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Analysis of Reference Design for Nuclear-Assisted Hydrogen Production at 750°C Reactor Outlet Temperature

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May 2010

Idaho National Laboratory

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High Temperature Electrolysis

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Name Title [optional]	Date
Name Title [optional]	Date
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ABSTRACT

The use of High Temperature Electrolysis (HTE) for the efficient production of hydrogen without the greenhouse gas emissions associated with conventional fossil-fuel hydrogen production techniques has been under investigation at the Idaho National Engineering Laboratory (INL) for the last several years. The activities at the INL have included the development, testing and analysis of large numbers of solid oxide electrolysis cells, and the analyses of potential plant designs for large scale production of hydrogen using a high-temperature gas-cooled reactor (HTGR) to provide the process heat and electricity to drive the electrolysis process. The results of this research led to the selection in 2009 of HTE as the preferred concept in the U.S. Department of Energy (DOE) hydrogen technology down-selection process. However, the down-selection process, along with continued technical assessments at the INL, has resulted in a number of proposed modifications and refinements to improve the original INL reference HTE design. These modifications include changes in plant configuration, operating conditions and individual component designs. This report describes the resulting new INL reference design coupled to two alternative HTGR power conversion systems, a Steam Rankine Cycle and a Combined Cycle (a Helium Brayton Cycle with a Steam Rankine Bottoming Cycle). Results of system analyses performed to optimize the design and to determine required plant performance and operating conditions when coupled to the two different power cycles are also presented. A 600 MWt high temperature gas reactor coupled with a Rankine steam power cycle at a thermal efficiency of 44.4% can produce 1.85 kg/s of hydrogen and 14.6 kg/s of oxygen. The same capacity reactor coupled with a combined cycle at a thermal efficiency of 42.5% can produce 1.78 kg/s of hydrogen and 14.0 kg/s of oxygen.

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ACRONYMS

Analysis of Reference Design for Nuclear-Assisted Hydrogen Production at 750°C Reactor Outlet Temperature

1. INTRODUCTION

As part of the ongoing activities at the INL to investigate the potential for large-scale production of hydrogen using the nuclear-driven High-Temperature Electrolysis (HTE) process, the INL has evaluated a number of alternative power cycle concepts coupled in different ways to alternative HTE process loop designs. This evaluation process led to the development in 2006 of a preliminary design for a HTGR direct Brayton power cycle coupled to an HTE hydrogen production plant that was designated as the original INL reference HTE design [1]. The HTGR utilized helium at a reactor outlet temperature of 900°C to provide electricity and high-temperature process heat for the electrolytic hydrogen production process. This initial reference design underwent extensive analyses and reviews to refine and optimize the concept. In addition, economic analyses were performed to determine the approximate cost for the commercial production of hydrogen at large scales [2]. The results of these studies, along with the testing and analyses of large numbers of solid oxide electrolysis cells, led to the selection in 2009 of HTE as the preferred concept in the U.S. Department of Energy hydrogen technology down-selection process [3]. However, these evaluations also led to a reconsideration of the reference design and the development of a new INL reference design that would address concerns or issues identified in the original design. These issues included potential materials problems associated with the relatively high reactor outlet temperature of 900°C, the technology development risks associated with the use of a high-temperature helium direct Brayton cycle, and the potential for tritium contamination of the hydrogen production process loop when process heat was transferred directly from the reactor primary loop to the hydrogen production process without an intermediate loop to provide additional separation between the reactor and hydrogen production loops.

To address these issues, a new INL reference design has been developed and evaluated using the HYSYS process analysis software. Initial HYSYS evaluations were also performed for two nuclear-driven power cycle concepts intended for the production of the electricity and process heat required by the INL reference HTE hydrogen production process. The optimized power cycle designs were then coupled to the new INL reference HTE hydrogen production process, and the HYSYS models of the integrated systems were optimized to maximize the total hydrogen production rates and overall hydrogen production efficiencies for the two integrated power cycle/INL reference hydrogen production concepts. This analysis process, along with the resulting optimized reference designs for the two integrated nuclear-driven hydrogen production plant concepts are discussed in the following sections of this report.

2. SELECTION OF POWER CYCLES

Two power cycles, a Steam Rankine Cycle and a Combined Cycle (an Indirect Helium Brayton Cycle with a Steam Rankine Bottoming Cycle), were evaluated as part of the development of the new INL Reference HTE hydrogen production process. These two power cycles were assumed to be powered by an HTGR whose configuration and operating conditions are based on the latest design parameters planned for the Next Generation Nuclear Plant

(NGNP). The current HTGR reference design specifies a reactor power of 600 MW_t, with a primary system pressure of 7.0 MPa, and reactor inlet and outlet fluid temperatures of 322°C and 750°C, respectively. Assuming the same reactor operating conditions, each of these power cycles was separately optimized, using the HYSYS process analysis software to maximize power cycle efficiency prior to coupling the power cycles to the new INL Reference HTE hydrogen production process. The following two sections describe the optimized power cycle designs, and Section 3 of this report describes the two integrated power cycle/HTE hydrogen production concepts optimized to maximize hydrogen production rates and overall hydrogen production efficiencies.

For this analysis the following assumptions were made:

- The minimum approach temperature for most of the heat exchangers is 25°C. This approximates heat exchangers with efficiencies near 95%.
- The high temperature recuperating heat exchangers in the high temperature electrolysis process have minimum approach temperatures of 20°C because they have relatively smaller temperature differences between the inlet and outlet conditions
- The primary and secondary helium loops and the HTE loop have heat exchanger pressure drops equal to 2% of the average pressure in the loops.
- The power cycles have 2% pressures drops based on inlet pressures except for the steam generator and the reheater of the Rankine cycle which have a 10% pressure drop.
- The primary and secondary circulators and the Brayton cycle turbines and compressors have adiabatic efficiencies of 90%
- The hydrogen recirculator and all pumps have adiabatic efficiencies of 75%
- The Rankine high pressure turbine, intermediate pressure turbine and low pressure turbine have adiabatic efficiencies of 85%, 90%, and 80%.

2.1 Steam Rankine cycle

The first power cycle evaluated for the new INL Reference Design was a Steam Rankine Cycle. This Steam Rankine cycle, shown in Figure 1, is powered by a 600 MW_t helium-cooled HTGR operating at a primary system pressure of 7.0 MPa, and reactor inlet and outlet fluid temperatures of 322°C and 750°C, respectively. As shown in Figure 1, hot helium from the reactor outlet at 750°C (Stream 2) is split (T13) with 77% of the flow transferring heat to the Rankine Cycle steam generator, and the remaining 23% of the flow transferring heat to the Rankine Cycle reheater.

The Rankine Cycle flow sheet in Figure 1 includes three turbines; a High Pressure Turbine, a two stage Intermediate Pressure Turbine, and a five stage Low Pressure Turbine. The steam generator delivers steam at approximately 593°C and 24MPa to the inlet of the High Pressure Turbine. To maximize the thermodynamic efficiency of the cycle, most of the steam exiting the High Pressure Turbine is passed through the reheater before entering the first stage of the

Intermediate Pressure Turbine. Between each stage of expansion, a portion of the steam flow is used to supply heat to seven feedwater heaters. One of these feedwater heaters (between Stages 1 and 2 of the Low Pressure Turbine) is an open heater that exchanges its heat by mixing, allowing for deaeration of the working fluid. A condenser is used to reject the remaining waste heat from the Stage 5 low pressure turbine exhaust. The feedwater is then returned to the steam generator inlet utilizing a condensate pump, booster pump, and boiler feed pump to recover pressure at various points in the feedwater return. Pressure control valves are also included in the process flow model to ensure appropriate operating conditions at each of the feedwater heaters locations.

The optimized power cycle efficiency for this configuration is 44.4%. The efficiency was calculated by summing the power generated by the turbines and subtracting the power from the pumps, the power needed to cool the condenser, and the fraction of the power of the primary loop circulator used for power production and dividing that total by the fraction of the reactor heat used for power production. The power to cool the condenser was calculated using a procedure found in reference 5.

The HYSYS calculated fluid conditions, flow rates, and component operating parameters for the Steam Rankine Cycle shown in Figure 1, are provided in Appendix A.

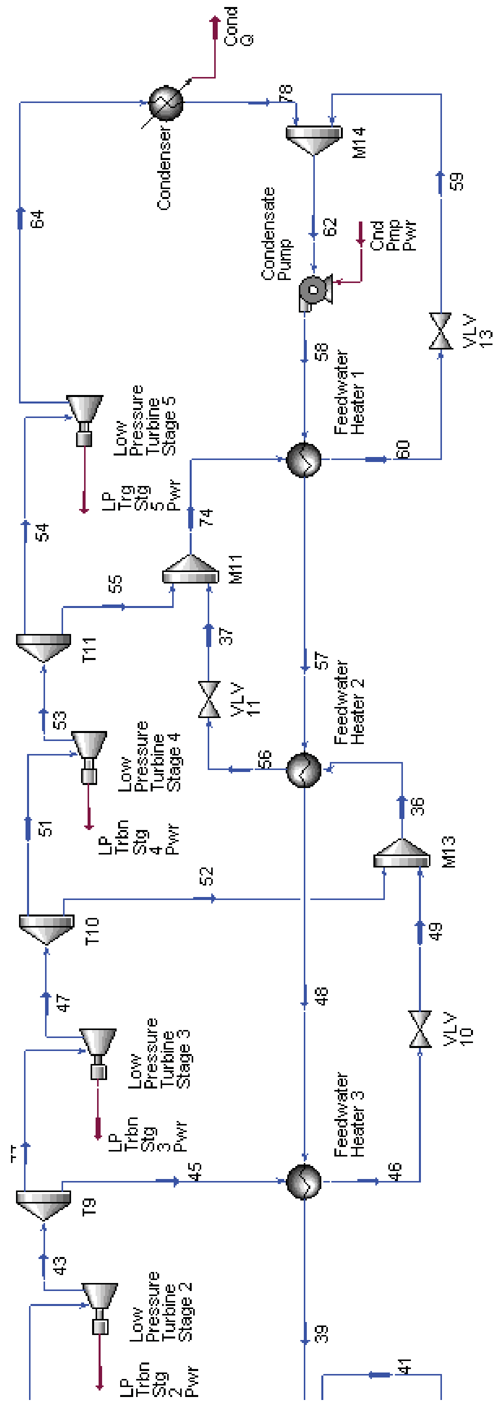


Figure 1 Part 1 Rankine Power Cycle

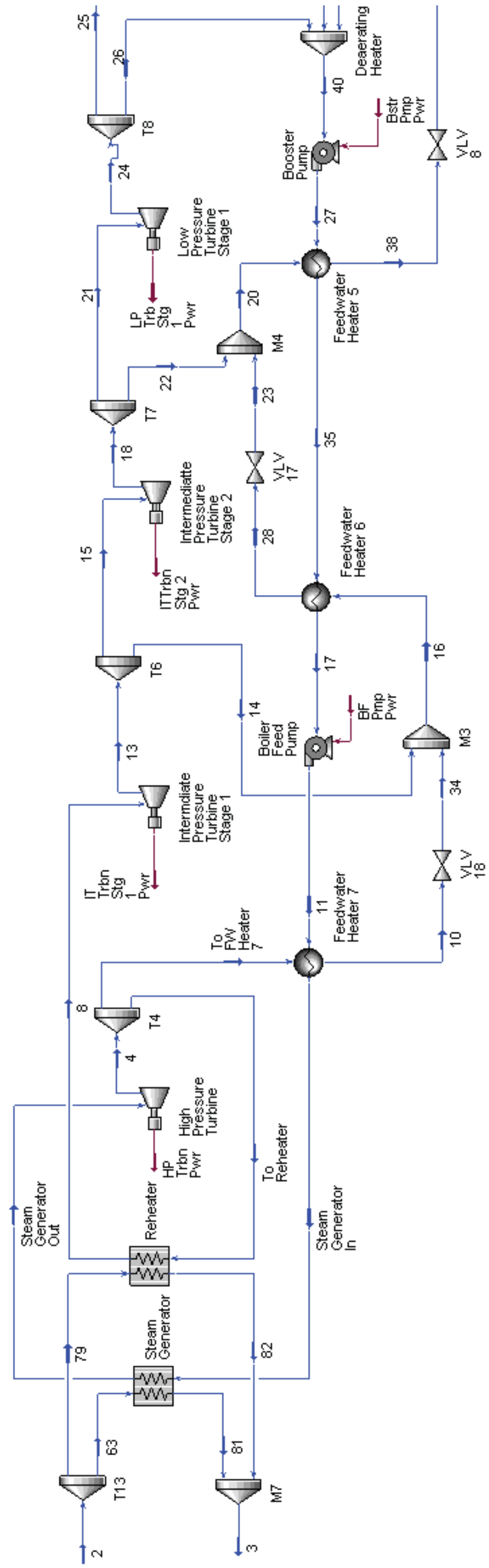


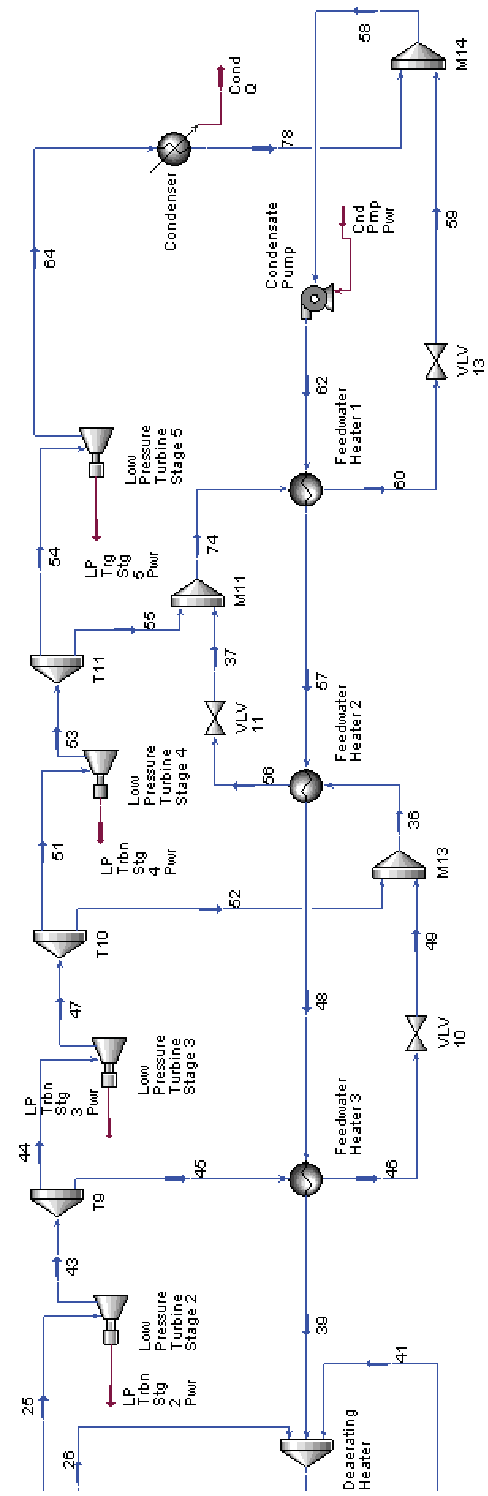
Figure 1 (Part 2) Rankine Power Cycle

2.2 Combined Indirect Helium Brayton and Steam Rankine Cycles

The second power cycle evaluated for the new INL Reference Design is an indirect helium recuperated Brayton cycle combined with a Steam Rankine bottoming cycle. The HYSYS model for this cycle, shown in Figure 2, again assumed a 600 MW_t, HTGR operating at a primary system pressure of 7.0 MPa and reactor inlet and outlet fluid temperatures of 322°C and 750°C, respectively.

Helium from the reactor outlet is split into two streams at "TEE-100" and transfers heat via two helium-to-helium heat exchangers to the secondary helium power conversion loop which is also operating at a maximum pressure of 7.0 MPa. The indirect helium recuperated Brayton cycle shown at the top of the process flow sheet consists of a High Pressure Turbine (HP Turbine) and a Low Pressure Turbine (HP Turbine). Heat transferred from the primary system at HX 1 raises the secondary helium temperature at the High Pressure Turbine inlet to 725°C at a secondary system pressure of 7 MPa. The secondary helium then flows through the high pressure turbine where the gas is expanded to produce approximately 98.8 MW of electric power. The secondary helium, at a reduced pressure (4.35 MPa) and temperature (570°C), then passes through the second helium-to-helium heat exchanger (IHX 2), where heat from the primary system fluid raises the secondary helium temperature back to 725°C before entering the Low Pressure Turbine (LP Turbine). The secondary helium expands through the Low Pressure Turbine producing approximately 96.4 MW of additional electric power. The secondary helium leaving the Low Pressure Turbine at 573°C and 2.68 MPa then passes through a recuperator and precooler where it is further cooled before entering the low-pressure compressor. To improve compression efficiencies, the helium is again cooled in an intercooler heat exchanger before entering the high-pressure compressor. The helium exits the high-pressure compressor at a pressure of approximately 7.3 MPa. The coolant then circulates back through the recuperator where the recovered heat raises its temperature to the inlet temperature of the IHX 1 heat exchanger, completing the secondary helium loop circuit. The primary helium flows leaving the IHX 1 and IHX2 heat exchangers recombine at MIX-100 and the total flow is delivered to the Steam Rankine bottoming cycle interface (T13) at a temperature and pressure of approximately 684°C and 6.9 MPa, respectively. Here the flow is again split with 78% of the flow going to the Rankine Cycle steam generator and the remaining flow going to the Rankine Cycle reheater.

The Steam Rankine Cycle shown at the bottom of the process flow sheet in Figure 2 is identical to that shown in Figure 1. The Rankine Cycle efficiency in this configuration is not as efficient because of the lower operating temperatures when operating in a bottoming cycle configuration, The resulting optimized Combined Cycle efficiency for the configuration shown in Figure 2 is 42.5%.



Low Pressure Turbine Stage 2
Low Pressure Turbine Stage 3
Low Pressure Turbine Stage 4
Low Pressure Turbine Stage 5
LP Trbn Stg 2 Pwr
LP Trbn Stg 3 Pwr
LP Trbn Stg 4 Pwr
LP Trg Stg 5 Pwr
T9
T10
T11
M11
M13
M14
VLV 10
VLV 11
VLV 13
Feedwater Heater 1
Feedwater Heater 2
Feedwater Heater 3
Deaerating Heater
Condenser
Cond Q
Condensate Pump
Cnd Pmp Pwr
25
26
36
37
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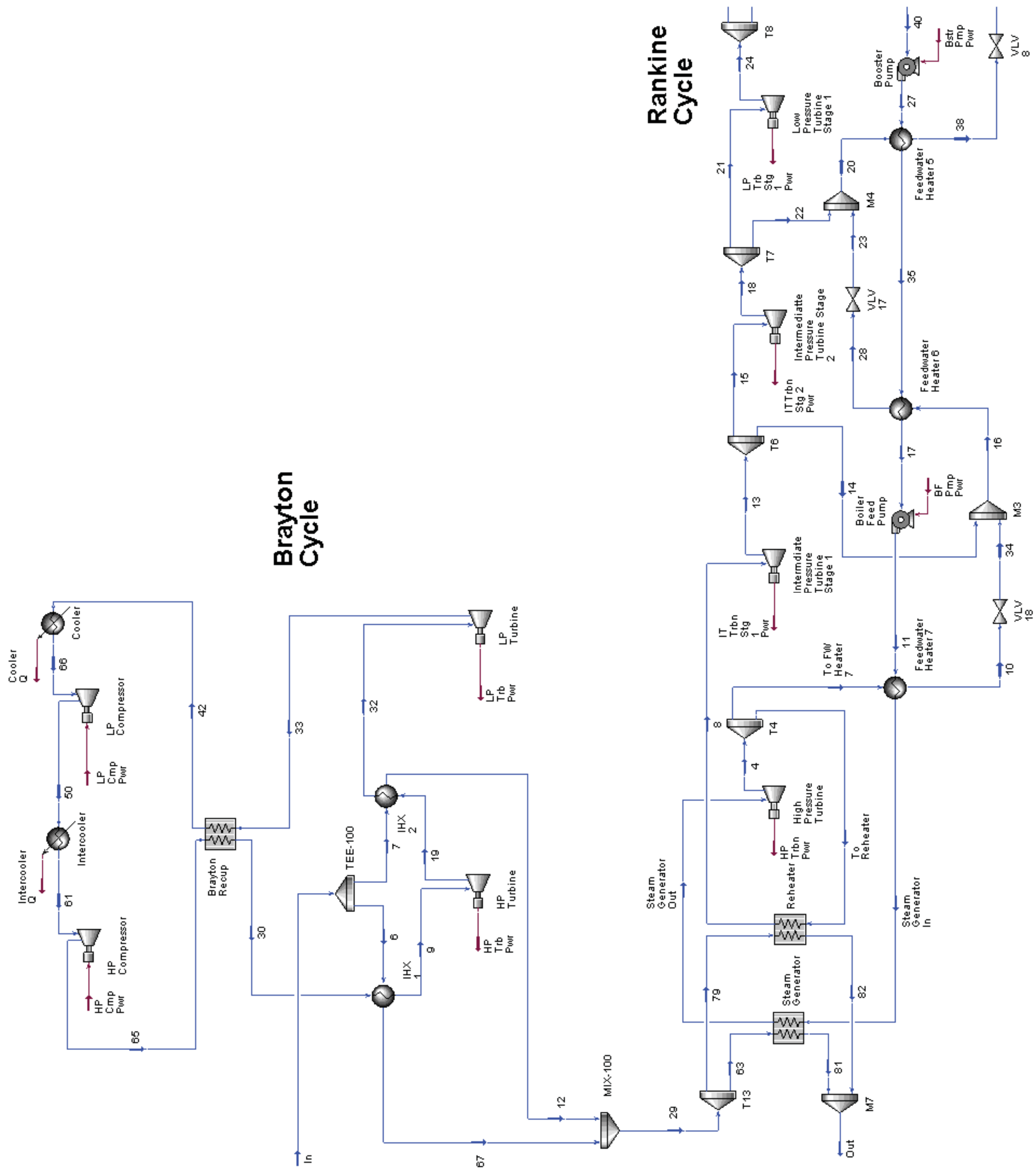

Figure 2. Combined Rankine and Brayton Cycle

3. DESCRIPTION OF REFERENCE HTE PROCESS

An INL reference design for HTE hydrogen production process was developed, and optimized for both the Steam Rankine and Combined power cycles described above. The HYSYS model of the reference HTE hydrogen production process coupled to the Rankine Steam cycle is shown in Figure 3. Since the process flow sheet of the reference HTE process is the same for both the Steam Rankine and Combined cycles, the system description of the HTE process coupled to the Steam Rankine power cycle (shown in Figure 3 and described here) also apply to the coupling of the reference HTE process to the Combined power cycle. However, because of differences in power cycle efficiency, the resulting hydrogen production rates and overall hydrogen production efficiencies will be different for the two integrated power cycle/HTE processes, as discussed in the Analysis Results Section of this report.

