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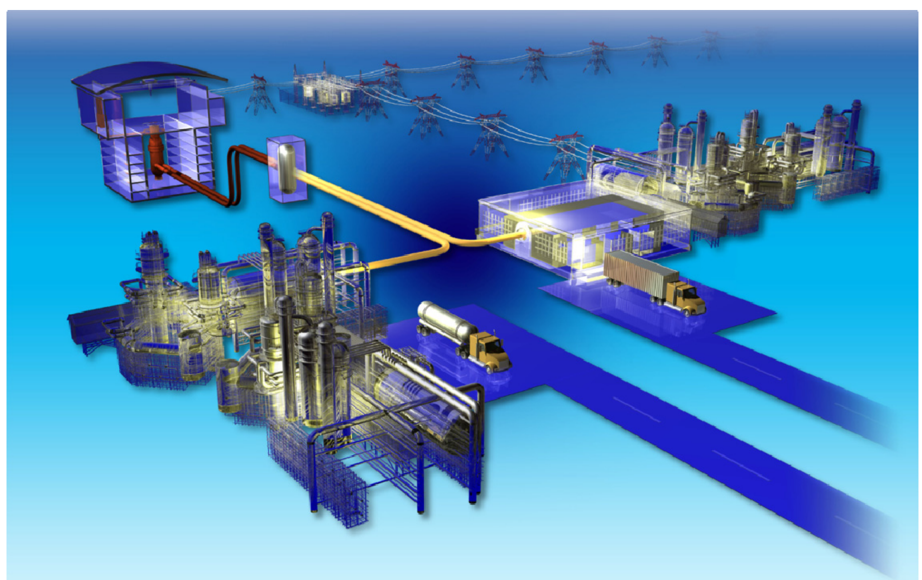
Technical Evaluation Study

Project No. 23843

Nuclear-Integrated Hydrogen Production Analysis



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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	11/03/09	All	Newly issued document.
1	05/15/10	All	Added economic sections and URS & INL comments

EXECUTIVE SUMMARY

This technical evaluation (TEV) has been prepared as part of a study for the Next Generation Nuclear Plant (NGNP) Project to evaluate integration of high temperature gas-cooled reactor (HTGR) technology with conventional chemical processes. This TEV addresses the integration of an HTGR with high-temperature steam electrolysis (HTSE). The main products are hydrogen and oxygen.

An HTGR can produce steam, high-temperature helium, and/or electricity. In conventional processes, these products are generated by the combustion of fossil fuels such as coal and natural gas, resulting in significant emissions of greenhouse gases such as carbon dioxide. Heat or electricity produced in an HTGR could be used to supply process heat or electricity to conventional processes without generating any greenhouse gases. This report describes how nuclear-generated heat and electricity could be integrated into the HTSE process, provides a preliminary economic analysis of the process, and assesses greenhouse gas (GHG) emissions of the conventional steam methane reforming (SMR) process and nuclear-integrated HTSE.

The following list identifies the major conclusions drawn by evaluating the nuclear-integrated HTSE process against the conventional process, SMR:

- Four and one third 600-MW_t HTGRs are required to support the production of 719 tons/day of hydrogen and 5,668 tons/day of oxygen using HTSE. An SMR process requires 2078 tons of natural gas to produce the same amount of hydrogen. The SMR process emits 3,393 tons/day of carbon dioxide (CO2). The nuclear-integrated HTSE process emits 0 tons/day.

- At a 12% internal rate of return (IRR), the price of hydrogen from an HTGR with a 750°C outlet temperature using HTSE is \$3.67/kg. Estimated SMR prices vary from \$1.26/kg to \$2.51/kg.

CONTENTS

1. INTRODUCTION

This technical evaluation (TEV) has been prepared as part of a study for the Next Generation Nuclear Plant (NGNP) Project to evaluate integration of high-temperature gas-cooled reactor (HTGR) technology with conventional chemical processes. The NGNP Project is being conducted under U.S. Department of Energy (DOE) direction to meet a national strategic need identified in the *National Energy Policy* to promote reliance on safe, clean, economic nuclear energy and to establish a greenhouse-gas-free technology for the production of hydrogen. The NGNP represents an integration of high-temperature reactor technology with advanced hydrogen, electricity, and process heat production capabilities, thereby meeting the mission need identified by DOE. The strategic goal of the NGNP Project is to broaden the environmental and economic benefits of nuclear energy in the U.S. economy by demonstrating its applicability to market sectors not being served by light water reactors.

An HTGR produces steam, high-temperature helium, or electricity. A summary of these products and a brief description is shown in Table 1. In conventional processes, these products are generated by the combustion of fossil fuels such as coal and natural gas, resulting in significant emissions of greenhouse gases such as carbon dioxide. Heat or electricity produced in an HTGR could be used to supply process heat or electricity to conventional processes without generating any greenhouse gases. The use of an HTGR to supply process heat or electricity to conventional processes is referred to as a nuclear-integrated process. This report describes how nuclear-generated heat or electricity could be integrated into conventional processes and provides a preliminary economic analysis to show which nuclear-integrated processes compare favorably with conventional processes.

Table 1. Project outputs of an HTGR.

HTGR Product	Product Description
Steam	540 to 593°C and 17 to 24 MPa
High-Temperature Helium	Up to 750°C and 9.1 MPa
Electricity	Generated by Rankine cycle with thermal efficiency of 40%

In 2009, an independent review team considered three hydrogen production technologies to be combined with a next generation nuclear plant.[1] Those technologies included the sulfur iodine (SI) process, the hybrid sulfur (HyS) process and the HTSE process. The review team recommended the HTSE process as the first choice for the NGNP Project, with HyS as the second option. The purpose of this TEV is to present the process modeling and economic results from producing hydrogen from high-temperature steam electrolysis combined with a high-temperature gas reactor. These results are used in other process models developed under the NGNP program where HTGR-integrated hydrogen may be integrated with industrial processes. The economics of this TEV are used to estimate the overall economics of these combined nuclear and industrial processes.

The Advanced Process and Decision Systems Department at Idaho National Laboratory (INL) has spent several years developing detailed process simulations of chemical and thermodynamic processes. The processes included HTSE combined with a variety of nuclear reactors. These simulations have been developed using HYSYS Process and ASPEN PLUS—state-of-the-art, steady-state, thermodynamic, and chemical process simulators developed by Hyprotech and

ASPEN. This study makes extensive use of these models and the modeling capability at INL to evaluate the integration of HTGR technology with potential hydrogen production technologies.

This TEV assumes familiarity with HYSYS Process and APSEN PLUS software, so a detailed explanation of the software capabilities, thermodynamic packages, unit operation models, and solver routines is beyond the scope of this TEV. Also assumed is a familiarity with thermodynamic, heat exchange, and heat recuperation systems; hence, a thorough explanation of these technologies is also considered to be beyond the scope of this TEV.

2. MODELING OVERVIEW

2.1 Introduction

The purpose of this modeling effort is to predict the flow of hydrogen output of HTSE combined with a 600 MWt reactor. The hydrogen and oxygen flows are used with other process models where the hydrogen may be used in substitute of hydrogen from other processes. The model also includes the resources needed to accomplish the production rates including electrical power and water usage. By combining this model with other process models being developed in the NGNP program, an overall picture of nuclear integrated chemical processing may be achieved. The scale of the modeling within Section 2 is based on a steam methane reforming (SMR) process that produces 719 tons/day of hydrogen.

2.2 Hydrogen Production via Steam Reforming of Methane

Hydrogen is a key element for making fuels and other industrial chemicals. Industry is currently making hydrogen from natural gas via steam reforming. Water and methane are feeds for the process in which some of the methane is used to make steam and the remainder is combined with the steam to create hydrogen and carbon dioxide. The two basic chemical equations describing the process, methane reforming and gas shift, are:

$$CH_4 + H_2O \Leftrightarrow CO + 3H_2 \tag{1}$$

$$CO + H_2O \Leftrightarrow CO_2 + H_2. \tag{2}$$

Figure 1 is a simplified block diagram showing the major process components. The process was modeled using ASPEN PLUS process modeling software. Four processes were modeled: methane reforming, gas shift, cleanup, and cooling.

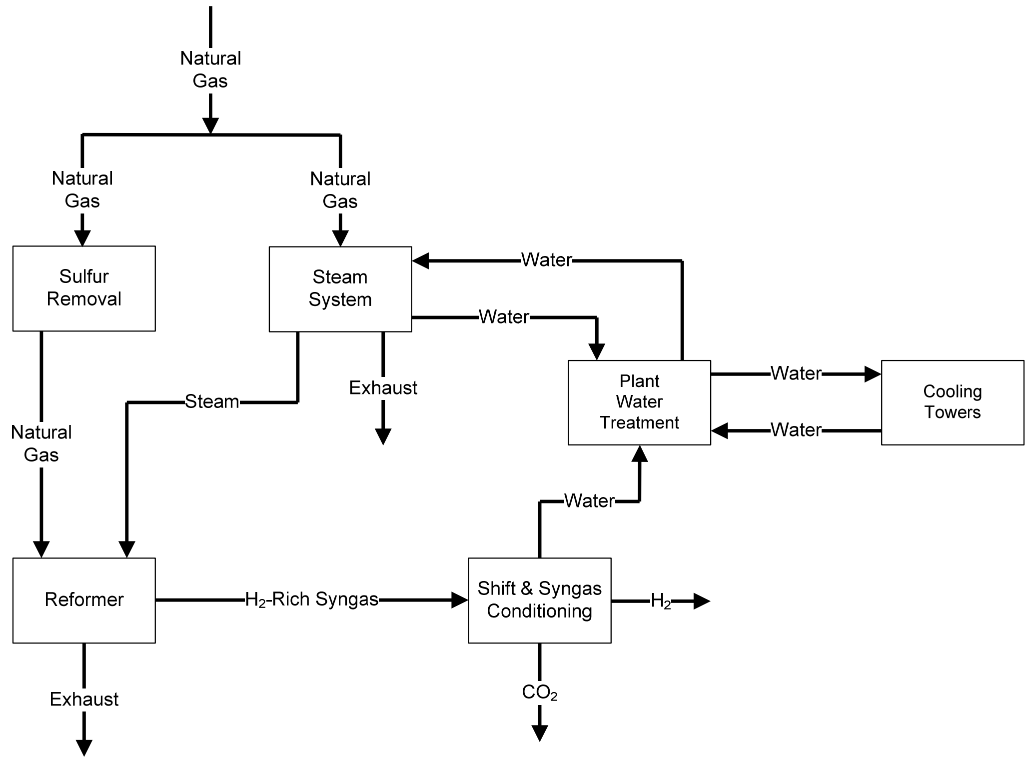

Figure 1. Hydrogen production through the steam reforming of natural gas.

2.3 Hydrogen Production via HTSE

Hydrogen can also be produced using a high-temperature nuclear reactor by way of HTSE. The heat and electrical power from the reactor can be used to split water using solid oxide electrolysis cells, (SOEC) to create hydrogen and oxygen. The process heat from the reactor reduces the amount of electricity needed to split the water, thus increasing the efficiency of the process when compared to low-temperature electrolysis. Figure 2 is a simplified diagram of the process. The HYSYS process modeling software was used to model the HTSE process. The process model included heat recuperation and the power from a nuclear high-temperature gas reactor. HYSYS allows for accurate mass and energy balances and contains components like compressors, turbines, pumps, valves, and heat exchangers to simulate components in the process. Figure 3 diagrams the HTSE process in detail.

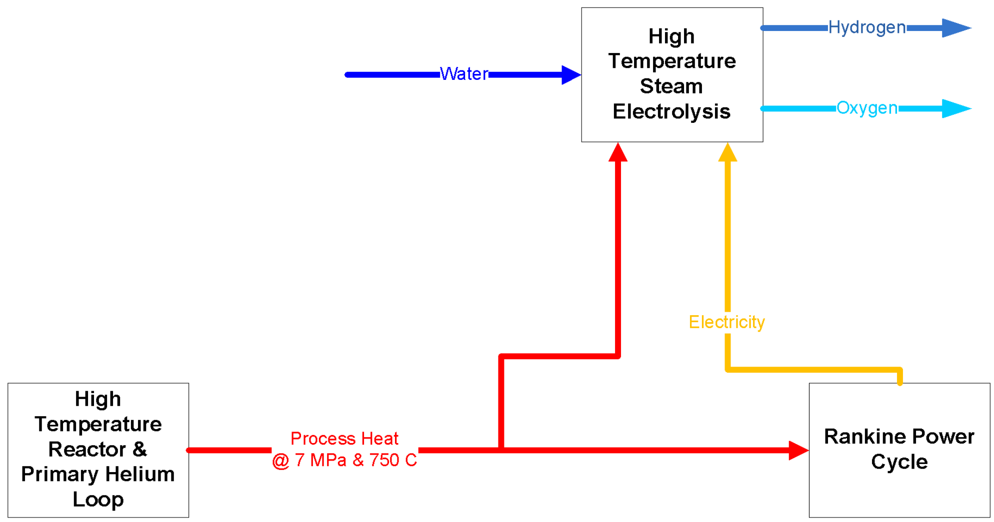

Figure 2. Hydrogen production via HTSE.

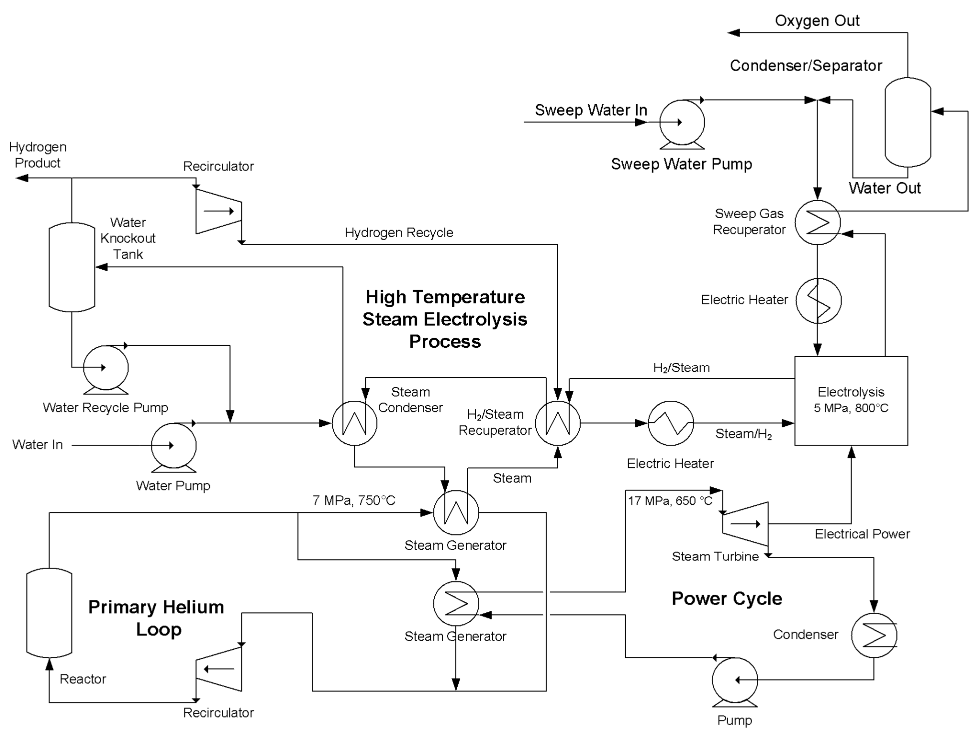

Figure 3. Process flow diagram of HTSE process.

RESULTS OF PROCESS MODEL

The block flow diagram of the hydrogen processes shown in Figure 4 includes the input and product streams for each process. The size of each process was adjusted to the hydrogen production expected from a typical steam reformer, equaling 700 tons/day of hydrogen. To achieve this, the steam reformer requires 2,000 tons/day of natural gas resulting in nearly 3,400 tons/day of carbon dioxide emissions. Nearly 12 MWe of electricity is needed to support the process along with 1,360 gal/minute of water to supply steam and cooling.

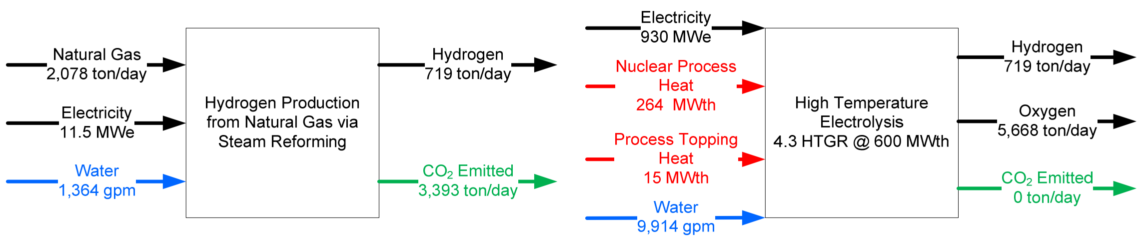

Figure 4. Block flow diagram of hydrogen production technologies.

The HTSE process produces no carbon dioxide but has a 930 MWe electrical load. The electrical power is primarily for the actual electrolysis process as shown in Table 2. The process requires 264 MWt of process heat from the reactor to create the steam necessary for the electrolysis process. The recuperating heat exchangers have a total duty of 230 MWt. It is assumed in this analysis that the steam generator can deliver 700°C steam to the electrolysis cells. The HTSE process requires the feed stream to be heated to 800°C, requiring additional topping heat from another heat source. This heat source could come from a combustor, electricheating or waste heat from a neighboring process, which may need to use the hydrogen from the HTSE process. The topping heat is 15 MWt. This analysis assumes that the topping heat either comes from electric heating or from other processes. If the heat is supplied by a neighboring process, the carbon footprint should already be accounted for by that process, making the carbon footprint of the hydrogen process at zero. This process requires much more water than the steam reforming process. The primary need for the water is for cooling of the reactors, as seen in Table 2. The electrical and process heat needs require 4.3 high-temperature gas reactors rated at 600 MWt. The hydrogen product has a purity of 99.9% with water as the remaining component. Oxygen is a by-product of the HTSE process that may also be used in other chemical processes. The purity of the oxygen stream is 99.99% with water as the remaining component.

The hydrogen production efficiency was calculated for both processes. The hydrogen production efficiency is defined as the thermal value of the hydrogen product divided by the sum of thermal value of the feed streams, process heat in, and thermal equivalent of the electric power. The efficiency is basically the thermal value of the hydrogen output divided by the thermal value of the input. For the steam reforming case, the hydrogen production efficiency is the higher heating value of the hydrogen divided by the sum of the higher heating value of the natural gas and the thermal energy equivalent of the electrical power input. The thermal value of the electricity is found by the electrical power divided by the efficiency of the power cycle. The power cycle efficiency in this study was assumed at 40%. The hydrogen production efficiency for the HTSE process is the higher heating value of the hydrogen product divided by the sum of the thermal energy of the electrical power produced, the process heat from the reactor, and the topping heat. The hydrogen production efficiency for the steam reforming case is influenced primarily by the natural gas input, whereas the electrical power has the greatest influence for the HTSE case (see Table 2). The HTSE case has an efficiency of 40.4%, very close the power cycle efficiency for the electrical power, whereas the steam reforming case has an efficiency of 79.4%.

Table 2. Hydrogen production summary.

	Steam Methane Reforming	High Temperature Steam Electrolysis
Inputs		
Natural Gas Rate (ton/day)	2,078	0
# 600 MWt HTGRs Required	n/a	4.3
Intermediate Products		
Syngas (ton/day)	8,768	n/a
Syngas Produced /Natural Gas Fed (lb/lb)	4.2	n/a
Outputs		
Hydrogen (ton/day)	719	719
Hydrogen Production Efficiency (Power Cycle Efficiency = 40%)	79.4%	40.4%
Oxygen (ton/day)	0	5,668
Utility Summary		
Total Power (MWe)	11.5	930
Electrolyzers	n/a	923
NG Reformer	3.5	n/a
Gas Cleaning	3.6	n/a
Water Treatment	2.8	0
Cooling Towers	0.6	6.9
Power Block	1.0	n/a
Pumps	n/a	0.5
Recirculator	n/a	0.1
Process Heat		
Total Process Heat (MWt)	n/a	278
Process Heat from Reactor (MWt)	n/a	264
Topping Process Heat (MWt)	n/a	14.9
Water Consumption		
Total Water (gpm)	1,364	9,914
Water Consumed/Hydrogen Produced (lbm/lbm)	11.5	83.3
CO2 Emissions		
Emitted (ton/day CO_2)	3,393	0

3. ECONOMIC MODELING

The economic viability of the HTSE process was assessed using standard economic evaluation methods. The economics were evaluated for the HTSE process combined with a single 600 MWt HTGR with a Rankine steam power cycle. Future work will include an economic analysis of the SMR process. The total capital investment (TCI), based on the total equipment costs, along with the variable and fixed operating costs were first calculated for the cases. The present worth of the annual cash flows (after taxes) was then calculated for the TCI, as well as the TCI at +50% and -30%of the HTGR cost, with the debt-to-equity ratios equal to 80%/20%. The following sections describe the methods used to calculate the capital costs, fixed and variable operating costs, and the methods used for the economic assessments. All calculations assume that a 600 MWt HTGR is used to produce only hydrogen and oxygen via HTSE by supplying electricity and process heat. The economic analysis includes the HTSE process, the power cycle, and the reactor.

For the nuclear-integrated cases, the estimates of capital costs and operating and maintenance costs assumed the nuclear plant was an "nth of a kind", (NOAK). In other words, the estimates were based on the costs expected after the HTGR technology is integrated into an industrial application more than 10 times. The economic modeling calculations were based on two capital cost scenarios: a current best estimate of $2,000/kWt *["INL/BEA Pre-Conceptual Design Report name"]* and a target of $1,400/kW$_{th}$ *[personal communications with Larry Demick]* where kW$_{th}$ is the thermal rating of the plant. In comparison, light water nuclear reactor costs are approximately $1,250/kW$_{th}$. Based on the two capital cost scenarios for HTGR technology, the nominal capital cost for a 600 MW$_{th}$ HTGR would be $1.2 billion; the target capital cost would be $840 million.

3.1 Capital Cost Estimation

The capital installed costs for the HTSE process are based on a report by Harvego et al.[2] which assumes hydrogen production from a 600 MWt high-temperature gas reactor with an outlet temperature of 900°C. At that temperature, the power cycle efficiency is 53% with a corresponding hydrogen production rate of 2.4 kg/sec. For the current NGNP case, the power cycle efficiency is 40% with a hydrogen production flow rate of 1.75 kg/sec. The hydrogen production system in the Harvego report used air as the sweep gas, whereas this analysis used steam for the sweep gas. The change in type of sweep gas was selected to be able to provide an oxygen product. Water as a sweep gas is more easily separated from oxygen generated than the nitrogen from the air in the air sweep option. Heat exchanger costs in the HTSE process were adjusted in this analysis to account for the different sizes. Air sweep compressor costs (including intercoolers) were removed and a water pump for the sweep gas was added. The water for the sweep side is heated to make steam which sweeps the oxygen from the electrolyzers. The water is removed from the oxygen by condensing and recycled. To size the sweep pump, the flow rate of the pump was adjusted until the outlet molar composition of the electrolysis unit was 50% oxygen and 50% steam. The same installed cost factors found in the Harvego report were used to adjust the cost of the equipment. The costs from the Harvego report are 2005 costs; Table 3 shows the adjusted capital costs. This analysis is performed using 2009 costs; therefore the Chemical Engineering Plant Cost Index (CEPCI) was used to adjust the costs to 2009 dollars. Uninstalled costs are the basic cost of the equipment from the manufacturer. Installed costs are the uninstalled costs plus the additional materials and labor needed to place and install the equipment.

Harvego et al. used *A Guide to Chemical Engineering Process Design and Economics*[3] to estimate the costs of the separation tanks, steam generators, and heat recuperators. This analysis uses the separation tank cost found in Harvego et al., but linearly interpolates the cost of the steam generators and recuperators based on the overall heat transfer coefficient and heat transfer area product (UA) of the heat exchangers, because the heat exchanger sizes differ between cases. The topping heaters do not have a UA in the process model, but a similar approach was used in scaling the cost using the heat duty instead of the UA.

The pumps and hydrogen circulator come directly from the Harvego report and differ only in quantity. Harvego et al. used the Matches' Process Equipment Cost Estimates Website[4] to obtain the capital costs for these components. The *H2-MHR Pre-Conceptual Design Report: HTE-Based Plant*[5] was used by Harvego et al. to cost the water supply system, piping, electrical capital, and miscellaneous equipment.

In the Harvego report, the cost of the electrolysis cells is $200/kWe, based on the power into the cells. This was derived from a 2007 goal of the Solid State Energy Conversion Alliance (SECA) for solid oxide fuel cells. The goal was set to $400/kWe for the fuel cells, but because solid oxide electrolysis cells run at twice the voltage for the same current density, the electrolysis cells are half the cost. At a recent SECA conference, the goal for solid oxide fuel cells has changed to $175/kWe, which when halved for SOEC comes to $87.5/kWe.[6] Consulting with HTSE experts, INL, and Ceramatec, a NOAK goal of $100/kWe was used for this study.[7,8]

The 4.74 installed cost factor is based on the Lang factor for predominately fluid processing plants. The Lang factor is the multiplier used on the major equipment cost to account for installing a process in a plant. The 1.2 cost factor is based on Reference 5. The 1.8 cost factor is based on consultation with experts at INL and Cerametec on HTSE.[7,8]

A percentage breakdown of the installed capital costs of the HTSE process without reactor and power cycle costs is shown in Figure 4. The results show that 2/3 of the cost is due to the electrolysis cells. The results indicate that a sensitivity study of the cell cost could be beneficial. However when cost of the reactor and the cost of the power cycle, the capital cost of the HTSE process is only 8.41% , see Figure 5.

Table 3. Capital costs of HTSE connected to a 600 MWt HTGR.

Equipment	2005 Uninstalled Costs	2009 Uninstalled Costs	Installed Cost Factors	2009 Installed Costs
Water Separation Tanks	$143,980	$157,449	4.74	$746,310
Recycle Pumps	$18,800	$20,559	4.74	$97,448
Water Supply System	$1,000,000	$1,093,550	1.2	$1,312,260
Water Pumps	$41,400	$45,273	4.74	$214,594
Heat Recuperators	$1,186,193	$1,297,161	4.74	$6,148,543
Steam Generators	$765,529	$837,144	4.74	$3,968,062
Topping Heaters	$190,000	$207,774	4.74	$984,851
Hydrogen Circulator	$19,600	$21,433	4.74	$101,595
HSTE Piping	$1,250,000	$1,366,937	1.2	$1,640,325
Electrical	$2,000,000	$2,187,100	1.2	$2,624,519
Misc. Equipment	$2,500,000	$2,733,874	1.2	$3,280,649
Solid Oxide Electrolyzer	$21,383,267	$23,383,667	1.8	$42,090,600
Total Installed Cost				**$63,209,757**

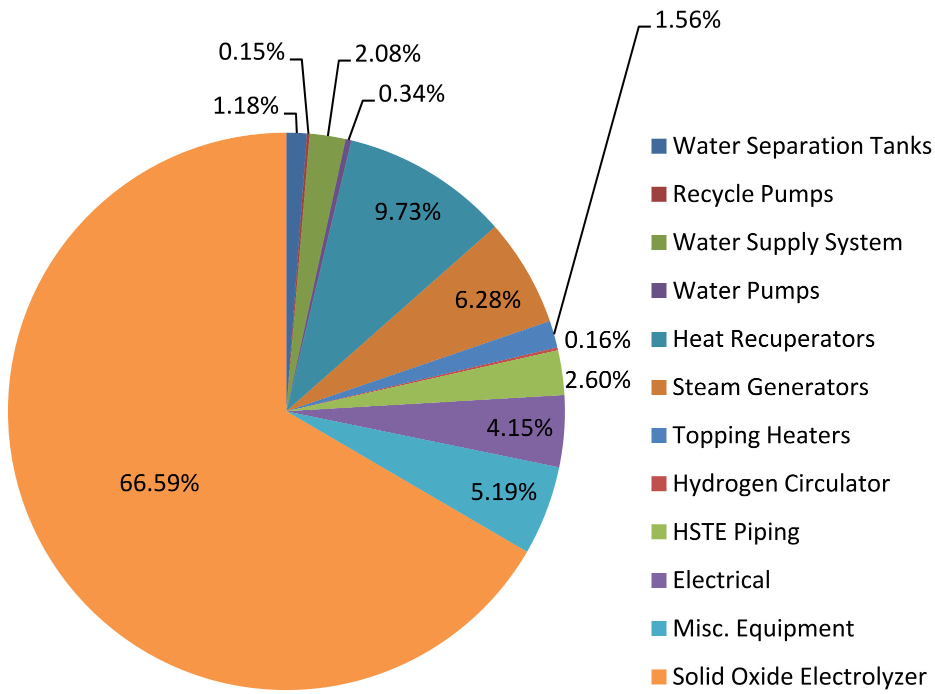

Figure 4. Installed capital costs of HTSE without reactor and power cycle costs.

The capital costs presented are for inside the battery limits, and exclude costs for administrative offices, storage areas, utilities, and other essential and nonessential auxiliary facilities. The estimate presented is a study (factored) estimate which has a probable error up to ±30%.[9] Fixed capital costs were estimated from literature estimates and scaled estimates (capacity, year, and material) from previous quotes. Capacity adjustments were based on the six-tenths factor rule:

$$C_2 = C_1\left(\frac{q_2}{q_1}\right)^n \tag{3}$$

where C_1 is the cost of the equipment item at capacity q_1, C_2 is the cost of the equipment at capacity q_2, and n is the exponential factor, which typically has a value of 0.6.[10] It was assumed that the number of trains did not have an impact on cost scaling. Cost indices were used to adjust equipment prices from previous years to values in July of 2009 using the CEPCI.

Table 4. CEPCI data.

Year	CEPCI	Year	CEPCI
1990	357.6	2000	394.1
1991	361.3	2001	394.3
1992	358.2	2002	395.6
1993	359.2	2003	402
1994	368.1	2004	444.2
1995	381.1	2005	468.2
1996	381.7	2006	499.6
1997	386.5	2007	525.4
1998	389.5	2008	575.4
1999	390.6	July 2009	512

After cost estimates were obtained for each of the process areas, the costs for water systems, piping, instrumentation and control, electrical systems, and buildings and structures were added based on scaling factors for the total installed equipment costs.[11] These factors were not added to the cost of the HTGR or the power cycle. Table presents the factors utilized in this study:

Table 5. Capital cost adjustment factors.

Year	Factor
Water Systems	7.1%
Piping	7.1%
Instrumentation and Control	2.6%
Electrical Systems	8.0%
Buildings and Structures	9.2%

Finally, an engineering fee of 10% and a project contingency of 18% were assumed to determine the total capital investment (TCI). Neither engineering fees nor contingencies were applied to the HTGR costs. Table presents the capital cost estimate breakdown for the HTSE. These cost factors are applied only to the installed costs of the HTSE equipment; therefore, the numbers in Table 6 show those costs only as applied to HTSE alone. The water systems, piping, instrumentation and control, electrical systems, and buildings and structures costs are already incorporated in the reactor and power cycle costs and are represented by the numbers shown. Figure 5 shows the total capital investment cost for all three major components for nuclear-integrated hydrogen production. The HTSE TCI is only 8.41% of the total TCI.

Cost estimators at the INL performed a capital cost analyses for a number of nuclear integrated industrial processes. The HTSE and power cycle capital costs are a part of many of these analyses. In appendix D is the capital cost analyses for ammonia production. Based on this analysis and scaled to a 600 MWt reactor, the total capital costs of the reactor, power cycle and HTSE are $1,025,100,000; $170,600,000; and $109,900,000. The total capital cost is $1,305,600,000.

