721	309,118	297,444	361,560	337,916	310,226	298,510
	Pressure, psia	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	Temperature, F	179.1	179.1	179.1	179.1	198.1	198.1	198.1	198.1	208.1	208.1	208.1	208.1
	Enthalpy, Btu/lb	147.2	147.1	147.1	147.1	166.2	166.2	166.2	166.2	176.3	176.3	176.2	176.2
Stack Exit	Flow, lb/h	1,747,011	1,597,016	1,452,023	1,399,726	1,747,011	1,597,016	1,452,023	1,399,726	1,747,011	1,597,016	1,452,023	1,399,726
	Temperature, F	270.8	269.9	270.0	269.6	281.0	280.2	280.3	279.9	286.5	285.6	285.7	285.3
Stack Exhaust Gas Constituents	% vol Ar	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%	0.91%	0.90%	0.89%	0.89%
	% vol CO2	2.86%	2.81%	2.72%	2.72%	2.86%	2.81%	2.72%	2.72%	2.86%	2.81%	2.72%	2.72%
	% vol H2O	5.58%	6.23%	7.65%	7.23%	5.58%	6.23%	7.65%	7.23%	5.58%	6.23%	7.65%	7.23%
	% vol N2	75.82%	75.28%	74.11%	74.44%	75.82%	75.28%	74.11%	74.44%	75.82%	75.28%	74.11%	74.44%
	% vol O2	14.82%	14.77%	14.63%	14.72%	14.82%	14.77%	14.63%	14.72%	14.82%	14.77%	14.63%	14.72%
	% vol SO2	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%	0.0000000%
		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	MW, lb/lbmol	28.612	28.537	28.373	28.419	28.612	28.537	28.373	28.419	28.612	28.537	28.373	28.419

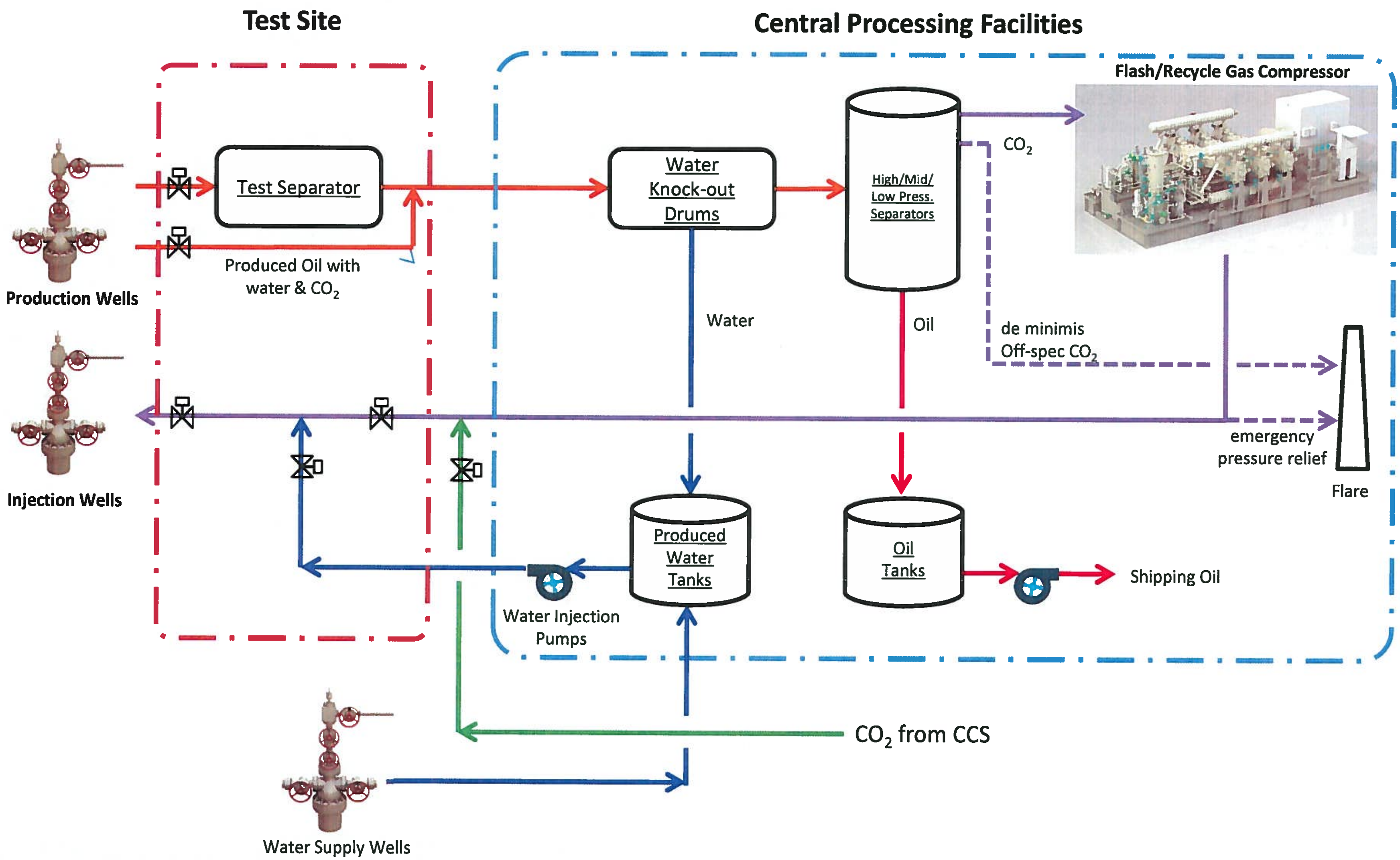
High Level Material Balance of Carbon Capture Process