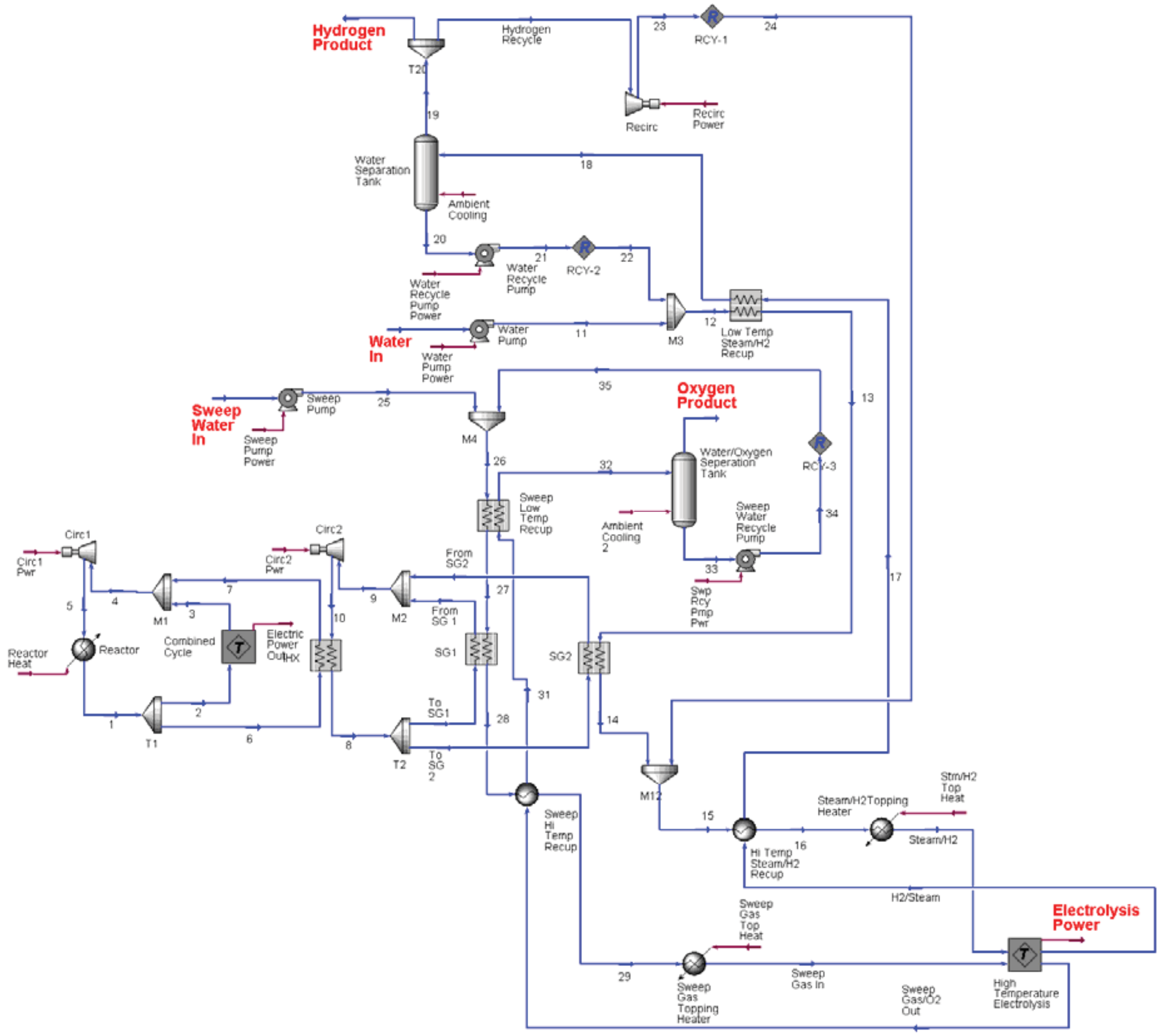

Figure 3. HYSYS process flow diagram of reference HTE hydrogen production process.

The optimized reference design for the HTE hydrogen production process shown in Figure 3 operates at a system pressure of 5 MPa and uses a steam sweep system rather than the air sweep system used in the original INL reference design to remove oxygen from the anode side of the electrolyzer. This change was made from the original reference design so that the oxygen product gas, which represents a valuable commodity, can be recovered by condensing the steam and recovering the dry oxygen product gas for later sale.

The HTGR (depicted on the left side of the process flow sheet in Figure 3) provides both electricity and process heat to drive the HTE process. The power conversion system used to produce electricity to drive the electrolysis process is modeled in a sub-flow sheet designated by the letter “T” on the left side of the process flow sheet in Figure 3. The sub-flow sheet models are depicted in Figure 1 for the Rankine cycle and Figure 2 for the Combined cycle. In both cases, an AC to DC power conversion efficiency of 96% was assumed for supplying DC power to the electrolyzer.

Process heat from the HTGR (which represents only about 10% of the total reactor power) is transferred from the primary loop through an intermediate heat exchanger (IHX) to an intermediate helium loop, and then to the two steam generators (SG1 and SG2) shown in Figure 3. The use of the intermediate loop between the reactor primary system and the HTE process was included in the new INL reference design as an added barrier to minimize the potential for tritium migration from the primary system, and potential tritium contamination of the HTE product hydrogen.

Feed water for the HTE process (Water In) is raised to the system operating pressure of 5 MPa by a pump, where it is then mixed with recycled water condensed from the hydrogen product water separation tank. The water stream is then partially vaporized in the recuperator (Low Temp Steam/H2 Recup) which recovers heat from the post-electrolysis process. The low quality feed stream then enters a steam generator (SG1) where the remaining water is vaporized and the steam is heated to approximately 100°C below the electrolysis operating temperature of 800 °C. Downstream of the recuperator, at M2, the steam is mixed with recycled hydrogen product gas. A fraction of the product gas is recycled in this way in order to assure that reducing conditions are maintained on the steam/hydrogen electrode. The resulting steam and hydrogen mixture (approximately 10% hydrogen) then passes through a second post-electrolysis process recuperator and a gas-fired or electric heater to raise its temperature to the desired electrolysis operating temperature of 800 °C.

The process stream then enters the electrolyzer, where oxygen is electrolytically removed from the steam, producing hydrogen and oxygen. The custom electrolyser module developed at INL for direct incorporation into the HYSYS process analysis code is described in more detail in the following section.

Downstream of the electrolyzer, the hydrogen-rich product stream (approximately 70 mol % hydrogen) passes back through the two post-electrolysis recuperators where the product stream is cooled and, as described earlier, the recovered heat is used to heat the inlet process stream to near the desired electrolysis process temperature. The product stream is then further cooled at the Water Separation Tank, where the majority of any residual steam is condensed and separated, yielding the dry hydrogen product. The cooled product stream is split at T2 and a fraction of the product gas is recycled into the inlet process stream as discussed previously. A recirculating blower is required to repressurize the hydrogen recycle stream to the upstream pressure at M2.

As mentioned earlier, the new INL reference design uses a steam sweep system to remove the excess oxygen that is evolved on the anode side of the electrolyzer. In the steam sweep system, the inlet water (Sweep Water In) is raised to the system operating pressure by the Sweep Pump, and then mixed with condensed water recirculated back from the Water/Oxygen separation tank at M4. The recirculation of condensed water from the oxygen product stream significantly reduces the net amount of water needed to operate the steam sweep system. After leaving the M4 mixer, the sweep water passes through a recuperator (Sweep Low Temp Recup), where recovered heat from the sweep system heats and vaporizes most of the feed water. The high quality steam then passes through steam generator SG1, where it is superheated to approximately 100°C below the electrolysis operating temperature of 800°C. The steam then passes through a second sweep system recuperator (Sweep Hi Temp Recup) and a gas fired or electric heater where the sweep steam is raised to 800°C before entering the electrolyzer stack.

After removing the excess oxygen from the anode of the electrolyzer, the steam/oxygen mixture (50% oxygen) then passes through the two previously discussed steam sweep system recuperators, where excess heat is recovered, and the post-electrolysis steam-oxygen mixture is cooled. The resulting high quality steam-oxygen mixture is then further cooled in the Water/Oxygen Separation Tank, where the majority of the water is condensed and recirculated back to be combined with the sweep water feed at M4. The relatively dry oxygen product leaving the Water/Oxygen Separation Tank at high pressure (4.9 MPa) is then available for immediate use or storage for later use.

4. ELECTROLIZER MODEL

The electrolyzer model process flow diagram is shown in Figure 4. The process inlet flow, consisting of steam and hydrogen passes through a conversion reactor where the steam is split into hydrogen and oxygen. The conversion reactor uses a stoichiometric equation for the splitting of water. Based upon the utilization, a specified percentage of the steam is converted. HYSYS calculates the heat of reaction for this conversion, which is shown as the "Electrolysis Heating" energy stream in Figure 4. The hydrogen, oxygen, and steam enter a component splitter labeled Electrodes. The oxygen is split from the other components and exits at the anode stream. The sweep gas mixes with the anode stream and exits as the "Sweep/Gas O2 Out" stream. An embedded spreadsheet is used to calculate the Nernst potential, operating voltage, current and electrolysis power [4]. In this reference case, the boundary conditions are isothermal and adiabatic which is referred as the thermal neutral point.

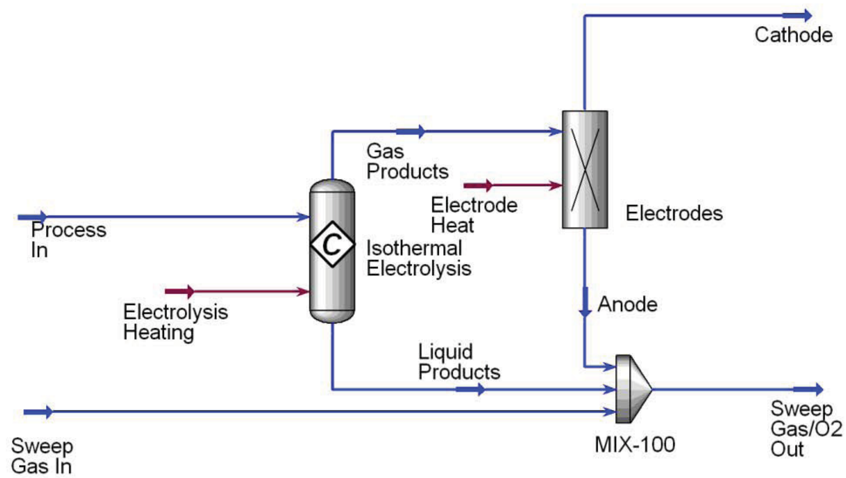

Figure 4. Electrolyzer model process flow diagram.

5. ANALYSIS RESULTS

5.1 HTE process coupled to Steam Rankine cycle

The HYSYS analysis of the above described new INL reference design coupled to the Steam Rankine cycle achieves a hydrogen production rate of 1.85 kg/s and an overall hydrogen production efficiency of 42.8% with a reactor power source of 600 MW_t operating at a reactor outlet temperature of 750 °C. The overall hydrogen production efficiency is the higher heating value of the hydrogen product divided by the total heat input. The total heat input for both cases is the sum of the reactor heat plus the heat needed by the two topping heaters in the HTE loop. The electrolysis stack consists of 1.119 million electrolysis cells operating at a current density of 0.6989 amp/cm^2, and a steam utilization rate of 66.67%. Each cell has an area of 225 cm^2. The fluid conditions, flow rates, stream composition and component operating parameters for this integrated configuration are summarized in Tables 1-6 for each of the locations shown in Figure 3. The temperature, pressure, molar and mass flow rates, and the vapor fraction for each stream are displayed in Table 1.

The composition of each stream is shown in Table 2. The thermal duty, overall heat transfer coefficient, UA, log-mean temperature difference, LMTD, and the minimum approach temperature for each heat exchanger is found in Table 3. Compressor and pump parameters are given in Tables 4. Table 5 provides the topping heater heat rates and the electrolysis power corresponding to the variables shown in Figure 3. Heater data are provided in Table 6.

Table 1. Stream properties of Rankine case.

Stream Name	Vapor Fraction	Temperature (C)	Pressure (MPa)	Molar Flow (kgmole/h)	Mass Flow (kg/s)
1	1	750	7	67.474	270.1
2	1	750	7	60.446	241.97
3	1	311.02	6.86	60.446	241.97
4	1	314.05	6.86	67.474	270.1
5	1	322	7.071	67.474	270.1
6	1	750	7	7.0275	28.131
7	1	340.11	6.86	7.0275	28.131
8	1	725	7	7.03	28.141
9	1	304.76	6.86	7.03	28.141
10	1	315.11	7.14	7.03	28.141
11	0	27.317	5.4	0.9144	16.473
12	0	26.897	5.4	1.3679	24.643
13	0.2712	268.86	5.3	1.3679	24.643
14	1	700	5.2	1.3679	24.643
15	1	650.93	5.2	1.52	24.951
16	1	756.9	5.1	1.52	24.951
17	1	670.93	4.9	1.52	10.36
18	0.7725	144.05	4.8	1.52	10.36
19	1	26	4.8	1.0649	2.1614
20	0	26	4.8	0.45512	8.1986
21	0	26.052	5.4	0.45512	8.1986
22	0	26.052	5.4	0.45351	8.1697
23	1	35.491	5.2	0.15254	0.30961
24	1	35.491	5.2	0.15211	0.30873
25	0	27.317	5.4	5.01E-04	9.03E-03
26	0	27.053	5.4	0.45611	8.2178
27	1	346.69	5.3	0.45611	8.2178
28	1	700	5.2	0.45611	8.2178
29	1	780	5.1	0.45611	8.2178
30	1	755.74	4.9	0.91209	22.809
31	0.8172	203.63	4.8	0.91209	22.809
32	0	27	4.8	0.45561	8.2087
33	0	27.052	5.4	0.45561	8.2087
34	0	27.052	5.4	0.45561	8.2088
From SG2	1	293.92	6.86	6.0955	24.4
From SG 1	1	375.42	6.86	0.93455	3.741
H2/Steam	1	800	5	1.52	10.36
Hydrogen Product	1	26	4.8	0.91236	1.8518
Hydrogen Recycle	1	26	4.8	0.15254	0.30961
Oxygen Product	1	27	4.8	0.45648	14.6
Steam/H2	1	800	5	1.52	24.951
Sweep Gas In	1	800	5	0.45611	8.2178

Stream Name	Vapor Fraction	Temperature (C)	Pressure (MPa)	Molar Flow (kgmole/h)	Mass Flow (kg/s)
Sweep Gas/O2 Out	1	800	5	0.91209	22.809
Sweep Water In	0	26.85	0.10132	5.01E-04	9.03E-03
To SG1	1	725	7	0.93455	3.741
To SG 2	1	725	7	6.0955	24.4
Water In	0	26.85	0.10132	0.9144	16.473

Table 2. Stream composition of Rankine case.

Stream Name	Comp Mole Frac (H_2)	Comp Mole Frac (H_2O)	Comp Mole Frac (O_2)	Comp Mole Frac (He)
1	0	0	0	1
2	0	0	0	1
3	0	0	0	1
4	0	0	0	1
5	0	0	0	1
6	0	0	0	1
7	0	0	0	1
8	0	0	0	1
9	0	0	0	1
10	0	0	0	1
11	0	1	0	0
12	0.00002	0.99998	0	0
13	0.00002	0.99998	0	0
14	0.00002	0.99998	0	0
15	0.1	0.9	0	0
16	0.1	0.9	0	0
17	0.7	0.3	0	0
18	0.7	0.3	0	0
19	0.99914	0.00086	0	0
20	0.00005	0.99995	0	0
21	0.00005	0.99995	0	0
22	0.00005	0.99995	0	0
23	0.99914	0.00086	0	0
24	0.99914	0.00086	0	0
25	0	1	0	0
26	0	0.99986	0.00014	0
27	0	0.99986	0.00014	0
28	0	0.99986	0.00014	0
29	0	0.99986	0.00014	0
30	0	0.50001	0.49999	0
31	0	0.50001	0.49999	0

Stream Name	Comp Mole Frac (H_2)	Comp Mole Frac (H_2O)	Comp Mole Frac (O_2)	Comp Mole Frac (He)
32	0	0.99986	0.00014	0
33	0	0.99986	0.00014	0
34	0	0.99986	0.00014	0
From SG2	0	0	0	1
From SG 1	0	0	0	1
H2/Steam	0.7	0.3	0	0
Hydrogen Product	0.99914	0.00086	0	0
Hydrogen Recycle	0.99914	0.00086	0	0
Oxygen Product	0	0.0011	0.9989	0
Steam/H2	0.1	0.9	0	0
Sweep Gas In	0	0.99986	0.00014	0
Sweep Gas/O2 Out	0	0.50001	0.49999	0
Sweep Water In	0	1	0	0
To SG1	0	0	0	1
To SG 2	0	0	0	1
Water In	0	1	0	0

Table 3. Heat exchanger data for Rankine case.

Name	Duty (kW)	UA (kJ/C-h)	LMTD (C)	MinimumApproach (C)
Sweep Hi Temp Recup	1,570	45,100	35	20
Hi Temp Steam/H2 Recup	6,668	221,100	30	20
Low Temp Steam/H2 Recup	39,010	447,600	87	25
SG1	6,790	253,700	27	25
SG2	54,600	544,000	100	25
Sweep Low Temp Recup	24,410	257,500	95	25
IHX	59,860	2,395,000	25	25

Table 4. Pump data.

Name	Water Pump	Water Recycle Pump	Sweep Pump	Sweep Water Recycle Pump
Delta P (MPa)	5.299	0.6	5.299	0.6
Energy (kW)	115.7	6.507	6.34E-02	6.52
Feed Pressure (MPa)	0.1013	4.8	0.1013	4.8
Product Pressure (MPa)	5.4	5.4	5.4	5.4
Molar Flow (kgmole/h)	0.9144	0.4551	5.01E-04	0.4556
Adiabatic Efficiency (%)	75	75	75	75

Table 5. Circulator data for Rankine case.

Name	Recirc	Circ1	Circ2
Feed Pressure (MPa)	4.8	6.86	6.86
Product Pressure (MPa)	5.2	7.071	7.14
Molar Flow (kgmole/s)	0.1525	67.47	7.03
Energy (kW)	42	11280	1531
Adiabatic Efficiency	75	90	90
Polytropic Efficiency	75	90	90

Table 6. Heater data for Rankine case

Name	Steam/H2Topping Heater	Sweep Gas Topping Heater	Reactor	Electrolysis Unit
Duty (kW)	2,752	399	600,000	
Power (kW)				226,354
Feed Temperature (C)	757	780	322	800
Product Temperature (C)	800	800	750	800

5.2 HTE process coupled to Combined cycle

The HYSYS analysis of the new INL reference design coupled to the Combined cycle (Indirect Helium Brayton with Steam Rankine Bottoming Cycle) achieves a hydrogen production rate of 1.78 kg/s and an overall hydrogen production efficiency of 41.0% with a reactor power source of 600 MW_t operating at a reactor outlet temperature of 750 °C. The electrolysis stack consists of 1.073 million electrolysis cells operating at a current density of 0.6989 amp/cm^2, and a steam utilization rate of 66.67%. Each cell has an area of 225 cm^2. The fluid conditions, flow rates, stream composition and component operating parameters for this integrated configuration are summarized in Tables 7-12 for each of the locations shown in Figure 3. The temperature, pressure, molar and mass flow rates, and the vapor fraction for each stream are displayed in Table 7.

The composition of each stream is shown in Table 8. The thermal duty, overall heat transfer coefficient, UA, log-mean temperature difference, LMTD, and the minimum approach temperature for each heat exchanger is found in Table 9. Compressor and pump parameters are given in Tables 10. Table 11 provides the topping heater heat rates and the electrolysis power corresponding to the variables shown in Figure 3. Heater data are provided in Table 12.