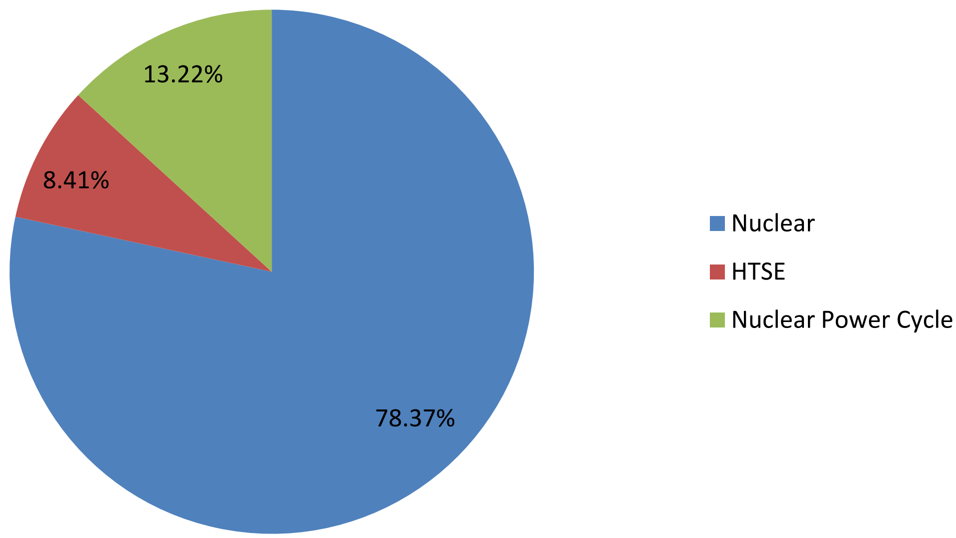

Figure 5. Total capital investment cost for HTSE hydrogen production connected to a 600 MWt HTGR.

Table 6. Total capital investment, HTSE connected to a 600 MWt HTGR.

	Installed Cost	Engineering Fee	Contingency	Total Capital Cost
Nuclear				**$1,025,000,000**
Power Cycle	**$133,258,047**	**$13,325,805**	**$26,385,093**	**$172,968,945**
HTSE Total	**$ 84,706,502**	**$ 8,470,650**	**$ 16,771,887**	**$ 109,949,039**
HTSE Major Equipment	$63,209,150	$6,320,915	$12,515,412	$82,045,477
Cooling Towers	$4,657	$466	$922	$6,045
Water Systems	$4,488,180	$448,818	$888,660	$5,825,658
Piping	$4,488,180	$448,818	$888,660	$5,825,658
I&C	$1,643,559	$164,356	$325,425	$2,133,340
Electrical Systems	$5,057,105	$505,710	$1,001,307	$6,564,122
Buildings and Structures	$5,815,670	$581,567	$1,151,503	$7,548,740
Total Capital Investment				**$1,307,917,985**
Total Capital Investment (+50% HTGR)				**$1,820,417,985**
Total Capital Investment (-30% HTGR)				**$1,000,417,985**

3.2 Estimation of Revenue

Yearly revenues were estimated for the HTSE case. Revenues were estimated for low, average, and high prices for hydrogen.

Table 7. Annual revenues, HTSE connected to a 600 MWt HTGR.

	Price		Generated		Annual Revenue
Oxygen	0.04586	$/kg	13.8	kg/s	$18,351,646
Hydrogen - Low	1.50	$/kg	1.75	kg/s	$76,158,819
Hydrogen – Avg.	3.25	$/kg	1.75	kg/s	$165,010,774
Hydrogen - High	5.00	$/kg	1.75	kg/s	$253,862,730
Annual Revenue, low					**$94,510,465**
Annual Revenue, average					**$183,362,420**
Annual Revenue, high					**$272,214,375**

3.3 Estimation of Manufacturing Costs

Manufacturing cost is the sum of direct and indirect manufacturing costs. Direct manufacturing costs for this project include the cost of raw materials, utilities, and operating labor and maintenance. Indirect manufacturing costs include estimates for the cost of overhead and insurance and taxes.[9]

Table 8 shows the items that need to be considered for operation and maintenance. The expected duration of the electrolysis cells for NOAK is 8 years. Assuming that one-eighth of the cells are replaced every year, and based on the $100/kWe cost of the cells, the yearly replacement cost is $2,714,310. The number of staff members is an estimate based on the Harvego document. The water usage for the electrolyzer and the sweep gas comes from the HTSE process model. The cooling tower water usage is calculated from the ambient heat load from the model and from using the estimation procedure found in Keeper.[12] The electrical power usage and product flow rates are found in the process model. Finally, it was necessary to estimate the water needed to start the system by considering the sweep gas and the electrolysis recycle loops. The volumes of each major component were estimated by allowing a 10-minute resident time of the flow in each vessel.

Labor costs are assumed to be 1.15% of the total capital investment. Maintenance costs were assumed to be 3% of the total capital investment.[13] The power cycles and HTSE were not included in the TCI for operation and maintenance costs, as they were calculated separately. Taxes and insurance were assumed to be 1.5% of the total capital investment, excluding the HTGR, an overhead of 65% of the labor and maintenance costs was assumed, and royalties were assumed to be 1% of the coal or natural gas cost.[13] Table 9 provides the manufacturing costs for the HTSE case. Availability of the nuclear plant was assumed to be 92%.

Table 8. Operations and maintenance cost considerations for HTSE.

Water usage (gpm)	436.9
Initial water need (gallons)	19,400
Electrical power (kWe)	214,000
Oxygen product (m^3/s)	10.2
Hydrogen product (m^3/s)	20.4

Table 9. Annual manufacturing costs, HTSE connected to a 600 MWt HTGR.

	Price		Consumed		Annual Cost
Direct Costs					
Materials					
Water Clarification	0.024	$/1000 gal	629,136	gal/day	$5,167
Water Treatment	1.315	$/1000 gal	356,976	gal/day	$157,621
HTSE Cell Replacements	0.024	$/lb H_2	333,333	lb/day H_2	$2,714,310
Nuclear Fuel	4.22	$/MWt-h	600	MWt	$20,416,590
Utilities					
Water	0.046	$/k-gal	629,136	gal/day	$9,718
Labor and Maintenance					$3,110,680
O&M Nuclear					$8,276,996
Indirect Costs					
Overhead					$2,021,942
Insurance and Taxes					$4,243,770
Manufacturing Costs					$40,956,793

3.4 Economic Comparison

To assess the economics of the HTSE case, several economic indicators were calculated. The IRR for low, average, and high hydrogen selling prices was calculated. In addition, the fuel price necessary for a return of 12% was calculated. The following assumptions were made for the economic analyses:

- The plant startup year is 2014
- A construction period of five years for the nuclear plant that begins in 2009
  - It is assumed that all reactors come online at the same time
  - Percent capital invested for the HTGR is 20% per year
- Plant startup time is one year
  - Operating costs are 85% of the total value during startup
  - Revenues are 60% of the total value during startup

- The analysis period for the economic evaluation assumes an economic life of 30 years, excluding construction time (the model is built to accommodate up to 40 years)
- An inflation rate of 2.5% is assumed
- Debt-to-equity ratios of 80%/20% and 55%/45% are calculated; however, results are only presented for 80%/20% as this would be most consistent for an NOAK plant
  - The interest rate on debt is assumed to be 8%
  - The repayment term on the loan is assumed to be 15 years
- The effective income tax rate is 38.9%
  - State tax is 6%
  - Federal tax is 35%
- Modified Accelerated Cost-Recovery System (MACRS) depreciation is assumed.

3.4.1 Cash Flow

To assess the IRR and present worth (PW) of each scenario, it is necessary to calculate the after tax cash flow. To calculate the after tax cash flow (ATCF) it is necessary to first calculate the revenues (R_k), cash outflows (E_k), sum of all noncash, or book, costs such as depreciation (d_k), net income before taxes (NIBT), the effective income tax rate (t), and the income taxes (T_k), for each year (k). The taxable income is revenue minus the sum of all cash outflow and noncash costs. Therefore the income taxes per year are defined as follows:

$$T_k = t(R_k - E_k - d_k) \quad (4)$$

Depreciation for the economic calculations was calculated using a standard MACRS depreciation method with a property class of 15 years. Depreciation was assumed for the total capital investment over the five year construction schedule, including inflation.

Table presents the recovery rates for a 15 year property class:

Table 10. MACRS depreciation.

Year	Recovery Rate	Year	Recovery Rate
1	0.05	9	0.0591
2	0.095	10	0.059
3	0.0855	11	0.0591
4	0.077	12	0.059
5	0.0693	13	0.0591
6	0.0623	14	0.059
7	0.059	15	0.0591
8	0.059	16	0.0295

The ATCF is then the sum of the before tax cash flow (BTCF) minus the income taxes owed. Note that the expenditures for capital are not taxed but are included in the BTCF each year there is a capital expenditure (C_k); this includes the equity capital and the debt principle. The BTCF is defined as follows:

$$BTCF_k = R_k - E_k - C_k \tag{5}$$

The ATCF can then be defined as:

$$ATCF_k = BTCF_k - T_k \tag{6}$$

3.4.2 Internal Rate of Return

The IRR method is the most widely used rate of return method for performing engineering economic analyses. This method solves for the interest rate that equates the equivalent worth of an alternative’s cash inflows to the equivalent worth of cash outflows (after tax cash flow), i.e., the interest rate at which the PW is zero. The resulting interest is the IRR (i'). For the project to be economically viable, the calculated IRR must be greater than the desired minimum annual rate of return (MARR).

$$PW(i'\%) = \sum_{k=0}^{N} ATCF_k \left(1 + i'\right)^{-k} = 0 \tag{7}$$

IRR calculations were performed for an 80%/20% debt-to-equity ratio (results for the 55%/45% ratio can be found in Appendix C for HTSE) for +50% TCI and -30% TCI for the HTGR at low, average, and high prices. In addition, the price of hydrogen necessary for an IRR of 12% and a PW of zero was calculated for each case at each debt-to-equity ratio. The IRR and hydrogen price required (for an IRR of 12%) was solved for using the Goal Seek function in Excel.

4. ECONOMIC MODELING RESULTS

Table 11 presents the results for an 80%/20% debt-to-equity ratio for HTSE. Figure depicts the associated IRR results for HTSE.

Table 11. HTSE connected to a 600 MWt HTGR IRR results for 80%/20% debt-to-equity ratio.

	TCI -30% HTGR		TCI		TCI +50% HTGR	
	IRR	$/kg	IRR	$/kg	IRR	$/kg
	$1,000,417,985		*$1,307,917,985*		*$1,820,417,985*	
HTSE	3.31	$1.50	1.22	$1.50	-1.08	$1.50
	13.79	$3.25	10.28	$3.25	6.70	$3.25
	21.65	$5.00	16.88	$5.00	12.10	$5.00
	12.00	$2.90	12.00	$3.67	12.00	$4.96

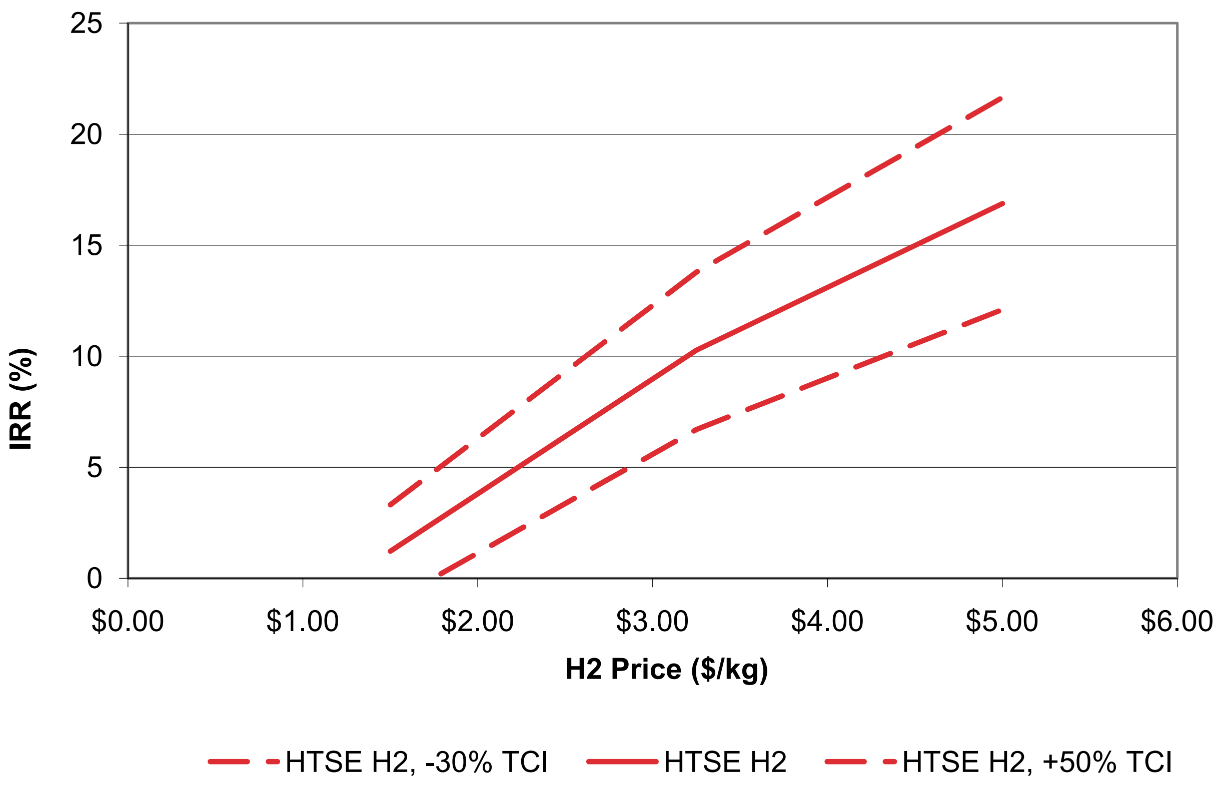

Figure 6. HTSE connected to a 600 MWt HTGR IRR 80%/20% debt-to-equity economic results.

The cost of hydrogen for an 80% debt to 20% equity and a 12% IRR is \$3.67/kg. The cost of the hydrogen ranges from \$2.90/kg to \$4.96 based a +50% to a -30% on the capital cost of the reactor.

It is likely that many industrial processes will require more than 1.75 kg/s of hydrogen. The price of hydrogen production would likely go down if considering economy of scale.

5. CONCLUSIONS AND RECOMMENDATIONS

For a 600 MWt high-temperature gas reactor with an outlet temperature of 750°C dedicated to hydrogen production using HTSE, the following conclusions may be made:

- HTSE delivers 1.75 kg/s of hydrogen and 13.8 kg/s of oxygen
- The hydrogen is produced with no production of carbon dioxide
- Based on a 12% IRR and 80/20 debt-to-equity, the cost of hydrogen is \$3.67/kg
- Total installed capital cost for HTSE is \$82 million
- Total capital investment is \$1.3 billion
- Two-thirds of the installed capital cost for the HTSE process is electrolysis cells excluding the cost of the reactor and power cycle
- 78% of the total capital investment is the reactor cost
- 2,300 gallons per minute of water is needed for the process, most of which is used for the condenser of the power cycle.

For these conclusions, one is assuming NOAK for the reactor and HTSE costs.

Based on an INL report,[2] a 600 MWt reactor with an outlet reactor temperature of 900°C can produce 2.36 kg/s of hydrogen. This is a 35% increase of hydrogen production. The increase is due to an increase in the power cycle efficiency from 40% to 53%, resulting in the higher production of hydrogen. At this temperature the need for topping heat goes away for the HTSE process.

Water is also a major concern due to the cooling need of the power cycle loop. By using an air-cooled tower, the reduction of water usage may be achieved.

It is recommended that:

- A similar analysis, as outlined in this TEV, is performed at a reactor outlet temperature of 900°C

- A process model is developed using air-cooled condensers as opposed to water cooled.
- A similar analysis is performed considering economy of scale.
- A sensitivity analysis of the cell costs should be performed.

6. REFERENCES

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7. APPENDIXES

Appendix A, Steam Methane Reforming Detailed Results

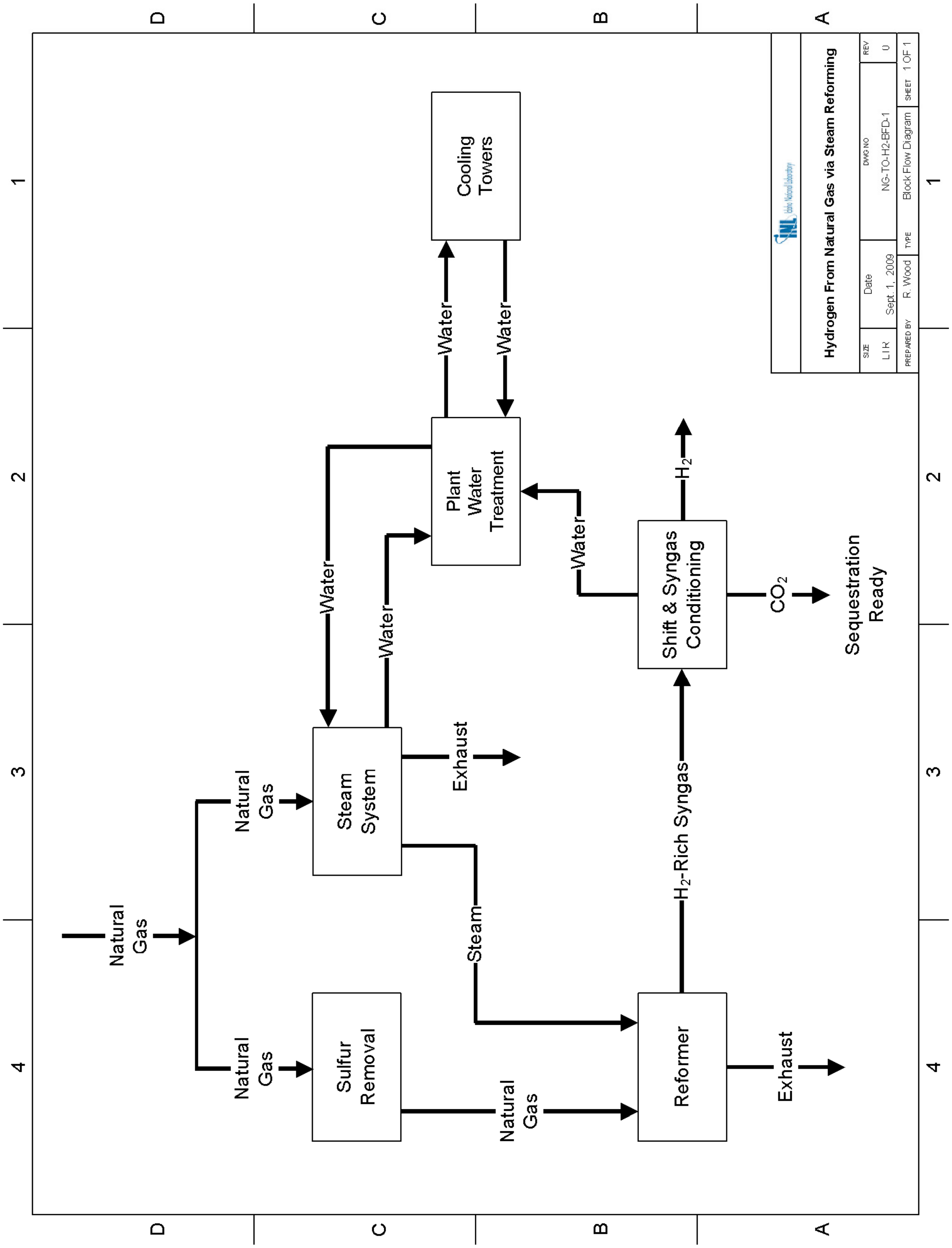
Appendix B, High-Temperature Steam Electrolysis Results

Appendix C, 55%/45% Debt-to-Equity Results

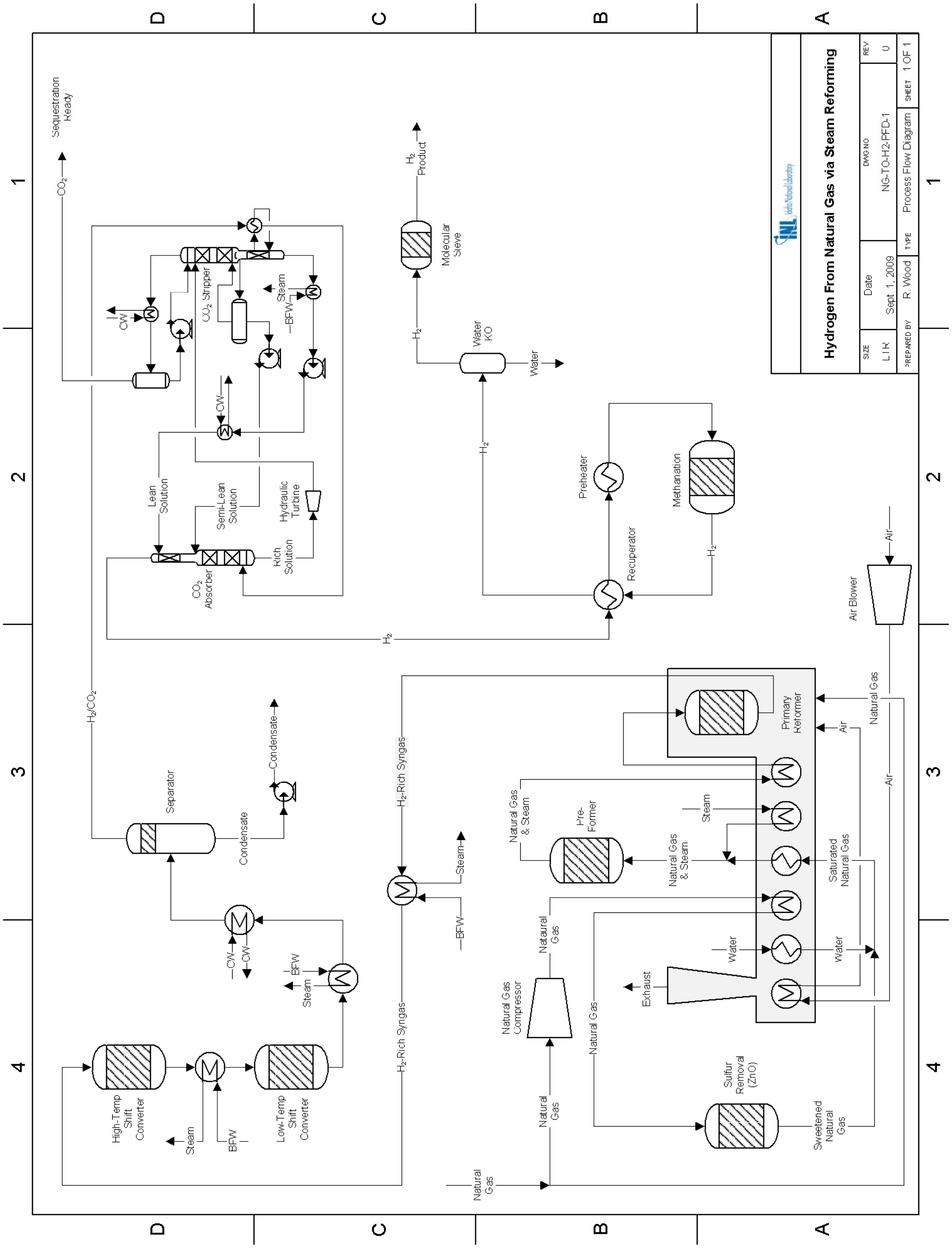
Appendix D, Cost Estimate Support Data Recapitulation

Appendix A
Steam Methane Reforming Detailed Results

The model of the steam methane reforming process and results in Appendix A were developed using Aspen Plus version 2006 (20.0.2.3781) from AspenTech on a desktop computer running Microsoft Windows XP Professional Version 2002 Service Pack 3.


Natural Gas
Natural Gas
Natural Gas
Sulfur Removal
Natural Gas
Steam System
Exhaust
Steam
Reformer
Exhaust
H2-Rich Syngas
Water
Water
Plant Water Treatment
Water
Water
Cooling Towers
Water
Shift & Syngas Conditioning
H2
CO2
Sequestration Ready
Hydrogen From Natural Gas via Steam Reforming
SIZE LTR
Date Sept. 1, 2009
DWG NO NG-TO-H2-BFD-1
REV 0
PREPARED BY R. Wood
TYPE Block Flow Diagram
SHEET 1 OF 1

Appendix A



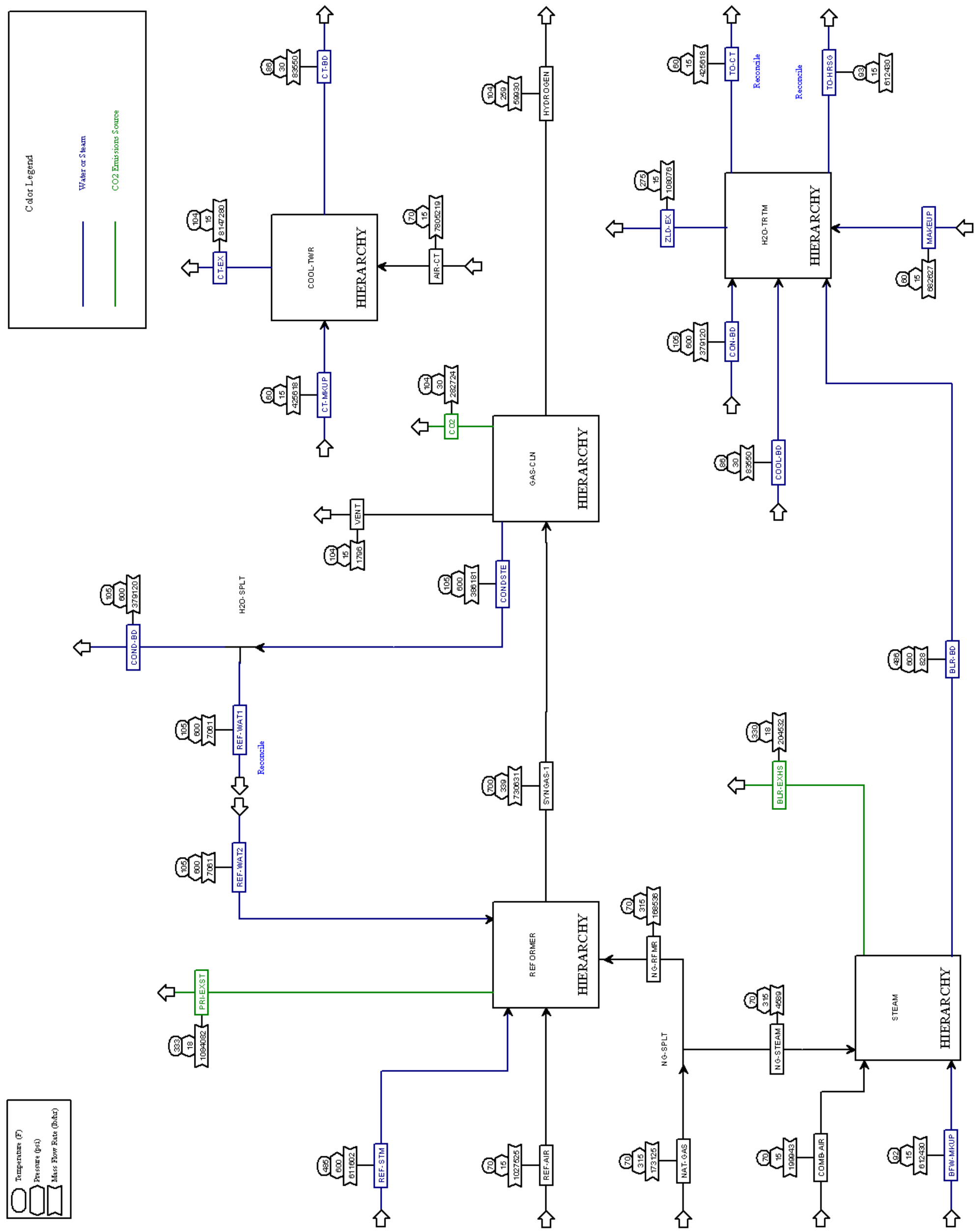
Hydrogen From Natural Gas via Steam Reforming
NG-TO-H2-PFD-1
Process Flow Diagram
Sept 1, 2009
R. Wood
1 OF 1
Primary Reformer
Pre-Former
Sulfur Removal (ZnO)
Natural Gas Compressor
Air Blower
High-Temp Shift Converter
Low-Temp Shift Converter
Separator
CO2 Absorber
CO2 Stripper
Hydraulic Turbine
Recuperator
Preheater
Methanation
Water KO
Molecular Sieve
H2 Product
CO2 Sequestration Ready
Lean Solution
Semi-Lean Solution
Rich Solution
H2-Rich Syngas
Condensate
Natural Gas
Sweetened Natural Gas
Saturated Natural Gas
Natural Gas & Steam
Exhaust

```
                    H2 Production from Natural Gas Summary
Calculator Block SUMMARY

   FEED SUMMARY:

     NATURAL GAS PROPERTIES:

       MASS FLOW =                         2078. TON/DY
       VOLUME FLOW =                         92. MMSCFD @ 60°F
       HHV =                              23061. BTU/LB
       HHV =                               1044. BTU/SCF @ 60°F
       ENERGY FLOW =                      95820. MMBTU/DY

       COMPOSITION:
          METHANE =                         93.568 MOL.%
          ETHANE =                           3.749 MOL.%
          PROPANE =                          0.920 MOL.%
          BUTANE =                           0.260 MOL.%
          PENTANE =                          0.040 MOL.%
          HEXANE =                           0.010 MOL.%
          NITROGEN =                         1.190 MOL.%
          OXYGEN =                           0.010 MOL.%
          CO2 =                              0.250 MOL.%
          C4H10S =                          30. PPMV
          C2H6S =                            3. PPMV
          H2S =                              5. PPMV

   INTERMEDIATE PRODUCT SUMMARY:

     RAW SYNGAS MASS FLOW =              730631. LB/HR
     RAW SYNGAS VOLUME FLOW =               490. MMSCFD @ 60°F
     RAW SYNGAS COMPOSITION:
       H2                                   41.0 MOL.%
       CO                                    6.3 MOL.%
       CO2                                   5.7 MOL.%
       N2                                    0.1 MOL.%
       H2O                                  46.1 MOL.%
       CH4                                   0.7 MOL.%

   FINAL PRODUCT SUMMARY:

     HYDROGEN MASS FLOW =                 59930. LB/HR
     HYDROGEN VOLUME FLOW =                 234. MMSCFD @ 60°F
     HYDROGEN COMPOSITION:
       H2                                   98.0 MOL.%
       N2                                    0.3 MOL.%
       CH4                                   1.7 MOL.%
       CO                                    0. PPMV
       CO2                                   0. PPMV
       H2O                                   1. PPMV
     H2 PRODUCED / NATURAL GAS FED =         0.346 LB/LB

     CARBON DIOXIDE MASS FLOW =          282724. LB/HR
     CARBON DIOXIDE VOLUME FLOW =            59. MMSCFD @ 60°F
     CARBON DIOXIDE COMPOSITION:
       CO2                                  99.3 MOL.%
       H2                                    0.6 MOL.%
       N2                                    0. PPMV
       CH4                                   0. PPMV
       CO                                    0. PPMV
       H2O                                   1. PPMV


   POWER SUMMARY:
```

```
                 H2 Production from Natural Gas Summary
   ELECTRICAL CONSUMERS:
     NG REFORMER POWER CONSUMPTION =          3.5 MW
     GAS CLEANING POWER CONSUMPTION =         3.6 MW
     POWER BLOCK POWER CONSUMPTION =          1.0 MW
     CO2 PROCESSING POWER CONSUMPTION =       0.0 MW
     AMMONIA SYNTH. POWER CONSUMPTION =       0.0 MW
     UREA SYNTHESIS POWER CONSUMPTION =       0.0 MW
     HNO3 SYNTHESIS POWER CONSUMPTION =       0.0 MW
     NH4NO3 SYNTH. POWER CONSUMPTION =        0.0 MW
     COOLING TOWER POWER CONSUMPTION =        0.5 MW
     WATER TREATMENT POWER CONSUMPTION =      2.8 MW
   CONSUMER SUBTOTAL =                       11.5 MW

   NET PLANT POWER CONSUMPTION =             11.5 MW


 WATER BALANCE:

   EVAPORATIVE LOSSES:
     COOLING TOWER EVAPORATION =            807.8 GPM
     ZLD SYSTEM EVAPORATION =               216.0 GPM
   TOTAL EVAPORATIVE LOSSES =              1023.8 GPM

   WATER CONSUMED:
     BOILER FEED WATER MAKEUP =            1223.9 GPM
     COOLING TOWER MAKEUP =                 850.6 GPM
   TOTAL WATER CONSUMED =                  2074.4 GPM

   WATER GENERATED:
     GAS CLEANING CONDENSATE =              757.6 GPM
     BOILER BLOWDOWN =                        1.7 GPM
     COOLING TOWER BLOWDOWN =               167.0 GPM
   TOTAL WATER GENERATED =                  926.3 GPM

   PLANT WATER SUMMARY:
     NET MAKEUP WATER REQUIRED =           1364.2 GPM
     WATER CONSUMED / NG FED =                3.94 LB/LB


 CO2 BALANCE:

   CO2 EMITTED (TOTAL) =                   5378. TON/DY
   CO2 EMITTED (TOTAL) =                     93. MMSCFD @ 60°F
     FROM HRSG =                            150. TON/DY
     FROM REFORMER =                       1838. TON/DY
     FROM GAS CLEANING =                   3390. TON/DY
       (THIS SOURCE IS "SEQUESTRATION READY")
   CO2 EMITTED / NG FED =                     2.59 LB/LB

Calculator Block NG-RFMR  Hierarchy: REFORMER

 SULFUR REMOVAL CONDITIONS:

   INLET BED TEMPERATURE =                 304. °F

 PREFORMER CONDITIONS:

   INLET TEMPERATURE =                     925. °F
   STEAM TO CARBON MOLAR RATIO =             5.00

 PRIMARY REFORMER CONDITIONS:

   INLET TEMPERATURE =                    1292. °F
```

```
              H2 Production from Natural Gas Summary
     STEAM TO CARBON MOLAR RATIO =          4.77
     NATURAL GAS BURNED FOR HEAT =         33.56 %
     OUTLET TEMPERATURE =                1598. °F
     METHANE CONVERSION =                  93.8 %


 Calculator Block AIRPROPS

   HUMIDITY DATA FOR STREAM PRI-AIR:
     HUMIDITY RATIO =                       43.5 GRAINS/LB
     RELATIVE HUMIDITY =                    39.0 %
```