Process Flow Diagram of CO_2 Pipeline



Process Flow Diagram of Oil Field



MITSUBISHI
HEAVY INDUSTRIES AMERICA, INC.

EQUIPMENT LIST

UNLIMITED DUCUMENT

6 SHEETS WITH COVER

STATUS	☑ FOR DOE ☑ UNLIMITED ☐ PROTECTED ☐ LIMITED

REVISIONS

NO.	DATE	DESCRIPTION	REFERENCE	PREP'D (DISCIPLINE)	CHK'D (DISCIPLINE)	APP'D (DISCIPLINE)	APP'D (PROJECT)

ORDER NO.	583110
PROJECT	PNC-EOR
APPROVED	
DISCIPLINE	Process Group
APPROVED	
CHECKED	
PREPARED	
DATE	03/17/2016

CUSTOMER: petra nova an NRG company / JX

PROJECT: PETRA NOVA WA PARISH CARBON CAPTURE PROJECT

MHI DRAWING NUMBER: 8150D B 242 - 30100 REV. 0

CUSTOMER DRAWING NUMBER: - REV. -

*Cover Only

DISTRIBUTION	
CUSTOMER	E
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LOGISTICS	
COST	
SCHEDULE	
BUSINESS	
PROCESS	E
MACHINE	
EQUIP.	
PIPING	
I&C	
ELECT.	
CIVIL	
CONST.	
VENDOR	
SITE	
TOTAL	0

SUMMARY OF REVISIONS

Doc No. : 8150D B242-30100

Cover Sheet		Item	Original		Revision		Reasons
Rev.	Date	No.	Rev.	Description	Rev.	Description	
0	03/17/2016		0	Issued for DOE.			

MITSUBISHI HEAVY INDUSTRIES AMERICA, INC.