Table 7. Stream data of combined cycle case.

Stream Name	Vapor Fraction	Temperature (C)	Pressure (MPa)	Molar Flow (kgmole/h)	Mass Flow (kg/s)
1	1	750	7	67.474	270.1
2	1	750	7	60.736	243.13
3	1	305.22	6.72	60.736	243.13
4	1	308.71	6.72	67.474	270.1
5	1	322	7.071	67.474	270.1
6	1	750	7	6.7377	26.971
7	1	340.15	6.72	6.7377	26.971
8	1	725	7	6.7412	26.985
9	1	304.8	6.86	6.7412	26.985
10	1	315.15	7.14	6.7412	26.985
11	0	27.317	5.4	0.87296	15.727
12	0	26.894	5.4	1.3115	23.627
13	0.2711	268.86	5.3	1.3115	23.627
14	1	700	5.2	1.3115	23.627
15	1	650.93	5.2	1.4574	23.923
16	1	756.9	5.1	1.4574	23.923
17	1	670.93	4.9	1.4574	9.933
18	0.7726	144.07	4.8	1.4574	9.933
19	1	26	4.8	1.021	2.0724
20	0	26	4.8	0.43636	7.8607
21	0	26.052	5.4	0.43636	7.8607
22	0	26.052	5.4	0.43857	7.9004
23	1	35.491	5.2	0.14626	0.29685
24	1	35.491	5.2	0.14585	0.29604
25	0	27.317	5.4	4.82E-04	8.68E-03
26	0	27.053	5.4	0.43731	7.879
27	1	346.76	5.3	0.43731	7.879
28	1	700	5.2	0.43731	7.879
29	1	780	5.1	0.43731	7.879
30	1	755.74	4.9	0.87449	21.869
31	0.8172	203.63	4.8	0.87449	21.869
32	0	27	4.8	0.43682	7.8703
33	0	27.052	5.4	0.43682	7.8703
34	0	27.052	5.4	0.43682	7.8703
From SG2	1	294	6.86	5.8456	23.4
From SG 1	1	375.32	6.86	0.89558	3.585
H2/Steam	1	800	5	1.4574	9.933

Stream Name	Vapor Fraction	Temperature (C)	Pressure (MPa)	Molar Flow (kgmole/h)	Mass Flow (kg/s)
Hydrogen Product	1	26	4.8	0.87477	1.7755
Hydrogen Recycle	1	26	4.8	0.14626	0.29685
Oxygen Product	1	27	4.8	0.43767	13.999
Steam/H2	1	800	5	1.4574	23.923
Sweep Gas In	1	800	5	0.43731	7.879
Sweep Gas/O2 Out	1	800	5	0.87449	21.869
Sweep Water In	0	26.85	0.10132	4.82E-04	8.68E-03
To SG1	1	725	7	0.89558	3.585
To SG 2	1	725	7	5.8456	23.4
Water In	0	26.85	0.10132	0.87296	15.727

Table 8. Composition data of combined cycle case.

Stream Name	Comp Mole Frac (H_2)	Comp Mole Frac (H_2O)	Comp Mole Frac (O_2)	Comp Mole Frac (He)
1	0	0	0	1
2	0	0	0	1
3	0	0	0	1
4	0	0	0	1
5	0	0	0	1
6	0	0	0	1
7	0	0	0	1
8	0	0	0	1
9	0	0	0	1
10	0	0	0	1
11	0	1	0	0
12	0.00002	0.99998	0	0
13	0.00002	0.99998	0	0
14	0.00002	0.99998	0	0
15	0.10001	0.89999	0	0
16	0.10001	0.89999	0	0
17	0.7	0.3	0	0
18	0.7	0.3	0	0
19	0.99914	0.00086	0	0
20	0.00005	0.99995	0	0
21	0.00005	0.99995	0	0
22	0.00005	0.99995	0	0
23	0.99914	0.00086	0	0
24	0.99914	0.00086	0	0
25	0	1	0	0
26	0	0.99986	0.00014	0

Stream Name	Comp Mole Frac (H_2)	Comp Mole Frac (H_2O)	Comp Mole Frac (O_2)	Comp Mole Frac (He)
27	0	0.99986	0.00014	0
28	0	0.99986	0.00014	0
29	0	0.99986	0.00014	0
30	0	0.5	0.5	0
31	0	0.5	0.5	0
32	0	0.99986	0.00014	0
33	0	0.99986	0.00014	0
34	0	0.99986	0.00014	0
From SG2	0	0	0	1
From SG 1	0	0	0	1
H2/Steam	0.7	0.3	0	0
Hydrogen Product	0.99914	0.00086	0	0
Hydrogen Recycle	0.99914	0.00086	0	0
Oxygen Product	0	0.0011	0.9989	0
Steam/H2	0.10001	0.89999	0	0
Sweep Gas In	0	0.99986	0.00014	0
Sweep Gas/O2 Out	0	0.5	0.5	0
Sweep Water In	0	1	0	0
To SG1	0	0	0	1
To SG 2	0	0	0	1
Water In	0	1	0	0

Table 9. Heat exchanger data for combined cycle case.

Name	Duty (kW)	UA (kJ/C-h)	LMTD (C)	MinimumApproach (C)
Sweep Hi Temp Recup	1,506	43,240	35	20
Hi Temp Steam/H2 Recup	6,394	212,000	30	20
Low Temp Steam/H2 Recup	37,400	428,800	87	25
SG1	6,508	243,900	27	25
SG2	52,360	521,300	100	25
Sweep Low Temp Recup	23,410	246,900	95	25
IHX	57,400	2,296,000	25	25

Table 10. Pump data for combined cycle case.

Name	Water Pump	Water Recycle Pump	Sweep Pump	Sweep Water Recycle Pump
Delta P (MPa)	5.299	0.6	5.299	0.6
Energy (kW)	110.4	6.239	6.09E-02	6.251
Feed Pressure (MPa)	0.1013	4.8	0.1013	4.8
Product Pressure (MPa)	5.4	5.4	5.4	5.4
Molar Flow (kgmole/h)	0.873	0.4364	4.82E-04	0.4368
Adiabatic Efficiency (%)	75	75	75	75

Table 11. Circulator data for combined cycle case

Name	Recirc	Circ1	Circ2
Feed Pressure (MPa)	4.80	6.72	6.86
Product Pressure (MPa)	5.20	7.07	7.14
Molar Flow (kgmole/s)	0.146	67.5	6.74
Energy (kW)	40.0	18,870	1,468
Adiabatic Efficiency	75	90	90
Polytropic Efficiency	75	91	90

Table 12. Heat data for combined cycle case.

Name	Steam/H2Topping Heater	Sweep Gas Topping Heater	Reactor	Electrolysis Unit
Duty (kW)	2,638	383	600,000	
Power (kW)				217025
Feed Temperature (C)	757	780	322	800
Product Temperature (C)	800	800	750	800

6. CONCLUSIONS

This report presents the results of a new INL reference design for a commercial-scale HTE plant for hydrogen production. The new reference HTE plant is driven by a 600 MWt HTGR coupled to either a Steam Rankine power cycle or a Combined power cycle (an Indirect Helium Brayton Cycle with a Steam Rankine Bottoming Cycle).

The following conclusions can be made.

- The HTE process coupled to a Steam Rankine cycle with a thermal efficiency of 44.4% produces hydrogen at a calculated rate of 1.85 kg/s and an overall hydrogen production efficiency of 42.8%. The process also produces 14.6 kg/s of oxygen

- The HTE process coupled to a combined cycle with a thermal efficiency of 42.5% produces hydrogen at a calculated rate of 1.78 kg/s and an overall hydrogen production efficiency of 41.0%. The process also produces 14.0 kg/s of oxygen.

- Based on the assumptions made for this analysis, the Rankine cycle alone produces more power than the combined cycle due to two reasons. First the Rankine cycle alone has a higher inlet steam temperature compared to the Rankine cycle within the combined cycle. Also the Brayton cycle operates at a lower efficiency than the Rankine cycle at these temperatures.

- At reactor outlet temperatures of 850°C or higher, the topping heaters could receive their heat from the reactor.

- High reactor outlet temperatures will produce more hydrogen due to high power cycle efficiency and more heat directly to electrolysis process.

This reference design provides the basis for planned future work, which will include sensitivity studies and economic analyses similar to those performed for the original reference design.

7. REFERENCES

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Appendix A

High Temperature Electrolysis with Rankine Cycle Process Flow Diagrams

The model of the HTE process with a Ranke power cycle and results in Appendix A 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.

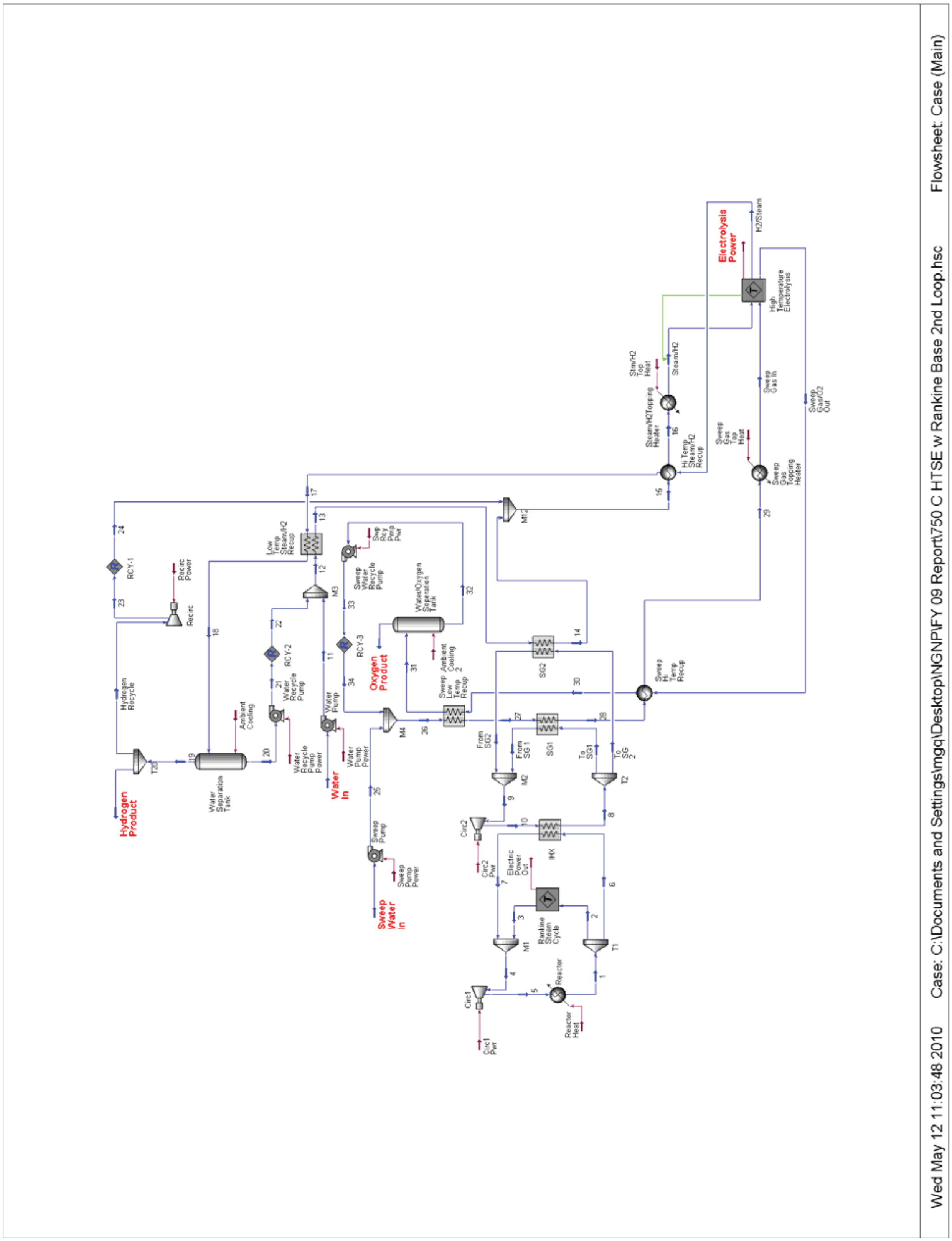

Figure A - 1 HTE Process Flow Diagram

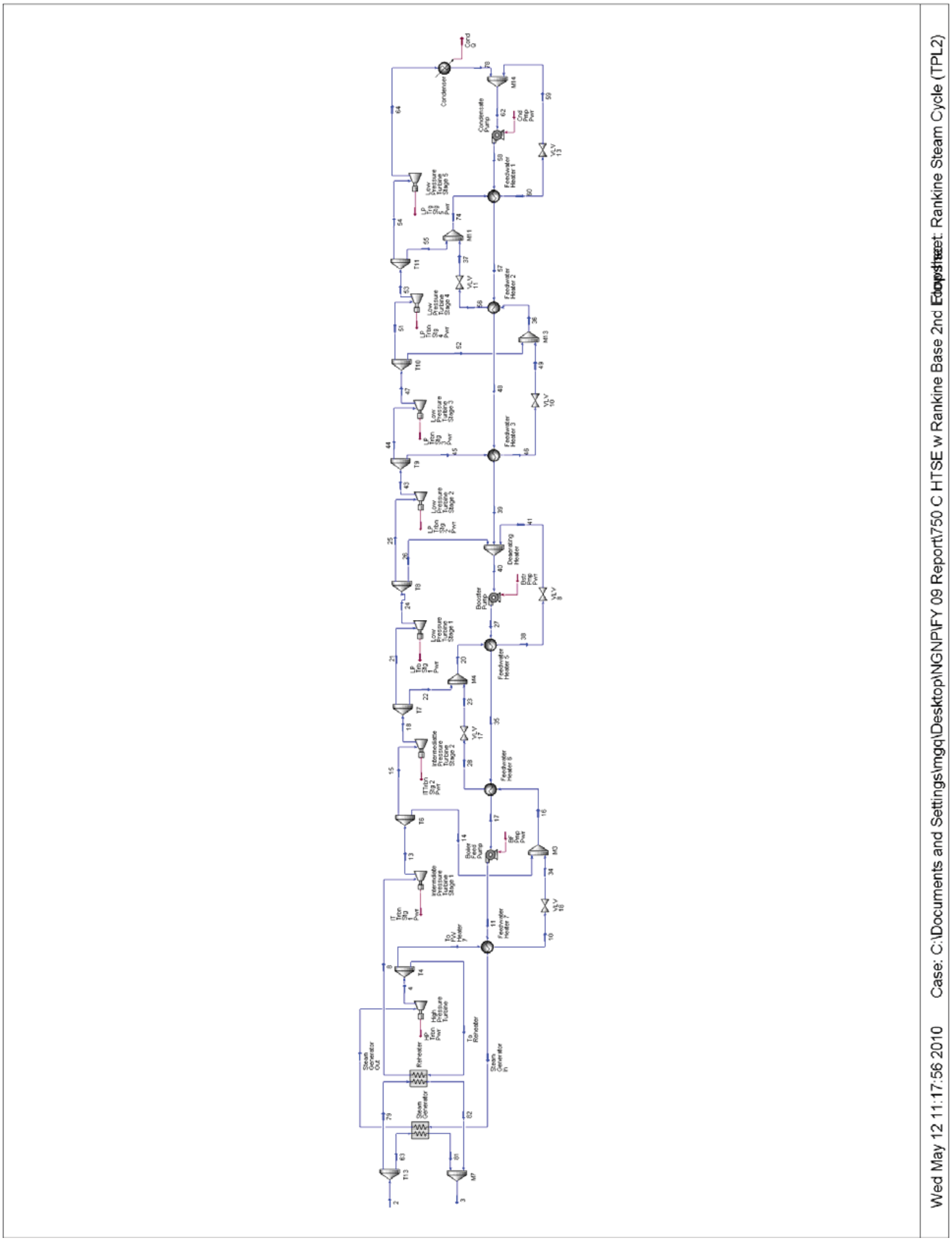

Figure A - 2 Rankine Power Cycle

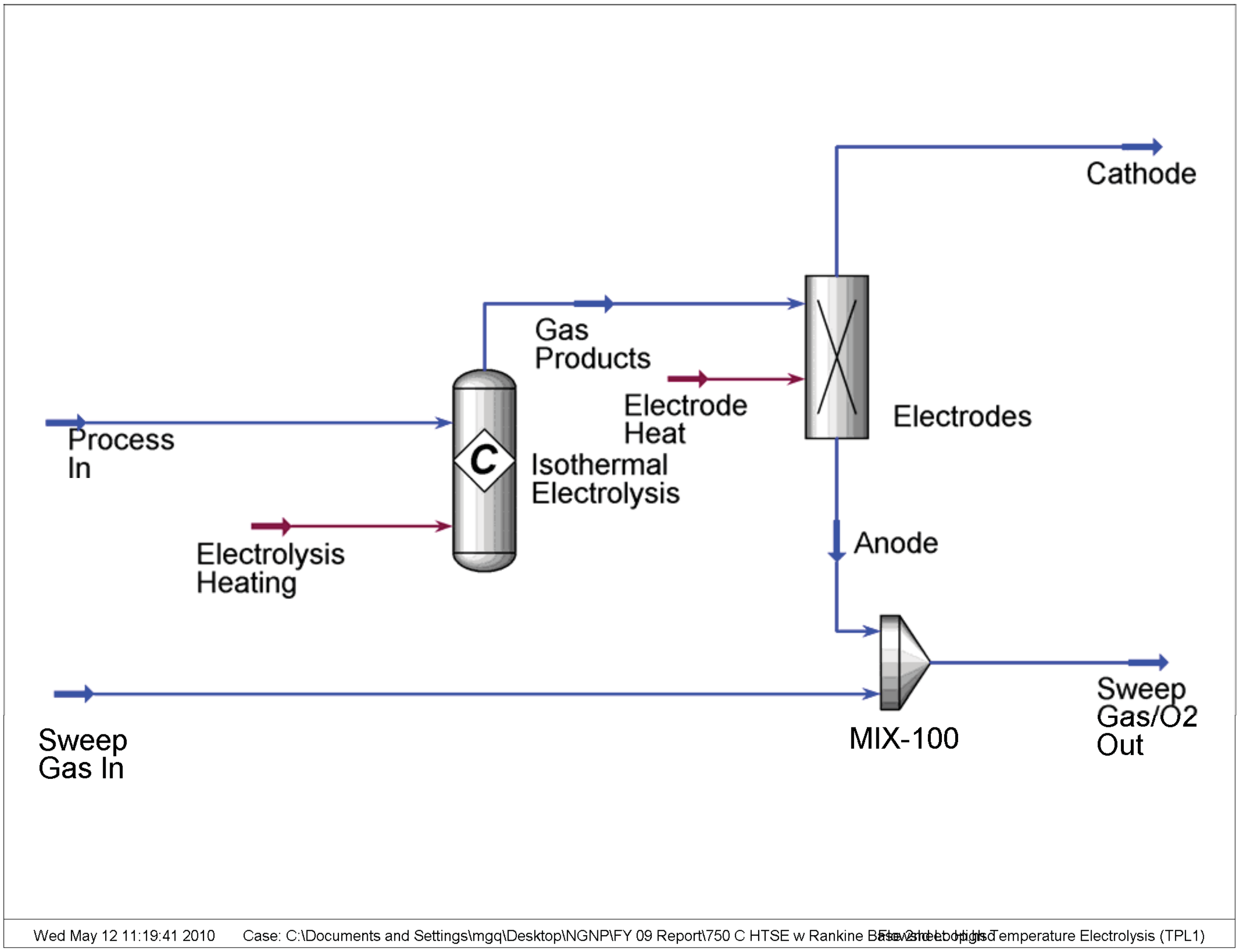

Figure A - 3 Electrolysis module

INL
Calgary, Alberta
CANADA

Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
Unit Set:	NGNP
Date/Time:	Wed May 12 10:51:54 2010

Workbook: Case (Main)