Hydrogen from Natural Gas



	AIR-CT	BFW-MKUP	BLR-BD	BLR-EXHS	CO2
Temperature F	70	92.4	486.3	330.4	104
Pressure psi	14.7	14.7	600	17.7	30
Vapor Frac	1	0	1	1	1
Mole Flow lbmol/hr	270488.931	33995.058	45.948	7204.534	6466.603
Mass Flow lb/hr	7.81E+06	612430.495	827.772	204531.946	282723.87
Volume Flow cuft/hr	1.05E+08	9864.271	637.439	3.45E+06	1.29E+06
Enthalpy MMBtu/hr	-305.429	-4170.543	-4.691	-98.709	-1085.797
Dew Temp					
	AIR-CT	BFW-MKUP	BLR-BD	BLR-EXHS	CO2
Mass Flow lb/hr					
H2O	48246.87	612430.495	827.772	11048.904	33.262
O2	1.80E+06	0	0	28378.321	0
N2	5.85E+06	0	0	150049.771	0
AR	100565.963	0	0	2576.154	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	53.987	0	0	0	81.988
CO	0	0	0	0	17.23
CO2	3535.89	0	0	12478.146	282531.577
H2S	0	0	0	0	0
SO2	0	0	0	0.65	0
METHANE	0	0	0	0	59.813
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0.001
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	AIR-CT	BFW-MKUP	BLR-BD	BLR-EXHS	CO2
Mass Frac					
H2O	0.006	1	1	0.054	0
O2	0.23	0	0	0.139	0
N2	0.75	0	0	0.734	0
AR	0.013	0	0	0.013	0

NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0.061	0.999
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	AIR-CT	BFW-MKUP	BLR-BD	BLR-EXHS	CO2
Mole Flow lbmol/hr					
H2O	2678.108	33995.058	45.948	613.307	1.846
O2	56213.492	0	0	886.856	0
N2	208972.785	0	0	5356.342	0
AR	2517.422	0	0	64.488	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	26.781	0	0	0	40.671
CO	0	0	0	0	0.615
CO2	80.343	0	0	283.531	6419.742
H2S	0	0	0	0	0
SO2	0	0	0	0.01	0
METHANE	0	0	0	0	3.728
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0

S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	AIR-CT	BFW-MKUP	BLR-BD	BLR-EXHS	CO2
Mole Frac					
H2O	0.01	1	1	0.085	0
O2	0.208	0	0	0.123	0
N2	0.773	0	0	0.743	0
AR	0.009	0	0	0.009	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0.006
CO	0	0	0	0	0
CO2	0	0	0	0.039	0.993
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0.001
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	28.856	18.015	18.015	28.389	43.721
RELHUMID					

	COMB-AIR	CON-BD	COND-BD	CONDSTE	COOL-BD
Temperature F	70	104.6	104.6	104.6	86
Pressure psi	14.7	600	600	600	30
Vapor Frac	1	0	0	0	0
Mole Flow lbmol/hr	6928.996	21042.898	21042.898	21434.816	4635.597
Mass Flow lb/hr	199942.946	379120.155	379120.155	386181.143	83549.613
Volume Flow cuft/hr	2.68E+06	7234.099	7234.099	7368.831	1343.362
Enthalpy MMBtu/hr	-7.85	-2590.846	-2590.846	-2639.099	-568.888
Dew Temp					
	COMB-AIR	CON-BD	COND-BD	CONDSTE	COOL-BD
Mass Flow lb/hr					
H2O	1235.919	379022.477	379022.477	386081.646	83450.127
O2	46078.155	0	0	0	26.057
N2	149960.757	0.002	0.002	0.002	71.281
AR	2576.154	0	0	0	1.545
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	44.763	44.763	45.596	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	1.383	0.253	0.253	0.257	0
CO	0	0.002	0.002	0.002	0
CO2	90.577	52.569	52.569	53.548	0.602
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0.089	0.089	0.091	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	COMB-AIR	CON-BD	COND-BD	CONDSTE	COOL-BD
Mass Frac					
H2O	0.006	1	1	1	0.999
O2	0.23	0	0	0	0
N2	0.75	0	0	0	0.001
AR	0.013	0	0	0	0

NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	COMB-AIR	CON-BD	COND-BD	CONDSTE	COOL-BD
Mole Flow lbmol/hr					
H2O	68.604	21038.945	21038.945	21430.788	4632.186
O2	1439.996	0	0	0	0.814
N2	5353.164	0	0	0	2.545
AR	64.488	0	0	0	0.039
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	2.628	2.628	2.677	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.686	0.125	0.125	0.128	0
CO	0	0	0	0	0
CO2	2.058	1.194	1.194	1.217	0.014
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0.006	0.006	0.006	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0

S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	COMB-AIR	CON-BD	COND-BD	CONDSTE	COOL-BD
Mole Frac					
H2O	0.01	1	1	1	0.999
O2	0.208	0	0	0	0
N2	0.773	0	0	0	0.001
AR	0.009	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	28.856	18.017	18.017	18.017	18.023
RELHUMID					

	CT-BD	CT-EX	CT-MKUP	HYDROGEN	MAKEUP
Temperature F	86	104.1	60	104	60
Pressure psi	30	14.7	14.7	259.29	14.7
Vapor Frac	0	0.996	0	1	0
Mole Flow lbmol/hr	4635.597	289771.942	23625.388	25664.228	37891.551
Mass Flow lb/hr	83549.613	8.15E+06	425617.984	59930.173	682626.908
Volume Flow cuft/hr	1343.362	1.19E+08	6823.637	601993.862	12820.295
Enthalpy MMBtu/hr	-568.888	-2315.3	-2912.212	-9.599	-4699.571
Dew Temp					
	CT-BD	CT-EX	CT-MKUP	HYDROGEN	MAKEUP
Mass Flow lb/hr					
H2O	83450.127	404232.525	425617.984	0.462	682626.908
O2	26.057	1.80E+06	0	0	0
N2	71.281	5.84E+06	0	2135.195	0
AR	1.545	100349.774	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	53.979	0	50689.51	0
CO	0	0	0	0	0
CO2	0.602	3451.702	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	7105.005	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	CT-BD	CT-EX	CT-MKUP	HYDROGEN	MAKEUP
Mass Frac					
H2O	0.999	0.05	1	0	1
O2	0	0.22	0	0	0
N2	0.001	0.717	0	0.036	0
AR	0	0.012	0	0	0

NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0.846	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.119	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	CT-BD	CT-EX	CT-MKUP	HYDROGEN	MAKEUP
Mole Flow lbmol/hr					
H2O	4632.186	22438.315	23625.388	0.026	37891.551
O2	0.814	56099.578	0	0	0
N2	2.545	208616.832	0	76.22	0
AR	0.039	2512.01	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	26.777	0	25145.103	0
CO	0	0	0	0	0
CO2	0.014	78.43	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	442.879	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0

S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	CT-BD	CT-EX	CT-MKUP	HYDROGEN	MAKEUP
Mole Frac					
H2O	0.999	0.077	1	0	1
O2	0	0.194	0	0	0
N2	0.001	0.72	0	0.003	0
AR	0	0.009	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0.98	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.017	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	18.023	28.116	18.015	2.335	18.015
RELHUMID					

	NAT-GAS	NG-RFMR	NG-STEAM	PRI-EXST	REF-AIR
Temperature F	70	70	70	333	70
Pressure psi	314.7	314.7	314.7	17.7	14.7
Vapor Frac	1	1	1	1	1
Mole Flow lbmol/hr	10076.025	9808.941	267.084	39007.232	35608.693
Mass Flow lb/hr	173125	168536	4589	1.08E+06	1.03E+06
Volume Flow cuft/hr	172389.296	167819.797	4569.499	1.87E+07	1.38E+07
Enthalpy MMBtu/hr	-330.118	-321.367	-8.75	-1249.957	-40.344
Dew Temp					
	NAT-GAS	NG-RFMR	NG-STEAM	PRI-EXST	REF-AIR
Mass Flow lb/hr					
H2O	0	0	0	127210.398	6351.491
O2	32.234	31.38	0.854	18723.078	236799.503
N2	3358.149	3269.135	89.014	771758.021	770660.899
AR	0	0	0	13239.072	13239.072
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	7.107
CO	0	0	0	0	0
CO2	1108.346	1078.967	29.379	153145.658	465.485
H2S	1.717	1.671	0.046	0	0
SO2	0	0	0	8.012	0
METHANE	151249.661	147240.507	4009.153	0	0
METHANOL	0	0	0	0	0
ETHANE	11359.138	11058.043	301.095	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	1.878	1.828	0.05	0	0
C4H10S	27.256	26.534	0.722	0	0
PROPANE	4086.75	3978.423	108.327	0	0
BUTANE	1522.335	1481.983	40.352	0	0
PENTANE	290.726	283.02	7.706	0	0
HEXANE	86.812	84.511	2.301	0	0
	NAT-GAS	NG-RFMR	NG-STEAM	PRI-EXST	REF-AIR
Mass Frac					
H2O	0	0	0	0.117	0.006
O2	0	0	0	0.017	0.23
N2	0.019	0.019	0.019	0.712	0.75
AR	0	0	0	0.012	0.013

NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0.006	0.006	0.006	0.141	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.874	0.874	0.874	0	0
METHANOL	0	0	0	0	0
ETHANE	0.066	0.066	0.066	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.024	0.024	0.024	0	0
BUTANE	0.009	0.009	0.009	0	0
PENTANE	0.002	0.002	0.002	0	0
HEXANE	0.001	0.001	0.001	0	0
	NAT-GAS	NG-RFMR	NG-STEAM	PRI-EXST	REF-AIR
Mole Flow lbmol/hr					
H2O	0	0	0	7061.25	352.561
O2	1.007	0.981	0.027	585.118	7400.262
N2	119.876	116.699	3.178	27549.523	27510.359
AR	0	0	0	331.408	331.408
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	3.526
CO	0	0	0	0	0
CO2	25.184	24.517	0.668	3479.808	10.577
H2S	0.05	0.049	0.001	0	0
SO2	0	0	0	0.125	0
METHANE	9427.908	9178.003	249.904	0	0
METHANOL	0	0	0	0	0
ETHANE	377.761	367.748	10.013	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0

	NAT-GAS	NG-RFMR	NG-STEAM	PRI-EXST	REF-AIR
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0.03	0.029	0.001	0	0
C4H10S	0.302	0.294	0.008	0	0
PROPANE	92.677	90.221	2.457	0	0
BUTANE	26.191	25.497	0.694	0	0
PENTANE	4.029	3.923	0.107	0	0
HEXANE	1.007	0.981	0.027	0	0
	NAT-GAS	NG-RFMR	NG-STEAM	PRI-EXST	REF-AIR
Mole Frac					
H2O	0	0	0	0.181	0.01
O2	0	0	0	0.015	0.208
N2	0.012	0.012	0.012	0.706	0.773
AR	0	0	0	0.008	0.009
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0.002	0.002	0.002	0.089	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.936	0.936	0.936	0	0
METHANOL	0	0	0	0	0
ETHANE	0.037	0.037	0.037	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.009	0.009	0.009	0	0
BUTANE	0.003	0.003	0.003	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	17.182	17.182	17.182	27.792	28.856
RELHUMID					

	REF-STM	REF-WAT1	REF-WAT2	SYNGAS-1	TO-CT
Temperature F	485.2	104.6	104.6	700	60
Pressure psi	600	600	600	338.59	14.7
Vapor Frac	1	0	0	1	0
Mole Flow lbmol/hr	33949.11	391.917	391.917	53812.435	23625.388
Mass Flow lb/hr	611602.723	7060.989	7060.989	730631.091	425617.984
Volume Flow cuft/hr	486069.137	134.733	134.733	1.96E+06	7993.456
Enthalpy MMBtu/hr	-3447.229	-48.254	-48.254	-3018.264	-2930.183
Dew Temp					
	REF-STM	REF-WAT1	REF-WAT2	SYNGAS-1	TO-CT
Mass Flow lb/hr					
H2O	611602.723	7059.169	7059.169	446631.689	425617.984
O2	0	0	0	0	0
N2	0	0	0	2129.142	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0.834	0.834	52.96	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0.005	0.005	44497.141	0
CO	0	0	0	95449.064	0
CO2	0	0.979	0.979	135889.567	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0.002	0.002	5981.418	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0.11	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	REF-STM	REF-WAT1	REF-WAT2	SYNGAS-1	TO-CT
Mass Frac					
H2O	1	1	1	0.611	1
O2	0	0	0	0	0
N2	0	0	0	0.003	0
AR	0	0	0	0	0

NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0.061	0
CO	0	0	0	0.131	0
CO2	0	0	0	0.186	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.008	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	REF-STM	REF-WAT1	REF-WAT2	SYNGAS-1	TO-CT
Mole Flow lbmol/hr					
H2O	33949.11	391.843	391.843	24791.826	23625.388
O2	0	0	0	0	0
N2	0	0	0	76.004	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0.049	0.049	3.11	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0.002	0.002	22073.308	0
CO	0	0	0	3407.629	0
CO2	0	0.022	0.022	3087.712	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	372.842	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0.004	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0

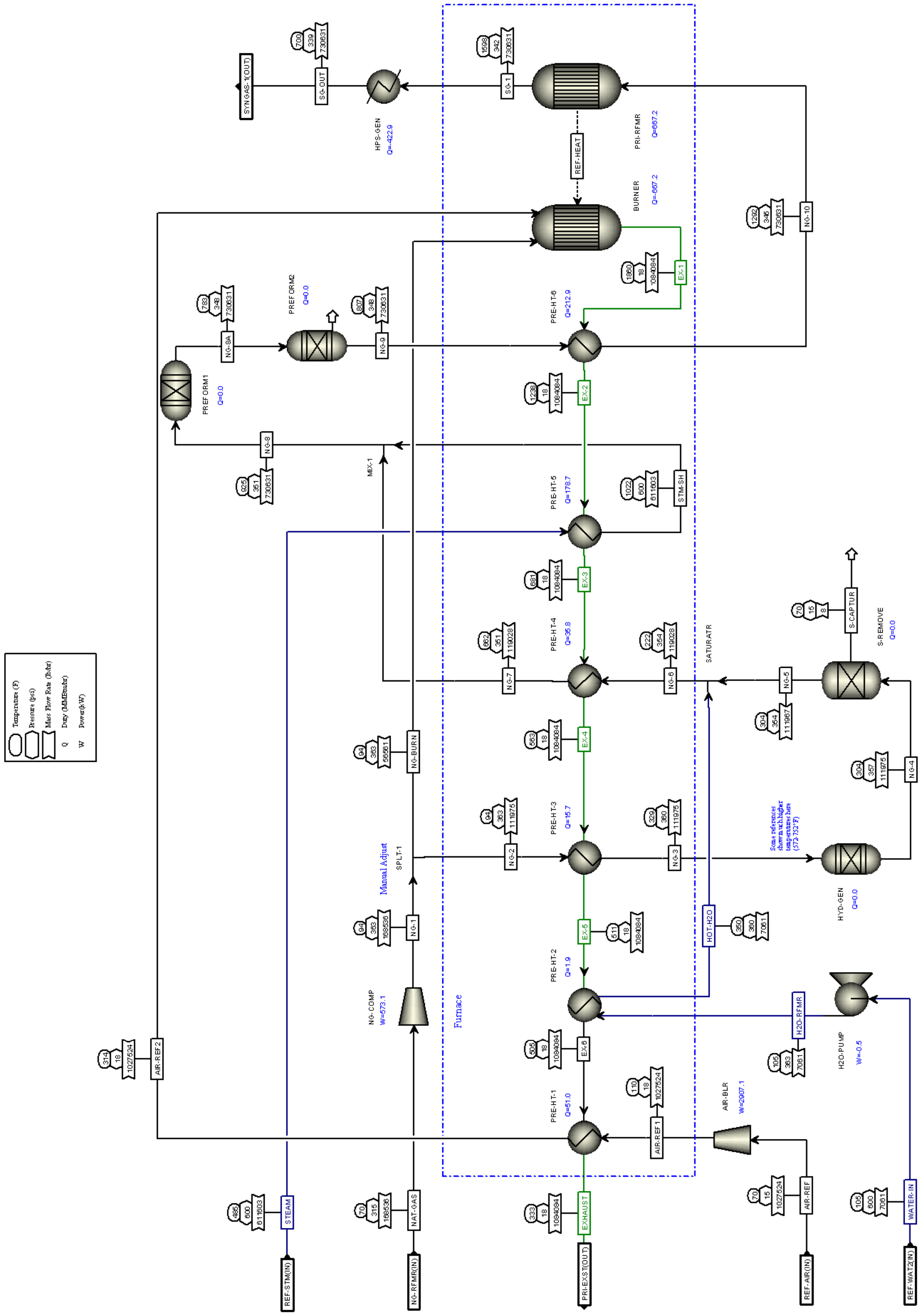
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	REF-STM	REF-WAT1	REF-WAT2	SYNGAS-1	TO-CT
Mole Frac					
H2O	1	1	1	0.461	1
O2	0	0	0	0	0
N2	0	0	0	0.001	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0.41	0
CO	0	0	0	0.063	0
CO2	0	0	0	0.057	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.007	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	18.015	18.017	18.017	13.577	18.015
RELHUMID					

	TO-HRSG	VENT	ZLD-EX
Temperature F	92.8	104	275
Pressure psi	14.7	14.7	14.7
Vapor Frac	0	0	1
Mole Flow lbmol/hr	33992.016	99.68	5998.591
Mass Flow lb/hr	612430.495	1795.76	108075.97
Volume Flow cuft/hr	13280.745	34.276	3.20E+06
Enthalpy MMBtu/hr	-4193.74	-12.278	-614.532
Dew Temp			
	TO-HRSG	VENT	ZLD-EX
Mass Flow lb/hr			
H2O	612262.904	1795.76	108046.395
O2	22.149	0	3.909
N2	60.592	0	10.693
AR	1.314	0	0.232
NO	0	0	0
NO2	0	0	0
N2O4	0	0	0
NH3	38.048	0	6.714
HNO3	0	0	0
NH4NO3	0	0	0
H2	0.215	0	0.038
CO	0.002	0	0
CO2	45.195	0	7.976
H2S	0	0	0
SO2	0	0	0
METHANE	0.076	0	0.013
METHANOL	0	0	0
ETHANE	0	0	0
ETHYLENE	0	0	0
C	0	0	0
S	0	0	0
UREA	0	0	0
CARB	0	0	0
ZNO	0	0	0
ZNS	0	0	0
C2H6S	0	0	0
C4H10S	0	0	0
PROPANE	0	0	0
BUTANE	0	0	0
PENTANE	0	0	0
HEXANE	0	0	0
	TO-HRSG	VENT	ZLD-EX
Mass Frac			
H2O	1	1	1
O2	0	0	0
N2	0	0	0
AR	0	0	0

NO	0	0	0
NO2	0	0	0
N2O4	0	0	0
NH3	0	0	0
HNO3	0	0	0
NH4NO3	0	0	0
H2	0	0	0
CO	0	0	0
CO2	0	0	0
H2S	0	0	0
SO2	0	0	0
METHANE	0	0	0
METHANOL	0	0	0
ETHANE	0	0	0
ETHYLENE	0	0	0
C	0	0	0
S	0	0	0
UREA	0	0	0
CARB	0	0	0
ZNO	0	0	0
ZNS	0	0	0
C2H6S	0	0	0
C4H10S	0	0	0
PROPANE	0	0	0
BUTANE	0	0	0
PENTANE	0	0	0
HEXANE	0	0	0
	TO-HRSG	VENT	ZLD-EX
Mole Flow lbmol/hr			
H2O	33985.756	99.68	5997.486
O2	0.692	0	0.122
N2	2.163	0	0.382
AR	0.033	0	0.006
NO	0	0	0
NO2	0	0	0
N2O4	0	0	0
NH3	2.234	0	0.394
HNO3	0	0	0
NH4NO3	0	0	0
H2	0.106	0	0.019
CO	0	0	0
CO2	1.027	0	0.181
H2S	0	0	0
SO2	0	0	0
METHANE	0.005	0	0.001
METHANOL	0	0	0
ETHANE	0	0	0
ETHYLENE	0	0	0
C	0	0	0

	TO-HRSG	VENT	ZLD-EX
S	0	0	0
UREA	0	0	0
CARB	0	0	0
ZNO	0	0	0
ZNS	0	0	0
C2H6S	0	0	0
C4H10S	0	0	0
PROPANE	0	0	0
BUTANE	0	0	0
PENTANE	0	0	0
HEXANE	0	0	0
	TO-HRSG	VENT	ZLD-EX
Mole Frac			
H2O	1	1	1
O2	0	0	0
N2	0	0	0
AR	0	0	0
NO	0	0	0
NO2	0	0	0
N2O4	0	0	0
NH3	0	0	0
HNO3	0	0	0
NH4NO3	0	0	0
H2	0	0	0
CO	0	0	0
CO2	0	0	0
H2S	0	0	0
SO2	0	0	0
METHANE	0	0	0
METHANOL	0	0	0
ETHANE	0	0	0
ETHYLENE	0	0	0
C	0	0	0
S	0	0	0
UREA	0	0	0
CARB	0	0	0
ZNO	0	0	0
ZNS	0	0	0
C2H6S	0	0	0
C4H10S	0	0	0
PROPANE	0	0	0
BUTANE	0	0	0
PENTANE	0	0	0
HEXANE	0	0	0
MWMX	18.017	18.015	18.017
RELHUMID			

Natural Gas Steam Reforming



	AIR-REF	AIR-REF1	AIR-REF2	EX-1	EX-2
Temperature F	70	110	314	1860.2	1238.4
Pressure psi	14.7	17.7	17.7	17.7	17.7
Vapor Frac	1	1	1	1	1
Mole Flow lbmol/hr	35608.693	35608.693	35608.693	39007.232	39007.232
Mass Flow lb/hr	1.03E+06	1.03E+06	1.03E+06	1.08E+06	1.08E+06
Volume Flow cuft/hr	1.38E+07	1.23E+07	1.67E+07	5.49E+07	4.02E+07
Enthalpy MMBtu/hr	-40.344	-30.425	20.605	-753.822	-966.695
	AIR-REF	AIR-REF1	AIR-REF2	EX-1	EX-2
Mass Flow lb/hr					
H2O	6351.491	6351.491	6351.491	127210.398	127210.398
O2	236799.503	236799.503	236799.503	18723.078	18723.078
N2	770660.899	770660.899	770660.899	771758.021	771758.021
AR	13239.072	13239.072	13239.072	13239.072	13239.072
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	7.107	7.107	7.107	0	0
CO	0	0	0	0	0
CO2	465.485	465.485	465.485	153145.658	153145.658
H2S	0	0	0	0	0
SO2	0	0	0	8.012	8.012
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	AIR-REF	AIR-REF1	AIR-REF2	EX-1	EX-2
Mass Frac					
H2O	0.006	0.006	0.006	0.117	0.117
O2	0.23	0.23	0.23	0.017	0.017
N2	0.75	0.75	0.75	0.712	0.712
AR	0.013	0.013	0.013	0.012	0.012
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0.141	0.141
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	AIR-REF	AIR-REF1	AIR-REF2	EX-1	EX-2
Mole Flow lbmol/hr					
H2O	352.561	352.561	352.561	7061.25	7061.25
O2	7400.262	7400.262	7400.262	585.118	585.118
N2	27510.359	27510.359	27510.359	27549.523	27549.523
AR	331.408	331.408	331.408	331.408	331.408
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	3.526	3.526	3.526	0	0
CO	0	0	0	0	0
CO2	10.577	10.577	10.577	3479.808	3479.808
H2S	0	0	0	0	0
SO2	0	0	0	0.125	0.125
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	AIR-REF	AIR-REF1	AIR-REF2	EX-1	EX-2
Mole Frac					
H2O	0.01	0.01	0.01	0.181	0.181
O2	0.208	0.208	0.208	0.015	0.015
N2	0.773	0.773	0.773	0.706	0.706
AR	0.009	0.009	0.009	0.008	0.008
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0.089	0.089
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	EX-3	EX-4	EX-5	EX-6	EXHAUST
Temperature F	680.8	563.4	511.2	504.8	333
Pressure psi	17.7	17.7	17.7	17.7	17.7
Vapor Frac	1	1	1	1	1
Mole Flow lbmol/hr	39007.232	39007.232	39007.232	39007.232	39007.232
Mass Flow lb/hr	1.08E+06	1.08E+06	1.08E+06	1.08E+06	1.08E+06
Volume Flow cuft/hr	2.70E+07	2.42E+07	2.30E+07	2.28E+07	1.87E+07
Enthalpy MMBtu/hr	-1145.434	-1181.278	-1197.012	-1198.928	-1249.957
	EX-3	EX-4	EX-5	EX-6	EXHAUST
Mass Flow lb/hr					
H2O	127210.398	127210.398	127210.398	127210.398	127210.398
O2	18723.078	18723.078	18723.078	18723.078	18723.078
N2	771758.021	771758.021	771758.021	771758.021	771758.021
AR	13239.072	13239.072	13239.072	13239.072	13239.072
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	153145.658	153145.658	153145.658	153145.658	153145.658
H2S	0	0	0	0	0
SO2	8.012	8.012	8.012	8.012	8.012
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	EX-3	EX-4	EX-5	EX-6	EXHAUST
Mass Frac					
H2O	0.117	0.117	0.117	0.117	0.117
O2	0.017	0.017	0.017	0.017	0.017
N2	0.712	0.712	0.712	0.712	0.712
AR	0.012	0.012	0.012	0.012	0.012
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0.141	0.141	0.141	0.141	0.141
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	EX-3	EX-4	EX-5	EX-6	EXHAUST
Mole Flow lbmol/hr					
H2O	7061.25	7061.25	7061.25	7061.25	7061.25
O2	585.118	585.118	585.118	585.118	585.118
N2	27549.523	27549.523	27549.523	27549.523	27549.523
AR	331.408	331.408	331.408	331.408	331.408
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	3479.808	3479.808	3479.808	3479.808	3479.808
H2S	0	0	0	0	0
SO2	0.125	0.125	0.125	0.125	0.125
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	EX-3	EX-4	EX-5	EX-6	EXHAUST
Mole Frac					
H2O	0.181	0.181	0.181	0.181	0.181
O2	0.015	0.015	0.015	0.015	0.015
N2	0.706	0.706	0.706	0.706	0.706
AR	0.008	0.008	0.008	0.008	0.008
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0.089	0.089	0.089	0.089	0.089
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	H2O-RFMR	HOT-H2O	LIQ	NAT-GAS	NG-1
Temperature F	105	350		70	94.2
Pressure psi	362.59	359.59	347.59	314.7	362.59
Vapor Frac	0	0		1	1
Mole Flow lbmol/hr	391.917	391.917	0	9808.941	9808.941
Mass Flow lb/hr	7060.989	7060.989	0	168536	168536
Volume Flow cuft/hr	134.783	154.085	0	167819.797	152520.256
Enthalpy MMBtu/hr	-48.255	-46.34		-321.367	-319.412
	H2O-RFMR	HOT-H2O	LIQ	NAT-GAS	NG-1
Mass Flow lb/hr					
H2O	7059.169	7059.169	0	0	0
O2	0	0	0	31.38	31.38
N2	0	0	0	3269.135	3269.135
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0.834	0.834	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.005	0.005	0	0	0
CO	0	0	0	0	0
CO2	0.979	0.979	0	1078.967	1078.967
H2S	0	0	0	1.671	1.671
SO2	0	0	0	0	0
METHANE	0.002	0.002	0	147240.507	147240.507
METHANOL	0	0	0	0	0
ETHANE	0	0	0	11058.043	11058.043
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	1.828	1.828
C4H10S	0	0	0	26.534	26.534
PROPANE	0	0	0	3978.423	3978.423
BUTANE	0	0	0	1481.983	1481.983
PENTANE	0	0	0	283.02	283.02
HEXANE	0	0	0	84.511	84.511
	H2O-RFMR	HOT-H2O	LIQ	NAT-GAS	NG-1
Mass Frac					
H2O	1	1		0	0
O2	0	0		0	0
N2	0	0		0.019	0.019
AR	0	0		0	0
NO	0	0		0	0