EQUIPMENT LIST		Rev.	0
		Date	March 17, 2016
		Check	
Project :	Section : CO2 Capture		

Item No.	Service	Description	Remark
K-001	FLUE GAS BLOWER	Centrifugal Type	
D-001	FLUE GAS QUENCHER		
D-002	CO2 ABSORBER		
D-003	REGENERATOR		
V-001	CO2 GAS CONDENSING UNIT		
V-002	STEAM CONDENSATE DRUM	Vertical	
T-001	SOLUTION STORAGE TANK		
T-002	SOLUTION SUMP TANK		Installed underground
T-003	CAUSTIC SODA TANK		Insulation required
	T-003 HEATER		Electrical Heater
T-004	RECLAIMED WASTE TANK		
	T-004 HEATER		Electrical Heater
F-001	AUTOMATED FILTRATION UNIT		
F-002	CARBON FILTER	Vertical	
F-003	DOWN STREAM GUARD FILTER	Vertical	
F-004	SOLUTION SUMP FILTER	Vertical	
E-001	FLUE GAS COOLING WATER COOLER	Plate Type	
E-002	WASH WATER COOLER	Plate Type	
E-003	SOLUTION HEAT EXCHANGER	Plate Type	
E-005	REGENERATOR REBOILER	Shell and Tube Type	
E-006	LEAN SOLUTION COOLER	Plate Type	
E-007	RECLAIMER	Shell and Tube Type	
P-001	FLUE GAS COOLING WATER PUMP		
P-002	1ST WASH WATER CIRCULATION PUMP		
P-003	RICH SOLUTION PUMP		
P-004	REGENERATOR REFLUX PUMP		
P-005	LEAN SOLUTION PUMP		
P-006	SOLUTION SUMP PUMP		*1) Intermittent
P-008	STEAM CONDENSATE RETURN PUMP		
P-013	RECLAIMER CAUSTIC SODA FEED PUMP		*1) Intermittent
P-014	RECLAIMED WASTE PUMP		*1) Intermittent
P-015	RECLAIMED WASTE TRANSFER PUMP		*1) Intermittent

EQUIPMENT LIST		Rev.	0
		Date	March 17, 2016
		Check	
Project :	Section : Trim FGD		

	Service	Description	Remark
T-203	CAUSTIC WASTE WATER RECEIVING TANK		Installed underground
P-201	TRIM FGD RECYCLE PUMP		
P-202	CAUSTIC SODA MAKE-UP PUMP		
P-203	CAUSTIC WASTE WATER TRANSFER PUMP		

MITSUBISHI HEAVY INDUSTRIES AMERICA, INC.

EQUIPMENT LIST		Rev.	0
		Date	March 17, 2016
		Check	
Project :	Section : CO2 Compression & Dehydration		

Item No.	Service	Description	Remarks
K-101	CO2 COMPRESSION UNIT		
U-111	DEHYDRATION UNIT		

EQUIPMENT LIST			Rev.	0
			Date	March 17, 2016
			Check	
Project :		Section : Others		
	Service	Description		Remark
T-601	AREA SUMP TANK	Installed underground		
P-601	AREA SUMP PUMP			*1) Intermittent
U-901	SANITARY DRAINAGE UNIT			
	U-901 SANITARY PUMP			*1) Centrifugal grinder pump
	U-901 SANITARY SEWAGE HOLDING TANK			