Streams

Name		1	2	3	4	5
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	750.00 *	750.00	311.02	314.05 *	322.00
Pressure	(MPa)	7.0000 *	7.0000	6.8600	6.8600	7.0710
Molar Flow	(kgmole/s)	67.474	60.446	60.446	67.474	67.474
Mass Flow	(kg/s)	270.10	241.97	241.97	270.10	270.10
Liquid Volume Flow	(m3/h)	7837	7021	7021	7837	7837
Heat Flow	(kW)	1.022e+006	9.152e+005	3.638e+005	4.103e+005	4.216e+005
Molar Enthalpy	(kJ/kgmole)	1.514e+004	1.514e+004	6018	6081	6248
Name		**6**	**7**	**8**	**9**	**10**
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	750.00	340.11	725.00 *	304.76	315.11
Pressure	(MPa)	7.0000	6.8600	7.0000 *	6.8600	7.1400
Molar Flow	(kgmole/s)	7.0275	7.0275	7.0300	7.0300	7.0300
Mass Flow	(kg/s)	28.131	28.131	28.141	28.141	28.141
Liquid Volume Flow	(m3/h)	816.3	816.3	816.6	816.6	816.6
Heat Flow	(kW)	1.064e+005	4.654e+004	1.028e+005	4.139e+004	4.292e+004
Molar Enthalpy	(kJ/kgmole)	1.514e+004	6622	1.462e+004	5888	6106
Name		**11**	**12**	**13**	**14**	**15**
Vapour Fraction		0.0000	0.0000	0.2712	1.0000	1.0000
Temperature	(C)	27.317	26.897	268.86	700.00 *	650.93
Pressure	(MPa)	5.4000	5.4000	5.3000	5.2000	5.2000
Molar Flow	(kgmole/s)	0.91440	1.3679	1.3679	1.3679	1.5200
Mass Flow	(kg/s)	16.473	24.643	24.643	24.643	24.951
Liquid Volume Flow	(m3/h)	59.42	88.89	88.89	88.89	104.7
Heat Flow	(kW)	-2.607e+005	-3.901e+005	-3.511e+005	-2.965e+005	-2.965e+005
Molar Enthalpy	(kJ/kgmole)	-2.851e+005	-2.852e+005	-2.566e+005	-2.167e+005	-1.950e+005
Name		**16**	**17**	**18**	**19**	**20**
Vapour Fraction		1.0000	1.0000	0.7725	1.0000	0.0000
Temperature	(C)	756.90	670.93	144.05	26.000	26.000 *
Pressure	(MPa)	5.1000	4.9000	4.8000	4.8000	4.8000
Molar Flow	(kgmole/s)	1.5200	1.5200	1.5200	1.0649	0.45512
Mass Flow	(kg/s)	24.951	10.360	10.360	2.1614	8.1986
Liquid Volume Flow	(m3/h)	104.7	140.2	140.2	110.6	29.58
Heat Flow	(kW)	-2.898e+005	-7.897e+004	-1.180e+005	-191.1	-1.298e+005
Molar Enthalpy	(kJ/kgmole)	-1.906e+005	-5.195e+004	-7.762e+004	-179.4	-2.852e+005
Name		**21**	**22**	**23**	**24**	**25**
Vapour Fraction		0.0000	0.0000	1.0000	1.0000	0.0000
Temperature	(C)	26.052	26.052 *	35.491	35.491 *	27.317
Pressure	(MPa)	5.4000	5.4000 *	5.2000	5.2000 *	5.4000
Molar Flow	(kgmole/s)	0.45512	0.45351 *	0.15254	0.15211 *	5.0130e-004
Mass Flow	(kg/s)	8.1986	8.1697	0.30961	0.30873	9.0311e-003
Liquid Volume Flow	(m3/h)	29.58	29.47	15.84	15.80	3.258e-002
Heat Flow	(kW)	-1.298e+005	-1.293e+005	14.33	14.29	-142.9
Molar Enthalpy	(kJ/kgmole)	-2.852e+005	-2.852e+005	93.95	93.95	-2.851e+005
Name		**26**	**27**	**28**	**29**	**30**
Vapour Fraction		0.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	27.053	346.69	700.00 *	780.00	755.74
Pressure	(MPa)	5.4000	5.3000	5.2000	5.1000	4.9000
Molar Flow	(kgmole/s)	0.45611	0.45611	0.45611	0.45611	0.91209
Mass Flow	(kg/s)	8.2178 *	8.2178	8.2178	8.2178	22.809
Liquid Volume Flow	(m3/h)	29.64	29.64	29.64	29.64	75.81
Heat Flow	(kW)	-1.300e+005	-1.056e+005	-9.884e+004	-9.727e+004	-8.682e+004
Molar Enthalpy	(kJ/kgmole)	-2.851e+005	-2.316e+005	-2.167e+005	-2.133e+005	-9.518e+004

* Specified by user.

Workbook: Case (Main) (continued)

Streams (continued)

Name		31	32	33	34	Ambient Cooling
Vapour Fraction		0.8172	0.0000	0.0000	0.0000	---
Temperature	(C)	203.63	27.000	27.052	27.052 *	---
Pressure	(MPa)	4.8000	4.8000	5.4000	5.4000 *	---
Molar Flow	(kgmole/s)	0.91209	0.45561	0.45561	0.45561 *	---
Mass Flow	(kg/s)	22.809	8.2087	8.2087	8.2088	---
Liquid Volume Flow	(m3/h)	75.81	29.61	29.61	29.61	---
Heat Flow	(kW)	-1.112e+005	-1.299e+005	-1.299e+005	-1.299e+005	-1.203e+004
Molar Enthalpy	(kJ/kgmole)	-1.220e+005	-2.851e+005	-2.851e+005	-2.851e+005	---
Name		**Ambient Cooling 2**	**Circ1 Pwr**	**Circ2 Pwr**	**Electric Power Out**	**Electrolysis Power**
Vapour Fraction		---	---	---	---	---
Temperature	(C)	---	---	---	---	---
Pressure	(MPa)	---	---	---	---	---
Molar Flow	(kgmole/s)	---	---	---	---	---
Mass Flow	(kg/s)	---	---	---	---	---
Liquid Volume Flow	(m3/h)	---	---	---	---	---
Heat Flow	(kW)	-1.897e+004	1.128e+004	1531	2.489e+005	-2.264e+005
Molar Enthalpy	(kJ/kgmole)	---	---	---	---	---
Name		**From SG2**	**From SG 1**	**H2/Steam**	**Hydrogen Product**	**Hydrogen Recycle**
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	293.92	375.42	800.00	26.000	26.000
Pressure	(MPa)	6.8600	6.8600	5.0000	4.8000	4.8000
Molar Flow	(kgmole/s)	6.0955	0.93455	1.5200	0.91236	0.15254
Mass Flow	(kg/s)	24.400	3.7410	10.360	1.8518	0.30961
Liquid Volume Flow	(m3/h)	708.0	108.6	140.2	94.75	15.84
Heat Flow	(kW)	3.452e+004	6874	-7.230e+004	-163.7	-27.37
Molar Enthalpy	(kJ/kgmole)	5663	7356	-4.757e+004	-179.4	-179.4
Name		**Oxygen Product**	**Process Heat 1**	**Reactor Heat**	**Recirc Power**	**Steam/H2**
Vapour Fraction		1.0000	---	---	---	1.0000
Temperature	(C)	27.000 *	---	---	---	800.00 *
Pressure	(MPa)	4.8000	---	---	---	5.0000 *
Molar Flow	(kgmole/s)	0.45648	---	---	---	1.5200
Mass Flow	(kg/s)	14.600	---	---	---	24.951 *
Liquid Volume Flow	(m3/h)	46.20	---	---	---	104.7
Heat Flow	(kW)	-293.1	2.384e-004	6.000e+005 *	41.70	-2.870e+005
Molar Enthalpy	(kJ/kgmole)	-642.0	---	---	---	-1.888e+005
Name		**Stm/H2 Top Heat**	**Sweep Gas In**	**Sweep Gas Top Heat**	**Sweep Gas/O2 Out**	**Sweep Pump Power**
Vapour Fraction		---	1.0000	---	1.0000	---
Temperature	(C)	---	800.00	---	800.00	---
Pressure	(MPa)	---	5.0000	---	5.0000	---
Molar Flow	(kgmole/s)	---	0.45611	---	0.91209	---
Mass Flow	(kg/s)	---	8.2178	---	22.809	---
Liquid Volume Flow	(m3/h)	---	29.64	---	75.81	---
Heat Flow	(kW)	2752	-9.687e+004	399.4	-8.525e+004	6.343e-002
Molar Enthalpy	(kJ/kgmole)	---	-2.124e+005	---	-9.346e+004	---
Name		**Sweep Water In**	**Swp Rcy Pmp Pwr**	**To SG1**	**To SG 2**	**Water In**
Vapour Fraction		0.0000	---	1.0000	1.0000	0.0000
Temperature	(C)	26.850 *	---	725.00	725.00	26.850 *
Pressure	(MPa)	0.10132 *	---	7.0000	7.0000	0.10132 *
Molar Flow	(kgmole/s)	5.0130e-004	---	0.93455	6.0955	0.91440
Mass Flow	(kg/s)	9.0311e-003	---	3.7410 *	24.400 *	16.473
Liquid Volume Flow	(m3/h)	3.258e-002	---	108.6	708.0	59.42
Heat Flow	(kW)	-143.0	6.520	1.366e+004	8.912e+004	-2.608e+005
Molar Enthalpy	(kJ/kgmole)	-2.853e+005	---	1.462e+004	1.462e+004	-2.853e+005

* Specified by user.

Workbook: Case (Main) (continued)

Streams (continued)

Name		Water Pump Power	Water Recycle Pump			
Vapour Fraction		---	---			
Temperature	(C)	---	---			
Pressure	(MPa)	---	---			
Molar Flow	(kgmole/s)	---	---			
Mass Flow	(kg/s)	---	---			
Liquid Volume Flow	(m3/h)	---	---			
Heat Flow	(kW)	115.7	6.507			
Molar Enthalpy	(kJ/kgmole)	---	---			

Composition

Name	1	2	3	4	5
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	0.00000
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)	1.00000 *	1.00000	1.00000	1.00000	1.00000
Name	6	7	8	9	10
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	0.00000
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)	1.00000	1.00000	1.00000	1.00000	1.00000
Name	11	12	13	14	15
Comp Mole Frac (Hydrogen)	0.00000	0.00002	0.00002	0.00002	0.10000
Comp Mole Frac (H2O)	1.00000	0.99998	0.99998	0.99998	0.90000
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	16	17	18	19	20
Comp Mole Frac (Hydrogen)	0.10000	0.70000	0.70000	0.99914	0.00005
Comp Mole Frac (H2O)	0.90000	0.30000	0.30000	0.00086	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	21	22	23	24	25
Comp Mole Frac (Hydrogen)	0.00005	0.00005 *	0.99914	0.99914 *	0.00000
Comp Mole Frac (H2O)	0.99995	0.99995 *	0.00086	0.00086 *	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	26	27	28	29	30
Comp Mole Frac (Hydrogen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (H2O)	0.99986	0.99986	0.99986	0.99986	0.50001
Comp Mole Frac (Oxygen)	0.00014	0.00014	0.00014	0.00014	0.49999
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	**31**	**32**	**33**	**34**	**From SG2**
Comp Mole Frac (Hydrogen)	0.00000	0.00000	0.00000	0.00000 *	0.00000
Comp Mole Frac (H2O)	0.50001	0.99986	0.99986	0.99986 *	0.00000
Comp Mole Frac (Oxygen)	0.49999	0.00014	0.00014	0.00014 *	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 *	1.00000
Name	**From SG 1**	**H2/Steam**	**Hydrogen Product**	**Hydrogen Recycle**	**Oxygen Product**
Comp Mole Frac (Hydrogen)	0.00000	0.70000	0.99914	0.99914	0.00000
Comp Mole Frac (H2O)	0.00000	0.30000	0.00086	0.00086	0.00110
Comp Mole Frac (Oxygen)	0.00000	0.00000	0.00000	0.00000	0.99890
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	0.00000	0.00000	0.00000	0.00000
Name	**Steam/H2**	**Sweep Gas In**	**Sweep Gas/O2 Out**	**Sweep Water In**	**To SG1**
Comp Mole Frac (Hydrogen)	0.10000	0.00000	0.00000	0.00000 *	0.00000 *
Comp Mole Frac (H2O)	0.90000	0.99986	0.50001	1.00000 *	0.00000 *
Comp Mole Frac (Oxygen)	0.00000	0.00014	0.49999	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 *	1.00000 *
Name	**To SG 2**	**Water In**			
Comp Mole Frac (Hydrogen)	0.00000 *	0.00000 *			
Comp Mole Frac (H2O)	0.00000 *	1.00000 *			
Comp Mole Frac (Oxygen)	0.00000 *	0.00000 *			
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)	1.00000 *	0.00000 *			

Coolers

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

Heat Exchangers

Name		Sweep Hi Temp Recu	Hi Temp Steam/H2 R			
Duty	(kW)	1570	6668			
UA	(W/C)	4.510e+004	2.211e+005			
LMTD	(C)	34.82	30.15			
Minimum Approach	(C)	20.00	20.00			

Workbook: Case (Main) (continued)

Heaters

Name		Steam/H2Topping He	Sweep Gas Topping	Reactor		
Duty	(kW)	2752	399.4	6.000e+005 *		
Feed Temperature	(C)	756.9	780.0	322.0		
Product Temperature	(C)	800.0 *	800.0	750.0 *		

LNGs

Name		Low Temp Steam/H2	SG1	SG2	Sweep Low Temp Re	IHX
UA (Calculated)	(W/C)	4.476e+005	2.537e+005	5.440e+005	2.575e+005	2.395e+006
LMTD	(C)	87.15 *	26.76 *	100.4 *	94.80 *	25.00 *
Exchanger Cold Duty	(kW)	3.901e+004	6790	5.460e+004	2.441e+004	5.986e+004
Minimum Approach	(C)	25.00	25.00	25.00	25.00	24.99

Compressors

Name		Recirc	Circ1	Circ2		
Feed Pressure	(MPa)	4.800	6.860	6.860		
Product Pressure	(MPa)	5.200	7.071	7.140		
Molar Flow	(kgmole/s)	0.1525	67.47	7.030		
Energy	(kW)	41.70	1.128e+004	1531		
Adiabatic Efficiency		75 *	90 *	90 *		
Polytropic Efficiency		75	90	90		

Expanders

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

Pumps

Name		Water Pump	Water Recycle Pump	Sweep Pump	Sweep Water Recyc	
Delta P	(MPa)	5.299	0.6000	5.299	0.6000	
Energy	(kW)	115.7	6.507	6.343e-002	6.520	
Feed Pressure	(MPa)	0.1013 *	4.800	0.1013 *	4.800	
Product Pressure	(MPa)	5.400	5.400	5.400	5.400	
Molar Flow	(kgmole/s)	0.9144	0.4551	5.013e-004	0.4556	
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 *
Rankine Steam Cycle	Standard Sub-Flowsheet	2	3 Electric Power Out	No	2500 *
Electrolysis Input and Outpu	Spreadsheet			No	500.0 *
Efficiency	Spreadsheet			No	500.0 *
Steam/H2Topping Heater	Heater	16 Stm/H2 Top Heat	Steam/H2	No	500.0 *
Sweep Gas Topping Heater	Heater	29 Sweep Gas Top Heat	Sweep Gas In	No	500.0 *
Reactor	Heater	5 Reactor Heat	1	No	500.0 *
T20	Tee	19	Hydrogen Product	No	500.0 *

* Specified by user.

Workbook: Case (Main) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
T20	Tee		Hydrogen Recycle	No	500.0 *
T1	Tee	1	2 6	No	500.0 *
T2	Tee	8	To SG1 To SG 2	No	500.0 *
Sweep Hi Temp Recup	Heat Exchanger	28 Sweep Gas/O2 Out	29 30	No	500.0 *
Hi Temp Steam/H2 Recup	Heat Exchanger	15 H2/Steam	16 17	No	500.0 *
M12	Mixer	14 24	15	No	500.0 *
M3	Mixer	11 22	12	No	500.0 *
M4	Mixer	25 34	26	No	500.0 *
M1	Mixer	3 7	4	No	500.0 *
M2	Mixer	From SG2 From SG 1	9	No	500.0 *
Recirc	Compressor	Hydrogen Recycle Recirc Power	23	No	500.0 *
Circ1	Compressor	4 Circ1 Pwr	5	No	500.0 *
Circ2	Compressor	9 Circ2 Pwr	10	No	500.0 *
Low Temp Steam/H2 Recup	LNG	12 17	13 18	No	500.0 *
SG1	LNG	To SG1 27	From SG 1 28	No	500.0 *
SG2	LNG	13 To SG 2	14 From SG2	No	500.0 *
Sweep Low Temp Recup	LNG	26 30	27 31	No	500.0 *
IHX	LNG	10 6	8 7	No	500.0 *
Water Pump	Pump	Water In Water Pump Power	11	No	500.0 *
Water Recycle Pump	Pump	20 Water Recycle Pump Power	21	No	500.0 *
Sweep Pump	Pump	Sweep Water In Sweep Pump Power	25	No	500.0 *
Sweep Water Recycle Pump	Pump	32 Swp Rcy Pmp Pwr	33	No	500.0 *
Water Separation Tank	Separator	18 Ambient Cooling	20 19 Ambient Cooling	No	500.0 *
Water/Oxygen Seperation T	Separator	31 Ambient Cooling 2	32 Oxygen Product Ambient Cooling 2	No	500.0 *
RCY-1	Recycle	23	24	No	3500 *
RCY-2	Recycle	21	22	No	3500 *
RCY-3	Recycle	33	34	No	3500 *
SET-1	Set			No	500.0 *
SET-2	Set			No	500.0 *

* Specified by user.

Workbook: Case (Main) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
SET-3	Set			No	500.0 *
ADJ-1	Adjust			No	3500 *
ADJ-2	Adjust			No	3500 *

Spreadsheet: Efficiency

Units Set: NGNP

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
B1	Energy Stream: Reactor Heat	Heat Flow	6.000e+005 kW
B2	Energy Stream: Electric Power Out	Power	2.489e+005 kW
B3	Energy Stream: Circ1 Pwr	Power	1.128e+004 kW
B4	Energy Stream: Electrolysis Power	Power	-2.264e+005 kW
B5	Energy Stream: Recirc Power	Power	41.70 kW
B6	Energy Stream: Water Pump Power	Power	115.7 kW
B7	Energy Stream: Sweep Pump Power	Power	6.343e-002 kW
B8	Energy Stream: Water Recycle Pump Po	Power	6.507 kW
B9	Energy Stream: Swp Rcy Pmp Pwr	Power	6.520 kW
D1	Energy Stream: Ambient Cooling	Heat Flow	-1.203e+004 kW
D2	Energy Stream: Ambient Cooling 2	Heat Flow	-1.897e+004 kW
D7	Material Stream: Hydrogen Product	Mass Higher Heating Value	1.393e+005 kJ/kg
D8	Material Stream: Hydrogen Product	Mass Flow	1.8518 kg/s
D9	Energy Stream: Sweep Gas Top Heat	Heat Flow	399.4 kW
D10	Energy Stream: Stm/H2 Top Heat	Heat Flow	2752 kW
F2	Energy Stream: Circ2 Pwr	Power	1531 kW
F3	Tee: T1	Flow Ratio (Flow Ratio_1)	0.8958

Exported Variables' Formula Results

Cell	Object	Variable Description	Value

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
B10	B10: Total Electrical Power	Total Electrical Power	Power	0.6194 kW
D3	D3:		Energy	3.100e+004 kW
D4	D4:		Energy	139.5 kW
D5	D5:		---	0.9600
D6	D6:		Power	-2.358e+005 kW
F1	F1: Hydrogen Production Efficiency	Hydrogen Production Efficiency	Percent	42.77
F4	F4:		Power	2.388e+005 kW
F5	F5:		Energy	5.375e+005 kW
F6	F6:		Percent	44.43

User Variables

FORMULAS

Cell	Formula	Result
B10	=B2-B3+D6-B5-B6-B7-B8-B9-D4-F2	0.6194 kW
D3	=-D1-D2	3.100e+004 kW
D4	=0.00450015022*D3- 0.000092174537	139.5 kW
D6	=B4/D5	-2.358e+005 kW

* Specified by user.

INL Calgary, Alberta CANADA	Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H Unit Set: NGNP Date/Time: Wed May 12 10:51:54 2010

Spreadsheet: Efficiency (continued)

Units Set: NGNP

FORMULAS

Cell	Formula	Result
F1	=(D7*D8)/(B1+D9+D10)*100	42.77
F4	=B2-B3*F3	2.388e+005 kW
F5	=B1*F3	5.375e+005 kW
F6	=F4/F5*100	44.43

Spreadsheet

	A	B	C	D	E	F
1	Reactor Heat *	6.000e+005 kW *	Ambient Cooling *	-1.203e+004 kW	n Production Efficiency *	42.77
2	Electric Power Out *	2.489e+005 kW	Ambient Cooling 2 *	-1.897e+004 kW	Circ 2 Pwr *	1531 kW
3	Circ Pwr *	1.128e+004 kW	Total Ambient Cooling *	3.100e+004 kW	Flow to Power Cycle *	0.8958
4	DC Electrolysis Power *	-2.264e+005 kW	Power to Ambient Cool *	139.5 kW	to Electrolysis Process *	2.388e+005 kW
5	Recirc Pwr *	41.70 kW	AC to DC conversion *	0.9600 *	Heat to Power Cycle *	5.375e+005 kW
6	Water Pump Power *	115.7 kW	AC Electrolysis Power *	-2.358e+005 kW	Power Cycle Efficiency *	44.43
7	Sweep Pump Pwr *	6.343e-002 kW	HHV H2 Product *	1.393e+005 kJ/kg		
8	Recycle Pmp Pwr *	6.507 kW	Mass Flow Hydrogen *	1.8518 kg/s		
9	Sweep Rcycl Pump Pwr *	6.520 kW	veep Gas Topping Heat *	399.4 kW		
10	Total Electrical Power *	0.6194 kW	Process Topping Heat *	2752 kW		

Spreadsheet: Electrolysis Input and Output

Units Set: Electrolysis

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
B6	Conversion Reactor: Isothermal Electrolysis @	Act. % Conversion (Act. % Conversion_1)	66.67

Exported Variables' Formula Results

Cell	Object	Variable Description	Value

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
A6	A6: Steam Utilization	Steam Utilization	Percent	66.67
B1	B1:		---	<empty>
B2	B2: Number of Cells	Number of Cells	---	1.119e+006
B3	B3: Cell Area	Cell Area	Small Area	225.0 cm2
B4	B4: Current Density (Amperes/cm^2)	Current Density (Amperes/cm^2)	---	0.6989
B5	B5: ASR @ 1100 K (ohms*cm^2)	ASR @ 1100 K (ohms*cm^2)	---	0.2776
B7	B7:		---	<empty>

User Variables

FORMULAS

Cell	Formula	Result
A6	=B6	66.67

Spreadsheet

	A	B	C	D		
1		<empty> *				
2	Number of Cells *	1.119e+006 *				
3	Cell Area *	225.0 cm2 *				
4	ensity (Amperes/cm^2) *	0.6989 *				

* Specified by user.