NO2	0	0		0	0
N2O4	0	0		0	0
NH3	0	0		0	0
HNO3	0	0		0	0
NH4NO3	0	0		0	0
H2	0	0		0	0
CO	0	0		0	0
CO2	0	0		0.006	0.006
H2S	0	0		0	0
SO2	0	0		0	0
METHANE	0	0		0.874	0.874
METHANOL	0	0		0	0
ETHANE	0	0		0.066	0.066
ETHYLENE	0	0		0	0
C	0	0		0	0
S	0	0		0	0
UREA	0	0		0	0
CARB	0	0		0	0
ZNO	0	0		0	0
ZNS	0	0		0	0
C2H6S	0	0		0	0
C4H10S	0	0		0	0
PROPANE	0	0		0.024	0.024
BUTANE	0	0		0.009	0.009
PENTANE	0	0		0.002	0.002
HEXANE	0	0		0.001	0.001
	H2O-RFMR	HOT-H2O	LIQ	NAT-GAS	NG-1
Mole Flow lbmol/hr					
H2O	391.843	391.843	0	0	0
O2	0	0	0	0.981	0.981
N2	0	0	0	116.699	116.699
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0.049	0.049	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.002	0.002	0	0	0
CO	0	0	0	0	0
CO2	0.022	0.022	0	24.517	24.517
H2S	0	0	0	0.049	0.049
SO2	0	0	0	0	0
METHANE	0	0	0	9178.003	9178.003
METHANOL	0	0	0	0	0
ETHANE	0	0	0	367.748	367.748
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0.029	0.029
C4H10S	0	0	0	0.294	0.294
PROPANE	0	0	0	90.221	90.221
BUTANE	0	0	0	25.497	25.497
PENTANE	0	0	0	3.923	3.923
HEXANE	0	0	0	0.981	0.981

	H2O-RFMR	HOT-H2O	LIQ	NAT-GAS	NG-1
Mole Frac					
H2O	1	1	0	0	0
O2	0	0	0	0	0
N2	0	0	0	0.012	0.012
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0.002	0.002
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.936	0.936
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0.037	0.037
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0.009	0.009
BUTANE	0	0	0	0.003	0.003
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	NG-2	NG-3	NG-4	NG-5	NG-6
Temperature F	94.2	329	303.9	303.9	221.6
Pressure psi	362.59	359.59	356.59	353.59	353.59
Vapor Frac	1	1	1	1	0.999
Mole Flow lbmol/hr	6517.06	6517.06	6549.886	6549.638	6941.555
Mass Flow lb/hr	111975.318	111975.318	111975.318	111967.379	119028.368
Volume Flow cuft/hr	101334.46	151972.981	148837.353	150111.484	139479.274
Enthalpy MMBtu/hr	-212.217	-196.485	-196.485	-196.499	-242.838
	NG-2	NG-3	NG-4	NG-5	NG-6
Mass Flow lb/hr					
H2O	0	0	0	0	7059.169
O2	20.849	20.849	20.849	20.849	20.849
N2	2172.013	2172.013	2172.013	2172.013	2172.013
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0.834
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	65.738	65.738	65.743
CO	0	0	912.51	912.51	912.51
CO2	716.866	716.866	0	0	0.979
H2S	1.11	1.11	0	0	0
SO2	0	0	0	0	0
METHANE	97826.593	97826.593	97565.276	97565.276	97565.278
METHANOL	0	0	0	0	0
ETHANE	7346.964	7346.964	7347.551	7347.551	7347.551
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	7.939	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	1.215	1.215	0	0	0
C4H10S	17.629	17.629	0	0	0
PROPANE	2643.264	2643.264	2643.264	2643.264	2643.264
BUTANE	984.629	984.629	995.99	995.99	995.99
PENTANE	188.038	188.038	188.038	188.038	188.038
HEXANE	56.149	56.149	56.149	56.149	56.149
	NG-2	NG-3	NG-4	NG-5	NG-6
Mass Frac					
H2O	0	0	0	0	0.059
O2	0	0	0	0	0
N2	0.019	0.019	0.019	0.019	0.018
AR	0	0	0	0	0
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0.001	0.001	0.001
CO	0	0	0.008	0.008	0.008
CO2	0.006	0.006	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.874	0.874	0.871	0.871	0.82
METHANOL	0	0	0	0	0
ETHANE	0.066	0.066	0.066	0.066	0.062
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.024	0.024	0.024	0.024	0.022
BUTANE	0.009	0.009	0.009	0.009	0.008
PENTANE	0.002	0.002	0.002	0.002	0.002
HEXANE	0.001	0.001	0.001	0.001	0
	NG-2	NG-3	NG-4	NG-5	NG-6
Mole Flow lbmol/hr					
H2O	0	0	0	0	391.843
O2	0.652	0.652	0.652	0.652	0.652
N2	77.535	77.535	77.535	77.535	77.535
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0.049
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	32.61	32.61	32.612
CO	0	0	32.578	32.578	32.578
CO2	16.289	16.289	0	0	0.022
H2S	0.033	0.033	0	0	0
SO2	0	0	0	0	0
METHANE	6097.866	6097.866	6081.577	6081.577	6081.577
METHANOL	0	0	0	0	0
ETHANE	244.332	244.332	244.351	244.351	244.351
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0.248	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0.02	0.02	0	0	0
C4H10S	0.195	0.195	0	0	0
PROPANE	59.943	59.943	59.943	59.943	59.943
BUTANE	16.94	16.94	17.136	17.136	17.136
PENTANE	2.606	2.606	2.606	2.606	2.606
HEXANE	0.652	0.652	0.652	0.652	0.652
	NG-2	NG-3	NG-4	NG-5	NG-6
Mole Frac					
H2O	0	0	0	0	0.056
O2	0	0	0	0	0
N2	0.012	0.012	0.012	0.012	0.011
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0.005	0.005	0.005
CO	0	0	0.005	0.005	0.005
CO2	0.002	0.002	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.936	0.936	0.929	0.929	0.876
METHANOL	0	0	0	0	0
ETHANE	0.037	0.037	0.037	0.037	0.035
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.009	0.009	0.009	0.009	0.009
BUTANE	0.003	0.003	0.003	0.003	0.002
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	NG-7	NG-8	NG-8A	NG-9	NG-10
Temperature F	662	925.1	782.6	806.8	1292
Pressure psi	350.59	350.59	347.59	347.59	344.59
Vapor Frac	1	1	1	1	1
Mole Flow lbmol/hr	6941.555	40890.665	42398.693	42458.587	42458.587
Mass Flow lb/hr	119028.368	730631.091	730631.091	730631.091	730631.091
Volume Flow cuft/hr	238937.519	1.70E+06	1.59E+06	1.63E+06	2.31E+06
Enthalpy MMBtu/hr	-206.994	-3475.484	-3475.484	-3475.502	-3262.629
	NG-7	NG-8	NG-8A	NG-9	NG-10
Mass Flow lb/hr					
H2O	7059.169	618661.893	605078.122	589976.758	589976.758
O2	20.849	20.849	20.849	20.849	20.849
N2	2172.013	2172.013	2172.013	2172.013	2172.013
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0.834	0.834	0.834	0.834	0.834
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	65.743	65.743	3760.277	5570.834	5570.834
CO	912.51	912.51	22032.74	230.597	230.597
CO2	0.979	0.979	0.979	35574.363	35574.363
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	97565.278	97565.278	97565.278	97084.844	97084.844
METHANOL	0	0	0	0	0
ETHANE	7347.551	7347.551	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	2643.264	2643.264	0	0	0
BUTANE	995.99	995.99	0	0	0
PENTANE	188.038	188.038	0	0	0
HEXANE	56.149	56.149	0	0	0
	NG-7	NG-8	NG-8A	NG-9	NG-10
Mass Frac					
H2O	0.059	0.847	0.828	0.807	0.807
O2	0	0	0	0	0
N2	0.018	0.003	0.003	0.003	0.003
AR	0	0	0	0	0
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.001	0	0.005	0.008	0.008
CO	0.008	0.001	0.03	0	0
CO2	0	0	0	0.049	0.049
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.82	0.134	0.134	0.133	0.133
METHANOL	0	0	0	0	0
ETHANE	0.062	0.01	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.022	0.004	0	0	0
BUTANE	0.008	0.001	0	0	0
PENTANE	0.002	0	0	0	0
HEXANE	0	0	0	0	0

	NG-7	NG-8	NG-8A	NG-9	NG-10
Mole Flow lbmol/hr					
H2O	391.843	34340.954	33586.94	32748.687	32748.687
O2	0.652	0.652	0.652	0.652	0.652
N2	77.535	77.535	77.535	77.535	77.535
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0.049	0.049	0.049	0.049	0.049
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	32.612	32.612	1865.328	2763.475	2763.475
CO	32.578	32.578	786.591	8.233	8.233
CO2	0.022	0.022	0.022	808.328	808.328
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	6081.577	6081.577	6081.577	6051.63	6051.63
METHANOL	0	0	0	0	0
ETHANE	244.351	244.351	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	59.943	59.943	0	0	0
BUTANE	17.136	17.136	0	0	0
PENTANE	2.606	2.606	0	0	0
HEXANE	0.652	0.652	0	0	0

	NG-7	NG-8	NG-8A	NG-9	NG-10
Mole Frac					
H2O	0.056	0.84	0.792	0.771	0.771
O2	0	0	0	0	0
N2	0.011	0.002	0.002	0.002	0.002
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.005	0.001	0.044	0.065	0.065
CO	0.005	0.001	0.019	0	0
CO2	0	0	0	0.019	0.019
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.876	0.149	0.143	0.143	0.143
METHANOL	0	0	0	0	0
ETHANE	0.035	0.006	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.009	0.001	0	0	0
BUTANE	0.002	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

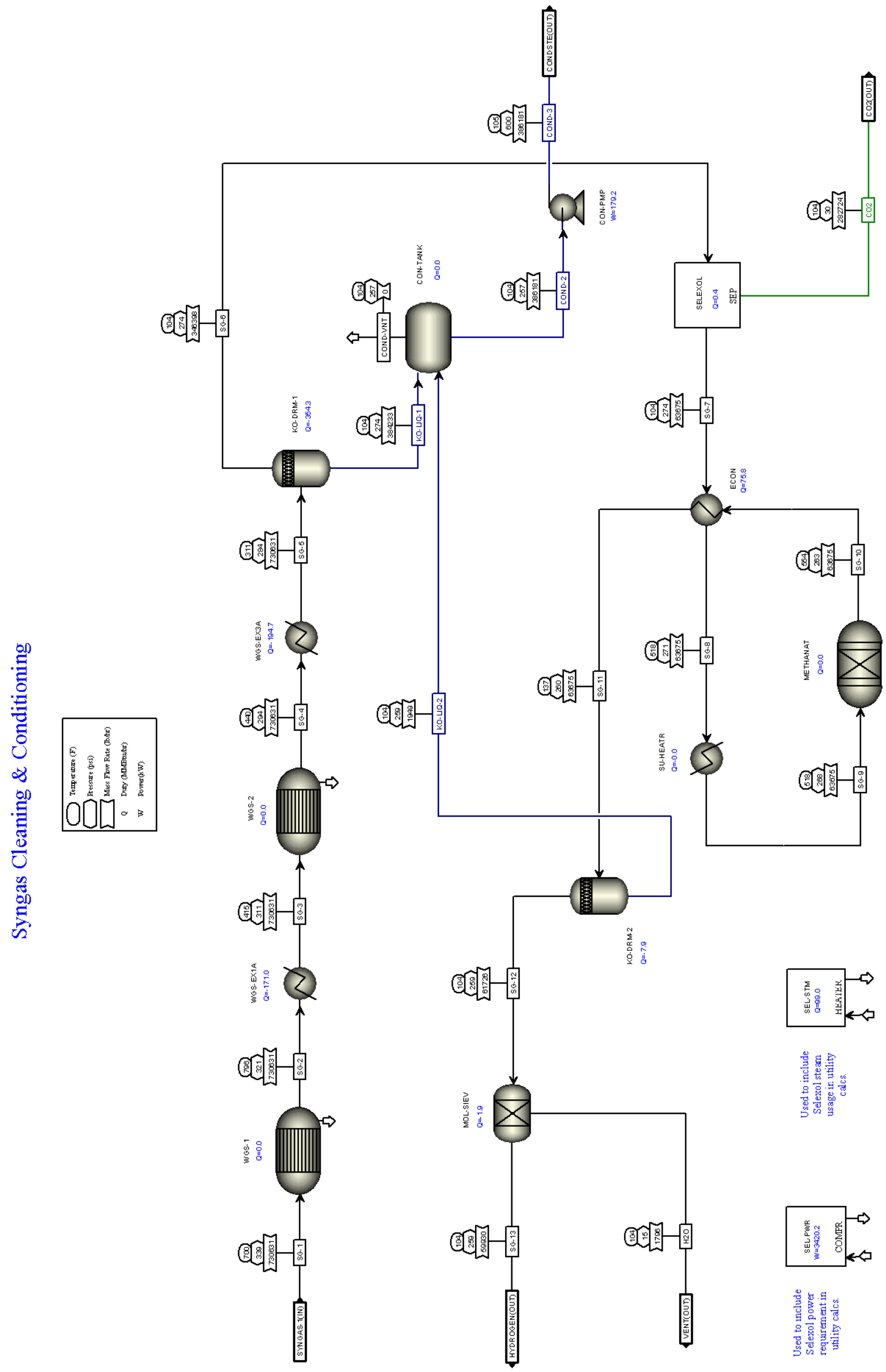
	NG-BURN	S-CAPTUR	SG-1	SG-OUT	STEAM
Temperature F	94.2	70	1598	700	485.2
Pressure psi	362.59	14.7	341.59	338.59	600
Vapor Frac	1	0	1	1	1
Mole Flow lbmol/hr	3291.881	0.248	53812.435	53812.435	33949.11
Mass Flow lb/hr	56560.682	7.939	730631.091	730631.091	611602.723
Volume Flow cuft/hr	51185.799	1.062	3.49E+06	1.96E+06	486069.137
Enthalpy MMBtu/hr	-107.195	0.019	-2595.397	-3018.264	-3447.229
	NG-BURN	S-CAPTUR	SG-1	SG-OUT	STEAM
Mass Flow lb/hr					
H2O	0	0	446631.689	446631.689	611602.723
O2	10.531	0	0	0	0
N2	1097.122	0	2129.142	2129.142	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	52.96	52.96	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	44497.141	44497.141	0
CO	0	0	95449.064	95449.064	0
CO2	362.101	0	135889.567	135889.567	0
H2S	0.561	0	0	0	0
SO2	0	0	0	0	0
METHANE	49413.914	0	5981.418	5981.418	0
METHANOL	0	0	0	0	0
ETHANE	3711.079	0	0.11	0.11	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	7.939	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0.613	0	0	0	0
C4H10S	8.905	0	0	0	0
PROPANE	1335.159	0	0	0	0
BUTANE	497.353	0	0	0	0
PENTANE	94.981	0	0	0	0
HEXANE	28.362	0	0	0	0
	NG-BURN	S-CAPTUR	SG-1	SG-OUT	STEAM
Mass Frac					
H2O	0	0	0.611	0.611	1
O2	0	0	0	0	0
N2	0.019	0	0.003	0.003	0
AR	0	0	0	0	0
NO	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0.01	0	0	0	0
C4H10S	0.099	0	0	0	0
PROPANE	30.278	0	0	0	0
BUTANE	8.557	0	0	0	0
PENTANE	1.316	0	0	0	0
HEXANE	0.329	0	0	0	0
	NG-BURN	S-CAPTUR	SG-1	SG-OUT	STEAM
Mole Frac					
H2O	0	0	0.461	0.461	1
O2	0	0	0	0	0
N2	0.012	0	0.001	0.001	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0.41	0.41	0
CO	0	0	0.063	0.063	0
CO2	0.002	0	0.057	0.057	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.936	0	0.007	0.007	0
METHANOL	0	0	0	0	0
ETHANE	0.037	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	1	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0.009	0	0	0	0
BUTANE	0.003	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	STM-SH	WATER-IN
Temperature F	1022	104.6
Pressure psi	600	600
Vapor Frac	1	0
Mole Flow lbmol/hr	33949.11	391.917
Mass Flow lb/hr	611602.723	7060.989
Volume Flow cuft/hr	873043.482	134.733
Enthalpy MMBtu/hr	-3268.49	-48.254
	STM-SH	WATER-IN
Mass Flow lb/hr		
H2O	611602.723	7059.169
O2	0	0
N2	0	0
AR	0	0
NO	0	0
NO2	0	0
N2O4	0	0
NH3	0	0.834
HNO3	0	0
NH4NO3	0	0
H2	0	0.005
CO	0	0
CO2	0	0.979
H2S	0	0
SO2	0	0
METHANE	0	0.002
METHANOL	0	0
ETHANE	0	0
ETHYLENE	0	0
C	0	0
S	0	0
UREA	0	0
CARB	0	0
ZNO	0	0
ZNS	0	0
C2H6S	0	0
C4H10S	0	0
PROPANE	0	0
BUTANE	0	0
PENTANE	0	0
HEXANE	0	0
	STM-SH	WATER-IN
Mass Frac		
H2O	1	1
O2	0	0
N2	0	0
AR	0	0
NO	0	0

NO2	0	0
N2O4	0	0
NH3	0	0
HNO3	0	0
NH4NO3	0	0
H2	0	0
CO	0	0
CO2	0	0
H2S	0	0
SO2	0	0
METHANE	0	0
METHANOL	0	0
ETHANE	0	0
ETHYLENE	0	0
C	0	0
S	0	0
UREA	0	0
CARB	0	0
ZNO	0	0
ZNS	0	0
C2H6S	0	0
C4H10S	0	0
PROPANE	0	0
BUTANE	0	0
PENTANE	0	0
HEXANE	0	0
	STM-SH	WATER-IN
Mole Flow lbmol/hr		
H2O	33949.11	391.843
O2	0	0
N2	0	0
AR	0	0
NO	0	0
NO2	0	0
N2O4	0	0
NH3	0	0.049
HNO3	0	0
NH4NO3	0	0
H2	0	0.002
CO	0	0
CO2	0	0.022
H2S	0	0
SO2	0	0
METHANE	0	0
METHANOL	0	0
ETHANE	0	0
ETHYLENE	0	0
C	0	0
S	0	0

	STM-SH	WATER-IN
UREA	0	0
CARB	0	0
ZNO	0	0
ZNS	0	0
C2H6S	0	0
C4H10S	0	0
PROPANE	0	0
BUTANE	0	0
PENTANE	0	0
HEXANE	0	0
	STM-SH	WATER-IN
Mole Frac		
H2O	1	1
O2	0	0
N2	0	0
AR	0	0
NO	0	0
NO2	0	0
N2O4	0	0
NH3	0	0
HNO3	0	0
NH4NO3	0	0
H2	0	0
CO	0	0
CO2	0	0
H2S	0	0
SO2	0	0
METHANE	0	0
METHANOL	0	0
ETHANE	0	0
ETHYLENE	0	0
C	0	0
S	0	0
UREA	0	0
CARB	0	0
ZNO	0	0
ZNS	0	0
C2H6S	0	0
C4H10S	0	0
PROPANE	0	0
BUTANE	0	0
PENTANE	0	0
HEXANE	0	0



Appendix A

	CO2	COND-2	COND-3	COND-VNT	H2O
Temperature F	104	104	104.6	104	104
Pressure psi	30	257.29	600	257.29	14.7
Vapor Frac	1	0	0	1	0
Mole Flow lbmol/hr	6466.603	21434.816	21434.816	0.013	99.68
Mass Flow lb/hr	282723.87	386181.143	386181.143	0.146	1795.76
Volume Flow cuft/hr	1.29E+06	7369.579	7368.831	0.309	34.276
Enthalpy MMBtu/hr	-1085.797	-2639.711	-2639.099	0	-12.278
	CO2	COND-2	COND-3	COND-VNT	H2O
Mass Flow lb/hr					
H2O	33.262	386081.646	386081.646	0.001	1795.76
O2	0	0	0	0	0
N2	0	0.002	0.002	0.001	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	45.596	45.596	0	0
H2	81.988	0.257	0.257	0.021	0
CO	17.23	0.002	0.002	0.001	0
CO2	282531.577	53.548	53.548	0.121	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	59.813	0.091	0.091	0.003	0
ETHANE	0.001	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	CO2	COND-2	COND-3	COND-VNT	H2O
Mass Frac					
H2O	0	1	1	0.007	1
O2	0	0	0	0	0
N2	0	0	0	0.005	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0.14	0
CO	0	0	0	0.004	0
CO2	0.999	0	0	0.827	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.017	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	CO2	COND-2	COND-3	COND-VNT	H2O
Mole Flow lbmol/hr					
H2O	1.846	21430.788	21430.788	0	99.68
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	2.677	2.677	0	0
H2	40.671	0.128	0.128	0.01	0
CO	0.615	0	0	0	0
CO2	6419.742	1.217	1.217	0.003	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	3.728	0.006	0.006	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	CO2	COND-2	COND-3	COND-VNT	H2O
Mole Frac					
H2O	0	1	1	0.004	1
O2	0	0	0	0	0
N2	0	0	0	0.002	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0.006	0	0	0.772	0
CO	0	0	0	0.002	0
CO2	0.993	0	0	0.209	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.001	0	0	0.012	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	43.721	18.017	18.017	11.101	18.015

	KO-LIQ-1	KO-LIQ-2	SG-1	SG-2	SG-3
Temperature F	104	104	700	795.9	415
Pressure psi	274.29	259.29	338.59	321.44	311.44
Vapor Frac	0	0	1	1	1
Mole Flow lbmol/hr	21326.664	108.165	53812.435	53812.435	53812.435
Mass Flow lb/hr	384232.688	1948.602	730631.091	730631.091	730631.091
Volume Flow cuft/hr	7332.154	37.185	1.96E+06	2.25E+06	1.59E+06
Enthalpy MMBtu/hr	-2626.39	-13.322	-3018.264	-3018.252	-3189.231
	KO-LIQ-1	KO-LIQ-2	SG-1	SG-2	SG-3
Mass Flow lb/hr					
H2O	384133.047	1948.599	446631.689	398314.618	398314.618
O2	0	0	0	0	0
N2	0.003	0	2129.142	2129.142	2129.142
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	45.596	0	52.96	52.96	52.96
H2	0.276	0.002	44497.141	49903.741	49903.741
CO	0.003	0	95449.064	20325.032	20325.032
CO2	53.67	0	135889.567	253924.071	253924.071
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.093	0.001	5981.418	5981.418	5981.418
ETHANE	0	0	0.11	0.11	0.11
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	KO-LIQ-1	KO-LIQ-2	SG-1	SG-2	SG-3
Mass Frac					
H2O	1	1	0.611	0.545	0.545
O2	0	0	0	0	0
N2	0	0	0.003	0.003	0.003
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0.061	0.068	0.068
CO	0	0	0.131	0.028	0.028
CO2	0	0	0.186	0.348	0.348
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0.008	0.008	0.008
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	KO-LIQ-1	KO-LIQ-2	SG-1	SG-2	SG-3
Mole Flow lbmol/hr					
H2O	21322.624	108.164	24791.826	22109.821	22109.821
O2	0	0	0	0	0
N2	0	0	76.004	76.004	76.004
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	2.677	0	3.11	3.11	3.11
H2	0.137	0.001	22073.308	24755.313	24755.313
CO	0	0	3407.629	725.624	725.624
CO2	1.219	0	3087.712	5769.717	5769.717
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.006	0	372.842	372.842	372.842
ETHANE	0	0	0.004	0.004	0.004
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	KO-LIQ-1	KO-LIQ-2	SG-1	SG-2	SG-3
Mole Frac					
H2O	1	1	0.461	0.411	0.411
O2	0	0	0	0	0
N2	0	0	0.001	0.001	0.001
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0.41	0.46	0.46
CO	0	0	0.063	0.013	0.013
CO2	0	0	0.057	0.107	0.107
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0.007	0.007	0.007
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	18.017	18.015	13.577	13.577	13.577

	SG-4	SG-5	SG-6	SG-7	SG-8
Temperature F	440.3	311	104	104	518
Pressure psi	294.29	284.29	274.29	274.29	271.29
Vapor Frac	1	0.845	1	0.999	1
Mole Flow lbmol/hr	53812.435	53812.435	32485.771	26019.168	26019.168
Mass Flow lb/hr	730631.093	730631.093	346398.405	63674.534	63674.534
Volume Flow cuft/hr	1.74E+06	1.30E+06	713261.636	576440.124	1.01E+06
Enthalpy MMBtu/hr	-3188.921	-3383.666	-1111.526	-25.369	50.405
	SG-4	SG-5	SG-6	SG-7	SG-8
Mass Flow lb/hr					
H2O	386350.481	386350.481	2217.434	2184.173	2184.173
O2	0	0	0	0	0
N2	2129.142	2129.142	2129.138	2129.138	2129.138
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	52.96	52.96	7.364	7.364	7.364
H2	51242.508	51242.508	51242.232	51160.244	51160.244
CO	1723.032	1723.032	1723.029	1705.799	1705.799
CO2	283151.442	283151.442	283097.772	566.196	566.196
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	5981.418	5981.418	5981.325	5921.512	5921.512
ETHANE	0.11	0.11	0.11	0.109	0.109
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	SG-4	SG-5	SG-6	SG-7	SG-8
Mass Frac					
H2O	0.529	0.529	0.006	0.034	0.034
O2	0	0	0	0	0
N2	0.003	0.003	0.006	0.033	0.033
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0.07	0.07	0.148	0.803	0.803
CO	0.002	0.002	0.005	0.027	0.027
CO2	0.388	0.388	0.817	0.009	0.009
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.008	0.008	0.017	0.093	0.093
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	SG-4	SG-5	SG-6	SG-7	SG-8
Mole Flow lbmol/hr					
H2O	21445.711	21445.711	123.086	121.24	121.24
O2	0	0	0	0	0
N2	76.004	76.004	76.004	76.004	76.004
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	3.11	3.11	0.432	0.432	0.432
H2	25419.424	25419.424	25419.287	25378.616	25378.616
CO	61.514	61.514	61.514	60.899	60.899
CO2	6433.827	6433.827	6432.608	12.865	12.865
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	372.842	372.842	372.836	369.108	369.108
ETHANE	0.004	0.004	0.004	0.004	0.004
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	SG-4	SG-5	SG-6	SG-7	SG-8
Mole Frac					
H2O	0.399	0.399	0.004	0.005	0.005
O2	0	0	0	0	0
N2	0.001	0.001	0.002	0.003	0.003
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0.472	0.472	0.782	0.975	0.975
CO	0.001	0.001	0.002	0.002	0.002
CO2	0.12	0.12	0.198	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.007	0.007	0.011	0.014	0.014
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	13.577	13.577	10.663	2.447	2.447

	SG-9	SG-10	SG-11	SG-12	SG-13
Temperature F	518	554	136.8	104	104
Pressure psi	268.29	263.29	260.29	259.29	259.29
Vapor Frac	1	1	1	1	1
Mole Flow lbmol/hr	26019.168	25872.072	25872.072	25763.908	25664.228
Mass Flow lb/hr	63674.534	63674.534	63674.534	61725.932	59930.173
Volume Flow cuft/hr	1.02E+06	1.07E+06	639494.424	604182.683	601993.862
Enthalpy MMBtu/hr	50.404	50.406	-25.368	-19.966	-9.599
	SG-9	SG-10	SG-11	SG-12	SG-13
Mass Flow lb/hr					
H2O	2184.173	3744.822	3744.822	1796.222	0.462
O2	0	0	0	0	0
N2	2129.138	2135.195	2135.195	2135.195	2135.195
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	7.364	0	0	0	0
H2	51160.244	50689.512	50689.512	50689.51	50689.51
CO	1705.799	0	0	0	0
CO2	566.196	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	5921.512	7105.006	7105.006	7105.005	7105.005
ETHANE	0.109	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	SG-9	SG-10	SG-11	SG-12	SG-13
Mass Frac					
H2O	0.034	0.059	0.059	0.029	0
O2	0	0	0	0	0
N2	0.033	0.034	0.034	0.035	0.036
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0.803	0.796	0.796	0.821	0.846
CO	0.027	0	0	0	0
CO2	0.009	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.093	0.112	0.112	0.115	0.119
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

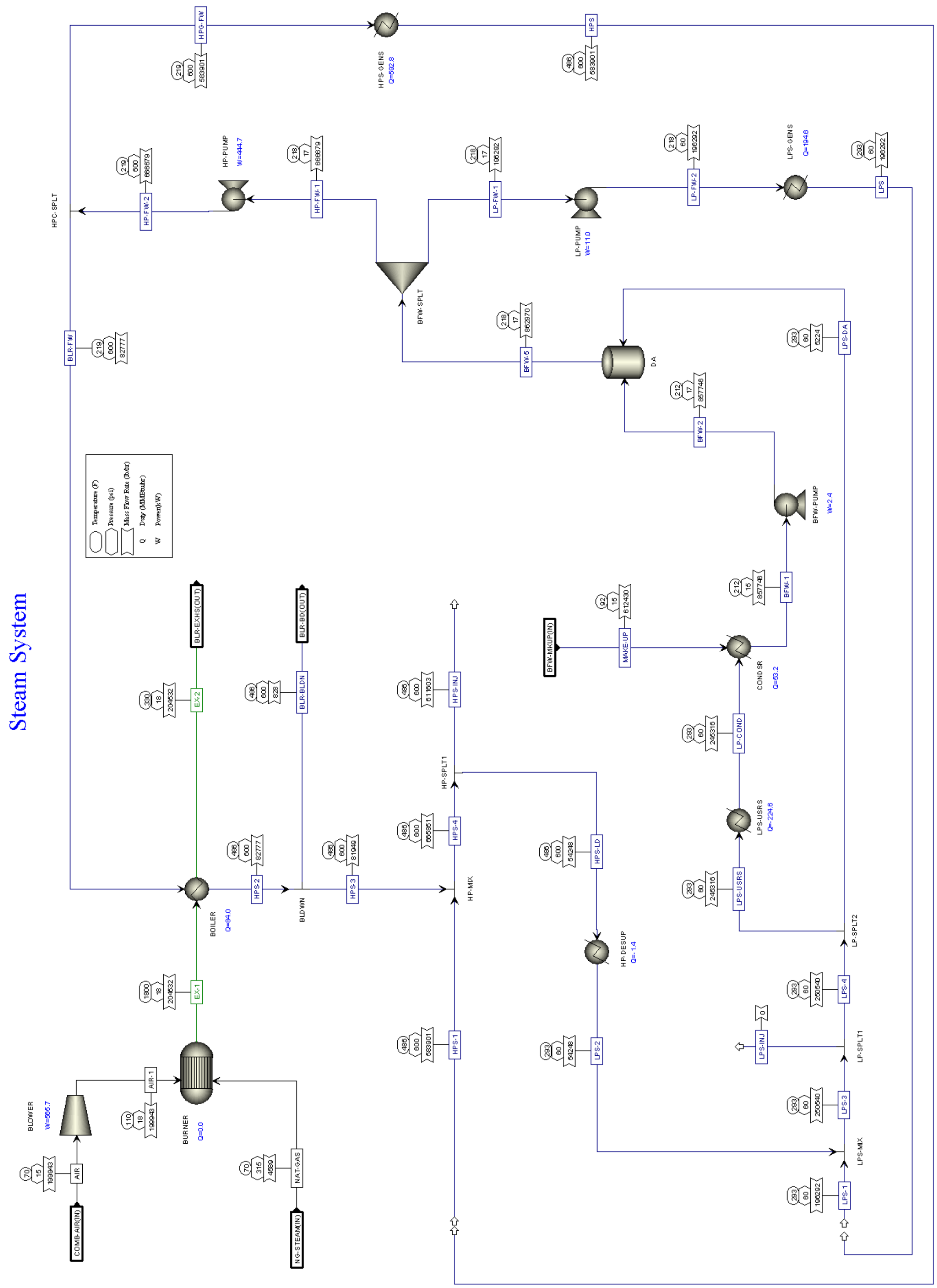
	SG-9	SG-10	SG-11	SG-12	SG-13
Mole Flow lbmol/hr					
H2O	121.24	207.869	207.869	99.705	0.026
O2	0	0	0	0	0
N2	76.004	76.22	76.22	76.22	76.22
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0.432	0	0	0	0
H2	25378.616	25145.104	25145.104	25145.103	25145.103
CO	60.899	0	0	0	0
CO2	12.865	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	369.108	442.879	442.879	442.879	442.879
ETHANE	0.004	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	SG-9	SG-10	SG-11	SG-12	SG-13
Mole Frac					
H2O	0.005	0.008	0.008	0.004	0
O2	0	0	0	0	0
N2	0.003	0.003	0.003	0.003	0.003
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0.975	0.972	0.972	0.976	0.98
CO	0.002	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.014	0.017	0.017	0.017	0.017
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	2.447	2.461	2.461	2.396	2.335