Environmental Impact Plan and Monitoring Status

Resource Area	Mitigation Plan	Actions	Verification	Party
Air Quality	Fugitive Dust	Water is sprayed on roads and open areas on non-rainy days	Daily Observations	TIC/NRG
	Surfacing unpaved access roads with stone when reasonable	Surfaces have been stabilized with flex base	Daily Observations	TIC/NRG
	Covering materials & stockpile soils	Stockpile soils are being allowed to re-vegetate naturally. TIC will seed stockpiles if natural vegetation does not occur.	Daily Observations	TIC/NRG
	Minimuzing the size of distrubted areas	Only areas under construction have been disturbed	Daily Observations	TIC/NRG
	Moistening soil before loading into dump trucks	TBD	TBD	TIC/NRG
	Covering material in dump trucks	Dump trucks at this time are not being covered when transporting materials onsite.		TIC/NRG
	Minimize use of diesel or gasing generators	Electricians have provided permanent electricity and removed generators.	Weekly, as needed	TIC/NRG
	Speed Limits	Included in TIC Safety Manual		
	a.) Earth Moving Equip 10 mph	a.) 5 mph in construction areas	Daily Safety Audits	TIC/NRG
	b.) Non Earth Moving Equip 15 mph	b.) 15 mph on established Road ways	Daily Safety Audits	TIC/NRG
	Revegetate of disturbed land	Plan to be implemented at the end of the project	TBD	NRG
	Use Modern well maintained Equipment	Equipment Inspections	Upon receipt and daily	TIC
	Minimize idling of Heavy Equipment	Equipment is not left idling	Unmanned heavy is a safety violation	TIC
	Demonstrate 90% carbon capture during demonstration period	Performance Test 1Q2017	TBD	NRG
Greenhouse Gases	Develop a CO2 Monitoring plan	TBD	TBD	NRG
	Implement additional mitigation measures when crossing or working near Ecologically Significant Stream Segments during Pipe Line	TBD	TBD	NRG
	Implement SWPPP	SWPPP implemented		TIC/NRG
	Grading Berming or Terracing to reduce runoff	TBD		TIC/NRG
	Discharge structures and erosion controls devices	Silt fencing, hay bales etc	As Needed	TIC/NRG
	Access to portable spill kits	Spill kits located throughout site	Weekly	TIC/NRG

Environmental Impact Plan and Monitoring Status

Resource Area	Mitigation Plan	Actions	Verification	Party
Geology and Soils	Secondary containment >/=55 gallons	Secondary Containment in place	Weekly	TIC/NRG
	Additional controls with high erosion potential (steep slopes, etc)	TBD		TIC/NRG
	Security measures for bulk storage areas (ie fuel & oils)	Fuel tanks are locked and only accessable with a security card. Gate is locked after hours.	daily	TIC/NRG
	Train personnel in spill prevention & controls measures (documentation)	This is done for every employee at orientation and is discussed during mass meetings	Weekly	TIC/NRG
	Pumps used for loading & unloading will have automatic shutoff switches or high level alarms to prevent overfilling.	Maint. department has installed automatic shutoff swithces for our fuel storage tanks		TIC/NRG
	Operator must be present during refueling	This is an SOP on site for TIC and its subcontractors		TIC/NRG
	Drip pans or pads placed under leaky vehicles	This is an SOP on site for TIC and its subcontractors	on-going	TIC/NRG
	Cleaning & maintenace of vechiles preformed indoors or in a controlled area. Control overspray	Maint. shop is now operational and is being utilized for repairs.	on-going	TIC/NRG
	Post Emergency contacts for large spills. (Company, local, state, federal)	Located in spill response plan which is distributed around the site and is discussed in orientation		TIC/NRG
	Spill and leaks would be cleaned up promptly and recorded.	Spills and leaks are promptly cleaned up and reported by PEC	As needed	TIC/NRG
Surface Water	Implement Mitigation Techniques	N/A for CCS Project TBD on Pipeline	TBD	NRG
Wetlands	Minimize potential impacts on Mussel species at river crossings	TBD	TBD	NRG
	Avoid disturbing activities during migratory bird nesting & breeding season	TBD	TBD	NRG
	Suspend pipeline construction during Whooping Crane migration (late March to April) if they are observed in the area	TBD	TBD	NRG
	Consult TPWD and USFWS if pipeline route is changed or other unforeseen areas of ground disturbance not included in the EIS	TBD	TBD	NRG

Environmental Impact Plan and Monitoring Status

Resource Area	Mitigation Plan	Actions	Verification	Party
Biological Resources	NRG must revegetate disturbed areas using approved methods	TBD	TBD	NRG
	Wildlife contact plan	Personel are directed to inform supervisors regarding wildlife issues. Supervisors will contact security who will then contact the appropriate NRG personel.		TIC/NRG
	Consult Texas Historical Commission if pipeline route is changed or other unforeseen areas of ground disturbance not included in the EIS	TBD	TBD	NRG
Cultural Resources (Pipeline)	NRG must install down-shielded lighting for permanent light need wherever possible	Included in final design and temporary lights are also following this guideline	Drawing reviews and temporary facility installation inspection	NRG
Aesthetics				