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C I
	Unit Set:	NGNP
	Date/Time:	Wed May 12 10:51:54 2010

Spreadsheet: Electrolysis Input and Output (contin

Units Set: Electrolysis

Spreadsheet

5	@ 1100 K (ohms*cm^2) *	0.2776 *				
6	66.67	66.67				
7		<empty> *				
8						
9						
10						

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/s)	1.5200	0.45611	1.5200	0.91209	1.9760
Mass Flow	(kg/s)	24.951	8.2178	10.360	22.809	24.951
Liquid Volume Flow	(m3/h)	104.7	29.64	140.2	75.81	186.3
Heat Flow	(kW)	-2.870e+005	-9.687e+004	-7.230e+004	-8.525e+004	-6.075e+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/s)	0.00000	0.45598	0.45598	---	---
Mass Flow	(kg/s)	0.00000	14.591	14.591	---	---
Liquid Volume Flow	(m3/h)	0.0000	46.17	46.17	---	---
Heat Flow	(kW)	0.0000	1.162e+004	---	2.263e+005	75.07
Molar Enthalpy	(kJ/kgmole)	-2.975e+004	2.549e+004	---	---	---
Name		**Process Heat @TPL1**	**Electrolysis Power @**			
Vapour Fraction		---	---			
Temperature	(C)	---	---			
Pressure	(MPa)	---	---			
Molar Flow	(kgmole/s)	---	---			
Mass Flow	(kg/s)	---	---			
Liquid Volume Flow	(m3/h)	---	---			
Heat Flow	(kW)	2.384e-004	-2.264e+005			
Molar Enthalpy	(kJ/kgmole)	---	---			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
Isothermal Electrolysis @TP	Conversion Reactor	Process In @TPL1 Electrolysis Heating @TPL1	Liquid Products @TPL1 Gas Products @TPL1 Electrolysis Heating @TPL1	No	500.0 *
MIX-100 @TPL1	Mixer	Liquid Products @TPL1 Anode @TPL1 Sweep Gas In @TPL1	Sweep Gas/O2 Out @TPL1	No	500.0 *
Electrodes @TPL1	Component Splitter	Gas Products @TPL1 Electrode Heat @TPL1	Cathode @TPL1 Anode @TPL1	No	500.0 *
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 *

* Specified by user.

INL Calgary, Alberta CANADA	Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C I Unit Set: NGNP Date/Time: Wed May 12 10:51:54 2010

Workbook: High Temperature Electrolysis (TPL1) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
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
D3	Material Stream:	Cathode @TPL1	Temperature	1073.1 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 @TP	Comp Mole Frac (Oxygen)	0.49999
B11	SpreadSheetCell:	Electrolysis Input and O	B2: Number of Cells	1.119e+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 @TP	Heat Flow	2.263e+005 kW
D12	Energy Stream:	Electrode Heat @TPL1	Heat Flow	75.07 kW

Exported Variables' Formula Results

Cell	Object	Variable Description	Value
B15	Molar Flow of Oxygen @TPL1	Molar Flow	455.98 gmole/s
B19	Electrolysis Power @TPL1	Power	-2.264e+005 kW
B20	Process Heat @TPL1	Heat Flow	2.384e-004 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	455.98 gmole/s
B17	B17:		---	1.007
B18	B18:		---	1.286
B19	B19: Power	Power	Power	-2.264e+005 kW
B20	B20: Heat Flow	Heat Flow	Energy	2.384e-004 kW
D4	D4:		Temperature	1.5557e-003 K
D6	D6:		Temperature	1073.1 K
D8	D8:		---	3.501e-007
D9	D9:		---	-2.251e-004

Spreadsheet: High Temperature Electrolysis @TPL1

Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
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:		---	6.803e-003
H3	H3:		---	24.67
H4	H4:		---	24.67
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:		---	0.7607
K3	K3:		---	1.091
K6	K6:		Vapour Fraction	1.0067
K7	K7:		---	1.007

User Variables

FORMULAS

Cell	Formula	Result
B14	=B12*B13	157.2
B15	=B11*B14/(4*A6)	455.98 gmole/s
B17	@IF(@ABS(D4)<1e-3,K6,K7)	1.007
B18	=B17+B13*B16	1.286
B19	=-B11*B18*B14/1000	-2.264e+005 kW
B20	=B19+D11+D12	2.384e-004 kW
D4	=D2-D3	1.5557e-003 K
D6	=(D2+D3)/2	1073.1 K
D8	=1/(2*A6*H4*F4)	3.501e-007
D9	=-1/(2*A6*H4*F4*D4)	-2.251e-004
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	6.803e-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)))	0.7607
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

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
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Units Set: Electrolysis_

FORMULAS

Cell	Formula	Result
K7	=D9*(A7/2*(D3^2-D2^2)*((E5+F5)*H4 + H5/2*F4) + F4*H4*(J3-J2))	1.007

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 *	1073.1 K *	0.30000	0.70000
4	-3.532e-008 *	n Energy (kJ/gmol-K^3) *	Delta *	1.5557e-003 K	-0.6000	0.6000
5	-12.85 J/gmole-K *	;ibbs Formation Energy *	Integration Coeff *		0.3336	-0.6194
6	9.649e+004 *	/ Number (J/Volt-gmole) *	Average *	1073.1 K		
7	8.314 J/gmole-K *	Jniversal Gas Constant *				
8	5.0000e+006 N/m2	Pressure *	C isothermal *	3.501e-007		
9	1.0132e+005 N/m2 *	Standard Pressure *	C average *	-2.251e-004		
10						
11	Number of Cells *	1.119e+006 *	Electrolysis Heating *	2.263e+005 kW		
12	Cell Area *	225.0 cm2 *	Electrode Heat *	75.07 kW		
13	ensity (Amperes/cm^2) *	0.6989 *				
14	Current (Amperes) *	157.2				
15	Molar Flow of Oxygen *	455.98 gmole/s				
16	Resistance (ohm*cm^2) *	0.4000 *				
17	Nernst Potential (Volts) *	1.007				
18	perating Voltage (Volts) *	1.286				
19	Electrolysis Power *	-2.264e+005 kW				
20	Process Heat *	2.384e-004 kW				

	G	H	I	J	K	
1	y O2 *	y A *	Delta G *	Integral Delta G dT *	Nernst Voltage *	
2	0.00014	6.803e-003	1.887e+005 J/gmole	2.321e+008 J/gmole-K	0.7607	
3	0.49999	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 *	1.007	
8						
9						
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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

* Specified by user.

Spreadsheet: Temp Average ASR @TPL1 (continue(

Units Set: Electrolysis_

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
A3	Material Stream: Process In @TPL1	Temperature	1073.1 K
E15	Material Stream: Cathode @TPL1	Temperature	1073.1 K

Exported Variables' Formula Results

Cell	Object	Variable Description	Value

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

* Specified by user.

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

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
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
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

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C I
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Spreadsheet: Temp Average ASR @TPL1 (continue(Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
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	-3.1114e-005 K

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

 * Specified by user.

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
	Unit Set:	NGNP
	Date/Time:	Wed May 12 10:51:54 2010

Spreadsheet: Temp Average ASR @TPL1 (continued

Units Set: Electrolysis_

FORMULAS

Cell	Formula	Result
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
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

 * Specified by user.

Spreadsheet: Temp Average ASR @TPL1 (continue(

Units Set: Electrolysis_

FORMULAS

Cell	Formula	Result
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	-3.1114e-005 K

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	1073.1 K *	0.4000
16	1073.1 K	0.4000	1073.1 K	0.4000	delta T *	-3.1114e-005 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				

Conversion: Electrolysis

STOICHIOMETRY

Component	Mole Weight	Stoichiometric Coeff.
H2O	18.015	-1 *
Hydrogen	2.016	1 *
Oxygen	32.000	0 *

Balance Error: 0.0000   Reaction Heat: 2.410e+005 kJ/kgmole

BASIS

Base Component: H2O	Conversion Percent: 100.00 *	Reaction Phase: VapourPhase

PARAMETERS

* Specified by user.

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C K
	Unit Set:	NGNP
	Date/Time:	Wed May 12 10:51:54 2010

Workbook: Rankine Steam Cycle (TPL2)

Material Streams

Name		Steam Generator Out	4 @TPL2	To Reheater @TPL2	To FW Heater 7 @TF	8 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	593.00 *	353.85	353.85	353.85	593.00 *
Pressure	(MPa)	24.000	5.4000 *	5.4000	5.4000	4.8600
Molar Flow	(kgmole/s)	11.007	11.007	10.446	0.56138	10.446
Mass Flow	(kg/s)	198.30	198.30	188.19	10.113	188.19
Liquid Volume Flow	(m3/h)	715.3	715.3	678.8	36.48	678.8
Heat Flow	(kW)	-2.474e+006	-2.547e+006	-2.417e+006	-1.299e+005	-2.311e+006
Name		10 @TPL2	11 @TPL2	Steam Generator In (	17 @TPL2	13 @TPL2
Vapour Fraction		0.0000	0.0000	0.0000	0.0000	1.0000
Temperature	(C)	252.09	246.54	265.71	238.98	542.04
Pressure	(MPa)	5.2920	27.211 *	26.667	3.2462	3.5800 *
Molar Flow	(kgmole/s)	0.56138	11.007	11.007	11.007	10.446
Mass Flow	(kg/s)	10.113	198.30	198.30 *	198.30	188.19
Liquid Volume Flow	(m3/h)	36.48	715.3	715.3	715.3	678.8
Heat Flow	(kW)	-1.496e+005	-2.939e+006	-2.919e+006	-2.946e+006	-2.330e+006
Name		14 @TPL2	15 @TPL2	16 @TPL2	18 @TPL2	21 @TPL2
Vapour Fraction		1.0000	1.0000	0.6759	1.0000	1.0000
Temperature	(C)	542.04	542.04	244.73	476.10	476.10
Pressure	(MPa)	3.5800	3.5800	3.5800	2.3500 *	2.3500
Molar Flow	(kgmole/s)	0.52230	9.9237	1.0837	9.9237	9.4275
Mass Flow	(kg/s)	9.4093	178.78	19.523	178.78	169.84
Liquid Volume Flow	(m3/h)	33.94	644.9	70.42	644.9	612.7
Heat Flow	(kW)	-1.165e+005	-2.214e+006	-2.661e+005	-2.237e+006	-2.125e+006
Name		22 @TPL2	20 @TPL2	24 @TPL2	25 @TPL2	26 @TPL2
Vapour Fraction		1.0000	0.4026	1.0000	1.0000	1.0000
Temperature	(C)	476.10	221.24	386.29	386.29	386.29
Pressure	(MPa)	2.3500	2.3500	1.1596	1.1596	1.1596
Molar Flow	(kgmole/s)	0.49619	1.5799	9.4275	8.9562	0.47138
Mass Flow	(kg/s)	8.9388	28.461	169.84	161.35	8.4919
Liquid Volume Flow	(m3/h)	32.24	102.7	612.7	582.0	30.63
Heat Flow	(kW)	-1.119e+005	-4.040e+005	-2.155e+006	-2.048e+006	-1.078e+005
Name		27 @TPL2	28 @TPL2	35 @TPL2	38 @TPL2	39 @TPL2
Vapour Fraction		0.0000	0.0000	0.0000	0.0000	0.0000
Temperature	(C)	187.04	219.05	213.50	192.60	158.16
Pressure	(MPa)	3.3800 *	3.5084	3.3124	2.3030	1.1596
Molar Flow	(kgmole/s)	11.007	1.0837	11.007	1.5799	8.9562
Mass Flow	(kg/s)	198.30	19.523	198.30	28.461	161.35
Liquid Volume Flow	(m3/h)	715.3	70.42	715.3	102.7	582.0
Heat Flow	(kW)	-2.998e+006	-2.921e+005	-2.972e+006	-4.296e+005	-2.461e+006
Name		40 @TPL2	41 @TPL2	43 @TPL2	44 @TPL2	45 @TPL2
Vapour Fraction		0.0000	0.0145	1.0000	1.0000	1.0000
Temperature	(C)	186.54	186.63	318.57	318.57	318.57
Pressure	(MPa)	1.1596	1.1596	0.64300 *	0.64300	0.64300
Molar Flow	(kgmole/s)	11.007	1.5799	8.9562	8.5084	0.44781
Mass Flow	(kg/s)	198.30	28.461	161.35	153.28	8.0673
Liquid Volume Flow	(m3/h)	715.3	102.7	582.0	552.9	29.10
Heat Flow	(kW)	-2.999e+006	-4.296e+005	-2.069e+006	-1.965e+006	-1.034e+005

* Specified by user.

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
	Unit Set:	NGNP
	Date/Time:	Wed May 12 10:51:54 2010

Workbook: Rankine Steam Cycle (TPL2) (continued)

Material Streams (continued)

Name		46 @TPL2	47 @TPL2	48 @TPL2	49 @TPL2	51 @TPL2
Vapour Fraction		0.0000	1.0000	0.0000	0.0001	1.0000
Temperature	(C)	135.82	246.82	130.26	135.82	246.82
Pressure	(MPa)	0.63014	0.32100 *	1.1759	0.32100	0.32100
Molar Flow	(kgmole/s)	0.44781	8.5084	8.9562	0.44781	8.0829
Mass Flow	(kg/s)	8.0673	153.28	161.35	8.0673	145.61
Liquid Volume Flow	(m3/h)	29.10	552.9	582.0	29.10	525.3
Heat Flow	(kW)	-1.239e+005	-1.987e+006	-2.482e+006	-1.239e+005	-1.887e+006
Name		52 @TPL2	53 @TPL2	54 @TPL2	55 @TPL2	56 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	0.0000
Temperature	(C)	246.82	167.46	167.46	167.46	107.38
Pressure	(MPa)	0.32100	0.13300 *	0.13300	0.13300	0.31458
Molar Flow	(kgmole/s)	0.42542	8.0829	7.2342	0.84871	0.87323
Mass Flow	(kg/s)	7.6639	145.61	130.33	15.290	15.731
Liquid Volume Flow	(m3/h)	27.65	525.3	470.1	55.15	56.75
Heat Flow	(kW)	-9.933e+004	-1.909e+006	-1.709e+006	-2.005e+005	-2.436e+005
Name		57 @TPL2	60 @TPL2	62 @TPL2	64 @TPL2	74 @TPL2
Vapour Fraction		0.0000	0.0000	0.0000	0.9459	0.5177
Temperature	(C)	101.83	43.291	37.613	38.957	107.75
Pressure	(MPa)	1.1999	0.13034	6.7569e-003	6.8948e-003 *	0.13300
Molar Flow	(kgmole/s)	8.9562	1.7219	8.9562	7.2342	1.7219
Mass Flow	(kg/s)	161.35	31.021	161.35	130.33	31.021
Liquid Volume Flow	(m3/h)	582.0	111.9	582.0	470.1	111.9
Heat Flow	(kW)	-2.502e+006	-4.890e+005	-2.547e+006	-1.757e+006	-4.441e+005
Name		78 @TPL2	34 @TPL2	23 @TPL2	36 @TPL2	37 @TPL2
Vapour Fraction		0.0000	0.0224	0.0000	0.5362	0.0000
Temperature	(C)	36.257	244.73	219.09	135.82	107.42
Pressure	(MPa)	6.7569e-003	3.5800	2.3500	0.32100	0.13300
Molar Flow	(kgmole/s)	7.2342	0.56138	1.0837	0.87323	0.87323
Mass Flow	(kg/s)	130.33	10.113	19.523	15.731	15.731
Liquid Volume Flow	(m3/h)	470.1	36.48	70.42	56.75	56.75
Heat Flow	(kW)	-2.058e+006	-1.496e+005	-2.921e+005	-2.232e+005	-2.436e+005
Name		58 @TPL2	59 @TPL2	63 @TPL2	79 @TPL2	81 @TPL2
Vapour Fraction		0.0000	0.0084	1.0000	1.0000	1.0000
Temperature	(C)	37.735	38.585	750.00	750.00	291.05
Pressure	(MPa)	1.2000 *	6.7569e-003	7.0000	7.0000	6.8600
Molar Flow	(kgmole/s)	8.9562	1.7219	46.695	13.751	46.695
Mass Flow	(kg/s)	161.35	31.021	186.92	55.045	186.92
Liquid Volume Flow	(m3/h)	582.0	111.9	5424	1597	5424
Heat Flow	(kW)	-2.547e+006	-4.890e+005	7.070e+005	2.082e+005	2.616e+005
Name		82 @TPL2	2 @TPL2	3 @TPL2		
Vapour Fraction		1.0000	1.0000	1.0000		
Temperature	(C)	378.85	750.00	311.02		
Pressure	(MPa)	6.8600	7.0000	6.8600		
Molar Flow	(kgmole/s)	13.751	60.446	60.446		
Mass Flow	(kg/s)	55.045	241.97	241.97		
Liquid Volume Flow	(m3/h)	1597	7021	7021		
Heat Flow	(kW)	1.021e+005	9.152e+005	3.638e+005		

Compositions

Name	Steam Generator Ou	4 @TPL2	To Reheater @TPL2	To FW Heater 7 @TF	8 @TPL2
Comp Mole Frac (H2O)	1.00000 *	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000 *	0.00000	0.00000	0.00000	0.00000

* Specified by user.

Workbook: Rankine Steam Cycle (TPL2) (continued)

Compositions (continued)

Name	10 @TPL2	11 @TPL2	Steam Generator In @	17 @TPL2	13 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	14 @TPL2	15 @TPL2	16 @TPL2	18 @TPL2	21 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	22 @TPL2	20 @TPL2	24 @TPL2	25 @TPL2	26 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	27 @TPL2	28 @TPL2	35 @TPL2	38 @TPL2	39 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	40 @TPL2	41 @TPL2	43 @TPL2	44 @TPL2	45 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	46 @TPL2	47 @TPL2	48 @TPL2	49 @TPL2	51 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	52 @TPL2	53 @TPL2	54 @TPL2	55 @TPL2	56 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	57 @TPL2	60 @TPL2	62 @TPL2	64 @TPL2	74 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	78 @TPL2	34 @TPL2	23 @TPL2	36 @TPL2	37 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	58 @TPL2	59 @TPL2	63 @TPL2	79 @TPL2	81 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000	1.00000	1.00000	1.00000
Name	82 @TPL2	2 @TPL2	3 @TPL2		
Comp Mole Frac (H2O)	0.00000	0.00000	0.00000		
Comp Mole Frac (Helium)	1.00000	1.00000	1.00000		

Energy Streams

Name		HP Trbn Pwr @TPL2	IT Trbn Stg 1 Pwr @T	ITTrbn Stg 2 Pwr @T	LP Trb Stg 1 Pwr @T	Bstr Pmp Pwr @TPL2
Heat Flow	(kW)	7.286e+004	1.946e+004	2.369e+004	2.998e+004	675.3
Name		LP Trbn Stg 2 Pwr @	LP Trbn Stg 3 Pwr @	LP Trbn Stg 4 Pwr @	LP Trg Stg 5 Pwr @T	Cond Q @TPL2
Heat Flow	(kW)	2.129e+004	2.119e+004	2.200e+004	4.837e+004	3.012e+005
Name		BF Pmp Pwr @TPL2	Cnd Pmp Pwr @TPL2	Electric Power Out @		
Heat Flow	(kW)	7639	257.2	2.489e+005		

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
High Pressure Turbine @TPI	Expander	Steam Generator Out @TPL	4 @TPL2 HP Trbn Pwr @TPL2	No	500.0 *
Intermdiate Pressure Turbine	Expander	8 @TPL2	13 @TPL2 IT Trbn Stg 1 Pwr @TPL2	No	500.0 *
Intermediatte Pressure Turbi	Expander	15 @TPL2	18 @TPL2 ITTrbn Stg 2 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	21 @TPL2	24 @TPL2 LP Trb Stg 1 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	25 @TPL2	43 @TPL2 LP Trbn Stg 2 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	44 @TPL2	47 @TPL2	No	500.0 *

* Specified by user.