	WGS-LIQ1	WGS-LIQ2	ZZDUMMY3	ZZDUMMY4	ZZDUMMY5
Temperature F			77	128.6	212
Pressure psi	321.44	294.29	1	1.26	14.7
Vapor Frac			1	1	0
Mole Flow lbmol/hr	0	0	32485.771	32485.771	32485.771
Mass Flow lb/hr	0	0	910039.499	910039.499	585240.263
Volume Flow cuft/hr	0	0	1.87E+08	1.62E+08	9781.653
Enthalpy MMBtu/hr			-0.007	11.663	-3915.332
	WGS-LIQ1	WGS-LIQ2	ZZDUMMY3	ZZDUMMY4	ZZDUMMY5
Mass Flow lb/hr					
H2O	0	0	0	0	585240.263
O2	0	0	0	0	0
N2	0	0	910039.499	910039.499	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	WGS-LIQ1	WGS-LIQ2	ZZDUMMY3	ZZDUMMY4	ZZDUMMY5
Mass Frac					
H2O			0	0	1
O2			0	0	0
N2			1	1	0
AR			0	0	0
NO			0	0	0
NO2			0	0	0
NH3			0	0	0
H2			0	0	0
CO			0	0	0
CO2			0	0	0
H2S			0	0	0
SO2			0	0	0
METHANE			0	0	0
ETHANE			0	0	0
ETHYLENE			0	0	0
METHANOL			0	0	0
C			0	0	0
S			0	0	0

	WGS-LIQ1	WGS-LIQ2	ZZDUMMY3	ZZDUMMY4	ZZDUMMY5
Mole Flow lbmol/hr					
H2O	0	0	0	0	32485.771
O2	0	0	0	0	0
N2	0	0	32485.771	32485.771	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	WGS-LIQ1	WGS-LIQ2	ZZDUMMY3	ZZDUMMY4	ZZDUMMY5
Mole Frac					
H2O	0	0	0	0	1
O2	0	0	0	0	0
N2	0	0	1	1	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX			28.013	28.013	18.015

	ZZDUMMY6
Temperature F	212
Pressure psi	14.7
Vapor Frac	0.174
Mole Flow lbmol/hr	32485.771
Mass Flow lb/hr	585240.263
Volume Flow cuft/hr	2.74E+06
Enthalpy MMBtu/hr	-3816.347
	ZZDUMMY6
Mass Flow lb/hr	
H2O	585240.263
O2	0
N2	0
AR	0
NO	0
NO2	0
NH3	0
H2	0
CO	0
CO2	0
H2S	0
SO2	0
METHANE	0
ETHANE	0
ETHYLENE	0
METHANOL	0
C	0
S	0
	ZZDUMMY6
Mass Frac	
H2O	1
O2	0
N2	0
AR	0
NO	0
NO2	0
NH3	0
H2	0
CO	0
CO2	0
H2S	0
SO2	0
METHANE	0
ETHANE	0
ETHYLENE	0
METHANOL	0
C	0
S	0

		ZZDUMMY6
Mole Flow	lbmol/hr	
H2O		32485.771
O2		0
N2		0
AR		0
NO		0
NO2		0
NH3		0
H2		0
CO		0
CO2		0
H2S		0
SO2		0
METHANE		0
ETHANE		0
ETHYLENE		0
METHANOL		0
C		0
S		0
		ZZDUMMY6
Mole Frac		
H2O		1
O2		0
N2		0
AR		0
NO		0
NO2		0
NH3		0
H2		0
CO		0
CO2		0
H2S		0
SO2		0
METHANE		0
ETHANE		0
ETHYLENE		0
METHANOL		0
C		0
S		0
MWMX		18.015


Steam System
HPS-GENS
LPS-GENS
HP-PUMP
LP-PUMP
BFW-PUMP
BFW-SPLT
DA
CONDSR
LPS-USRS
HP-DESUP
BOILER
BURNER
BLOWER
COMB-AIR(IN)
NG-STEAM(IN)
BLR-EXHS(OUT)
BLR-BD(OUT)
BFW-MKUP(IN)
Temperature (F)
Pressure (psi)
Mass Flow Rate (lb/hr)
Duty (MMBtu/hr)
Power(kW)

	AIR	AIR-1	BFW-1	BFW-2	BFW-5
Temperature F	70	110	212	212	218
Pressure psi	14.7	17.7	14.7	17.19	17.19
Vapor Frac	1	1	0	0	0
Mole Flow lbmol/hr	6928.996	6928.996	47612.154	47612.154	47902.126
Mass Flow lb/hr	199942.946	199942.946	857746.286	857746.286	862970.211
Volume Flow cuft/hr	2.68E+06	2.39E+06	14336.298	14336.2	14460.012
Enthalpy MMBtu/hr	-7.85	-5.92	-5738.432	-5738.424	-5768.16
	AIR	AIR-1	BFW-1	BFW-2	BFW-5
Mass Flow lb/hr					
H2O	1235.919	1235.919	857746.286	857746.286	862970.211
O2	46078.155	46078.155	0	0	0
N2	149960.757	149960.757	0	0	0
AR	2576.154	2576.154	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	1.383	1.383	0	0	0
CO	0	0	0	0	0
CO2	90.577	90.577	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	AIR	AIR-1	BFW-1	BFW-2	BFW-5
Mass Frac					
H2O	0.006	0.006	1	1	1
O2	0.23	0.23	0	0	0
N2	0.75	0.75	0	0	0
AR	0.013	0.013	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	AIR	AIR-1	BFW-1	BFW-2	BFW-5
Mole Flow lbmol/hr					
H2O	68.604	68.604	47612.154	47612.154	47902.126
O2	1439.996	1439.996	0	0	0
N2	5353.164	5353.164	0	0	0
AR	64.488	64.488	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0.686	0.686	0	0	0
CO	0	0	0	0	0
CO2	2.058	2.058	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	AIR	AIR-1	BFW-1	BFW-2	BFW-5
Mole Frac					
H2O	0.01	0.01	1	1	1
O2	0.208	0.208	0	0	0
N2	0.773	0.773	0	0	0
AR	0.009	0.009	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	28.856	28.856	18.015	18.015	18.015

	BLR-BLDN	BLR-FW	EX-1	EX-2	HP-FW-1
Temperature F	486.3	219	1800	330.4	218
Pressure psi	600	600	17.7	17.7	17.19
Vapor Frac	1	0	1	1	0
Mole Flow lbmol/hr	45.948	4594.832	7204.534	7204.534	37006.284
Mass Flow lb/hr	827.772	82777.188	204531.946	204531.946	666678.575
Volume Flow cuft/hr	637.439	1384.853	9.88E+06	3.45E+06	11170.931
Enthalpy MMBtu/hr	-4.691	-553.101	-14.671	-98.709	-4456.131
	BLR-BLDN	BLR-FW	EX-1	EX-2	HP-FW-1
Mass Flow lb/hr					
H2O	827.772	82777.188	11048.904	11048.904	666678.575
O2	0	0	28378.321	28378.321	0
N2	0	0	150049.771	150049.771	0
AR	0	0	2576.154	2576.154	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	12478.146	12478.146	0
H2S	0	0	0	0	0
SO2	0	0	0.65	0.65	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	BLR-BLDN	BLR-FW	EX-1	EX-2	HP-FW-1
Mass Frac					
H2O	1	1	0.054	0.054	1
O2	0	0	0.139	0.139	0
N2	0	0	0.734	0.734	0
AR	0	0	0.013	0.013	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0.061	0.061	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	BLR-BLDN	BLR-FW	EX-1	EX-2	HP-FW-1
Mole Flow lbmol/hr					
H2O	45.948	4594.832	613.307	613.307	37006.284
O2	0	0	886.856	886.856	0
N2	0	0	5356.342	5356.342	0
AR	0	0	64.488	64.488	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	283.531	283.531	0
H2S	0	0	0	0	0
SO2	0	0	0.01	0.01	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	BLR-BLDN	BLR-FW	EX-1	EX-2	HP-FW-1
Mole Frac					
H2O	1	1	0.085	0.085	1
O2	0	0	0.123	0.123	0
N2	0	0	0.743	0.743	0
AR	0	0	0.009	0.009	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0.039	0.039	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	18.015	18.015	28.389	28.389	18.015

	HP-FW-2	HPG-FW	HPS	HPS-1	HPS-2
Temperature F	219	219	486.3	486.3	486.3
Pressure psi	600	600	600	600	600
Vapor Frac	0	0	1	1	1
Mole Flow lbmol/hr	37006.284	32411.452	32411.452	32411.452	4594.832
Mass Flow lb/hr	666678.575	583901.387	583901.387	583901.387	82777.188
Volume Flow cuft/hr	11153.461	9768.607	449643.823	449645.054	63743.927
Enthalpy MMBtu/hr	-4454.614	-3901.513	-3308.715	-3308.714	-469.062
	HP-FW-2	HPG-FW	HPS	HPS-1	HPS-2
Mass Flow lb/hr					
H2O	666678.575	583901.387	583901.387	583901.387	82777.188
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	HP-FW-2	HPG-FW	HPS	HPS-1	HPS-2
Mass Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	HP-FW-2	HPG-FW	HPS	HPS-1	HPS-2
Mole Flow lbmol/hr					
H2O	37006.284	32411.452	32411.452	32411.452	4594.832
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	HP-FW-2	HPG-FW	HPS	HPS-1	HPS-2
Mole Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	18.015	18.015	18.015	18.015	18.015

	HPS-3	HPS-4	HPS-INJ	HPS-LD	LP-COND
Temperature F	486.3	486.3	486.3	486.3	292.7
Pressure psi	600	600	600	600	60
Vapor Frac	1	1	1	1	0
Mole Flow lbmol/hr	4548.884	36960.336	33949.11	3011.226	13617.096
Mass Flow lb/hr	81949.417	665850.803	611602.723	54248.08	245315.79
Volume Flow cuft/hr	63106.488	512750.453	470975.739	41774.715	4262.938
Enthalpy MMBtu/hr	-464.372	-3773.086	-3465.686	-307.4	-1621.042
	HPS-3	HPS-4	HPS-INJ	HPS-LD	LP-COND
Mass Flow lb/hr					
H2O	81949.417	665850.803	611602.723	54248.08	245315.79
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	HPS-3	HPS-4	HPS-INJ	HPS-LD	LP-COND
Mass Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

	HPS-3	HPS-4	HPS-INJ	HPS-LD	LP-COND
Mole Flow lbmol/hr					
H2O	4548.884	36960.336	33949.11	3011.226	13617.096
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	HPS-3	HPS-4	HPS-INJ	HPS-LD	LP-COND
Mole Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	18.015	18.015	18.015	18.015	18.015

	LP-FW-1	LP-FW-2	LPS	LPS-1	LPS-2
Temperature F	218	218.1	292.7	292.7	292.7
Pressure psi	17.19	60	60	60	60
Vapor Frac	0	0	1	1	1
Mole Flow lbmol/hr	10895.842	10895.842	10895.842	10895.842	3011.226
Mass Flow lb/hr	196291.636	196291.636	196291.636	196291.636	54248.08
Volume Flow cuft/hr	3289.082	3288.734	1.41E+06	1.41E+06	389349.857
Enthalpy MMBtu/hr	-1312.028	-1311.991	-1117.349	-1117.349	-308.796
	LP-FW-1	LP-FW-2	LPS	LPS-1	LPS-2
Mass Flow lb/hr					
H2O	196291.636	196291.636	196291.636	196291.636	54248.08
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	LP-FW-1	LP-FW-2	LPS	LPS-1	LPS-2
Mass Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

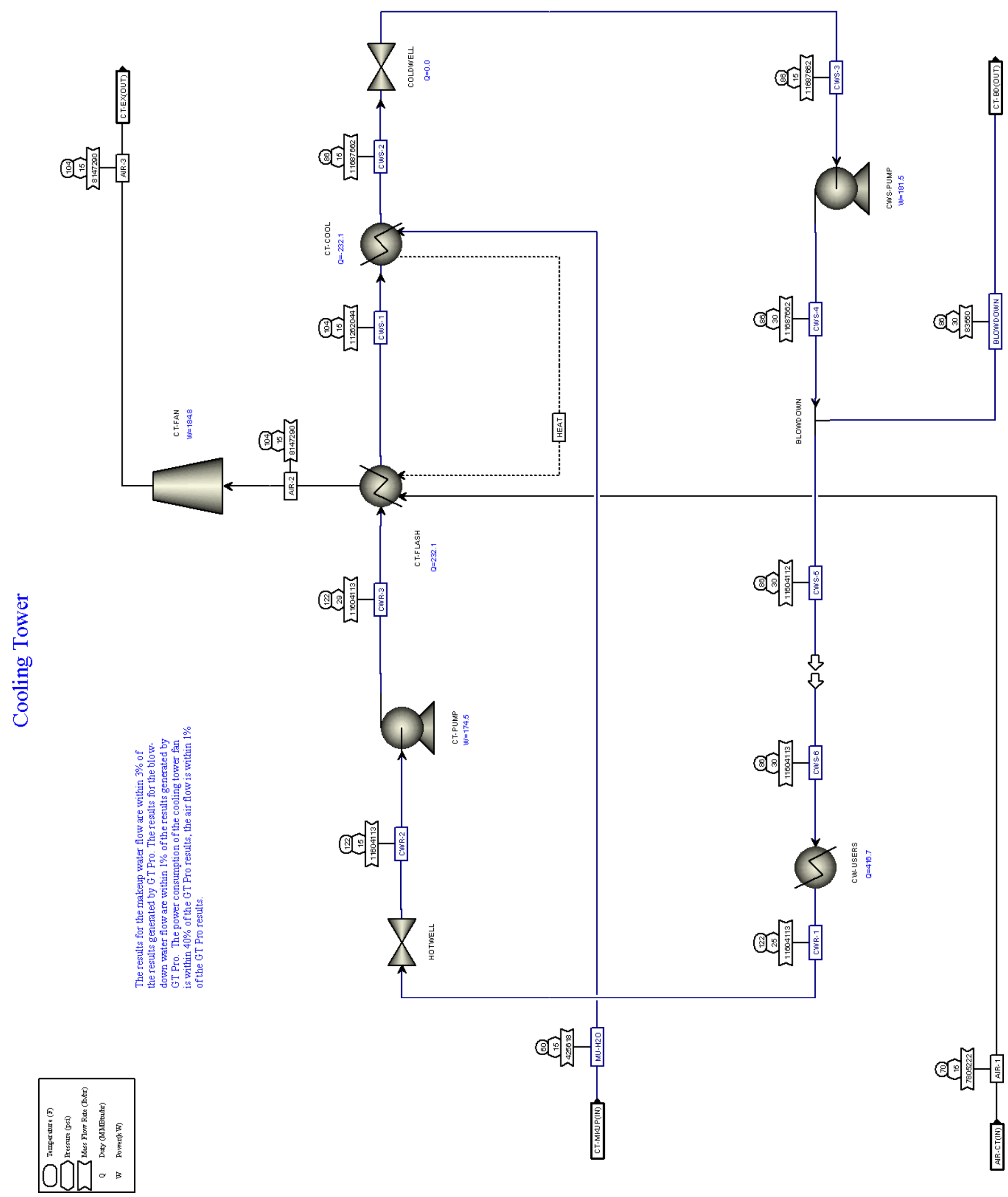
	LP-FW-1	LP-FW-2	LPS	LPS-1	LPS-2
Mole Flow lbmol/hr					
H2O	10895.842	10895.842	10895.842	10895.842	3011.226
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	LP-FW-1	LP-FW-2	LPS	LPS-1	LPS-2
Mole Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	18.015	18.015	18.015	18.015	18.015

	LPS-3	LPS-4	LPS-DA	LPS-INJ	LPS-USRS
Temperature F	292.7	292.7	292.7		292.7
Pressure psi	60	60	60		60
Vapor Frac	1	1	1		1
Mole Flow lbmol/hr	13907.067	13907.067	289.972	0	13617.096
Mass Flow lb/hr	250539.716	250539.716	5223.925	0	245315.79
Volume Flow cuft/hr	1.80E+06	1.80E+06	37493.19	0	1.76E+06
Enthalpy MMBtu/hr	-1426.145	-1426.145	-29.736		-1396.409
	LPS-3	LPS-4	LPS-DA	LPS-INJ	LPS-USRS
Mass Flow lb/hr					
H2O	250539.716	250539.716	5223.925	0	245315.79
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	LPS-3	LPS-4	LPS-DA	LPS-INJ	LPS-USRS
Mass Frac					
H2O	1	1	1		1
O2	0	0	0		0
N2	0	0	0		0
AR	0	0	0		0
NO	0	0	0		0
NO2	0	0	0		0
NH3	0	0	0		0
H2	0	0	0		0
CO	0	0	0		0
CO2	0	0	0		0
H2S	0	0	0		0
SO2	0	0	0		0
METHANE	0	0	0		0
METHANOL	0	0	0		0
ETHANE	0	0	0		0
ETHYLENE	0	0	0		0
C	0	0	0		0
S	0	0	0		0

	LPS-3	LPS-4	LPS-DA	LPS-INJ	LPS-USRS
Mole Flow lbmol/hr					
H2O	13907.067	13907.067	289.972	0	13617.096
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
	LPS-3	LPS-4	LPS-DA	LPS-INJ	LPS-USRS
Mole Frac					
H2O	1	1	1	0	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
MWMX	18.015	18.015	18.015		18.015

	MAKE-UP	NAT-GAS
Temperature F	92.4	70
Pressure psi	14.7	314.7
Vapor Frac	0	1
Mole Flow lbmol/hr	33995.058	267.084
Mass Flow lb/hr	612430.495	4589
Volume Flow cuft/hr	9864.271	4569.499
Enthalpy MMBtu/hr	-4170.543	-8.75
	MAKE-UP	NAT-GAS
Mass Flow lb/hr		
H2O	612430.495	0
O2	0	0.854
N2	0	89.014
AR	0	0
NO	0	0
NO2	0	0
NH3	0	0
H2	0	0
CO	0	0
CO2	0	29.379
H2S	0	0.046
SO2	0	0
METHANE	0	4009.153
METHANOL	0	0
ETHANE	0	301.095
ETHYLENE	0	0
C	0	0
S	0	0
	MAKE-UP	NAT-GAS
Mass Frac		
H2O	1	0
O2	0	0
N2	0	0.019
AR	0	0
NO	0	0
NO2	0	0
NH3	0	0
H2	0	0
CO	0	0
CO2	0	0.006
H2S	0	0
SO2	0	0
METHANE	0	0.874
METHANOL	0	0
ETHANE	0	0.066
ETHYLENE	0	0
C	0	0
S	0	0

	MAKE-UP	NAT-GAS
Mole Flow lbmol/hr		
H2O	33995.058	0
O2	0	0.027
N2	0	3.178
AR	0	0
NO	0	0
NO2	0	0
NH3	0	0
H2	0	0
CO	0	0
CO2	0	0.668
H2S	0	0.001
SO2	0	0
METHANE	0	249.904
METHANOL	0	0
ETHANE	0	10.013
ETHYLENE	0	0
C	0	0
S	0	0
	MAKE-UP	NAT-GAS
Mole Frac		
H2O	1	0
O2	0	0
N2	0	0.012
AR	0	0
NO	0	0
NO2	0	0
NH3	0	0
H2	0	0
CO	0	0
CO2	0	0.002
H2S	0	0
SO2	0	0
METHANE	0	0.936
METHANOL	0	0
ETHANE	0	0.037
ETHYLENE	0	0
C	0	0
S	0	0
MWMX	18.015	17.182

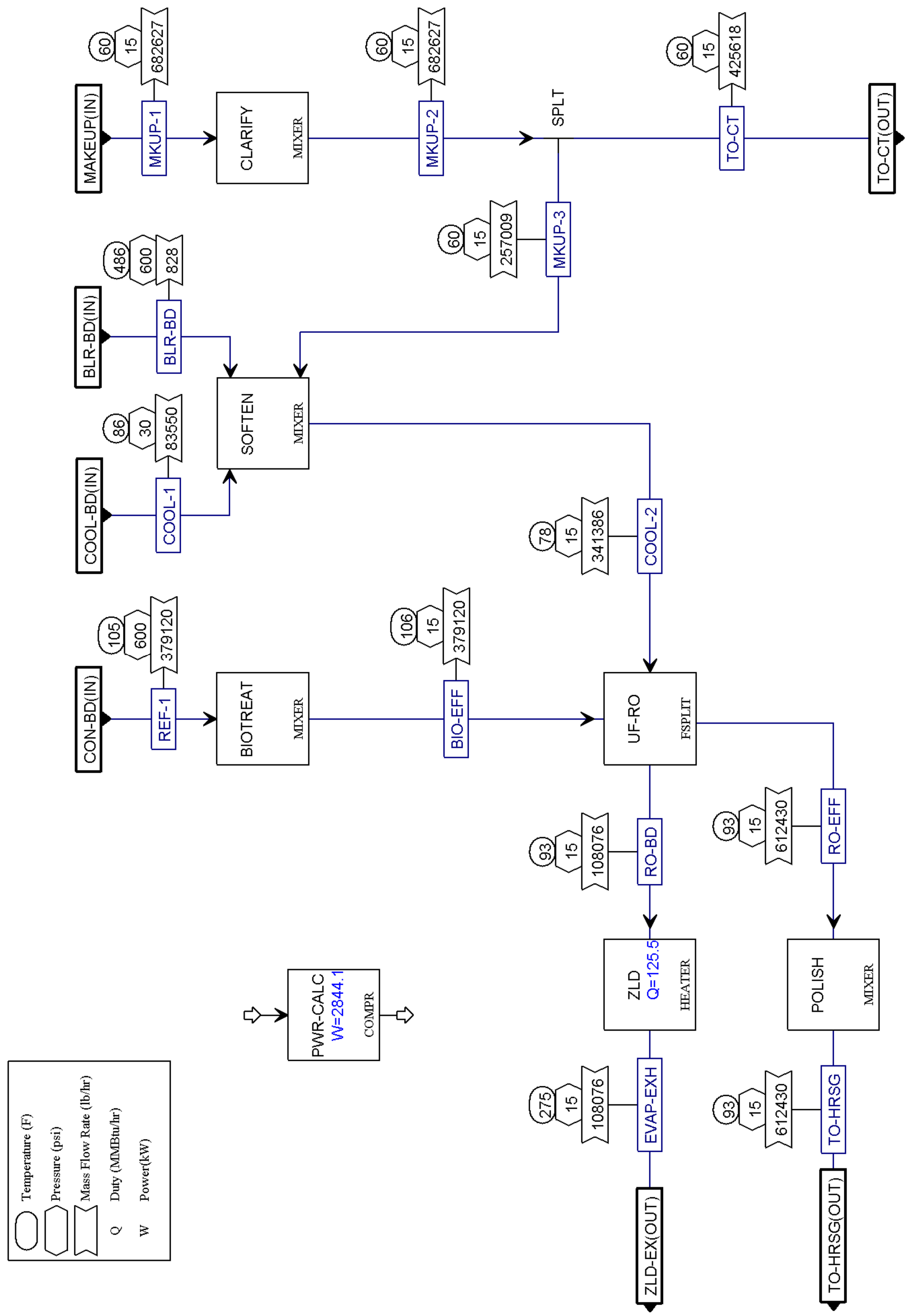

Cooling Tower
The results for the makeup water flow are within 3% of the results generated by GT Pro. The results for the blow-down water flow are within 1% of the results generated by GT Pro. The power consumption of the cooling tower fan is within 40% of the GT Pro results, the air flow is within 1% of the GT Pro results.
CT-FAN
CT-COOL
CT-FLASH
CT-PUMP
CWS-PUMP
CW-USERS
COLDWELL
HOTWELL
BLOWDOWN
HEAT
CT-EX(OUT)
CT-BD(OUT)
CT-MKUP(IN)
AIR-CT(IN)
MU-H2O
Temperature (F)
Pressure (psi)
Mass Flow Rate (lb/hr)
Duty (MMBtu/hr)
Power(kW)

	AIR-1	AIR-2	AIR-3	BLOWDOWN	CWR-1
Temperature F	70	104	104.1	86	122
Pressure psi	14.7	14.67	14.7	30	25
Vapor Frac	1	0.996	0.996	0	0
Mole Flow lbmol/hr	270488.931	289771.942	289771.942	4635.597	644126.149
Mass Flow lb/hr	7.81E+06	8.15E+06	8.15E+06	83549.613	1.16E+07
Volume Flow cuft/hr	1.05E+08	1.19E+08	1.19E+08	1343.362	188117.123
Enthalpy MMBtu/hr	-305.429	-2315.929	-2315.299	-568.888	-78680.561
Dew Temp F	43.078	105.801	105.854	250.315	240.052
Mole Flow lbmol/hr					
H2O	2678.108	22438.315	22438.315	4632.186	644126.149
O2	56213.492	56099.578	56099.578	0.814	0
N2	208972.785	208616.832	208616.832	2.545	0
AR	2517.422	2512.01	2512.01	0.039	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	26.781	26.777	26.777	0	0
CO	0	0	0	0	0
CO2	80.343	78.43	78.43	0.014	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
Mole Frac					
H2O	0.01	0.077	0.077	0.999	1
O2	0.208	0.194	0.194	0	0
N2	0.773	0.72	0.72	0.001	0
AR	0.009	0.009	0.009	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
RELHUMID	38.956	99.924	99.924		

	CWR-2	CWR-3	CWS-1	CWS-2	CWS-3
Temperature F	122	122	104	86	86
Pressure psi	14.7	29.39	14.67	14.67	14.7
Vapor Frac	0	0	0	0	0
Mole Flow lbmol/hr	644126.149	644126.149	624843.138	648468.526	648468.526
Mass Flow lb/hr	1.16E+07	1.16E+07	1.13E+07	1.17E+07	1.17E+07
Volume Flow cuft/hr	188124.333	188116.532	184435.897	187929.903	187929.888
Enthalpy MMBtu/hr	-78680.561	-78679.966	-76437.388	-79581.678	-79581.678
Dew Temp F	211.983	249.146	211.973	211.904	211.983
Mole Flow lbmol/hr					
H2O	644126.149	644126.149	624365.942	647991.33	647991.33
O2	0	0	113.914	113.914	113.914
N2	0	0	355.953	355.953	355.953
AR	0	0	5.412	5.412	5.412
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0.004	0.004	0.004
CO	0	0	0	0	0
CO2	0	0	1.913	1.913	1.913
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
Mole Frac					
H2O	1	1	0.999	0.999	0.999
O2	0	0	0	0	0
N2	0	0	0.001	0.001	0.001
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
NH3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
METHANOL	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
RELHUMID					

	CWS-4	CWS-5	CWS-6	MU-H2O
Temperature F	86	86	86	60
Pressure psi	30	30	30	14.7
Vapor Frac	0	0	0	0
Mole Flow lbmol/hr	648468.526	643832.929	644126.149	23625.388
Mass Flow lb/hr	1.17E+07	1.16E+07	1.16E+07	425617.984
Volume Flow cuft/hr	187921.419	186578.058	186662.662	6823.637
Enthalpy MMBtu/hr	-79581.058	-79012.171	-79097.279	-2912.212
Dew Temp F	250.315	250.315	250.316	211.983
Mole Flow lbmol/hr				
H2O	647991.33	643359.144	644126.149	23625.388
O2	113.914	113.1	0	0
N2	355.953	353.408	0	0
AR	5.412	5.373	0	0
NO	0	0	0	0
NO2	0	0	0	0
NH3	0	0	0	0
H2	0.004	0.004	0	0
CO	0	0	0	0
CO2	1.913	1.899	0	0
H2S	0	0	0	0
SO2	0	0	0	0
METHANE	0	0	0	0
ETHANE	0	0	0	0
ETHYLENE	0	0	0	0
METHANOL	0	0	0	0
C	0	0	0	0
S	0	0	0	0
Mole Frac				
H2O	0.999	0.999	1	1
O2	0	0	0	0
N2	0.001	0.001	0	0
AR	0	0	0	0
NO	0	0	0	0
NO2	0	0	0	0
NH3	0	0	0	0
H2	0	0	0	0
CO	0	0	0	0
CO2	0	0	0	0
H2S	0	0	0	0
SO2	0	0	0	0
METHANE	0	0	0	0
ETHANE	0	0	0	0
ETHYLENE	0	0	0	0
METHANOL	0	0	0	0
C	0	0	0	0
S	0	0	0	0
RELHUMID				

Simplified Water Treatment



	BIO-EFF	BLR-BD	COOL-1	COOL-2	EVAP-EXH
Temperature F	106.1	486.3	86	78.1	275
Pressure psi	14.7	600	30	14.7	14.7
Vapor Frac	0	1	0	0	1
Mole Flow lbmol/hr	21042.898	45.948	4635.597	18947.709	5998.591
Mass Flow lb/hr	379120.155	827.772	83549.613	341386.309	108075.97
Volume Flow cuft/hr	7698.79	637.439	1343.362	7823.069	3.20E+06
Enthalpy MMBtu/hr	-2590.846	-4.691	-568.888	-2342.966	-614.532
	BIO-EFF	BLR-BD	COOL-1	COOL-2	EVAP-EXH
Mass Flow lb/hr					
H2O	379022.477	827.772	83450.126	341286.822	108046.395
O2	0	0	26.058	26.058	3.909
N2	0.002	0	71.283	71.283	10.693
AR	0	0	1.545	1.545	0.232
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	44.763	0	0	0	6.714
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.253	0	0	0	0.038
CO	0.002	0	0	0	0
CO2	52.569	0	0.602	0.602	7.976
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.089	0	0	0	0.013
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	BIO-EFF	BLR-BD	COOL-1	COOL-2	EVAP-EXH
Mass Frac					
H2O	1	1	0.999	1	1
O2	0	0	0	0	0
N2	0	0	0.001	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	BIO-EFF	BLR-BD	COOL-1	COOL-2	EVAP-EXH
Mole Flow lbmol/hr					
H2O	21038.945	45.948	4632.186	18944.297	5997.486
O2	0	0	0.814	0.814	0.122
N2	0	0	2.545	2.545	0.382
AR	0	0	0.039	0.039	0.006
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	2.628	0	0	0	0.394
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.125	0	0	0	0.019
CO	0	0	0	0	0
CO2	1.194	0	0.014	0.014	0.181
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.006	0	0	0	0.001
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	BIO-EFF	BLR-BD	COOL-1	COOL-2	EVAP-EXH
Mole Frac					
H2O	1	1	0.999	1	1
O2	0	0	0	0	0
N2	0	0	0.001	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	18.017	18.015	18.023	18.017	18.017

	MKUP-1	MKUP-2	MKUP-3	REF-1	RO-BD
Temperature F	60	60	60	104.6	92.8
Pressure psi	14.7	14.7	14.7	600	14.7
Vapor Frac	0	0	0	0	0
Mole Flow lbmol/hr	37891.551	37891.551	14266.163	21042.898	5998.591
Mass Flow lb/hr	682626.908	682626.908	257008.925	379120.155	108075.97
Volume Flow cuft/hr	12820.295	12820.295	4826.839	7234.099	2343.661
Enthalpy MMBtu/hr	-4699.571	-4699.571	-1769.388	-2590.846	-740.072
	MKUP-1	MKUP-2	MKUP-3	REF-1	RO-BD
Mass Flow lb/hr					
H2O	682626.908	682626.908	257008.925	379022.477	108046.395
O2	0	0	0	0	3.909
N2	0	0	0	0.002	10.693
AR	0	0	0	0	0.232
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	44.763	6.714
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0.253	0.038
CO	0	0	0	0.002	0
CO2	0	0	0	52.569	7.976
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.089	0.013
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	MKUP-1	MKUP-2	MKUP-3	REF-1	RO-BD
Mass Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	MKUP-1	MKUP-2	MKUP-3	REF-1	RO-BD
Mole Flow lbmol/hr					
H2O	37891.551	37891.551	14266.163	21038.945	5997.486
O2	0	0	0	0	0.122
N2	0	0	0	0	0.382
AR	0	0	0	0	0.006
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	2.628	0.394
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0.125	0.019
CO	0	0	0	0	0
CO2	0	0	0	1.194	0.181
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0.006	0.001
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	MKUP-1	MKUP-2	MKUP-3	REF-1	RO-BD
Mole Frac					
H2O	1	1	1	1	1
O2	0	0	0	0	0
N2	0	0	0	0	0
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	18.015	18.015	18.015	18.017	18.017

	RO-EFF	TO-CT	TO-HRSG	ZZ-PWR-1	ZZ-PWR-2
Temperature F	92.8	60	92.8	60	360.7
Pressure psi	14.7	14.7	14.7	14.7	50
Vapor Frac	0	0	0	1	1
Mole Flow lbmol/hr	33992.016	23625.388	33992.016	4619.261	4619.261
Mass Flow lb/hr	612430.495	425617.984	612430.495	129401.566	129401.566
Volume Flow cuft/hr	13280.745	7993.456	13280.745	1.75E+06	814324.789
Enthalpy MMBtu/hr	-4193.74	-2930.183	-4193.74	-0.564	9.141
	RO-EFF	TO-CT	TO-HRSG	ZZ-PWR-1	ZZ-PWR-2
Mass Flow lb/hr					
H2O	612262.904	425617.984	612262.904	0	0
O2	22.149	0	22.149	0	0
N2	60.592	0	60.592	129401.566	129401.566
AR	1.314	0	1.314	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	38.048	0	38.048	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.215	0	0.215	0	0
CO	0.002	0	0.002	0	0
CO2	45.195	0	45.195	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.076	0	0.076	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	RO-EFF	TO-CT	TO-HRSG	ZZ-PWR-1	ZZ-PWR-2
Mass Frac					
H2O	1	1	1	0	0
O2	0	0	0	0	0
N2	0	0	0	1	1
AR	0	0	0	0	0
NO	0	0	0	0	0

NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0

	RO-EFF	TO-CT	TO-HRSG	ZZ-PWR-1	ZZ-PWR-2
Mole Flow lbmol/hr					
H2O	33985.756	23625.388	33985.756	0	0
O2	0.692	0	0.692	0	0
N2	2.163	0	2.163	4619.261	4619.261
AR	0.033	0	0.033	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	2.234	0	2.234	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0.106	0	0.106	0	0
CO	0	0	0	0	0
CO2	1.027	0	1.027	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0.005	0	0.005	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0

UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
	RO-EFF	TO-CT	TO-HRSG	ZZ-PWR-1	ZZ-PWR-2
Mole Frac					
H2O	1	1	1	0	0
O2	0	0	0	0	0
N2	0	0	0	1	1
AR	0	0	0	0	0
NO	0	0	0	0	0
NO2	0	0	0	0	0
N2O4	0	0	0	0	0
NH3	0	0	0	0	0
HNO3	0	0	0	0	0
NH4NO3	0	0	0	0	0
H2	0	0	0	0	0
CO	0	0	0	0	0
CO2	0	0	0	0	0
H2S	0	0	0	0	0
SO2	0	0	0	0	0
METHANE	0	0	0	0	0
METHANOL	0	0	0	0	0
ETHANE	0	0	0	0	0
ETHYLENE	0	0	0	0	0
C	0	0	0	0	0
S	0	0	0	0	0
UREA	0	0	0	0	0
CARB	0	0	0	0	0
ZNO	0	0	0	0	0
ZNS	0	0	0	0	0
C2H6S	0	0	0	0	0
C4H10S	0	0	0	0	0
PROPANE	0	0	0	0	0
BUTANE	0	0	0	0	0
PENTANE	0	0	0	0	0
HEXANE	0	0	0	0	0
MWMX	18.017	18.015	18.017	28.013	28.013

Appendix B
High Temperature Electrolysis Results

The model of the high-temperature steam electrolysis process and results in Appendix B were developed using HYSYS.Plant version 2.2.2 (Build 3806) from Hyprotech Ltd. on a desktop computer running Microsoft Windows XP Professional Version 2002 Service Pack 3.

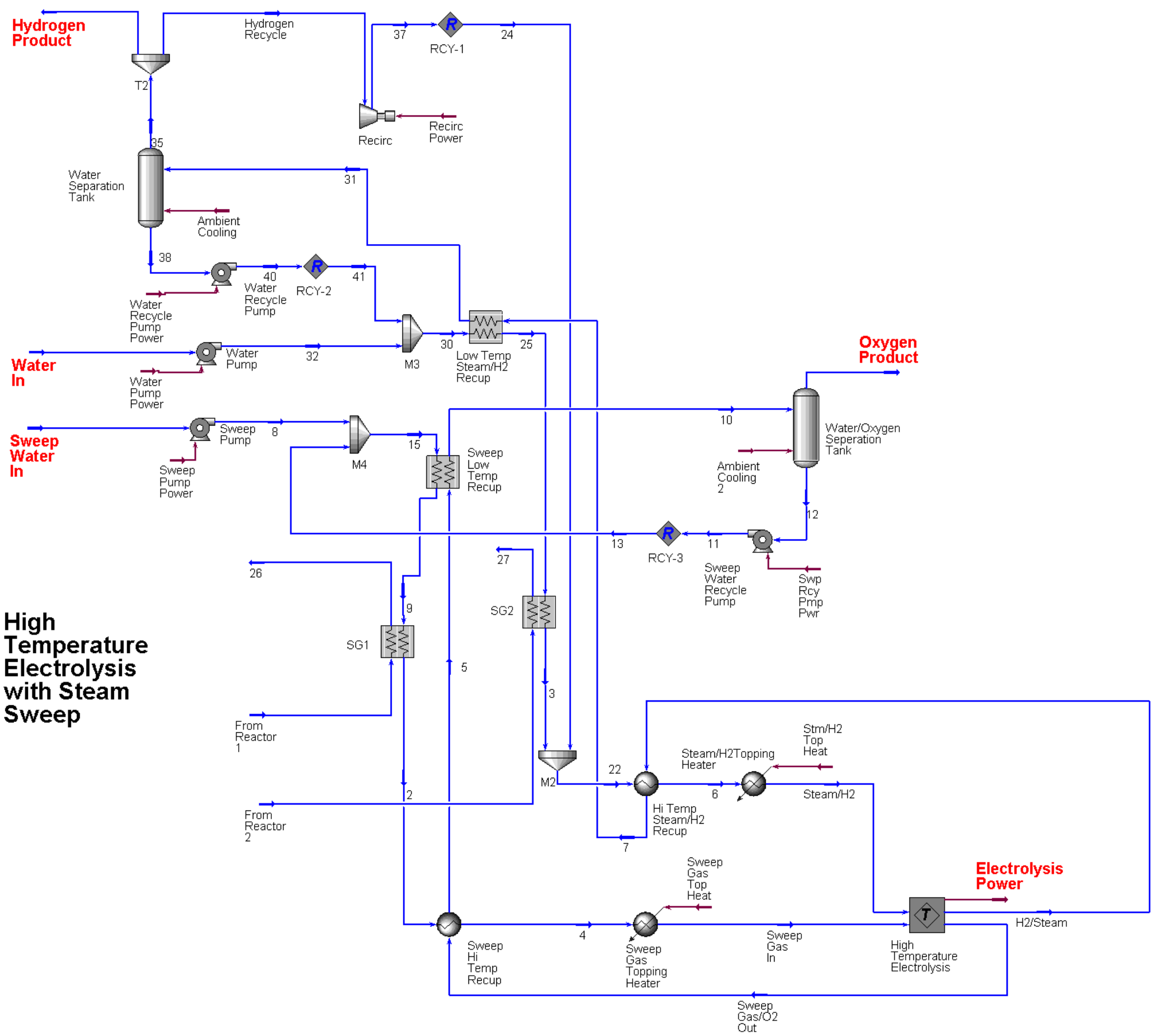


Figure B-1. Flow diagram of HTSE process.

INL
Calgary, Alberta
CANADA

Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV
Unit Set:	NGNP1
Date/Time:	Thu Oct 01 11:50:20 2009

Workbook: Case (Main)

Streams

Name		Steam/H2	Sweep Gas In	H2/Steam	Sweep Gas/O2 Out	15
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	0.0000
Temperature	(C)	800.00 *	800.00	800.00	800.00	27.029
Pressure	(MPa)	5.0000 *	5.0000	5.0000	5.0000	5.2000
Molar Flow	(kgmole/h)	5169.3	1551.2	5169.3	3101.9	1551.2
Mass Flow	(kg/s)	23.571 *	7.7631	9.7869	21.547	7.7631 *
Liquid Volume Flow	(m3/h)	98.90	28.00	132.4	71.62	28.00
Heat Flow	(kW)	-2.712e+005	-9.151e+004	-6.830e+004	-8.053e+004	-1.229e+005
Molar Enthalpy	(kJ/kgmole)	-1.888e+005	-2.124e+005	-4.757e+004	-9.346e+004	-2.851e+005
Name		22	Sweep Water In	24	25	Water In
Vapour Fraction		1.0000	0.0000	1.0000	0.1491	0.0000
Temperature	(C)	603.79	26.850 *	30.717 *	267.01	26.850 *
Pressure	(MPa)	5.1000	0.10132 *	5.1000 *	5.1500	0.10132 *
Molar Flow	(kgmole/h)	5169.3	14.749	517.29 *	4652.1	3104.1
Mass Flow	(kg/s)	23.571	7.3805e-002	0.29162	23.279	15.534
Liquid Volume Flow	(m3/h)	98.90	0.2662	14.92	83.98	56.03
Heat Flow	(kW)	-2.828e+005	-1169	-5.776	-3.365e+005	-2.460e+005
Molar Enthalpy	(kJ/kgmole)	-1.969e+005	-2.853e+005	-40.20	-2.604e+005	-2.853e+005
Name		32	41	30	31	35
Vapour Fraction		0.0000	0.0000	0.0000	0.8062	1.0000
Temperature	(C)	27.299	26.026 *	26.876	157.63	26.000
Pressure	(MPa)	5.2000	5.2000 *	5.2000	4.9000	4.9000
Molar Flow	(kgmole/h)	3104.1	1548.0 *	4652.1	5169.3	3621.5
Mass Flow	(kg/s)	15.534	7.7459	23.279	9.7869	2.0416
Liquid Volume Flow	(m3/h)	56.03	27.94	83.98	132.4	104.5
Heat Flow	(kW)	-2.459e+005	-1.226e+005	-3.685e+005	-1.088e+005	-177.1
Molar Enthalpy	(kJ/kgmole)	-2.851e+005	-2.852e+005	-2.852e+005	-7.580e+004	-176.0
Name		38	37	Hydrogen Product	Hydrogen Recycle	40
Vapour Fraction		0.0000	1.0000	1.0000	1.0000	0.0000
Temperature	(C)	26.000 *	30.717	26.000	26.000	26.026
Pressure	(MPa)	4.9000	5.1000	4.9000	4.9000	5.2000
Molar Flow	(kgmole/h)	1547.8	517.29	3104.2	517.29 *	1547.8
Mass Flow	(kg/s)	7.7453	0.29162	1.7500	0.29162	7.7453
Liquid Volume Flow	(m3/h)	27.94	14.92	89.55	14.92	27.94
Heat Flow	(kW)	-1.226e+005	-5.776	-151.8	-25.30	-1.226e+005
Molar Enthalpy	(kJ/kgmole)	-2.852e+005	-40.20	-176.0	-176.0	-2.852e+005
Name		From Reactor 1	From Reactor 2	26	27	2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	700.00 *	700.00 *	353.00 *	318.00 *	650.00 *
Pressure	(MPa)	7.0000 *	7.0000 *	6.9300	6.9300	5.1000
Molar Flow	(kgmole/h)	3659.0	24376	3659.0	24376	1551.2
Mass Flow	(kg/s)	4.0685	27.105	4.0685	27.105	7.7631
Liquid Volume Flow	(m3/h)	118.1	786.5	118.1	786.5	28.00
Heat Flow	(kW)	1.433e+004	9.548e+004	7004	4.174e+004	-9.428e+004
Molar Enthalpy	(kJ/kgmole)	1.410e+004	1.410e+004	6891	6164	-2.188e+005
Name		4	5	3	9	10
Vapour Fraction		1.0000	1.0000	1.0000	0.9732	0.8442
Temperature	(C)	780.00	728.55	650.00 *	267.01	207.14
Pressure	(MPa)	5.0500	4.9500	5.1000	5.1500	4.9000
Molar Flow	(kgmole/h)	1551.2	3101.9	4652.1	1551.2	3101.9
Mass Flow	(kg/s)	7.7631	21.547	23.279	7.7631	21.547
Liquid Volume Flow	(m3/h)	28.00	71.62	83.98	28.00	71.62
Heat Flow	(kW)	-9.189e+004	-8.292e+004	-2.828e+005	-1.016e+005	-1.042e+005
Molar Enthalpy	(kJ/kgmole)	-2.133e+005	-9.624e+004	-2.188e+005	-2.358e+005	-1.209e+005

* Specified by user.

INL
Calgary, Alberta
CANADA

Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV

Unit Set: NGNP1

Date/Time: Thu Oct 01 11:50:20 2009

Workbook: Case (Main) (continued)

Streams (continued)

Name		Oxygen Product	12	6	7	8
Vapour Fraction		1.0000	0.0000	1.0000	1.0000	0.0000
Temperature	(C)	27.000 *	27.000	748.90	623.79	27.299
Pressure	(MPa)	4.9000	4.9000	5.0500	4.9500	5.2000
Molar Flow	(kgmole/h)	1552.4	1549.5	5169.3	5169.3	14.749
Mass Flow	(kg/s)	13.793	7.7547	23.571	9.7869	7.3805e-002
Liquid Volume Flow	(m3/h)	43.65	27.97	98.90	132.4	0.2662
Heat Flow	(kW)	-279.2	-1.227e+005	-2.742e+005	-7.687e+004	-1168
Molar Enthalpy	(kJ/kgmole)	-647.4	-2.851e+005	-1.910e+005	-5.354e+004	-2.851e+005
Name		11	13	Process Heat 1	Electrolysis Power	Water Pump Power
Vapour Fraction		0.0000	0.0000	---	---	---
Temperature	(C)	27.026	27.026 *	---	---	---
Pressure	(MPa)	5.2000 *	5.2000 *	---	---	---
Molar Flow	(kgmole/h)	1549.5	1536.4 *	---	---	---
Mass Flow	(kg/s)	7.7547	7.6893	---	---	---
Liquid Volume Flow	(m3/h)	27.97	27.74	---	---	---
Heat Flow	(kW)	-1.227e+005	-1.217e+005	-4.865e-005	-2.138e+005	105.0
Molar Enthalpy	(kJ/kgmole)	-2.851e+005	-2.851e+005	---	---	---
Name		Recirc Power	Ambient Cooling	Water Recycle Pump	Stm/H2 Top Heat	Sweep Gas Top Heat
Vapour Fraction		---	---	---	---	---
Temperature	(C)	---	---	---	---	---
Pressure	(MPa)	---	---	---	---	---
Molar Flow	(kgmole/h)	---	---	---	---	---
Mass Flow	(kg/s)	---	---	---	---	---
Liquid Volume Flow	(m3/h)	---	---	---	---	---
Heat Flow	(kW)	19.52	-1.397e+004	3.074	3070	374.8
Molar Enthalpy	(kJ/kgmole)	---	---	---	---	---
Name		Sweep Pump Power	Ambient Cooling 2	Swp Rcy Pmp Pwr		
Vapour Fraction		---	---	---		
Temperature	(C)	---	---	---		
Pressure	(MPa)	---	---	---		
Molar Flow	(kgmole/h)	---	---	---		
Mass Flow	(kg/s)	---	---	---		
Liquid Volume Flow	(m3/h)	---	---	---		
Heat Flow	(kW)	0.4988	-1.883e+004	3.079		
Molar Enthalpy	(kJ/kgmole)	---	---	---		

Composition

Name	Steam/H2	Sweep Gas In	H2/Steam	Sweep Gas/O2 Out	15
Comp Mole Frac (Hydrogen)	0.10000	0.00000	0.70000	0.00000	0.00000
Comp Mole Frac (H2O)	0.90000	0.99986	0.30000	0.50000	0.99986
Comp Mole Frac (Oxygen)	0.00000	0.00014	0.00000	0.50000	0.00014
Comp Mole Frac (Nitrogen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (CO2)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Argon)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	22	Sweep Water In	24	25	Water In
Comp Mole Frac (Hydrogen)	0.10000	0.00000 *	0.99916 *	0.00002	0.00000 *
Comp Mole Frac (H2O)	0.90000	1.00000 *	0.00084 *	0.99998	1.00000 *
Comp Mole Frac (Oxygen)	0.00000	0.00000 *	0.00000 *	0.00000	0.00000 *
Comp Mole Frac (Nitrogen)	0.00000	0.00000 *	0.00000 *	0.00000	0.00000 *
Comp Mole Frac (CO2)	0.00000	0.00000 *	0.00000 *	0.00000	0.00000 *
Comp Mole Frac (Argon)	0.00000	0.00000 *	0.00000 *	0.00000	0.00000 *
Comp Mole Frac (Helium)	0.00000	0.00000 *	0.00000 *	0.00000	0.00000 *

* Specified by user.

Workbook: Case (Main) (continued)

Composition (continued)

Name	32	41	30	31	35
Comp Mole Frac (Hydrogen)	0.00000	0.00005 *	0.00002	0.70000	0.99916
Comp Mole Frac (H2O)	1.00000	0.99995 *	0.99998	0.30000	0.00084
Comp Mole Frac (Oxygen)	0.00000	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (Nitrogen)	0.00000	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (CO2)	0.00000	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (Argon)	0.00000	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000 *	0.00000	0.00000	0.00000
Name	38	37	Hydrogen Product	Hydrogen Recycle	40
Comp Mole Frac (Hydrogen)	0.00005	0.99916	0.99916	0.99916	0.00005
Comp Mole Frac (H2O)	0.99995	0.00084	0.00084	0.00084	0.99995
Comp Mole Frac (Oxygen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Nitrogen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (CO2)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Argon)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	From Reactor 1	From Reactor 2	26	27	2
Comp Mole Frac (Hydrogen)	0.00000 *	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (H2O)	0.00000 *	0.00000 *	0.00000	0.00000	0.99986
Comp Mole Frac (Oxygen)	0.00000 *	0.00000 *	0.00000	0.00000	0.00014
Comp Mole Frac (Nitrogen)	0.00000 *	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (CO2)	0.00000 *	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (Argon)	0.00000 *	0.00000 *	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	1.00000 *	1.00000 *	1.00000	1.00000	0.00000
Name	4	5	3	9	10
Comp Mole Frac (Hydrogen)	0.00000	0.00000	0.00002	0.00000	0.00000
Comp Mole Frac (H2O)	0.99986	0.50000	0.99998	0.99986	0.50000
Comp Mole Frac (Oxygen)	0.00014	0.50000	0.00000	0.00014	0.50000
Comp Mole Frac (Nitrogen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (CO2)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Argon)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	Oxygen Product	12	6	7	8
Comp Mole Frac (Hydrogen)	0.00000	0.00000	0.10000	0.70000	0.00000
Comp Mole Frac (H2O)	0.00109	0.99986	0.90000	0.30000	1.00000
Comp Mole Frac (Oxygen)	0.99891	0.00014	0.00000	0.00000	0.00000
Comp Mole Frac (Nitrogen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (CO2)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Argon)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	11	13			
Comp Mole Frac (Hydrogen)	0.00000	0.00000 *			
Comp Mole Frac (H2O)	0.99986	0.99986 *			
Comp Mole Frac (Oxygen)	0.00014	0.00014 *			
Comp Mole Frac (Nitrogen)	0.00000	0.00000 *			
Comp Mole Frac (CO2)	0.00000	0.00000 *			
Comp Mole Frac (Argon)	0.00000	0.00000 *			
Comp Mole Frac (Helium)	0.00000	0.00000 *			

Coolers

Name					
Duty (kW)					
Feed Temperature (C)					
Product Temperature (C)					

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Workbook: Case (Main) (continued)

Heat Exchangers

Name		Sweep Hi Temp Recu	Hi Temp Steam/H2 R			
Duty	(kW)	2394	8571			
UA	(kJ/C-h)	2.021e+005	9.275e+005			
LMTD	(C)	42.65	33.27			
Minimum Approach	(C)	20.00	20.00			

Heaters

Name		Steam/H2Topping He	Sweep Gas Topping I			
Duty	(kW)	3070	374.8			
Feed Temperature	(C)	748.9	780.0			
Product Temperature	(C)	800.0 *	800.0			

LNGs

Name		Low Temp Steam/H2	SG1	SG2	Sweep Low Temp Re	
UA (Calculated)	(kJ/C-h)	1.007e+006	3.515e+005	1.425e+006	6.161e+005	
LMTD	(C)	114.3 *	75.07 *	135.8 *	124.1 *	
Exchanger Cold Duty	(kW)	3.197e+004	7329	5.375e+004	2.124e+004	
Minimum Approach	(C)	50.00	50.00	50.00	50.00	

Compressors

Name		Recirc				
Feed Pressure	(MPa)	4.900				
Product Pressure	(MPa)	5.100				
Molar Flow	(kgmole/h)	517.3 *				
Energy	(kW)	19.52				
Adiabatic Efficiency		75 *				
Polytropic Efficiency		75				

Expanders

Name						
Feed Pressure	(MPa)					
Product Pressure	(MPa)					
Molar Flow	(kgmole/h)					
Energy	(kW)					
Adiabatic Efficiency						
Polytropic Efficiency						

Pumps

Name		Water Pump	Water Recycle Pump	Sweep Pump	Sweep Water Recycl	
Delta P	(kPa)	5099	300.0	5099	300.0	
Energy	(kW)	105.0	3.074	0.4988	3.079	
Feed Pressure	(MPa)	0.1013 *	4.900	0.1013 *	4.900	
Product Pressure	(MPa)	5.200	5.200	5.200	5.200 *	
Molar Flow	(kgmole/h)	3104	1548	14.75	1549	
Adiabatic Efficiency	(%)	75.00 *	75.00 *	75.00 *	75.00 *	

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
High Temperature Electrolys	Standard Sub-Flowsheet	Steam/H2 Sweep Gas In Process Heat 1	H2/Steam Sweep Gas/O2 Out Electrolysis Power	No	2500 *
Electrolysis Input and Outpu	Spreadsheet			No	500.0 *
Efficiency	Spreadsheet			No	500.0 *
Steam/H2Topping Heater	Heater	6 Stm/H2 Top Heat	Steam/H2	No	500.0 *

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Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV
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Workbook: Case (Main) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
Sweep Gas Topping Heater	Heater	4 Sweep Gas Top Heat	Sweep Gas In	No	500.0 *
T2	Tee	35	Hydrogen Product Hydrogen Recycle	No	500.0 *
Sweep Hi Temp Recup	Heat Exchanger	2 Sweep Gas/O2 Out	4 5	No	500.0 *
Hi Temp Steam/H2 Recup	Heat Exchanger	22 H2/Steam	6 7	No	500.0 *
M2	Mixer	3 24	22	No	500.0 *
M3	Mixer	32 41	30	No	500.0 *
M4	Mixer	13 8	15	No	500.0 *
Recirc	Compressor	Hydrogen Recycle Recirc Power	37	No	500.0 *
Low Temp Steam/H2 Recup	LNG	30 7	25 31	No	500.0 *
SG1	LNG	From Reactor 1 9	26 2	No	500.0 *
SG2	LNG	25 From Reactor 2	3 27	No	500.0 *
Sweep Low Temp Recup	LNG	15 5	9 10	No	500.0 *
Water Pump	Pump	Water In Water Pump Power	32	No	500.0 *
Water Recycle Pump	Pump	38 Water Recycle Pump Power	40	No	500.0 *
Sweep Pump	Pump	Sweep Water In Sweep Pump Power	8	No	500.0 *
Sweep Water Recycle Pump	Pump	12 Swp Rcy Pmp Pwr	11	No	500.0 *
Water Separation Tank	Separator	31 Ambient Cooling	38 35 Ambient Cooling	No	500.0 *
Water/Oxygen Seperation T	Separator	10 Ambient Cooling 2	12 Oxygen Product Ambient Cooling 2	No	500.0 *
RCY-1	Recycle	37	24	No	3500 *
RCY-2	Recycle	40	41	No	3500 *
RCY-3	Recycle	11	13	No	3500 *
SET-1	Set			No	500.0 *
SET-2	Set			No	500.0 *
ADJ-1	Adjust			No	3500 *

* Specified by user.

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Workbook: High Temperature Electrolysis (TPL1)

Streams

Name		Process In @TPL1	Sweep Gas In @TPL	Cathode @TPL1	Sweep Gas/O2 Out @	Gas Products @TPL
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	800.00	800.00	800.00 *	800.00	800.00
Pressure	(MPa)	5.0000	5.0000	5.0000	5.0000	5.0000
Molar Flow	(kgmole/h)	5169.3	1551.2	5169.3	3101.9	6720.1
Mass Flow	(kg/s)	23.571	7.7631	9.7869	21.547	23.571
Liquid Volume Flow	(m3/h)	98.90	28.00	132.4	71.62	176.0
Heat Flow	(kW)	-2.712e+005	-9.151e+004	-6.830e+004	-8.053e+004	-5.739e+004
Molar Enthalpy	(kJ/kgmole)	-1.888e+005	-2.124e+005	-4.757e+004	-9.346e+004	-3.075e+004
Name		Liquid Products @TP	Anode @TPL1	Molar Flow of Oxyger	Electrolysis Heating (	Electrode Heat @TPI
Vapour Fraction		0.0000	1.0000	---	---	---
Temperature	(C)	800.00	804.96	---	---	---
Pressure	(MPa)	5.0000	5.0000	---	---	---
Molar Flow	(kgmole/h)	0.00000	1550.7	1550.7	---	---
Mass Flow	(kg/s)	0.00000	13.784	13.784	---	---
Liquid Volume Flow	(m3/h)	0.0000	43.62	43.62	---	---
Heat Flow	(kW)	0.0000	1.098e+004	---	2.138e+005	71.04
Molar Enthalpy	(kJ/kgmole)	-2.975e+004	2.549e+004	---	---	---
Name		Process Heat @TPL	Electrolysis Power @			
Vapour Fraction		---	---			
Temperature	(C)	---	---			
Pressure	(MPa)	---	---			
Molar Flow	(kgmole/h)	---	---			
Mass Flow	(kg/s)	---	---			
Liquid Volume Flow	(m3/h)	---	---			
Heat Flow	(kW)	-4.865e-005	-2.138e+005			
Molar Enthalpy	(kJ/kgmole)	---	---			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
Isothermal Electrolysis @TP	Conversion Reactor	Process In @TPL1	Liquid Products @TPL1	No	500.0 *
		Electrolysis Heating @TPL1	Gas Products @TPL1		
			Electrolysis Heating @TPL1		
MIX-100 @TPL1	Mixer	Liquid Products @TPL1	Sweep Gas/O2 Out @TPL1	No	500.0 *
		Anode @TPL1			
		Sweep Gas In @TPL1			
Electrodes @TPL1	Component Splitter	Gas Products @TPL1	Cathode @TPL1	No	500.0 *
		Electrode Heat @TPL1	Anode @TPL1		
Gas Product Temperature @	Set			No	500.0 *
Outlet Temperature @TPL1	Set			No	500.0 *
Outlet Pressure @TPL1	Set			No	500.0 *
Inlet Temperature @TPL1	Set			No	500.0 *
High Temperature Electrolys	Spreadsheet			No	500.0 *
Temp Average ASR @TPL1	Spreadsheet			No	500.0 *
ADJ-1 @TPL1	Adjust			No	3500 *
ADJ-2 @TPL1	Adjust			No	3500 *

Spreadsheet: High Temperature Electrolysis @TPL1

Units Set: Electrolysis_

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
D2	Material Stream: Process In @TPL1	Temperature	1073.1 K

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Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV
Unit Set:	NGNP1
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Spreadsheet: High Temperature Electrolysis @TPL1

Units Set: Electrolysis_

CONNECTIONS

Imported Variables

Cell	Object		Variable Description	Value
D3	Material Stream:	Cathode @TPL1	Temperature	1073.2 K
A8	Material Stream:	Process In @TPL1	Pressure	5.0000e+006 N/m2
E2	Material Stream:	Process In @TPL1	Comp Mole Frac (H2O)	0.90000
F2	Material Stream:	Process In @TPL1	Comp Mole Frac (Hydrogen)	0.10000
G2	Material Stream:	Sweep Gas In @TPL1	Comp Mole Frac (Oxygen)	0.00014
E3	Material Stream:	Cathode @TPL1	Comp Mole Frac (H2O)	0.30000
F3	Material Stream:	Cathode @TPL1	Comp Mole Frac (Hydrogen)	0.70000
G3	Material Stream:	Sweep Gas/O2 Out @TF	Comp Mole Frac (Oxygen)	0.50000
B11	SpreadSheetCell:	Electrolysis Input and O	B2: Number of Cells	1.057e+006
B12	SpreadSheetCell:	Electrolysis Input and O	B3: Cell Area	225.0 cm2
B13	SpreadSheetCell:	Electrolysis Input and O	B4: Current Density (Amperes/cm^2)	0.6989
B16	SpreadSheetCell:	Temp Average ASR@B2	B2: Temp Aver ASR	0.4000
D11	Energy Stream:	Electrolysis Heating @TI	Heat Flow	2.138e+005 kW
D12	Energy Stream:	Electrode Heat @TPL1	Heat Flow	71.04 kW

Exported Variables' Formula Results

Cell	Object	Variable Description	Value
B15	Molar Flow of Oxygen @TPL1	Molar Flow	430.75 gmole/s
B19	Electrolysis Power @TPL1	Power	-2.138e+005 kW
B20	Process Heat @TPL1	Heat Flow	-4.865e-005 kW