Workbook: Rankine Steam Cycle (TPL2) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
Low Pressure Turbine Stage	Expander		LP Trbn Stg 3 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	51 @TPL2	53 @TPL2 LP Trbn Stg 4 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	54 @TPL2	64 @TPL2 LP Trg Stg 5 Pwr @TPL2	No	500.0 *
T4 @TPL2	Tee	4 @TPL2	To Reheater @TPL2 To FW Heater 7 @TPL2	No	500.0 *
T6 @TPL2	Tee	13 @TPL2	14 @TPL2 15 @TPL2	No	500.0 *
T7 @TPL2	Tee	18 @TPL2	21 @TPL2 22 @TPL2	No	500.0 *
T8 @TPL2	Tee	24 @TPL2	25 @TPL2 26 @TPL2	No	500.0 *
T9 @TPL2	Tee	43 @TPL2	44 @TPL2 45 @TPL2	No	500.0 *
T10 @TPL2	Tee	47 @TPL2	51 @TPL2 52 @TPL2	No	500.0 *
T11 @TPL2	Tee	53 @TPL2	54 @TPL2 55 @TPL2	No	500.0 *
T13 @TPL2	Tee	2 @TPL2	79 @TPL2 63 @TPL2	No	500.0 *
Feedwater Heater 7 @TPL2	Heat Exchanger	11 @TPL2 To FW Heater 7 @TPL2	Steam Generator In @TPL2 10 @TPL2	No	500.0 *
Feedwater Heater 6 @TPL2	Heat Exchanger	35 @TPL2 16 @TPL2	17 @TPL2 28 @TPL2	No	500.0 *
Feedwater Heater 5 @TPL2	Heat Exchanger	27 @TPL2 20 @TPL2	35 @TPL2 38 @TPL2	No	500.0 *
Feedwater Heater 3 @TPL2	Heat Exchanger	48 @TPL2 45 @TPL2	39 @TPL2 46 @TPL2	No	500.0 *
Feedwater Heater 2 @TPL2	Heat Exchanger	57 @TPL2 36 @TPL2	48 @TPL2 56 @TPL2	No	500.0 *
Feedwater Heater 1 @TPL2	Heat Exchanger	58 @TPL2 74 @TPL2	57 @TPL2 60 @TPL2	No	500.0 *
Boiler Feed Pump @TPL2	Pump	17 @TPL2 BF Pmp Pwr @TPL2	11 @TPL2	No	500.0 *
Booster Pump @TPL2	Pump	40 @TPL2 Bstr Pmp Pwr @TPL2	27 @TPL2	No	500.0 *
Condensate Pump @TPL2	Pump	62 @TPL2 Cnd Pmp Pwr @TPL2	58 @TPL2	No	500.0 *
M3 @TPL2	Mixer	34 @TPL2 14 @TPL2	16 @TPL2	No	500.0 *
M4 @TPL2	Mixer	22 @TPL2 23 @TPL2	20 @TPL2	No	500.0 *
Deaerating Heater @TPL2	Mixer	39 @TPL2 41 @TPL2 26 @TPL2	40 @TPL2	No	500.0 *
M11 @TPL2	Mixer	55 @TPL2 37 @TPL2	74 @TPL2	No	500.0 *
M13 @TPL2	Mixer	52 @TPL2 49 @TPL2	36 @TPL2	No	500.0 *
M14 @TPL2	Mixer	59 @TPL2 78 @TPL2	62 @TPL2	No	500.0 *
M7 @TPL2	Mixer	81 @TPL2 82 @TPL2	3 @TPL2	No	500.0 *

* Specified by user.

Workbook: Rankine Steam Cycle (TPL2) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
VLV 8 @TPL2	Valve	38 @TPL2	41 @TPL2	No	500.0 *
VLV 10 @TPL2	Valve	46 @TPL2	49 @TPL2	No	500.0 *
VLV 11 @TPL2	Valve	56 @TPL2	37 @TPL2	No	500.0 *
VLV 18 @TPL2	Valve	10 @TPL2	34 @TPL2	No	500.0 *
VLV 17 @TPL2	Valve	28 @TPL2	23 @TPL2	No	500.0 *
VLV 13 @TPL2	Valve	60 @TPL2	59 @TPL2	No	500.0 *
Condenser @TPL2	Cooler	64 @TPL2	78 @TPL2 Cond Q @TPL2	No	500.0 *
Steam Generator @TPL2	LNG	63 @TPL2 Steam Generator In @TPL2	81 @TPL2 Steam Generator Out @TPL	No	500.0 *
Reheater @TPL2	LNG	79 @TPL2 To Reheater @TPL2	82 @TPL2 8 @TPL2	No	500.0 *
ADJ-1 @TPL2	Adjust			Yes	3500 *
ADJ-2 @TPL2	Adjust			Yes	3500 *
Efficiency Calculations @TP	Spreadsheet			No	500.0 *
Pressure Drops @TPL2	Spreadsheet			No	500.0 *

* Specified by user.

Appendix B
High Temperature Electrolysis with Combined Cycle Process Flow Diagrams

The model of the HTE process with a Ranke power cycle and results in Appendix A 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.

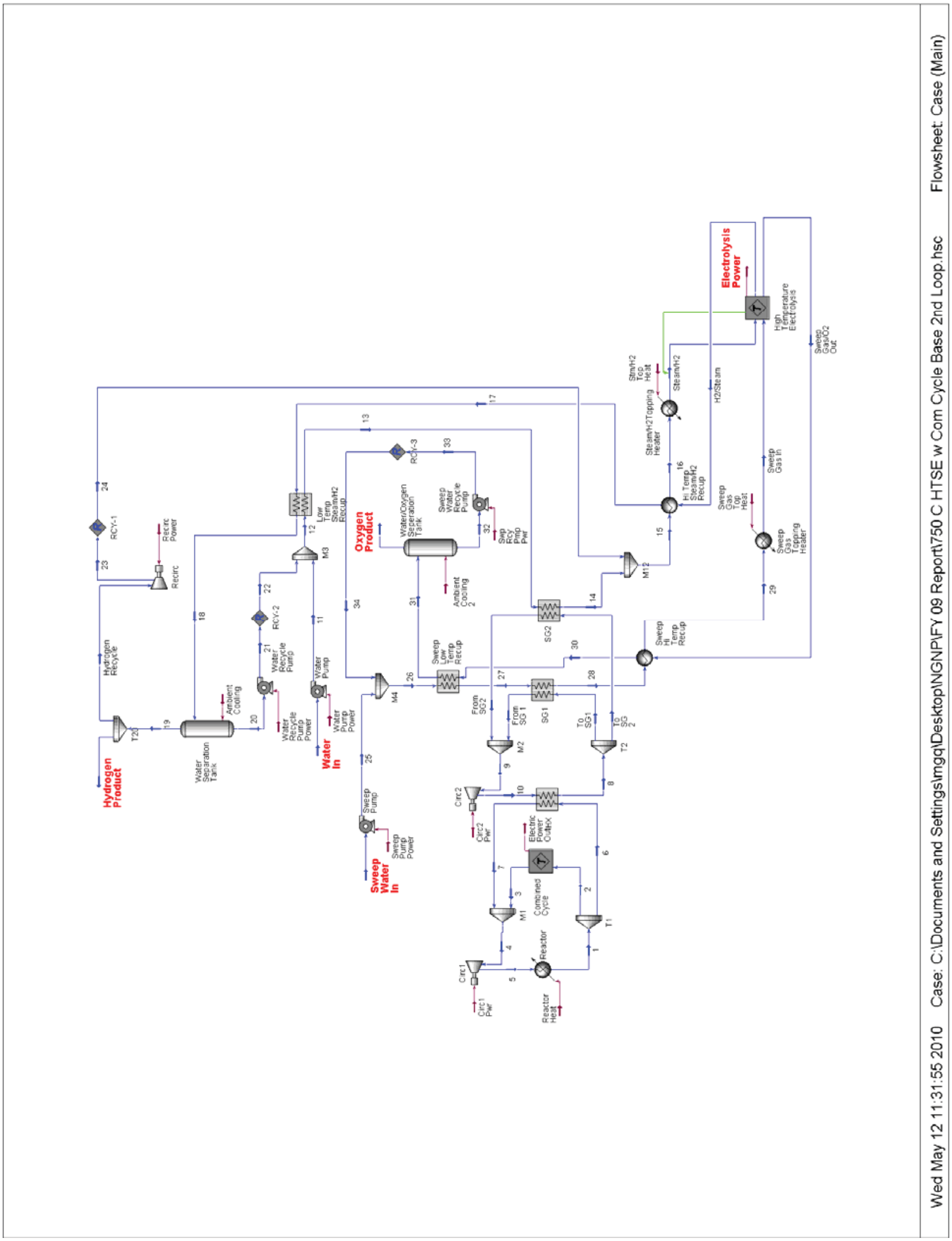

Figure B - 1 HTE Process Flow Diagram

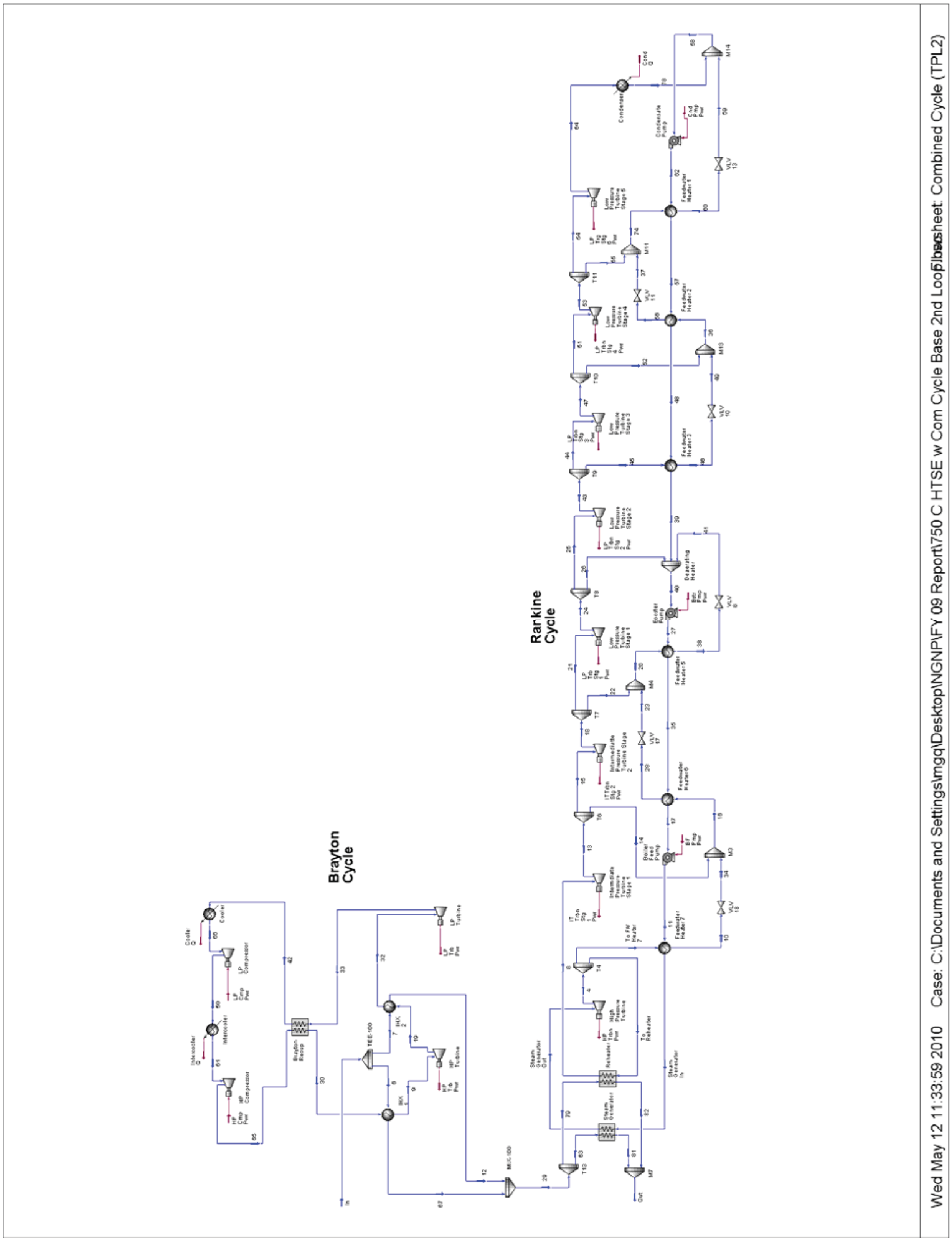

Figure B - 2 Combined Power Cycle

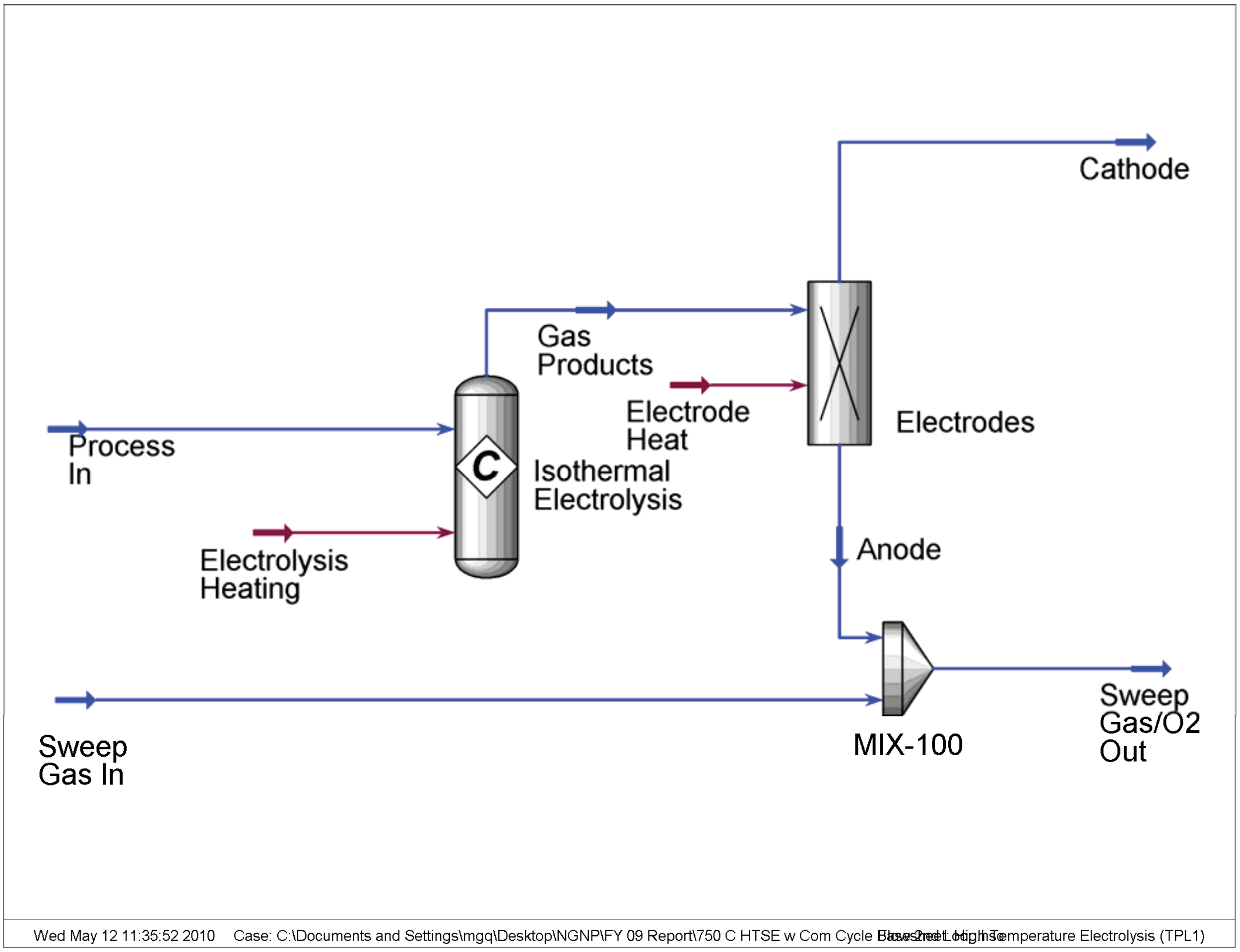

Figure B - 3 Electrolysis Module

INL Calgary, Alberta CANADA	Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
	Unit Set: NGNP
	Date/Time: Wed May 12 11:37:15 2010

Workbook: Case (Main)

Streams

Name		1	2	3	4	5
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	750.00 *	750.00	305.22	308.71	322.00 *
Pressure	(MPa)	7.0000 *	7.0000	6.7200	6.7200	7.0710
Molar Flow	(kgmole/s)	67.474	60.736	60.736	67.474	67.474
Mass Flow	(kg/s)	270.10	243.13	243.13	270.10	270.10
Liquid Volume Flow	(m3/h)	7837	7055	7055	7837	7837
Heat Flow	(kW)	1.022e+006	9.196e+005	3.581e+005	4.027e+005	4.216e+005
Molar Enthalpy	(kJ/kgmole)	1.514e+004	1.514e+004	5896	5969	6248
Name		6	7	8	9	10
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	750.00	340.15	725.00 *	304.80	315.15
Pressure	(MPa)	7.0000	6.7200	7.0000 *	6.8600	7.1400
Molar Flow	(kgmole/s)	6.7377	6.7377	6.7412	6.7412	6.7412
Mass Flow	(kg/s)	26.971	26.971	26.985	26.985	26.985
Liquid Volume Flow	(m3/h)	782.6	782.6	783.0	783.0	783.0
Heat Flow	(kW)	1.020e+005	4.462e+004	9.856e+004	3.970e+004	4.117e+004
Molar Enthalpy	(kJ/kgmole)	1.514e+004	6622	1.462e+004	5889	6107
Name		11	12	13	14	15
Vapour Fraction		0.0000	0.0000	0.2711	1.0000	1.0000
Temperature	(C)	27.317	26.894	268.86	700.00 *	650.93
Pressure	(MPa)	5.4000	5.4000	5.3000	5.2000	5.2000
Molar Flow	(kgmole/s)	0.87296	1.3115	1.3115	1.3115	1.4574
Mass Flow	(kg/s)	15.727	23.627	23.627	23.627	23.923
Liquid Volume Flow	(m3/h)	56.73	85.23	85.23	85.23	100.4
Heat Flow	(kW)	-2.489e+005	-3.740e+005	-3.366e+005	-2.842e+005	-2.842e+005
Molar Enthalpy	(kJ/kgmole)	-2.851e+005	-2.852e+005	-2.567e+005	-2.167e+005	-1.950e+005
Name		16	17	18	19	20
Vapour Fraction		1.0000	1.0000	0.7726	1.0000	0.0000
Temperature	(C)	756.90	670.93	144.07	26.000	26.000 *
Pressure	(MPa)	5.1000	4.9000	4.8000	4.8000	4.8000
Molar Flow	(kgmole/s)	1.4574	1.4574	1.4574	1.0210	0.43636
Mass Flow	(kg/s)	23.923	9.9330	9.9330	2.0724	7.8607
Liquid Volume Flow	(m3/h)	100.4	134.4	134.4	106.0	28.36
Heat Flow	(kW)	-2.778e+005	-7.572e+004	-1.131e+005	-183.2	-1.245e+005
Molar Enthalpy	(kJ/kgmole)	-1.906e+005	-5.195e+004	-7.761e+004	-179.4	-2.852e+005
Name		21	22	23	24	25
Vapour Fraction		0.0000	0.0000	1.0000	1.0000	0.0000
Temperature	(C)	26.052	26.052 *	35.491	35.491 *	27.317
Pressure	(MPa)	5.4000	5.4000 *	5.2000	5.2000 *	5.4000
Molar Flow	(kgmole/s)	0.43636	0.43857 *	0.14626	0.14585 *	4.8166e-004
Mass Flow	(kg/s)	7.8607	7.9004	0.29685	0.29604	8.6772e-003
Liquid Volume Flow	(m3/h)	28.36	28.50	15.19	15.15	3.130e-002
Heat Flow	(kW)	-1.245e+005	-1.251e+005	13.74	13.70	-137.3
Molar Enthalpy	(kJ/kgmole)	-2.852e+005	-2.852e+005	93.95	93.95	-2.851e+005
Name		26	27	28	29	30
Vapour Fraction		0.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	27.053	346.76	700.00 *	780.00	755.74
Pressure	(MPa)	5.4000	5.3000	5.2000	5.1000	4.9000
Molar Flow	(kgmole/s)	0.43731	0.43731	0.43731	0.43731	0.87449
Mass Flow	(kg/s)	7.8790 *	7.8790	7.8790	7.8790	21.869
Liquid Volume Flow	(m3/h)	28.42	28.42	28.42	28.42	72.69
Heat Flow	(kW)	-1.247e+005	-1.013e+005	-9.477e+004	-9.326e+004	-8.324e+004
Molar Enthalpy	(kJ/kgmole)	-2.851e+005	-2.316e+005	-2.167e+005	-2.133e+005	-9.518e+004

* Specified by user.