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
A1	A1: A1 for Gibbs Formation Energy	A1 for Gibbs Formation Energy	Gibbs. Coeff. CA	2.382e+005 J/gmole
A2	A2: A2 for Gibbs Formation Energy	A2 for Gibbs Formation Energy	Gibbs. Coeff. CB	39.95 J/gmole-K
A3	A3: A3 for Gibbs Formation Energy	A3 for Gibbs Formation Energy	Gibbs. Coeff. CC	3.319e-003 kJ/gmol-K
A4	A4: A4 for Gibbs Formation Energy (kJ/gmol-K^	A4 for Gibbs Formation Energy (kJ/gmol-K^3)	---	-3.532e-008
A5	A5: A5 for Gibbs Formation Energy	A5 for Gibbs Formation Energy	Gibbs. Coeff. CB	-12.85 J/gmole-K
A6	A6: Fa Faraday Number (J/Volt-gmole)	Fa Faraday Number (J/Volt-gmole)	---	9.649e+004
A7	A7: R Universal Gas Constant	R Universal Gas Constant	Entropy	8.314 J/gmole-K
A9	A9: Standard Pressure	Standard Pressure	Pressure	1.0132e+005 N/m2
B14	B14:		---	157.2
B15	B15: Molar Flow	Molar Flow	Flow	430.75 gmole/s
B17	B17:		Vapour Fraction	1.0067
B18	B18:		Vapour Fraction	1.2862
B19	B19: Power	Power	Power	-2.138e+005 kW
B20	B20: Heat Flow	Heat Flow	Energy	-4.865e-005 kW
D4	D4:		Temperature	-1.3642e-012 K
D6	D6:		Temperature	1073.1 K
D8	D8:		---	3.501e-007
D9	D9:		---	2.567e+005
E4	E4:		Vapour Fraction	-0.6000
E5	E5:		Vapour Fraction	0.3336
F4	F4:		Vapour Fraction	0.6000
F5	F5:		Vapour Fraction	-0.6194
G4	G4:		Vapour Fraction	0.4999
G5	G5:		Vapour Fraction	-0.8452
H2	H2:		---	6.875e-003
H3	H3:		---	24.67
H4	H4:		---	24.67

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	Unit Set: NGNP1
	Date/Time: Thu Oct 01 11:50:20 2009

Spreadsheet: High Temperature Electrolysis @TPL1

Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
H5	H5:		---	54.46
I2	I2:		Molar Enthalpy	1.887e+005 J/gmole
I3	I3:		Molar Enthalpy	1.887e+005 J/gmole
I6	I6:		Molar Enthalpy	1.887e+005 J/gmole
J2	J2:		Entropy	2.321e+008 J/gmole-K
J3	J3:		Entropy	2.321e+008 J/gmole-K
K2	K2:		---	0.7610
K3	K3:		---	1.091
K6	K6:		Vapour Fraction	1.0067
K7	K7:		---	0.9333

User Variables

FORMULAS

Cell	Formula	Result
B14	=B12*B13	157.2
B15	=B11*B14/(4*A6)	430.75 gmole/s
B17	@IF(@ABS(D4)<1e-3,K6,K7)	1.0067
B18	=B17+B13*B16	1.2862
B19	=-B11*B18*B14/1000	-2.138e+005 kW
B20	=B19+D11+D12	-4.865e-005 kW
D4	=D2-D3	-1.3642e-012 K
D6	=(D2+D3)/2	1073.1 K
D8	=1/(2*A6*H4*F4)	3.501e-007
D9	=-1/(2*A6*H4*F4*D4)	2.567e+005
E4	=E3-E2	-0.6000
E5	=(E3*@LN(E3)-E3) - (E2*@LN(E2)-E2)	0.3336
F4	=F3-F2	0.6000
F5	=(F3*@LN(F3)-F3) - (F2*@LN(F2)-F2)	-0.6194
G4	=G3-G2	0.4999
G5	=(G3*@LN(G3)-G3) - (G2*@LN(G2)-G2)	-0.8452
H2	=G2*A8/A9	6.875e-003
H3	=G3*A8/A9	24.67
H4	=H3-H2	24.67
H5	=(H3*@LN(H3)-H3) - (H2*@LN(H2)-H2)	54.46
I2	=A1 + A2*D2+ A3*D2^2 + A4*D2^3 + A5*D2*@LN(D2)	1.887e+005 J/gmole
I3	=A1 + A2*D3+ A3*D3^2 + A4*D3^3 + A5*D3*@LN(D3)	1.887e+005 J/gmole
I6	=A1 + A2*D6+ A3*D6^2 + A4*D6^3 + A5*D6*@LN(D6)	1.887e+005 J/gmole
J2	= A1*D2 + A2/2*D2^2 + A3/3*D2^3 + A4/4*D2^4 + A5/2*D2^2*(@LN(D2)-0.5)	2.321e+008 J/gmole-K
J3	= A1*D3 + A2/2*D3^2 + A3/3*D3^3 + A4/4*D3^4 + A5/2*D3^2*(@LN(D3)-0.5)	2.321e+008 J/gmole-K
K2	=1/(2*A6)*(I2-A7*D2*@LN(E2/(F2*H2^0.5)))	0.7610
K3	=1/(2*A6)*(I3-A7*D3*@LN(E3/(F3*H3^0.5)))	1.091
K6	=D8*(I6*F4*H4 + A7*D6*((E5+F5)*H4 + H5/2*F4))	1.0067
K7	=D9*(A7/2*(D3^2-D2^2)*((E5+F5)*H4 + H5/2*F4) + F4*H4*(J3-J2))	0.9333

Spreadsheet

	A	B	C	D	E	F
1	2.382e+005 J/gmole *	ibbs Formation Energy *		Temperature *	y H2O *	h H2 *
2	39.95 J/gmole-K *	ibbs Formation Energy *	in *	1073.1 K	0.90000	0.10000
3	.319e-003 kJ/gmol-K^2 *	ibbs Formation Energy *	out *	1073.2 K *	0.30000	0.70000
4	-3.532e-008 *	n Energy (kJ/gmol-K^3) *	Delta *	-1.3642e-012 K	-0.6000	0.6000
5	-12.85 J/gmole-K *	ibbs Formation Energy *	Integration Coeff *		0.3336	-0.6194

* Specified by user.

INL Calgary, Alberta CANADA	Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV
	Unit Set: NGNP1
	Date/Time: Thu Oct 01 11:50:20 2009

Spreadsheet: High Temperature Electrolysis @TPL1

Units Set: Electrolysis_

Spreadsheet

6	9.649e+004 *	/ Number (J/Volt-gmole) *	Average *	1073.1 K		
7	8.314 J/gmole-K *	Universal Gas Constant *				
8	5.0000e+006 N/m2	Pressure *	C isothermal *	3.501e-007		
9	1.0132e+005 N/m2 *	Standard Pressure *	C average *	2.567e+005		
10						
11	Number of Cells *	1.057e+006 *	Electrolysis Heating *	2.138e+005 kW		
12	Cell Area *	225.0 cm2 *	Electrode Heat *	71.04 kW		
13	ensity (Amperes/cm^2) *	0.6989 *				
14	Current (Amperes) *	157.2				
15	Molar Flow of Oxygen *	430.75 gmole/s				
16	Resistance (ohm*cm^2) *	0.4000 *				
17	Nernst Potential (Volts) *	1.0067				
18	erating Voltage (Volts) *	1.2862				
19	Electrolysis Power *	-2.138e+005 kW				
20	Process Heat *	-4.865e-005 kW				

	G	H	I	J	K	
1	y O2 *	y A *	Delta G *	Integral Delta G dT *	Nernst Voltage *	
2	0.00014	6.875e-003	1.887e+005 J/gmole	2.321e+008 J/gmole-K	0.7610	
3	0.50000	24.67	1.887e+005 J/gmole	2.321e+008 J/gmole-K	1.091	
4	0.4999	24.67				
5	-0.8452	54.46				
6			1.887e+005 J/gmole	Isothermal *	1.0067	
7				Average *	0.9333	
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Spreadsheet: Temp Average ASR @TPL1

Units Set: Electrolysis_

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
B1	SpreadSheetCell: Electrolysis Input and O	B5: ASR @ 1100 K (ohms*cm^2)	0.2776
A3	Material Stream: Process In @TPL1	Temperature	1073.1 K
E15	Material Stream: Cathode @TPL1	Temperature	1073.2 K

Exported Variables' Formula Results

Cell	Object	Variable Description	Value

INL Calgary, Alberta CANADA	Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV
	Unit Set: NGNP1
	Date/Time: Thu Oct 01 11:50:20 2009

Spreadsheet: Temp Average ASR @TPL1 (continue(

Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
A4	A4:		Temperature	1073.1 K
A5	A5:		Temperature	1073.1 K
A6	A6:		Temperature	1073.1 K
A7	A7:		Temperature	1073.1 K
A8	A8:		Temperature	1073.1 K
A9	A9:		Temperature	1073.1 K
A10	A10:		Temperature	1073.1 K
A11	A11:		Temperature	1073.1 K
A12	A12:		Temperature	1073.1 K
A13	A13:		Temperature	1073.1 K
A14	A14:		Temperature	1073.1 K
A15	A15:		Temperature	1073.1 K
A16	A16:		Temperature	1073.1 K
A17	A17:		Temperature	1073.1 K
A18	A18:		Temperature	1073.1 K
A19	A19:		Temperature	1073.1 K
A20	A20:		---	40.00
B2	B2: Temp Aver ASR	Temp Aver ASR	---	0.4000
B3	B3:		---	0.4000
B4	B4:		---	0.4000
B5	B5:		---	0.4000
B6	B6:		---	0.4000
B7	B7:		---	0.4000
B8	B8:		---	0.4000
B9	B9:		---	0.4000
B10	B10:		---	0.4000
B11	B11:		---	0.4000
B12	B12:		---	0.4000
B13	B13:		---	0.4000
B14	B14:		---	0.4000
B15	B15:		---	0.4000
B16	B16:		---	0.4000
B17	B17:		---	0.4000
B18	B18:		---	0.4000
B19	B19:		---	0.4000
B20	B20:		---	19.20
C1	C1:		Temperature	1073.1 K
C2	C2:		Temperature	1073.1 K
C3	C3:		Temperature	1073.1 K
C4	C4:		Temperature	1073.1 K
C5	C5:		Temperature	1073.1 K
C6	C6:		Temperature	1073.1 K
C7	C7:		Temperature	1073.1 K
C8	C8:		Temperature	1073.1 K
C9	C9:		Temperature	1073.1 K
C10	C10:		Temperature	1073.1 K
C11	C11:		Temperature	1073.1 K
C12	C12:		Temperature	1073.1 K
C13	C13:		Temperature	1073.1 K
C14	C14:		Temperature	1073.1 K
C15	C15:		Temperature	1073.1 K
C16	C16:		Temperature	1073.1 K

* Specified by user.

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CANADA

Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV

Unit Set: NGNP1

Date/Time: Thu Oct 01 11:50:20 2009

Spreadsheet: Temp Average ASR @TPL1 (continue(Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
C17	C17:		Temperature	1073.1 K
C18	C18:		Temperature	1073.1 K
C19	C19:		Temperature	1073.1 K
D1	D1:		---	0.4000
D2	D2:		---	0.4000
D3	D3:		---	0.4000
D4	D4:		---	0.4000
D5	D5:		---	0.4000
D6	D6:		---	0.4000
D7	D7:		---	0.4000
D8	D8:		---	0.4000
D9	D9:		---	0.4000
D10	D10:		---	0.4000
D11	D11:		---	0.4000
D12	D12:		---	0.4000
D13	D13:		---	0.4000
D14	D14:		---	0.4000
D15	D15:		---	0.4000
D16	D16:		---	0.4000
D17	D17:		---	0.4000
D18	D18:		---	0.4000
D19	D19:		---	0.4000
E1	E1:		Temperature	1073.1 K
E2	E2:		Temperature	1073.1 K
E3	E3:		Temperature	1073.1 K
E4	E4:		Temperature	1073.1 K
E5	E5:		Temperature	1073.1 K
E6	E6:		Temperature	1073.1 K
E7	E7:		Temperature	1073.1 K
E8	E8:		Temperature	1073.1 K
E9	E9:		Temperature	1073.1 K
E10	E10:		Temperature	1073.1 K
E11	E11:		Temperature	1073.1 K
E12	E12:		Temperature	1073.1 K
E13	E13:		Temperature	1073.1 K
E14	E14:		Temperature	1073.1 K
F1	F1:		---	0.4000
F2	F2:		---	0.4000
F3	F3:		---	0.4000
F4	F4:		---	0.4000
F5	F5:		---	0.4000
F6	F6:		---	0.4000
F7	F7:		---	0.4000
F8	F8:		---	0.4000
F9	F9:		---	0.4000
F10	F10:		---	0.4000
F11	F11:		---	0.4000
F12	F12:		---	0.4000
F13	F13:		---	0.4000
F14	F14:		---	0.4000
F15	F15:		---	0.4000
F16	F16:		Temperature	2.7285e-014 K

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Spreadsheet: Temp Average ASR @TPL1 (continue(Units Set: Electrolysis_

User Variables

FORMULAS

Cell	Formula	Result
A4	=A3+F16	1073.1 K
A5	=A4+F16	1073.1 K
A6	=A5+F16	1073.1 K
A7	=A6+F16	1073.1 K
A8	=A7+F16	1073.1 K
A9	=A8+F16	1073.1 K
A10	=A9+F16	1073.1 K
A11	=A10+F16	1073.1 K
A12	=A11+F16	1073.1 K
A13	=A12+F16	1073.1 K
A14	=A13+F16	1073.1 K
A15	=A14+F16	1073.1 K
A16	=A15+F16	1073.1 K
A17	=A16+F16	1073.1 K
A18	=A17+F16	1073.1 K
A19	=A18+F16	1073.1 K
A20	=4*(B4+B6+B8+B10+B12+B14+B16+B18+D1+D3+D5+D7+D9+D11+D13+D15+D17+D19+F2+F4+F6+F8+F10+F12+F1	40.00
B2	@if(E15==A3,F15,(1/3*F16*(B3+A20+B20+F15))/(E15-A3))	0.4000
B3	@EXP(10300/A3)*0.00003973+(B1-0.463)	0.4000
B4	@EXP(10300/A4)*0.00003973+(B1-0.463)	0.4000
B5	@EXP(10300/A5)*0.00003973+(B1-0.463)	0.4000
B6	@EXP(10300/A6)*0.00003973+(B1-0.463)	0.4000
B7	@EXP(10300/A7)*0.00003973+(B1-0.463)	0.4000
B8	@EXP(10300/A8)*0.00003973+(B1-0.463)	0.4000
B9	@EXP(10300/A9)*0.00003973+(B1-0.463)	0.4000
B10	@EXP(10300/A10)*0.00003973+(B1-0.463)	0.4000
B11	@EXP(10300/A11)*0.00003973+(B1-0.463)	0.4000
B12	@EXP(10300/A12)*0.00003973+(B1-0.463)	0.4000
B13	@EXP(10300/A13)*0.00003973+(B1-0.463)	0.4000
B14	@EXP(10300/A14)*0.00003973+(B1-0.463)	0.4000
B15	@EXP(10300/A15)*0.00003973+(B1-0.463)	0.4000
B16	@EXP(10300/A16)*0.00003973+(B1-0.463)	0.4000
B17	@EXP(10300/A17)*0.00003973+(B1-0.463)	0.4000
B18	@EXP(10300/A18)*0.00003973+(B1-0.463)	0.4000
B19	@EXP(10300/A19)*0.00003973+(B1-0.463)	0.4000
B20	=2*(B5+B7+B9+B11+B13+B15+B17+B19+D2+D4+D6+D8+D10+D12+D14+D16+D18+F1+F3+F5+F7+F9+F11+F13)	19.20
C1	=A19+F16	1073.1 K
C2	=C1+F16	1073.1 K
C3	=C2+F16	1073.1 K
C4	=C3+F16	1073.1 K
C5	=C4+F16	1073.1 K
C6	=C5+F16	1073.1 K
C7	=C6+F16	1073.1 K
C8	=C7+F16	1073.1 K
C9	=C8+F16	1073.1 K
C10	=C9+F16	1073.1 K
C11	=C10+F16	1073.1 K
C12	=C11+F16	1073.1 K
C13	=C12+F16	1073.1 K
C14	=C13+F16	1073.1 K
C15	=C14+F16	1073.1 K
C16	=C15+F16	1073.1 K

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV
	Unit Set:	NGNP1
	Date/Time:	Thu Oct 01 11:50:20 2009

Spreadsheet: Temp Average ASR @TPL1 (continue(

Units Set: Electrolysis_

FORMULAS

Cell	Formula	Result
C17	=C16+F16	1073.1 K
C18	=C17+F16	1073.1 K
C19	=C18+F16	1073.1 K
D1	@EXP(10300/C1)*0.00003973+(B1-0.463)	0.4000
D2	@EXP(10300/C2)*0.00003973+(B1-0.463)	0.4000
D3	@EXP(10300/C3)*0.00003973+(B1-0.463)	0.4000
D4	@EXP(10300/C4)*0.00003973+(B1-0.463)	0.4000
D5	@EXP(10300/C5)*0.00003973+(B1-0.463)	0.4000
D6	@EXP(10300/C6)*0.00003973+(B1-0.463)	0.4000
D7	@EXP(10300/C7)*0.00003973+(B1-0.463)	0.4000
D8	@EXP(10300/C8)*0.00003973+(B1-0.463)	0.4000
D9	@EXP(10300/C9)*0.00003973+(B1-0.463)	0.4000
D10	@EXP(10300/C10)*0.00003973+(B1-0.463)	0.4000
D11	@EXP(10300/C11)*0.00003973+(B1-0.463)	0.4000
D12	@EXP(10300/C12)*0.00003973+(B1-0.463)	0.4000
D13	@EXP(10300/C13)*0.00003973+(B1-0.463)	0.4000
D14	@EXP(10300/C14)*0.00003973+(B1-0.463)	0.4000
D15	@EXP(10300/C15)*0.00003973+(B1-0.463)	0.4000
D16	@EXP(10300/C16)*0.00003973+(B1-0.463)	0.4000
D17	@EXP(10300/C17)*0.00003973+(B1-0.463)	0.4000
D18	@EXP(10300/C18)*0.00003973+(B1-0.463)	0.4000
D19	@EXP(10300/C19)*0.00003973+(B1-0.463)	0.4000
E1	=C19+F16	1073.1 K
E2	=E1+F16	1073.1 K
E3	=E2+F16	1073.1 K
E4	=E3+F16	1073.1 K
E5	=E4+F16	1073.1 K
E6	=E5+F16	1073.1 K
E7	=E6+F16	1073.1 K
E8	=E7+F16	1073.1 K
E9	=E8+F16	1073.1 K
E10	=E9+F16	1073.1 K
E11	=E10+F16	1073.1 K
E12	=E11+F16	1073.1 K
E13	=E12+F16	1073.1 K
E14	=E13+F16	1073.1 K
F1	@EXP(10300/E1)*0.00003973+(B1-0.463)	0.4000
F2	@EXP(10300/E2)*0.00003973+(B1-0.463)	0.4000
F3	@EXP(10300/E3)*0.00003973+(B1-0.463)	0.4000
F4	@EXP(10300/E4)*0.00003973+(B1-0.463)	0.4000
F5	@EXP(10300/E5)*0.00003973+(B1-0.463)	0.4000
F6	@EXP(10300/E6)*0.00003973+(B1-0.463)	0.4000
F7	@EXP(10300/E7)*0.00003973+(B1-0.463)	0.4000
F8	@EXP(10300/E8)*0.00003973+(B1-0.463)	0.4000
F9	@EXP(10300/E9)*0.00003973+(B1-0.463)	0.4000
F10	@EXP(10300/E10)*0.00003973+(B1-0.463)	0.4000
F11	@EXP(10300/E11)*0.00003973+(B1-0.463)	0.4000
F12	@EXP(10300/E12)*0.00003973+(B1-0.463)	0.4000
F13	@EXP(10300/E13)*0.00003973+(B1-0.463)	0.4000
F14	@EXP(10300/E14)*0.00003973+(B1-0.463)	0.4000
F15	@EXP(10300/E15)*0.00003973+(B1-0.463)	0.4000
F16	=(E15-A3)/50	2.7285e-014 K

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Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\600 MV

Unit Set: NGNP1

Date/Time: Thu Oct 01 11:50:20 2009

Spreadsheet: Temp Average ASR @TPL1 (continue(

Units Set: Electrolysis_

Spreadsheet

	A	B	C	D	E	F
1	ASR @ 1100 K *	0.2776 *	1073.1 K	0.4000	1073.1 K	0.4000
2	Temp Average ASR *	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
3	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
4	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
5	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
6	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
7	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
8	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
9	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
10	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
11	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
12	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
13	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
14	1073.1 K	0.4000	1073.1 K	0.4000	1073.1 K	0.4000
15	1073.1 K	0.4000	1073.1 K	0.4000	1073.2 K *	0.4000
16	1073.1 K	0.4000	1073.1 K	0.4000	delta T *	2.7285e-014 K
17	1073.1 K	0.4000	1073.1 K	0.4000		
18	1073.1 K	0.4000	1073.1 K	0.4000		
19	1073.1 K	0.4000	1073.1 K	0.4000		
20	40.00	19.20				

* Specified by user.

Appendix C
55%/45% Debt to Equity Results

Table C-1. HTSE connected to a 600MWt HTGR IRR results for 55%/45% debt-to-equity ratio.

	TCI -30% HTGR		TCI		TCI +50% HTGR	
	IRR	$/kg	IRR	$/kg	IRR	$/kg
	$1,000,417,985		*$1,307,917,985*		*$1,820,417,985*	
HTSE	3.66	$1.50	1.83	$1.50	-0.20	$1.50
	12.27	$3.25	9.48	$3.25	6.54	$3.25
	18.30	$5.00	14.69	$5.00	10.96	$5.00
	12.00	$3.18	12.00	$4.04	12.00	$5.48

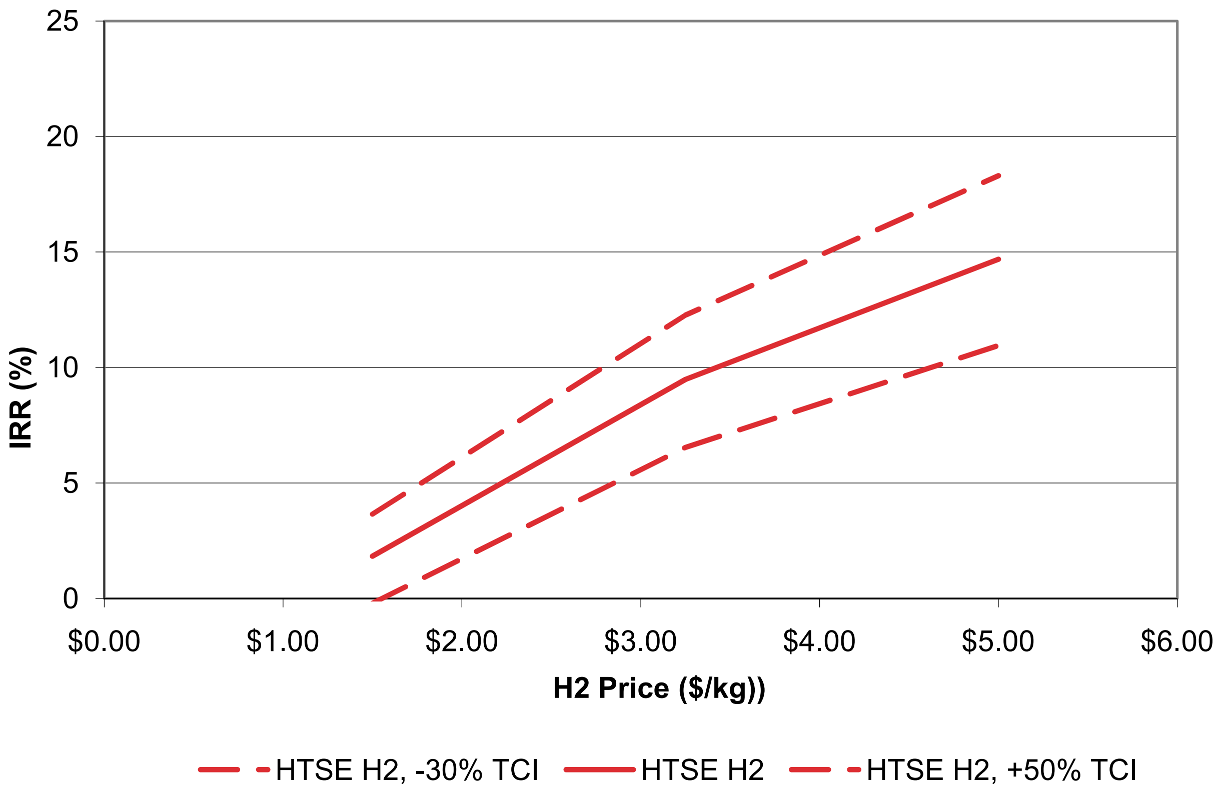

Figure C-1. HTSE connected to a 600 MWt HTGR IRR economic results for 55%/45% debt-to-equity ratio.

Appendix D
Cost Estimate Support Data Recapitulation

Appendix D is a cost estimate of the nuclear assisted production of ammonia using high temperature steam electrolysis without an air separation unit. The cost estimate was performed by a team of cost estimators at the INL. The capital cost of hydrogen production can be found by summing the HTGR, Rankine power cycle, and HTSE costs for the production of 7.51 kg/s of hydrogen.

NGNP HTSE Ammonia w/o ASU Summary

Project Name: NGNP Process Integration
Process: HTSE Ammonia w/o ASU
Estimate Number: MA36-O

Client: M. Patterson
Prepared By: B. Wallace, R. Honsinger, J. Martin
Estimate Type: Class 5

Process Component	Subtotal From Detail Sheets	Engineering %	Engineering	Contingency %	Contingency	Total Cost
High Temperature Gas Reactor (HTGR)	$ 4,201,101,415	0%	$ -	0%	$ -	$ 4,201,101,415
Rankine Power Cycle	$ 615,345,051	10%	$ 61,534,505	18%	$ 121,838,320	$ 798,717,876
High Temperature Steam Electrolysis (HTSE)	$ 363,429,475	10%	$ 36,342,947	18%	$ 71,959,036	$ 471,731,458
N2 Generation	$ 17,287,060	10%	$ 1,728,706	18%	$ 3,422,838	$ 22,438,603
CO2 Generation	$ 15,022,364	10%	$ 1,502,236	18%	$ 2,974,428	$ 19,499,029
Methanation	$ 9,518,338	10%	$ 951,834	18%	$ 1,884,631	$ 12,354,803
Ammonia Synthesis	$ 297,160,814	10%	$ 29,716,081	18%	$ 58,837,841	$ 385,714,736
Urea Synthesis	$ 288,347,019	10%	$ 28,834,702	18%	$ 57,092,710	$ 374,274,430
Nitric Acid Synthesis	$ 272,169,749	10%	$ 27,216,975	18%	$ 53,889,610	$ 353,276,334
Ammonium Nitrate Synthesis	$ 173,948,476	10%	$ 17,394,848	18%	$ 34,441,798	$ 225,785,122
Steam Turbines	$ 49,012,114	10%	$ 4,901,211	18%	$ 9,704,398	$ 63,617,723
Heat Recovery Steam Generator (HRSG)	$ -	10%	$ -	18%	$ -	$ -
Cooling Towers	$ 5,735,762	10%	$ 573,576	18%	$ 1,135,681	$ 7,445,019
Total Cost - HTSE Ammonia w/o ASU						$ 6,935,956,549
Total Cost Rounded to the Nearest $10M						$ 6,940,000,000

Checked By: SNW	Remarks
Approved By: John R	

4/20/2010

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Rev. 03-04-10

Battelle Energy Alliance, LLC

COST ESTIMATE SUPPORT DATA RECAPITULATION

Project Title: NGNP Process Integration – HTSE Ammonia without ASU
Estimator: B. W. Wallace/CEP, R. R. Honsinger/CEP, J. B. Martin/CCT
Date: April 20, 2010
Estimate Type: Class 5
File: MA36-O
Approved By:

Page 1 of 9

I. **PURPOSE:** *Brief description of the intent of how the estimate is to be used (i.e., for engineering study, comparative analysis, request for funding, proposal, etc.).*

It is expected that the capital costs identified in these estimates will be used in a model producing an economic analysis for each specific integrated application and subsequently will be considered in a related feasibility study.

II. **SCOPE OF WORK:** *Brief statement of the project's objective. Thorough overview and description of the proposed project. Identify work to be accomplished, as well as any specific work to be excluded.*

A. **Objective:**
Develop Class 5 estimates as defined by the Association for Advancement of Cost Engineering (AACEi) that will identify the current capital cost associated with high-temperature gas reactors (HTGRs) integrated with a nuclear ammonia without an air separation unit process.

B. **Included:**
The scope of work required to achieve this objective includes the following:

1. Engineering
2. The allowance provided for the HTGR represents a complete and operable system. All elements required for construction of this nuclear reactor capability, including an initial steam generator, security systems, contingency, and owner's costs are included in the turn-key allowance. Owner's costs are included only in the case of the reactor capability. It is considered that the total value represents all inside of battery limits (ISBL) elements, outside of battery limits (OSBL) elements, site development, and all ancillary control and operational functions and capabilities.
3. Construction of a new integrated refinery capability to produce ammonia that consists of the following:
   a. Overnight island-type costs for HTGRs
   b. High-temperature steam electrolysis (HTSE) hydrogen production unit
   c. H_2 combustor (N_2 generation)
   d. Natural gas combustor (CO_2 generation)
   e. Methanation
   f. Ammonia synthesis
   g. Urea synthesis
   h. Nitric acid synthesis

COST ESTIMATE SUPPORT DATA RECAPITULATION
– Continued –
Project Title: NGNP Process Integration – HTSE Ammonia without ASU
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i. Ammonium nitrate synthesis
j. Steam turbines, internal to process
k. Heat recovery steam generator, internal to process
l. Cooling towers, internal to process
m. Allowances for Balance of Plant (BOP)/offsite/OSBL, including the following:
   (1.) Site development/improvements
   (2.) Provisions for general and administrative buildings and structures
   (3.) Provisions for OSBL piping
   (4.) Provisions for OSBL instrumentation and control
   (5.) Provisions for OSBL electrical
   (6.) Provisions for facility supply and OSBL water systems
   (7.) Provisions for site development/improvements
   (8.) Project/construction management.

C. **Excluded**:
This scope of work specifically excludes the following elements:
1. Licensing and permitting costs
2. Operational costs
3. Land costs
4. Sales taxes
5. Royalties
6. Owner's fees and owner's costs, except those included for the HTGR
7. The allowance provided for the HTGR capability excludes all costs associated with materials development, or costs that would not be appropriately associated with an nth of a kind (NOAK) reactor/facility.

III. **ESTIMATE METHODOLOGY**: *Overall methodology and rationale of how the estimate was developed (i.e., parametric, forced detail, bottoms up, etc.). Total dollars/hours and rough order magnitude (ROM) allocations of the methodologies used to develop the cost estimate.*

Consistent with the AACEi Class 5 estimates, the level of definition and engineering development available at the time they were prepared, their intended use in a feasibility study, and the time and resources available for their completion, the costs included in this estimate have been developed using parametric evaluations. These evaluations have used publicly available and published project costs to represent similar islands utilized in this project. Analysis and selection of the published costs used have been performed by the project technical lead and Cost Estimating. Suitability for use in this effort was determined considering the correctness and completeness of the data available, the manner in which total capital costs were represented, the age of the previously performed work, and the similarity to the capacity/trains required by this project. The specific sources, selected and used in this cost estimate, are identified in the capital cost estimate detail sheets. Adjustments have been made to these published costs using escalation factors identified in the Chemical Engineering Price Cost Index. Scaling of the published island costs has been accomplished using the six-tenths capacity factoring method. Costs included for the HTGR, power cycles, and HTSE, have been identified and provided by the respective BEA subject matter experts. The total cost for each of these items has been linearly calculated from the respective base unit costs. Any normalization to provide for geographic factors was considered using geographic factors available from RS Means Construction Cost Data references. Cost-estimating relationships have been used to identify allowances to complete the costs.