Workbook: Case (Main) (continued)

Streams (continued)

Name		31	32	33	34	Ambient Cooling
Vapour Fraction		0.8172	0.0000	0.0000	0.0000	---
Temperature	(C)	203.63	27.000	27.052	27.052 *	---
Pressure	(MPa)	4.8000	4.8000	5.4000 *	5.4000 *	---
Molar Flow	(kgmole/s)	0.87449	0.43682	0.43682	0.43682 *	---
Mass Flow	(kg/s)	21.869	7.8703	7.8703	7.8703	---
Liquid Volume Flow	(m3/h)	72.69	28.39	28.39	28.39	---
Heat Flow	(kW)	-1.066e+005	-1.246e+005	-1.245e+005	-1.245e+005	-1.154e+004
Molar Enthalpy	(kJ/kgmole)	-1.220e+005	-2.851e+005	-2.851e+005	-2.851e+005	---
Name		Ambient Cooling 2	Circ1 Pwr	Circ2 Pwr	Electric Power Out	Electrolysis Power
Vapour Fraction		---	---	---	---	---
Temperature	(C)	---	---	---	---	---
Pressure	(MPa)	---	---	---	---	---
Molar Flow	(kgmole/s)	---	---	---	---	---
Mass Flow	(kg/s)	---	---	---	---	---
Liquid Volume Flow	(m3/h)	---	---	---	---	---
Heat Flow	(kW)	-1.819e+004	1.887e+004	1468	2.467e+005	-2.170e+005
Molar Enthalpy	(kJ/kgmole)	---	---	---	---	---
Name		From SG2	From SG 1	H2/Steam	Hydrogen Product	Hydrogen Recycle
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	294.00	375.32	800.00	26.000	26.000
Pressure	(MPa)	6.8600	6.8600	5.0000	4.8000	4.8000
Molar Flow	(kgmole/s)	5.8456	0.89558	1.4574	0.87477	0.14626
Mass Flow	(kg/s)	23.400	3.5850	9.9330	1.7755	0.29685
Liquid Volume Flow	(m3/h)	679.0	104.0	134.4	90.85	15.19
Heat Flow	(kW)	3.311e+004	6586	-6.932e+004	-157.0	-26.25
Molar Enthalpy	(kJ/kgmole)	5664	7354	-4.757e+004	-179.4	-179.4
Name		Oxygen Product	Process Heat 1	Reactor Heat	Recirc Power	Steam/H2
Vapour Fraction		1.0000	---	---	---	1.0000
Temperature	(C)	27.000 *	---	---	---	800.00 *
Pressure	(MPa)	4.8000	---	---	---	5.0000 *
Molar Flow	(kgmole/s)	0.43767	---	---	---	1.4574
Mass Flow	(kg/s)	13.999	---	---	---	23.923 *
Liquid Volume Flow	(m3/h)	44.30	---	---	---	100.4
Heat Flow	(kW)	-281.0	2.957e-007	6.000e+005 *	39.99	-2.752e+005
Molar Enthalpy	(kJ/kgmole)	-642.0	---	---	---	-1.888e+005
Name		Stm/H2 Top Heat	Sweep Gas In	Sweep Gas Top Heat	Sweep Gas/O2 Out	Sweep Pump Power
Vapour Fraction		---	1.0000	---	1.0000	---
Temperature	(C)	---	800.00	---	800.00	---
Pressure	(MPa)	---	5.0000	---	5.0000	---
Molar Flow	(kgmole/s)	---	0.43731	---	0.87449	---
Mass Flow	(kg/s)	---	7.8790	---	21.869	---
Liquid Volume Flow	(m3/h)	---	28.42	---	72.69	---
Heat Flow	(kW)	2638	-9.288e+004	382.8	-8.173e+004	6.094e-002
Molar Enthalpy	(kJ/kgmole)	---	-2.124e+005	---	-9.346e+004	---
Name		Sweep Water In	Swp Rcy Pmp Pwr	To SG1	To SG 2	Water In
Vapour Fraction		0.0000	---	1.0000	1.0000	0.0000
Temperature	(C)	26.850 *	---	725.00	725.00	26.850 *
Pressure	(MPa)	0.10132 *	---	7.0000	7.0000	0.10132 *
Molar Flow	(kgmole/s)	4.8166e-004	---	0.89558	5.8456	0.87296
Mass Flow	(kg/s)	8.6772e-003	---	3.5850 *	23.400 *	15.727
Liquid Volume Flow	(m3/h)	3.130e-002	---	104.0	679.0	56.73
Heat Flow	(kW)	-137.4	6.251	1.309e+004	8.547e+004	-2.490e+005
Molar Enthalpy	(kJ/kgmole)	-2.853e+005	---	1.462e+004	1.462e+004	-2.853e+005

* Specified by user.

Workbook: Case (Main) (continued)

Streams (continued)

Name		Water Pump Power	Water Recycle Pump			
Vapour Fraction		---	---			
Temperature	(C)	---	---			
Pressure	(MPa)	---	---			
Molar Flow	(kgmole/s)	---	---			
Mass Flow	(kg/s)	---	---			
Liquid Volume Flow	(m3/h)	---	---			
Heat Flow	(kW)	110.4	6.239			
Molar Enthalpy	(kJ/kgmole)	---	---			

Composition

Name	1	2	3	4	5
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	0.00000
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)	1.00000 *	1.00000 *	1.00000	1.00000	1.00000
Name	6	7	8	9	10
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	0.00000
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)	1.00000	1.00000	1.00000	1.00000	1.00000
Name	11	12	13	14	15
Comp Mole Frac (Hydrogen)	0.00000	0.00002	0.00002	0.00002	0.10001
Comp Mole Frac (H2O)	1.00000	0.99998	0.99998	0.99998	0.89999
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	16	17	18	19	20
Comp Mole Frac (Hydrogen)	0.10001	0.70000	0.70000	0.99914	0.00005
Comp Mole Frac (H2O)	0.89999	0.30000	0.30000	0.00086	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	21	22	23	24	25
Comp Mole Frac (Hydrogen)	0.00005	0.00005 *	0.99914	0.99914 *	0.00000
Comp Mole Frac (H2O)	0.99995	0.99995 *	0.00086	0.00086 *	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	26	27	28	29	30
Comp Mole Frac (Hydrogen)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (H2O)	0.99986	0.99986	0.99986	0.99986	0.50000
Comp Mole Frac (Oxygen)	0.00014	0.00014	0.00014	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	31	32	33	34	From SG2
Comp Mole Frac (Hydrogen)	0.00000	0.00000	0.00000	0.00000 *	0.00000
Comp Mole Frac (H2O)	0.50000	0.99986	0.99986	0.99986 *	0.00000
Comp Mole Frac (Oxygen)	0.50000	0.00014	0.00014	0.00014 *	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 *	1.00000
Name	From SG 1	H2/Steam	Hydrogen Product	Hydrogen Recycle	Oxygen Product
Comp Mole Frac (Hydrogen)	0.00000	0.70000	0.99914	0.99914	0.00000
Comp Mole Frac (H2O)	0.00000	0.30000	0.00086	0.00086	0.00110
Comp Mole Frac (Oxygen)	0.00000	0.00000	0.00000	0.00000	0.99890
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	0.00000	0.00000	0.00000	0.00000
Name	Steam/H2	Sweep Gas In	Sweep Gas/O2 Out	Sweep Water In	To SG1
Comp Mole Frac (Hydrogen)	0.10001	0.00000	0.00000	0.00000 *	0.00000 *
Comp Mole Frac (H2O)	0.89999	0.99986	0.50000	1.00000 *	0.00000 *
Comp Mole Frac (Oxygen)	0.00000	0.00014	0.50000	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 *	1.00000 *
Name	To SG 2	Water In			
Comp Mole Frac (Hydrogen)	0.00000 *	0.00000 *			
Comp Mole Frac (H2O)	0.00000 *	1.00000 *			
Comp Mole Frac (Oxygen)	0.00000 *	0.00000 *			
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)	1.00000 *	0.00000 *			

Coolers

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

Heat Exchangers

Name		Sweep Hi Temp Recu	Hi Temp Steam/H2 R			
Duty	(kW)	1506	6394			
UA	(W/C)	4.324e+004	2.120e+005			
LMTD	(C)	34.82	30.15			
Minimum Approach	(C)	20.00	20.00			

Workbook: Case (Main) (continued)

Heaters

Name		Steam/H2Topping He	Sweep Gas Topping	Reactor		
Duty	(kW)	2638	382.8	6.000e+005 *		
Feed Temperature	(C)	756.9	780.0	322.0 *		
Product Temperature	(C)	800.0 *	800.0	750.0 *		

LNGs

Name		Low Temp Steam/H2	SG1	SG2	Sweep Low Temp Re	IHX
UA (Calculated)	(W/C)	4.288e+005	2.439e+005	5.213e+005	2.469e+005	2.296e+006
LMTD	(C)	87.20 *	26.68 *	100.4 *	94.81 *	25.00 *
Exchanger Cold Duty	(kW)	3.740e+004	6508	5.236e+004	2.341e+004	5.740e+004
Minimum Approach	(C)	25.00	25.00	25.00	25.00	24.99

Compressors

Name		Recirc	Circ1	Circ2		
Feed Pressure	(MPa)	4.800	6.720	6.860		
Product Pressure	(MPa)	5.200	7.071	7.140		
Molar Flow	(kgmole/s)	0.1463	67.47	6.741		
Energy	(kW)	39.99	1.887e+004	1468		
Adiabatic Efficiency		75 *	90 *	90 *		
Polytropic Efficiency		75	91	90		

Expanders

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

Pumps

Name		Water Pump	Water Recycle Pump	Sweep Pump	Sweep Water Recyc	
Delta P	(MPa)	5.299	0.6000	5.299	0.6000	
Energy	(kW)	110.4	6.239	6.094e-002	6.251	
Feed Pressure	(MPa)	0.1013 *	4.800	0.1013 *	4.800	
Product Pressure	(MPa)	5.400	5.400	5.400	5.400 *	
Molar Flow	(kgmole/s)	0.8730	0.4364	4.817e-004	0.4368	
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 *
Combined Cycle	Standard Sub-Flowsheet	2	3 Electric Power Out	No	2500 *
Electrolysis Input and Outpu	Spreadsheet			No	500.0 *
Efficiency	Spreadsheet			No	500.0 *
Steam/H2Topping Heater	Heater	16 Stm/H2 Top Heat	Steam/H2	No	500.0 *
Sweep Gas Topping Heater	Heater	29 Sweep Gas Top Heat	Sweep Gas In	No	500.0 *
Reactor	Heater	5 Reactor Heat	1	No	500.0 *
T20	Tee	19	Hydrogen Product	No	500.0 *

* Specified by user.

Workbook: Case (Main) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
T20	Tee		Hydrogen Recycle	No	500.0 *
T1	Tee	1	6 2	No	500.0 *
T2	Tee	8	To SG1 To SG 2	No	500.0 *
Sweep Hi Temp Recup	Heat Exchanger	28 Sweep Gas/O2 Out	29 30	No	500.0 *
Hi Temp Steam/H2 Recup	Heat Exchanger	15 H2/Steam	16 17	No	500.0 *
M12	Mixer	14 24	15	No	500.0 *
M3	Mixer	11 22	12	No	500.0 *
M4	Mixer	34 25	26	No	500.0 *
M1	Mixer	7 3	4	No	500.0 *
M2	Mixer	From SG2 From SG 1	9	No	500.0 *
Recirc	Compressor	Hydrogen Recycle Recirc Power	23	No	500.0 *
Circ1	Compressor	4 Circ1 Pwr	5	No	500.0 *
Circ2	Compressor	9 Circ2 Pwr	10	No	500.0 *
Low Temp Steam/H2 Recup	LNG	12 17	13 18	No	500.0 *
SG1	LNG	To SG1 27	From SG 1 28	No	500.0 *
SG2	LNG	13 To SG 2	14 From SG2	No	500.0 *
Sweep Low Temp Recup	LNG	26 30	27 31	No	500.0 *
IHX	LNG	10 6	8 7	No	500.0 *
Water Pump	Pump	Water In Water Pump Power	11	No	500.0 *
Water Recycle Pump	Pump	20 Water Recycle Pump Power	21	No	500.0 *
Sweep Pump	Pump	Sweep Water In Sweep Pump Power	25	No	500.0 *
Sweep Water Recycle Pump	Pump	32 Swp Rcy Pmp Pwr	33	No	500.0 *
Water Separation Tank	Separator	18 Ambient Cooling	20 19 Ambient Cooling	No	500.0 *
Water/Oxygen Seperation T	Separator	31 Ambient Cooling 2	32 Oxygen Product Ambient Cooling 2	No	500.0 *
RCY-1	Recycle	23	24	No	3500 *
RCY-2	Recycle	21	22	No	3500 *
RCY-3	Recycle	33	34	No	3500 *
SET-1	Set			No	500.0 *
SET-2	Set			No	500.0 *

* Specified by user.

Workbook: Case (Main) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
ADJ-1	Adjust			No	3500 *

Spreadsheet: Efficiency

Units Set: NGNP

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
B1	Energy Stream: Reactor Heat	Heat Flow	6.000e+005 kW
B2	Energy Stream: Electric Power Out	Power	2.467e+005 kW
B3	Energy Stream: Circ1 Pwr	Power	1.887e+004 kW
B4	Energy Stream: Electrolysis Power	Power	-2.170e+005 kW
B5	Energy Stream: Recirc Power	Power	39.99 kW
B6	Energy Stream: Water Pump Power	Power	110.4 kW
B7	Energy Stream: Sweep Pump Power	Power	6.094e-002 kW
B8	Energy Stream: Water Recycle Pump Po	Power	6.239 kW
B9	Energy Stream: Swp Rcy Pmp Pwr	Power	6.251 kW
D1	Energy Stream: Ambient Cooling	Heat Flow	-1.154e+004 kW
D2	Energy Stream: Ambient Cooling 2	Heat Flow	-1.819e+004 kW
D7	Material Stream: Hydrogen Product	Mass Higher Heating Value	1.393e+005 kJ/kg
D8	Material Stream: Hydrogen Product	Mass Flow	1.7755 kg/s
D9	Energy Stream: Sweep Gas Top Heat	Heat Flow	382.8 kW
D10	Energy Stream: Stm/H2 Top Heat	Heat Flow	2638 kW
F2	Energy Stream: Circ2 Pwr	Power	1468 kW
F3	Tee: T1	Flow Ratio (Flow Ratio_2)	0.9001

Exported Variables' Formula Results

Cell	Object	Variable Description	Value

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
B10	B10: Total Electrical Power	Total Electrical Power	Power	-0.2106 kW
D3	D3:		Energy	2.972e+004 kW
D4	D4:		Energy	133.8 kW
D5	D5:		---	0.9600
D6	D6:		Power	-2.261e+005 kW
F1	F1: Hydrogen Production Efficiency	Hydrogen Production Efficiency	Percent	41.02
F4	F4:		---	0.4253

User Variables

FORMULAS

Cell	Formula	Result
B10	=B2-B3+D6-B5-B6-B7-B8-B9-D4-F2	-0.2106 kW
D3	=-D1-D2	2.972e+004 kW
D4	=0.00450015022*D3- 0.000092174537	133.8 kW
D6	=B4/D5	-2.261e+005 kW
F1	=(D7*D8)/(B1+D9+D10)*100	41.02
F4	=(B2-F3*B3)/(B1*F3)	0.4253

* Specified by user.

Spreadsheet: Efficiency (continued)

Units Set: NGNP

Spreadsheet

	A	B	C	D	E	F
1	Reactor Heat *	6.000e+005 kW *	Ambient Cooling *	-1.154e+004 kW	n Production Efficiency *	41.02
2	Electric Power Out *	2.467e+005 kW	Ambient Cooling 2 *	-1.819e+004 kW	Circ 2 Pwr *	1468 kW
3	Circ Pwr *	1.887e+004 kW	Total Ambient Cooling *	2.972e+004 kW	flo frc into pwr cycl *	0.9001
4	DC Electrolysis Power *	-2.170e+005 kW	Power to Ambient Cool *	133.8 kW	Power Cycle Efficiency *	0.4253
5	Recirc Pwr *	39.99 kW	AC to DC conversion *	0.9600 *		
6	Water Pump Power *	110.4 kW	AC Electrolysis Power *	-2.261e+005 kW		
7	Sweep Pump Pwr *	6.094e-002 kW	HHV H2 Product *	1.393e+005 kJ/kg		
8	Recycle Pmp Pwr *	6.239 kW	Mass Flow Hydrogen *	1.7755 kg/s		
9	Sweep Rcycl Pump Pwr *	6.251 kW	veep Gas Topping Heat *	382.8 kW		
10	Total Electrical Power *	-0.2106 kW	Process Topping Heat *	2638 kW		

Spreadsheet: Electrolysis Input and Output

Units Set: Electrolysis

CONNECTIONS

Imported Variables

Cell	Object	Variable Description	Value
B6	Conversion Reactor: Isothermal Electrolysis @	Act. % Conversion (Act. % Conversion_1)	66.67

Exported Variables' Formula Results

Cell	Object	Variable Description	Value

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
B1	B1:		---	<empty>
B2	B2: Number of Cells	Number of Cells	---	1.073e+006
B3	B3: Cell Area	Cell Area	Small Area	225.0 cm2
B4	B4: Current Density (Amperes/cm^2)	Current Density (Amperes/cm^2)	---	0.6989
B5	B5: ASR @ 1100 K (ohms*cm^2)	ASR @ 1100 K (ohms*cm^2)	---	0.2776
B7	B7:		---	<empty>

User Variables

FORMULAS

Cell	Formula	Result

Spreadsheet

	A	B	C	D		
1		<empty> *				
2	Number of Cells *	1.073e+006 *				
3	Cell Area *	225.0 cm2 *				
4	ensity (Amperes/cm^2) *	0.6989 *				
5	@ 1100 K (ohms*cm^2) *	0.2776 *				
6		66.67				
7		<empty> *				
8						
9						
10						

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
	Unit Set:	NGNP
	Date/Time:	Wed May 12 11:37:15 2010

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/s)	1.4574	0.43731	1.4574	0.87449	1.8946
Mass Flow	(kg/s)	23.923	7.8790	9.9330	21.869	23.923
Liquid Volume Flow	(m3/h)	100.4	28.42	134.4	72.69	178.7
Heat Flow	(kW)	-2.752e+005	-9.288e+004	-6.932e+004	-8.173e+004	-5.825e+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 @TPl**
Vapour Fraction		0.0000	1.0000	---	---	---
Temperature	(C)	800.00	804.96	---	---	---
Pressure	(MPa)	5.0000	5.0000	---	---	---
Molar Flow	(kgmole/s)	0.00000	0.43719	0.43719	---	---
Mass Flow	(kg/s)	0.00000	13.990	13.990	---	---
Liquid Volume Flow	(m3/h)	0.0000	44.27	44.27	---	---
Heat Flow	(kW)	0.0000	1.115e+004	---	2.170e+005	72.15
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/s)	---	---			
Mass Flow	(kg/s)	---	---			
Liquid Volume Flow	(m3/h)	---	---			
Heat Flow	(kW)	2.957e-007	-2.170e+005			
Molar Enthalpy	(kJ/kgmole)	---	---			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
Isothermal Electrolysis @TP	Conversion Reactor	Process In @TPL1 Electrolysis Heating @TPL1	Liquid Products @TPL1 Gas Products @TPL1 Electrolysis Heating @TPL1	No	500.0 *
MIX-100 @TPL1	Mixer	Liquid Products @TPL1 Anode @TPL1 Sweep Gas In @TPL1	Sweep Gas/O2 Out @TPL1	No	500.0 *
Electrodes @TPL1	Component Splitter	Gas Products @TPL1 Electrode Heat @TPL1	Cathode @TPL1 Anode @TPL1	No	500.0 *
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

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C	
	Unit Set:	NGNP	
	Date/Time:	Wed May 12 11:37:15 2010	

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)	0.89999
F2	Material Stream: Process In @TPL1	Comp Mole Frac (Hydrogen)	0.10001
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	1.073e+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	2.170e+005 kW
D12	Energy Stream: Electrode Heat @TPL1	Heat Flow	72.15 kW

Exported Variables' Formula Results

Cell	Object	Variable Description	Value
B15	Molar Flow of Oxygen @TPL1	Molar Flow	437.19 gmole/s
B19	Electrolysis Power @TPL1	Power	-2.170e+005 kW
B20	Process Heat @TPL1	Heat Flow	2.957e-007 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	437.19 gmole/s
B17	B17:		Vapour Fraction	1.0067
B18	B18:		Vapour Fraction	1.2862
B19	B19: Power	Power	Power	-2.170e+005 kW
B20	B20: Heat Flow	Heat Flow	Energy	2.957e-007 kW
D4	D4:		Temperature	-5.9483e-004 K
D6	D6:		Temperature	1073.2 K
D8	D8:		---	3.501e-007
D9	D9:		---	5.887e-004
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:		---	6.803e-003
H3	H3:		---	24.67
H4	H4:		---	24.67

* Specified by user.