It was identified to the Next Generation Nuclear Plant (NGNP) Process Integration team that the methodology employed by NGNP to develop the nuclear capability included constituents of parametric modeling, vendor quotes, actual costs, and proprietary costing databases. These preconceptual design estimates were reviewed by NGNP Project Engineering for credibility with regard to assumptions and bases of estimate and performed multiple studies to reconcile variations in the scope and assumptions within the three estimates.

BOP/OSBL costs were determined by the project team, considering data provided by Shell Gasifier IGCC Base Case report NETL 2000, *Conceptual Cost Estimating Manual* Second Edition by John S. Page, and additional adjusted sources. Because the allowances identified did not show significant variability, the allowances identified in the NETL 2000 report were chosen for this effort in order to minimize the mixing of data sources.

IV. **BASIS OF THE ESTIMATE**: *Overall explanation of sources for resource pricing and schedules.*

A. **Quantification Basis**: *The source for the measurable quantities in the estimate that can be used in support of earned value management. Source documents may include drawings, design reports, engineers' notes, and other documentation upon which the estimate is originated.*

All islands and capacities have been provided to Cost Estimating by the project respective expert.

B. **Planning Basis**: *The source for the execution and strategies of the work that can be used to support the project execution plan, acquisition strategy, schedules, and market conditions and other documentation upon which the estimate is originated.*

1. All islands and HTGRs represent NOAK projects.
2. Projects will be constructed and operated by commercial entities.
3. All projects, with the exception of the Steam-Assisted Gravity Drainage Project, will be located in the U.S. Gulf Coast refinery region.
4. Costs are presented as overnight costs.
5. The cost estimate does not consider or address funding or labor resource restrictions. Sufficient funding and labor resources will be available in a manner that allows optimum usage of the funding and resources as estimated and scheduled.

COST ESTIMATE SUPPORT DATA RECAPITULATION
– Continued –

Project Title: NGNP Process Integration – HTSE Ammonia without ASU
File: MA36-O Page 4 of 9

C. **Cost Basis**: *The source for the costing on the estimate that can be used in support of earned value management, funding profiles, and schedule of values. Sources may include published costing references, judgment, actual costs, preliminary quotes or other documentation upon which the estimate is originated.*

1. All costs are represented as current value costs. Factors for forward-looking escalation and inflation factors are not included in this estimate.
2. Where required, published cost factors, as identified in the Chemical Engineering Plant Cost Index, will be applied to previous years' values to determine current year values.
3. Geographic location factors, as identified in RS Means Construction Cost Data reference manual, were considered for each source cost.
4. The cost provided for the HTGR reflects internal BEA cost data that was developed for the HTGR and presented to the NGNP Process Integration team by L. Demmick. Considered in the cost is a pre-conceptual cost estimate prepared by three separate contractor teams. All contractor teams proposed 4-unit NOAK plants with thermal power levels between 2,000 MW_t and 2,400 MW_t at a cost of roughly \$4B, including owner's cost. This equates to \$1,667 to \$2,000 per kW_t. For the purposes of this report, the nominal cost of an HTGR will be set at the upper end of this range, \$2,000 per kW_t. This is a complete turnkey cost and includes engineering and construction of a NOAK HTGR, the power cycle, and contingency. The total HTGR cost for each process is calculated linearly as \$1,708,333 per MWth of required capacity, excluding the cost of the power cycles.
5. The cost included for the power cycle was provided by the INL project team expert. The power cycle cost is based on the definition of a 240-MWe capacity and \$618,176 per MWe. The total power cycle cost for each process is calculated linearly as \$618,176 per MWe of required capacity. BOP, engineering, and contingency costs are added to the base cost.
6. The cost included for HTSE was provided by the INL project team expert. The total HTSE cost for each process is calculated linearly as \$36,120,156 per kg/s of required capacity. BOP, engineering, and contingency costs are added to the base cost.
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COST ESTIMATE SUPPORT DATA RECAPITULATION		
– Continued –		
Project Title:	NGNP Process Integration – HTSE Ammonia without ASU	
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Project Title: NGNP Process Integration – HTSE Ammonia without ASU
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V. **ESTIMATE QUALITY ASSURANCE**: *A listing of all estimate reviews that have taken place and the actions taken from those reviews.*

A review of the cost estimate was held on January 14, 2010, with the project team and the cost estimators. This review allowed for the project team to review and comment, in detail, on the perceived scope, basis of estimates, assumptions, project risks, and resources that make up this cost estimate. Comments from this review have been incorporated into this estimate to reflect a project team consensus of this document.

VI. **ASSUMPTIONS**: *Condition statements accepted or supposed true without proof of demonstration; statements adding clarification to scope. An assumption has a direct impact on total estimated cost.*

General Assumptions:

A. All costs are represented in 2009 values.

B. Costs that were included from sources representing years prior to 2009 have been normalized to 2009 values using the Chemical Engineering Plant Cost Index. This index was selected due to its widespread recognition and acceptance and its specific orientation toward work associated with chemical and refinery plants.

C. Capital costs are based on process islands. The majority of these islands are interchangeable, after factoring for the differing capacities, flowsheet-to-flowsheet.

D. All chemical processing and refinery processes will be located in the U.S. Gulf Coast region.

E. All costs considered to be BOP costs that can be specifically identified have been factored out of the reported source data and added into the estimate in a manner consistent with that identified in the NETL 2000 IGCC Base Cost report. Inclusion of the source costs in this manner normalizes all reported cost information to the bare-erected costs.

COST ESTIMATE SUPPORT DATA RECAPITULATION
– Continued –
Project Title: NGNP Process Integration – HTSE Ammonia without ASU
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HTGR:

A. The linearly scalable cost included for an HTGR reflects an NOAK reactor with a 750°C-operating temperature.
B. HTGR is considered to be linearly scalable, by required capacity, per the direction of the project team. This allows the process integration feasibility studies to showcase the financial analysis of the process without the added burden of integer quantity 600-MWth HTGRs.
C. The allowance represents a turnkey condition for the reactor and its supporting infrastructure.
D. A high-temperature, high-pressure steam generator is included in the cost represented for HTGR.
E. A contingency allowance is included in the HTGR cost, but is not identified as a separate line item in this estimate. This allowance was identified and included by the NGNP HTGR project team.
F. Total cost range, including contingency, for HTGR is -50%, +100%.
G. Cost included for the power cycle reflects NOAK research and manufacturing developments to allow for assumed high pressures and temperatures.
H. The power cycle is considered to be linearly scalable, by required capacity, per the direction of the project team. This allows the process integration feasibility studies to showcase the financial analysis of the process.
I. The cost included for HTSE reflects NOAK research and manufacturing developments, which will increase the expected lifespan of the electrolysis cells.
J. The HTSE is considered to be linearly scalable, by required capacity, per the direction of the project team. This allows the process integration feasibility studies to showcase the financial analysis of the process.

HTSE Ammonia without Air Separation Unit

Some estimated island costs are based on figures from a verbal conversation with Casale, a leading world vendor of process industry services. These costs were used in cases where other acceptable costs were not available.

VII. **CONTINGENCY GUIDELINE IMPLEMENTATION**:

Contingency Methodologies: *Explanation of methodology used in determining overall contingency. Identify any specific drivers or items of concern.*

At a project risk review on December 9, 2009, the project team discussed risks to the project. An 18% allowance for capital construction contingency has been included at an island level based on the discussion and is included in the summary sheet. The contingency level that was included in the island cost source documents and additional threats and opportunities identified here were considered during this review. The contingency identified was considered by the project team and included in Cost and Performance Baseline for Fossil Energy Plants DOE/NETL-2007/1281 and similar reports. Typically, contingency allowance provided in these reports ranged from 15% to 20%. Since much of

COST ESTIMATE SUPPORT DATA RECAPITULATION

– Continued –

Project Title: NGNP Process Integration – HTSE Ammonia without ASU
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the data contained in this estimate has been derived from these reports, the project team has also chosen a level of contingency consistent with them.

While the level of contingency provided for the HTGR capability is not identified as a line item, the cost data provided to the NGNP Process Integration team was identified as including an appropriate allocation for contingency. No additional contingency has been added to this element.

A. **Threats**: *Uncertain events that are potentially negative or reduce the probability that the desired outcome will happen.*

1. The singularly largest threat to this estimate surrounds the lump sum cost included for the HTGR reactor(s). This is followed by the HTSE process, where applicable. While the overriding assumption is that these elements will be NOAK, currently, a complete HTGR has not been commissioned and the HTSE has been successfully developed in an integrated laboratory-scale model, but has not been completed in either pilot plant or production scales.
2. The level of project definition/development that was available at the time the estimate was prepared represents a substantial risk to the project and is likely to occur. The high level at which elements were considered and included has the potential to include additional elements that are within the work scope but not sufficiently provided for or addressed at this level.
3. The estimate methodology employed is one of a stochastic parametrically evaluated process. This process used publicly available published costs that were related to the process required, costs were normalized using price indices, and the cost was scaled to provide the required capacity. The cost-estimating relationships that were used represent typical costs for BOP allowances, but source cost data from which the initial island costs were derived were not completely descriptive of the elements included, not included, or simply referred to with different nomenclature or combined with other elements. While every effort has been made to correctly normalize and factor the costs for use in this effort, the risk exists that not all of these were correctly captured due to the varied information available.
4. This project is heavily dependent on metals, concrete, petroleum, and petroleum products. Competition for these commodities in today's environment due to global expansion, uncertainty, and product shortages affects the basic concepts of the supply and demand theories, thus increasing costs.
5. Impacts due to large quantities of materials, special alloy materials, fabrication capability, and labor availability could all represent conditions that may increase the total cost of the project.

COST ESTIMATE SUPPORT DATA RECAPITULATION

– Continued –

Project Title: NGNP Process Integration – HTSE Ammonia without ASU

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B. **Opportunities**: *Uncertain events that could improve the results or improve the probability that the desired outcome will happen.*

1. Additional research and work performed with both vendors and potential owner/operators for a specific process or refinery may identify efficiencies and production means that have not been available for use in this analysis.
2. Recent historical data may identify and include technological advancements and efficiencies not included or reflected in the publicly available source data used in this effort.

Note: Contingency does not increase the overall accuracy of the estimate; it does, however, reduce the level of risk associated with the estimate. Contingency is intended to cover the inadequacies in the complete project scope definition, estimating methods, and estimating data. Contingency specifically excludes changes in project scope, unexpected work stoppages (e.g., strikes, disasters, and earthquakes) and excessive or unexpected inflation or currency fluctuations.

VIII. **OTHER COMMENTS/CONCERNS SPECIFIC TO THE ESTIMATE**:

None.

Detail Item Report - High Temperature Gas Reactor (HTGR)

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
INL Internal Cost Data (INL 2009)	1	MWth		2009	$ 1,708,333	$ 1,708,333	$ 1,708,333	2,459	MWt h				$ 4,201,101,415	$ 4,201,101,415

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
INL Internal Cost Data (INL 2009)	1	MWth		2009	$ 1,708,333	$ 1,708,333	$ 1,708,333	2,459	MWt h				$ 4,201,101,415	$ 4,201,101,415

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	0.00%		$ -	$ -
Civil/Structural/Buildings	0.00%		$ -	$ -
Piping	0.00%		$ -	$ -
Control and Instrumentation	0.00%		$ -	$ -
Electrical Systems	0.00%		$ -	$ -
		Total Balance of Plant	$ -	$ -
		Total Balance of Plant Plus the Selected Source	$ 4,201,101,415	$ 4,201,101,415

Basis of Estimate Notes:

Single source cost point. This cost has been provided by the subcontracted subject matter expert L. Demick to the INL NGNP Process Integration team. This cost represents a complete turnkey cost. The cost of an HTGR reactor, as provided by L. Demick, is $2,000,000 per MWth required. This cost used has been reduced to $1,708,333 per MWth to exclude the cost of power cycles.

Detail Item Report - Rankine Cycle - Case 11, Supercritical PC Case

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
INL Internal Cost Data (INL 2009)	240	MWe	1	2009	$ 148,362,255	$ 148,362,255	$ 148,362,255	879	MWe	5	176	MWe	$ 123,069,010	$ 615,345,051

Summary:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
INL Internal Cost Data (INL 2009)	240	MWe	1	2009	$ 148,362,255	$ 148,362,255	$ 148,362,255	879	MWe	5	176	MWe	$ 123,069,010	$ 615,345,051

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	0.00%		$ -	$ -
Civil/Structural/Buildings	0.00%		$ -	$ -
Piping	0.00%		$ -	$ -
Control and Instrumentation	0.00%		$ -	$ -
Electrical Systems	0.00%		$ -	$ -
		Total Balance of Plant	$ -	$ -
		Total Balance of Plant Plus the Selected Source	$ 123,069,010	$ 615,345,051

Basis of Estimate Notes:

Single source cost. The reported costs are from the INL project team expert. The reported cost represents a Rankine power cycle, excluding the steam generator. The cost is based on information found in NETL 2007b, which has been adjusted and customized for this project by the INL project team expert. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996. The allowances have been adjusted and customized for this project based on estimator judgment. The reduced civil/structural/buildings allowance accounts for the buildings that are included in the Rankine power cycle cost. Water and electrical systems BOP allowances are included in the reported cost for the Rankine power cycle.

Detail Item Report - High Temperature Steam Electrolysis (HTSE)

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
INL Feasibility Study (INL 2009)	1.00	kg/s	1	2009	$ 36,120,156	$ 36,120,156	$ 36,120,156	7.51	kg/s				$ 271,216,026	$ 271,216,026

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
INL Feasibility Study (INL 2009	1.00	kg/s	1	2009	$ 36,120,156	$ 36,120,156	$ 36,120,156	7.51	kg/s				$ 271,216,026	$ 271,216,026

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 19,256,338	$ 19,256,338
Civil/Structural/Buildings	9.20%		$ 24,951,874	$ 24,951,874
Piping	7.10%		$ 19,256,338	$ 19,256,338
Control and Instrumentation	2.60%		$ 7,051,617	$ 7,051,617
Electrical Systems	8.00%		$ 21,697,282	$ 21,697,282
		Total Balance of Plant	$ 92,213,449	$ 92,213,449
		Total Balance of Plant Plus the Selected Source	$ 363,429,475	$ 363,429,475

Rationale for Selection:

Single source cost. The reported costs are from the INL project team expert. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - N2 Generation

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
N2 Generator Cost (Wood 2009)	239,265	lb/hr	1	2007	$13,317,500	$ 13,317,500	$ 12,977,845	236,902	lb/hr	1	236,902	lb/hr	$ 12,900,791	$ 12,900,791

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
N2 Generator Cost (Wood 2009)	239,265	lb/hr	1	2007	$13,317,500	$ 13,317,500	$ 12,977,845	236,902	lb/hr	1	236,902	lb/hr	$ 12,900,791	$ 12,900,791

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 915,956	$ 915,956
Civil/Structural/Buildings	9.20%		$ 1,186,873	$ 1,186,873
Piping	7.10%		$ 915,956	$ 915,956
Control and Instrumentation	2.60%		$ 335,421	$ 335,421
Electrical Systems	8.00%		$ 1,032,063	$ 1,032,063
		Total Balance of Plant	$ 4,386,269	$ 4,386,269
		Total Balance of Plant Plus the Selected Source	$ 17,287,060	$ 17,287,060

Rationale for Selection:

Single source cost point. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - CO_2 Generation

Project Name:	NGNP Process Integration	Client:	M. Patterson
Process:	HTSE Ammonia w/o ASU	Prepared By:	B. Wallace, R. Honsinger, J. Martin
Estimate Number:	MA36-O	Estimate Type:	Class 5

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
CO2 Compression - Subcritical														
Princeton Report (Kreutz 2008)	10	MW	1	2007	$ 6,310,000	$ 6,310,000	$ 6,149,067	2	MW	1	2	MW	$ 2,329,179	$ 2,329,179
CO2 Compression - Supercritical														
Princeton Report (Kreutz 2008)	13	MW	1	2007	$ 9,520,000	$ 9,520,000	$ 9,277,198	0.3	MW	1	0.3	MW	$ 987,887	$ 987,887
CO2 Generation														
CO2 Generator (Wood 2009)	184,095	lb/hr	1	2007	$ 8,102,200	$ 8,102,200	$ 7,895,558	184,021	lb/hr	1	184,021	lb/hr	$ 7,893,654	$ 7,893,654

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Kreutz 2008: Combined Subcritical and Supercritical Processes													$ 11,210,720	$ 11,210,720

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 795,961	$ 795,961
Civil/Structural/Buildings	9.20%		$ 1,031,386	$ 1,031,386
Piping	7.10%		$ 795,961	$ 795,961
Control and Instrumentation	2.60%		$ 291,479	$ 291,479
Electrical Systems	8.00%		$ 896,858	$ 896,858
		Total Balance of Plant	$ 3,811,645	$ 3,811,645
		Total Balance of Plant Plus the Selected Source	$ 15,022,364	$ 15,022,364

Rationale for Selection:

Single source cost point. The only CO2 generation source considered was Wood 2009. This cost was supplemented with CO2 compression costs from Kreutz 2008 to represent a full island cost. Both subcritical and supercritica process costs were included under the CO2 Compression heading. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, su as Page 1996.

Appendix D

Detail Item Report - Methanation

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
DOE FE Report (DOE 1978)	1,000	tpd	1	1978	$ 1,467,000	$ 1,467,000	$ 3,432,834	3,360	tpd	1	3,360	tpd	$ 7,103,237	$ 7,103,237

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
DOE FE Report (DOE 1978)	1,000	tpd	1	1978	$ 1,467,000	$ 1,467,000	$ 3,432,834	3,360	tpd	1	3,360	tpd	$ 7,103,237	$ 7,103,237

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 504,330	$ 504,330
Civil/Structural/Buildings	9.20%		$ 653,498	$ 653,498
Piping	7.10%		$ 504,330	$ 504,330
Control and Instrumentation	2.60%		$ 184,684	$ 184,684
Electrical Systems	8.00%		$ 568,259	$ 568,259
		Total Balance of Plant	$ 2,415,101	$ 2,415,101
		Total Balance of Plant Plus the Selected Source	$ 9,518,338	$ 9,518,338

Rationale for Selection:

Single source island cost identified by the project technical lead. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such Page 1996.

Detail Item Report - Ammonia Synthesis

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Vendor - Verbal 2009	360	tpd	1	2009	$ 44,000,000	$ 44,000,000	$ 44,000,000	3,360	tpd	2	1,680	tpd	$ 110,880,901	$ 221,761,801
Economics Ammonia Coal Gasification (Morel 1977)	1,000	tpd	1	1977	$ 50,748,000	$ 50,748,000	$ 80,243,904	3,360	tpd	2	1,680	tpd	$ 109,546,276	$ 219,092,551
Stamicarbon, Middle East Fertilizer Symposium, March 2009	4,297	tpd	1	2008	$ 800,000,000	$ 800,000,000	$ 779,596,498	3,360	tpd	2	1,680	tpd	$ 443,768,260	$ 887,536,519
Ammonia, Chem Systems, 1998	1,653	tpd	1	1998	$ 160,000,000	$ 160,000,000	$ 210,320,924	3,360	tpd	2	1,680	tpd	$ 212,375,463	$ 424,750,926

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Vendor - Verbal 2009	360	tpd	1	2009	$ 44,000,000	$ 44,000,000	$ 44,000,000	3,360	tpd	2	1,680	tpd	$ 110,880,901	$ 221,761,801

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 7,872,544	$ 15,745,088
Civil/Structural/Buildings	9.20%		$ 10,201,043	$ 20,402,086
Piping	7.10%		$ 7,872,544	$ 15,745,088
Control and Instrumentation	2.60%		$ 2,882,903	$ 5,765,807
Electrical Systems	8.00%		$ 8,870,472	$ 17,740,944
		Total Balance of Plant	$ 37,699,506	$ 75,399,012
		Total Balance of Plant Plus the Selected Source	$ 148,580,407	$ 297,160,814

Rationale for Selection:

The verbal cost was selected as recommended by the project team expert. The Stamicarbon information shows a roughly 350% increase in prices between 2003 and 2008 emphasizing the importance of using the most recent information available. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - Urea Synthesis

Project Name:	NGNP Process Integration	Client:	M. Patterson
Process:	HTSE Ammonia w/o ASU	Prepared By:	B. Wallace, R. Honsinger, J. Martin
Estimate Number:	MA36-O	Estimate Type:	Class 5

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Vendor - Verbal 2009	625	tpd	1	2009	$ 85,000,000	$ 85,000,000	$ 85,000,000	2,939	tpd	1	2,939	tpd	$ 215,184,342	$ 215,184,342
Perry's Chemical Engineering Handbook, 7th Edition	200	tpd	1	1994	$ 8,800,000	$ 8,800,000	$ 12,240,152	2,939	tpd	1	2,939	tpd	$ 61,388,719	$ 61,388,719
PNNL	4681	tpd	1	2009	$ 182,000,000	$ 182,000,000	$ 182,000,000	2,939	tpd	1	2,939	tpd	$ 137,653,721	$ 137,653,721
Stamicarbon, Middle East Fertilizer Symposium, March 2009	3,582	tpd	1	2008	$ 550,000,000	$ 550,000,000	$ 535,972,592	2,939	tpd	1	2,939	tpd	$ 475,978,115	$ 475,978,115

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Vendor - Verbal 2009	625	tpd	1	2009	$ 85,000,000	$ 85,000,000	$ 85,000,000	2,939	tpd	1	2,939	tpd	$ 215,184,342	$ 215,184,342

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 15,278,088	$ 15,278,088
Civil/Structural/Buildings	9.20%		$ 19,796,959	$ 19,796,959
Piping	7.10%		$ 15,278,088	$ 15,278,088
Control and Instrumentation	2.60%		$ 5,594,793	$ 5,594,793
Electrical Systems	8.00%		$ 17,214,747	$ 17,214,747
		Total Balance of Plant	$ 73,162,676	$ 73,162,676
		Total Balance of Plant Plus the Selected Source	$ 288,347,019	$ 288,347,019

Rationale for Selection:

The verbal cost was selected as recommended by the project team expert. The Stamicarbon information shows a roughly 350% increase in prices between 2003 and 2008 emphasizing the importance of using the most recent information available. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - Nitric Acid Synthesis

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Perry's Chemical Engineering Handbook, 7th Edition	334	tpd	1	1994	$ 6,600,000	$ 6,600,000	$ 9,180,114	5,192	tpd	6	865	tpd	$ 16,252,129	$ 97,512,774
Fertilizer Manual	359	tpd	1	1998	$ 15,200,000	$ 15,200,000	$ 19,980,488	5,192	tpd	6	865	tpd	$ 33,851,959	$ 203,111,753

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Fertilizer Manual	359	tpd	1	1998	$ 15,200,000	$ 15,200,000	$ 19,980,488	5,192	tpd	6	865	tpd	$ 33,851,959	$ 203,111,753

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 2,403,489	$ 14,420,934
Civil/Structural/Buildings	9.20%		$ 3,114,380	$ 18,686,281
Piping	7.10%		$ 2,403,489	$ 14,420,934
Control and Instrumentation	2.60%		$ 880,151	$ 5,280,906
Electrical Systems	8.00%		$ 2,708,157	$ 16,248,940
		Total Balance of Plant	$ 11,509,666	$ 69,057,996
		Total Balance of Plant Plus the Selected Source	$ 45,361,625	$ 272,169,749

Rationale for Selection:

The Fertilizer Manual was selected for being both the newest cost point and the most conservative. The data from Perry's Chemical Engineering Handbook is based on earlier data from Peters and Timmerhaus, making it even less desirable. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - Ammonium Nitrate Synthesis

Project Name:	**NGNP Process Integration**	**Client:**	**M. Patterson**
Process:	**HTSE Ammonia w/o ASU**	**Prepared By:**	**B. Wallace, R. Honsinger, J. Martin**
Estimate Number:	**MA36-O**	**Estimate Type:**	**Class 5**

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Perry's Chemical Engineering Handbook, 7th Edition	334	tpd	1	1994	$ 6,000,000	$ 6,000,000	$ 8,345,558	3,779	tpd	3	1,260	tpd	$ 18,507,052	$ 55,521,157
Fertilizer Manual	1,395	tpd	1	1998	$ 35,000,000	$ 35,000,000	$ 46,007,702	3,779	tpd	3	1,260	tpd	$ 43,270,765	$ 129,812,295
EPA Report	1,200	tpd	1	1981	$ 9,480,000	$ 9,480,000	$ 13,434,154	3,779	tpd	3	1,260	tpd	$ 13,831,044	$ 41,493,133

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Fertilizer Manual	1,395	tpd	1	1998	$ 35,000,000	$ 35,000,000	$ 46,007,702	3,779	tpd	3	1,260	tpd	$ 43,270,765	$ 129,812,295

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 3,072,224	$ 9,216,673
Civil/Structural/Buildings	9.20%		$ 3,980,910	$ 11,942,731
Piping	7.10%		$ 3,072,224	$ 9,216,673
Control and Instrumentation	2.60%		$ 1,125,040	$ 3,375,120
Electrical Systems	8.00%		$ 3,461,661	$ 10,384,984
		Total Balance of Plant	$ 14,712,060	$ 44,136,180
		Total Balance of Plant Plus the Selected Source	$ 57,982,825	$ 173,948,476

Rationale for Selection:

The Fertilizer Manual was selected for being both the newest cost point and the most conservative. The data from Perry's Chemical Engineering Handbook is based on earlier data from Peters and Timmerhaus, making it even less desirable. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - Steam Turbines

Project Name:	NGNP Process Integration	Client:	M. Patterson
Process:	HTSE Ammonia w/o ASU	Prepared By:	B. Wallace, R. Honsinger, J. Martin
Estimate Number:	MA36-O	Estimate Type:	Class 5

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Steam Turbine and HRSG														
Shell IGCC Base Cases (NETL 2000)	189	MW	1	1999	$ 50,671,000	$ 50,671,000	$ 66,419,744	159	MW	1	159	MW	$ 59,899,366	$ 59,899,366
Steam Turbine														
NETL Baseline Report (NETL 2007a)	401	MW	4	2006	$ 74,651,000	$ 18,662,750	$ 19,125,957	159	MW	1	159	MW	$ 25,233,335	$ 25,233,335
Princeton Report (Kreutz 2008)	275	MW	1	2007	$ 66,700,000	$ 66,700,000	$ 64,998,858	159	MW	1	159	MW	$ 46,806,721	$ 46,806,721
Shell IGCC Power Plant with CO2 Capture (NETL 2007b)	230	MW	1	2006	$ 44,515,000	$ 44,515,000	$ 45,619,856	159	MW	1	159	MW	$ 36,576,204	$ 36,576,204

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Shell IGCC Power Plant with CO2 Capture (NETL 2007b)	230	MW	1	2006	$ 44,515,000	$ 44,515,000	$ 45,619,856	159	MW	1	159	MW	$ 36,576,204	$ 36,576,204

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 2,596,910	$ 2,596,910
Civil/Structural/Buildings	9.20%		$ 3,365,011	$ 3,365,011
Piping	7.10%		$ 2,596,910	$ 2,596,910
Control and Instrumentation	2.60%		$ 950,981	$ 950,981
Electrical Systems	8.00%		$ 2,926,096	$ 2,926,096
		Total Balance of Plant	$ 12,435,909	$ 12,435,909
		Total Balance of Plant Plus the Selected Source	$ 49,012,114	$ 49,012,114

Rationale for Selection:

Shell IGCC PowerPlant with CO2 Capture (NETL 2007b) is a recently reported cost point that closely reflects this project's requirements. The Princeton Report (Kreutz 2008) source for the steam turbine cost point is the NETL 2007b report. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - HRSG

Project Name: NGNP Process Integration
Process: HTSE Ammonia w/o ASU
Estimate Number: MA36-O

Client: M. Patterson
Prepared By: B. Wallace, R. Honsinger, J. Martin
Estimate Type: Class 5

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Steam Turbine and HRSG														
Shell IGCC Base Cases (NETL 2000)	189	MW	1	1999	$ 50,671,000	$ 50,671,000	$ 66,419,744	-	MW	1	-	MW	$ -	$ -
HRSG														
NETL Baseline Report (NETL 2007a)	5,155,983	lb/hr	3	2006	$ 27,581,000	$ 9,193,667	$ 9,421,852	-	lb/hr	1	-	lb/hr	$ -	$ -
Princeton Report (Kreutz 2008)	355	MW	1	2007	$ 52,000,000	$ 52,000,000	$ 50,673,772	-	MW	1	-	MW	$ -	$ -
Shell IGCC Power Plant with CO2 Capture (NETL 2007b)	8,438,000	lb/hr	2	2006	$ 45,291,000	$ 22,645,500	$ 23,207,558	-	lb/hr	1	-	lb/hr	$ -	$ -

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Shell IGCC Power Plant with CO2 Capture (NETL 2007b)	8,438,000	lb/hr	2	2006	$ 45,291,000	$ 22,645,500	$ 23,207,558	-	lb/hr	1	-	lb/hr	$ -	$ -

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ -	$ -
Civil/Structural/Buildings	9.20%		$ -	$ -
Piping	7.10%		$ -	$ -
Control and Instrumentation	2.60%		$ -	$ -
Electrical Systems	8.00%		$ -	$ -
		Total Balance of Plant	$ -	$ -
		Total Balance of Plant Plus the Selected Source	$ -	$ -

Rationale for Selection:

Shell IGCC PowerPlant with CO2 Capture (NETL 2007b) is a recently reported cost point that closely reflects this project's requirements. The Princeton Report (Kreutz 2008) source for the steam turbine cost point is the NETL 2007b report. The allowances listed under 'Balance of Plant' are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.

Detail Item Report - Cooling Towers

Project Name:	NGNP Process Integration	Client:	M. Patterson
Process:	HTSE Ammonia w/o ASU	Prepared By:	B. Wallace, R. Honsinger, J. Martin
Estimate Number:	MA36-O	Estimate Type:	Class 5

Sources Considered:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Cooling Tower Depot	182,142	gpm	5	2009	$ 4,611,840	$ 922,368	$ 922,368	160,853	gpm	5	32,171	gpm	$ 856,084	$ 4,280,419

Source Selected:

Source	Reported Capacity		Reported Trains	Report Cost Year	Reported Cost	Reporting Year Cost Per Train	Normalized Cost Per Train using CEPCI Index	Capacity Required		Trains Reqd.	Capacity per Train		Factored Cost per Train from Normalized Cost	Total Current Cost for Required Trains
Cooling Tower Depot	182,142	gpm	5	2009	$ 4,611,840	$ 922,368	$ 922,368	160,853	gpm	5	32,171	gpm	$ 856,084	$ 4,280,419

Balance of Plant:

Description	% of Total Cost		Cost Per Train	Total Cost
Water Systems	7.10%		$ 60,782	$ 303,910
Civil/Structural/Buildings	9.20%		$ 78,760	$ 393,799
Piping	7.10%		$ 60,782	$ 303,910
Control and Instrumentation	2.60%		$ 22,258	$ 111,291
Electrical Systems	8.00%		$ 68,487	$ 342,434
		Total Balance of Plant	$ 291,069	$ 1,455,343
		Total Balance of Plant Plus the Selected Source	$ 1,147,152	$ 5,735,762

Rationale for Selection:

Single source cost. Publically available current data. Calculated capital costs based on publically available cost data from a vendor regularly engaged in the building of cooling towers. The allowances listed under 'Balance of Pla are based on NETL 2000. These allowance values are comparable to additional published estimating guides, such as Page 1996.