HYPROTECH	INL Calgary, Alberta CANADA	Case Name: C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H Unit Set: NGNP Date/Time: Wed May 12 11:37:15 2010

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:		---	0.7607
K3	K3:		---	1.091
K6	K6:		Vapour Fraction	1.0067
K7	K7:		---	1.007

User Variables

FORMULAS

Cell	Formula	Result
B14	=B12*B13	157.2
B15	=B11*B14/(4*A6)	437.19 gmole/s
B17	@IF(@ABS(D4)<1e-3,K6,K7)	1.0067
B18	=B17+B13*B16	1.2862
B19	=-B11*B18*B14/1000	-2.170e+005 kW
B20	=B19+D11+D12	2.957e-007 kW
D4	=D2-D3	-5.9483e-004 K
D6	=(D2+D3)/2	1073.2 K
D8	=1/(2*A6*H4*F4)	3.501e-007
D9	=-1/(2*A6*H4*F4*D4)	5.887e-004
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	6.803e-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)))	0.7607
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))	1.007

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	0.89999	0.10001
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 *	-5.9483e-004 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\750 C I Unit Set: NGNP Date/Time: Wed May 12 11:37:15 2010

Spreadsheet: High Temperature Electrolysis @TPL1

Units Set: Electrolysis_

Spreadsheet

6	9.649e+004 *	/ Number (J/Volt-gmole) *	Average *	1073.2 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 *	5.887e-004		
10						
11	Number of Cells *	1.073e+006 *	Electrolysis Heating *	2.170e+005 kW		
12	Cell Area *	225.0 cm2 *	Electrode Heat *	72.15 kW		
13	ensity (Amperes/cm^2) *	0.6989 *				
14	Current (Amperes) *	157.2				
15	Molar Flow of Oxygen *	437.19 gmole/s				
16	Resistance (ohm*cm^2) *	0.4000 *				
17	Nernst Potential (Volts) *	1.0067				
18	perating Voltage (Volts) *	1.2862				
19	Electrolysis Power *	-2.170e+005 kW				
20	Process Heat *	2.957e-007 kW				

	G	H	I	J	K	
1	y O2 *	y A *	Delta G *	Integral Delta G dT *	Nernst Voltage *	
2	0.00014	6.803e-003	1.887e+005 J/gmole	2.321e+008 J/gmole-K	0.7607	
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 *	1.007	
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\750 C H
	Unit Set:	NGNP
	Date/Time:	Wed May 12 11:37:15 2010

Spreadsheet: Temp Average ASR @TPL1 (continued

Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
A4	A4:		Temperature	1073.2 K
A5	A5:		Temperature	1073.2 K
A6	A6:		Temperature	1073.2 K
A7	A7:		Temperature	1073.2 K
A8	A8:		Temperature	1073.2 K
A9	A9:		Temperature	1073.2 K
A10	A10:		Temperature	1073.2 K
A11	A11:		Temperature	1073.2 K
A12	A12:		Temperature	1073.2 K
A13	A13:		Temperature	1073.2 K
A14	A14:		Temperature	1073.2 K
A15	A15:		Temperature	1073.2 K
A16	A16:		Temperature	1073.2 K
A17	A17:		Temperature	1073.2 K
A18	A18:		Temperature	1073.2 K
A19	A19:		Temperature	1073.2 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	1073.2 K
C2	C2:		Temperature	1073.2 K
C3	C3:		Temperature	1073.2 K
C4	C4:		Temperature	1073.2 K
C5	C5:		Temperature	1073.2 K
C6	C6:		Temperature	1073.2 K
C7	C7:		Temperature	1073.2 K
C8	C8:		Temperature	1073.2 K
C9	C9:		Temperature	1073.2 K
C10	C10:		Temperature	1073.2 K
C11	C11:		Temperature	1073.2 K
C12	C12:		Temperature	1073.2 K
C13	C13:		Temperature	1073.2 K
C14	C14:		Temperature	1073.2 K
C15	C15:		Temperature	1073.2 K
C16	C16:		Temperature	1073.2 K

* Specified by user.

Spreadsheet: Temp Average ASR @TPL1 (continued

Units Set: Electrolysis_

PARAMETERS

Exportable Variables

Cell	Visible Name	Variable Description	Variable Type	Value
C17	C17:		Temperature	1073.2 K
C18	C18:		Temperature	1073.2 K
C19	C19:		Temperature	1073.2 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	1073.2 K
E2	E2:		Temperature	1073.2 K
E3	E3:		Temperature	1073.2 K
E4	E4:		Temperature	1073.2 K
E5	E5:		Temperature	1073.2 K
E6	E6:		Temperature	1073.2 K
E7	E7:		Temperature	1073.2 K
E8	E8:		Temperature	1073.2 K
E9	E9:		Temperature	1073.2 K
E10	E10:		Temperature	1073.2 K
E11	E11:		Temperature	1073.2 K
E12	E12:		Temperature	1073.2 K
E13	E13:		Temperature	1073.2 K
E14	E14:		Temperature	1073.2 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	1.1897e-005 K

Spreadsheet: Temp Average ASR @TPL1 (continuec

Units Set: Electrolysis_

User Variables

FORMULAS

Cell	Formula	Result
A4	=A3+F16	1073.2 K
A5	=A4+F16	1073.2 K
A6	=A5+F16	1073.2 K
A7	=A6+F16	1073.2 K
A8	=A7+F16	1073.2 K
A9	=A8+F16	1073.2 K
A10	=A9+F16	1073.2 K
A11	=A10+F16	1073.2 K
A12	=A11+F16	1073.2 K
A13	=A12+F16	1073.2 K
A14	=A13+F16	1073.2 K
A15	=A14+F16	1073.2 K
A16	=A15+F16	1073.2 K
A17	=A16+F16	1073.2 K
A18	=A17+F16	1073.2 K
A19	=A18+F16	1073.2 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	1073.2 K
C2	=C1+F16	1073.2 K
C3	=C2+F16	1073.2 K
C4	=C3+F16	1073.2 K
C5	=C4+F16	1073.2 K
C6	=C5+F16	1073.2 K
C7	=C6+F16	1073.2 K
C8	=C7+F16	1073.2 K
C9	=C8+F16	1073.2 K
C10	=C9+F16	1073.2 K
C11	=C10+F16	1073.2 K
C12	=C11+F16	1073.2 K
C13	=C12+F16	1073.2 K
C14	=C13+F16	1073.2 K
C15	=C14+F16	1073.2 K
C16	=C15+F16	1073.2 K

	INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
		Unit Set:	NGNP
		Date/Time:	Wed May 12 11:37:15 2010

Spreadsheet: Temp Average ASR @TPL1 (continued

Units Set: Electrolysis_

FORMULAS

Cell	Formula	Result
C17	=C16+F16	1073.2 K
C18	=C17+F16	1073.2 K
C19	=C18+F16	1073.2 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	1073.2 K
E2	=E1+F16	1073.2 K
E3	=E2+F16	1073.2 K
E4	=E3+F16	1073.2 K
E5	=E4+F16	1073.2 K
E6	=E5+F16	1073.2 K
E7	=E6+F16	1073.2 K
E8	=E7+F16	1073.2 K
E9	=E8+F16	1073.2 K
E10	=E9+F16	1073.2 K
E11	=E10+F16	1073.2 K
E12	=E11+F16	1073.2 K
E13	=E12+F16	1073.2 K
E14	=E13+F16	1073.2 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	1.1897e-005 K

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

Spreadsheet

	A	B	C	D	E	F
1	ASR @ 1100 K *	0.2776 *	1073.2 K	0.4000	1073.2 K	0.4000
2	Temp Average ASR *	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
3	1073.1 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
4	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
5	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
6	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
7	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
8	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
9	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
10	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
11	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
12	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
13	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
14	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K	0.4000
15	1073.2 K	0.4000	1073.2 K	0.4000	1073.2 K *	0.4000
16	1073.2 K	0.4000	1073.2 K	0.4000	delta T *	1.1897e-005 K
17	1073.2 K	0.4000	1073.2 K	0.4000		
18	1073.2 K	0.4000	1073.2 K	0.4000		
19	1073.2 K	0.4000	1073.2 K	0.4000		
20	40.00	19.20				

Conversion: Electrolysis

STOICHIOMETRY

Component	Mole Weight	Stoichiometric Coeff.
H2O	18.015	-1 *
Hydrogen	2.016	1 *
Oxygen	32.000	0 *

Balance Error: 0.0000 | Reaction Heat: 2.410e+005 kJ/kgmole

BASIS

Base Component: H2O | Conversion Percent: 100.00 * | Reaction Phase: VapourPhase

PARAMETERS

Workbook: Combined Cycle (TPL2)

Material Streams

Name		Steam Generator Out	4 @TPL2	To Reheater @TPL2	To FW Heater 7 @TI	8 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	558.85	301.48	301.48	301.48	558.85
Pressure	(MPa)	24.000	4.5800 *	4.5800	4.5800	4.1220
Molar Flow	(kgmole/s)	7.0441	7.0441	6.6919	0.35220	6.6919
Mass Flow	(kg/s)	126.90	126.90	120.56	6.3450	120.56
Liquid Volume Flow	(m3/h)	457.8	457.8	434.9	22.89	434.9
Heat Flow	(kW)	-1.596e+006	-1.643e+006	-1.561e+006	-8.215e+004	-1.489e+006

Workbook: Combined Cycle (TPL2) (continued)

Material Streams (continued)

Name		10 @TPL2	11 @TPL2	Steam Generator In @	17 @TPL2	13 @TPL2
Vapour Fraction		0.0000	0.0000	0.0000	0.0000	1.0000
Temperature	(C)	241.24	235.68	254.47	228.56	506.59
Pressure	(MPa)	4.4884	27.211 *	26.667	2.7083	2.9800 *
Molar Flow	(kgmole/s)	0.35220	7.0441	7.0441	7.0441	6.6919
Mass Flow	(kg/s)	6.3450	126.90	126.90 *	126.90	120.56
Liquid Volume Flow	(m3/h)	22.89	457.8	457.8	457.8	434.9
Heat Flow	(kW)	-9.420e+004	-1.888e+006	-1.875e+006	-1.892e+006	-1.501e+006

Name		14 @TPL2	15 @TPL2	16 @TPL2	18 @TPL2	21 @TPL2
Vapour Fraction		1.0000	1.0000	0.6590	1.0000	1.0000
Temperature	(C)	506.59	506.59	234.20	434.17	434.17
Pressure	(MPa)	2.9800	2.9800	2.9800	1.8400 *	1.8400
Molar Flow	(kgmole/s)	0.33459	6.3573	0.68680	6.3573	6.0394
Mass Flow	(kg/s)	6.0278	114.53	12.373	114.53	108.80
Liquid Volume Flow	(m3/h)	21.74	413.1	44.63	413.1	392.5
Heat Flow	(kW)	-7.507e+004	-1.426e+006	-1.693e+005	-1.443e+006	-1.371e+006

Name		22 @TPL2	20 @TPL2	24 @TPL2	25 @TPL2	26 @TPL2
Vapour Fraction		1.0000	0.3947	1.0000	1.0000	1.0000
Temperature	(C)	434.17	208.61	349.55	349.55	349.55
Pressure	(MPa)	1.8400	1.8400	0.91534	0.91534	0.91534
Molar Flow	(kgmole/s)	0.31786	1.0047	6.0394	5.7375	0.30197
Mass Flow	(kg/s)	5.7264	18.099	108.80	103.36	5.4400
Liquid Volume Flow	(m3/h)	20.66	65.29	392.5	372.8	19.62
Heat Flow	(kW)	-7.215e+004	-2.579e+005	-1.389e+006	-1.319e+006	-6.944e+004

Name		27 @TPL2	28 @TPL2	35 @TPL2	38 @TPL2	39 @TPL2
Vapour Fraction		0.0000	0.0000	0.0000	0.0000	0.0000
Temperature	(C)	176.14	208.27	202.71	181.69	147.26
Pressure	(MPa)	2.8200 *	2.9204	2.7636	1.8032	0.91534
Molar Flow	(kgmole/s)	7.0441	0.68680	7.0441	1.0047	5.7375
Mass Flow	(kg/s)	126.90	12.373	126.90	18.099	103.36
Liquid Volume Flow	(m3/h)	457.8	44.63	457.8	65.29	372.8
Heat Flow	(kW)	-1.925e+006	-1.858e+005	-1.909e+006	-2.741e+005	-1.582e+006

Name		40 @TPL2	41 @TPL2	43 @TPL2	44 @TPL2	45 @TPL2
Vapour Fraction		0.0000	0.0129	1.0000	1.0000	1.0000
Temperature	(C)	175.74	176.21	278.93	278.93	278.93
Pressure	(MPa)	0.91534	0.91534	0.47800 *	0.47800	0.47800
Molar Flow	(kgmole/s)	7.0441	1.0047	5.7375	5.4506	0.28687
Mass Flow	(kg/s)	126.90	18.099	103.36	98.193	5.1680
Liquid Volume Flow	(m3/h)	457.8	65.29	372.8	354.2	18.64
Heat Flow	(kW)	-1.926e+006	-2.741e+005	-1.333e+006	-1.267e+006	-6.667e+004

Name		46 @TPL2	47 @TPL2	48 @TPL2	49 @TPL2	51 @TPL2
Vapour Fraction		0.0000	1.0000	0.0000	0.0000	1.0000
Temperature	(C)	124.97	209.27	119.41	125.01	209.27
Pressure	(MPa)	0.46844	0.23300 *	0.93159	0.23300	0.23300
Molar Flow	(kgmole/s)	0.28687	5.4506	5.7375	0.28687	5.1781
Mass Flow	(kg/s)	5.1680	98.193	103.36	5.1680	93.283
Liquid Volume Flow	(m3/h)	18.64	354.2	372.8	18.64	336.5
Heat Flow	(kW)	-7.962e+004	-1.280e+006	-1.595e+006	-7.962e+004	-1.216e+006

* Specified by user.

Workbook: Combined Cycle (TPL2) (continued)

Material Streams (continued)

Name		52 @TPL2	53 @TPL2	54 @TPL2	55 @TPL2	56 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	0.0000
Temperature	(C)	209.27	129.77	129.77	129.77	96.628
Pressure	(MPa)	0.23300	9.0000e-002 *	9.0000e-002	9.0000e-002	0.22834
Molar Flow	(kgmole/s)	0.27253	5.1781	4.7172	0.46085	0.55940
Mass Flow	(kg/s)	4.9096	93.283	84.981	8.3022	10.078
Liquid Volume Flow	(m3/h)	17.71	336.5	306.5	29.95	36.35
Heat Flow	(kW)	-6.399e+004	-1.230e+006	-1.120e+006	-1.095e+005	-1.565e+005

Name		57 @TPL2	60 @TPL2	62 @TPL2	64 @TPL2	74 @TPL2
Vapour Fraction		0.0000	0.0000	0.0000	0.9411	0.4642
Temperature	(C)	91.072	43.698	38.142	38.958	96.678
Pressure	(MPa)	0.95060	8.8200e-002	0.97000 *	6.8948e-003 *	9.0000e-002
Molar Flow	(kgmole/s)	5.7375	1.0202	5.7375	4.7172	1.0202
Mass Flow	(kg/s)	103.36	18.380	103.36	84.981	18.380
Liquid Volume Flow	(m3/h)	372.8	66.30	372.8	306.5	66.30
Heat Flow	(kW)	-1.608e+006	-2.897e+005	-1.632e+006	-1.147e+006	-2.660e+005

Name		78 @TPL2	34 @TPL2	23 @TPL2	36 @TPL2	37 @TPL2
Vapour Fraction		0.0000	0.0203	0.0000	0.5233	0.0000
Temperature	(C)	36.817	234.20	208.33	125.07	96.654
Pressure	(MPa)	6.7569e-003	2.9800	1.8400	0.23300	9.0000e-002
Molar Flow	(kgmole/s)	4.7172	0.35220	0.68680	0.55940	0.55940
Mass Flow	(kg/s)	84.981	6.3450	12.373	10.078	10.078
Liquid Volume Flow	(m3/h)	306.5	22.89	44.63	36.35	36.35
Heat Flow	(kW)	-1.342e+006	-9.420e+004	-1.858e+005	-1.436e+005	-1.565e+005

Name		58 @TPL2	59 @TPL2	63 @TPL2	79 @TPL2	81 @TPL2
Vapour Fraction		0.0000	0.0091	1.0000	1.0000	1.0000
Temperature	(C)	38.042	38.582	583.85	583.85	299.15
Pressure	(MPa)	6.7569e-003	6.7569e-003	6.8600	6.8600	6.7200
Molar Flow	(kgmole/s)	5.7375	1.0202	47.247	13.489	47.247
Mass Flow	(kg/s)	103.36	18.380	189.13	53.997	189.13
Liquid Volume Flow	(m3/h)	372.8	66.30	5488	1567	5488
Heat Flow	(kW)	-1.632e+006	-2.897e+005	5.522e+005	1.576e+005	2.726e+005

Name		82 @TPL2	6 @TPL2	7 @TPL2	29 @TPL2	32 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	326.48	750.00	750.00	583.85	725.00 *
Pressure	(MPa)	6.7200	7.0000	7.0000	6.8600	4.2630
Molar Flow	(kgmole/s)	13.489	30.368	30.368	60.736	30.381
Mass Flow	(kg/s)	53.997	121.56	121.56	243.13	121.61
Liquid Volume Flow	(m3/h)	1567	3527	3527	7055	3529
Heat Flow	(kW)	8.549e+004	4.598e+005	4.598e+005	7.098e+005	4.435e+005

Name		33 @TPL2	42 @TPL2	50 @TPL2	61 @TPL2	65 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	573.00	143.02	114.09	35.000 *	117.58
Pressure	(MPa)	2.6800 *	2.6264	4.3300 *	4.2434	7.2886 *
Molar Flow	(kgmole/s)	30.381	30.381	30.381	30.381	30.381
Mass Flow	(kg/s)	121.61	121.61	121.61	121.61	121.61
Liquid Volume Flow	(m3/h)	3529	3529	3529	3529	3529
Heat Flow	(kW)	3.470e+005	7.543e+004	5.772e+004	7755	6.090e+004

* Specified by user.

Workbook: Combined Cycle (TPL2) (continued)

Material Streams (continued)

Name		66 @TPL2	67 @TPL2	12 @TPL2	9 @TPL2	19 @TPL2
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	1.0000
Temperature	(C)	35.000 *	573.06	594.65	725.00 *	569.65
Pressure	(MPa)	2.5739	6.8600	6.8600	7.0000	4.3500 *
Molar Flow	(kgmole/s)	30.381	30.368	30.368	30.381	30.381
Mass Flow	(kg/s)	121.61	121.56	121.56	121.61	121.61
Liquid Volume Flow	(m3/h)	3529	3527	3527	3529	3529
Heat Flow	(kW)	7190	3.481e+005	3.617e+005	4.442e+005	3.454e+005
Name		30 @TPL2	In @TPL2	Out @TPL2		
Vapour Fraction		1.0000	1.0000	1.0000		
Temperature	(C)	548.00	750.00	305.22		
Pressure	(MPa)	7.1429	7.0000	6.7200		
Molar Flow	(kgmole/s)	30.381	60.736	60.736		
Mass Flow	(kg/s)	121.61	243.13	243.13		
Liquid Volume Flow	(m3/h)	3529	7055	7055		
Heat Flow	(kW)	3.325e+005	9.196e+005	3.581e+005		

Compositions

Name	Steam Generator Out	4 @TPL2	To Reheater @TPL2	To FW Heater 7 @TI	8 @TPL2
Comp Mole Frac (H2O)	1.00000 *	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000 *	0.00000	0.00000	0.00000	0.00000
Name	10 @TPL2	11 @TPL2	Steam Generator In @	17 @TPL2	13 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	14 @TPL2	15 @TPL2	16 @TPL2	18 @TPL2	21 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	22 @TPL2	20 @TPL2	24 @TPL2	25 @TPL2	26 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	27 @TPL2	28 @TPL2	35 @TPL2	38 @TPL2	39 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	40 @TPL2	41 @TPL2	43 @TPL2	44 @TPL2	45 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	46 @TPL2	47 @TPL2	48 @TPL2	49 @TPL2	51 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	52 @TPL2	53 @TPL2	54 @TPL2	55 @TPL2	56 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	57 @TPL2	60 @TPL2	62 @TPL2	64 @TPL2	74 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	78 @TPL2	34 @TPL2	23 @TPL2	36 @TPL2	37 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	1.00000	1.00000	1.00000
Comp Mole Frac (Helium)	0.00000	0.00000	0.00000	0.00000	0.00000
Name	58 @TPL2	59 @TPL2	63 @TPL2	79 @TPL2	81 @TPL2
Comp Mole Frac (H2O)	1.00000	1.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	0.00000	0.00000	1.00000	1.00000	1.00000
Name	82 @TPL2	6 @TPL2	7 @TPL2	29 @TPL2	32 @TPL2
Comp Mole Frac (H2O)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	1.00000	1.00000	1.00000	1.00000	1.00000

* Specified by user.

INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C H
	Unit Set:	NGNP
	Date/Time:	Wed May 12 11:37:15 2010

Workbook: Combined Cycle (TPL2) (continued)

Compositions (continued)

Name	33 @TPL2	42 @TPL2	50 @TPL2	61 @TPL2	65 @TPL2
Comp Mole Frac (H2O)	0.00000	0.00000	0.00000	0.00000	0.00000
Comp Mole Frac (Helium)	1.00000	1.00000	1.00000	1.00000	1.00000
Name	66 @TPL2	67 @TPL2	12 @TPL2	9 @TPL2	19 @TPL2
Comp Mole Frac (H2O)	0.00000	0.00000	0.00000	0.00000 *	0.00000
Comp Mole Frac (Helium)	1.00000	1.00000	1.00000	1.00000 *	1.00000
Name	30 @TPL2	In @TPL2	Out @TPL2		
Comp Mole Frac (H2O)	0.00000	0.00000	0.00000		
Comp Mole Frac (Helium)	1.00000	1.00000	1.00000		

Energy Streams

Name		HP Trbn Pwr @TPL2	IT Trbn Stg 1 Pwr @T	ITTrbn Stg 2 Pwr @T	LP Trb Stg 1 Pwr @T	Bstr Pmp Pwr @TPL2
Heat Flow	(kW)	4.716e+004	1.268e+004	1.652e+004	1.794e+004	366.2
Name		LP Trbn Stg 2 Pwr @	LP Trbn Stg 3 Pwr @	LP Trbn Stg 4 Pwr @	LP Trg Stg 5 Pwr @T	Cond Q @TPL2
Heat Flow	(kW)	1.410e+004	1.307e+004	1.401e+004	2.649e+004	1.952e+005
Name		BF Pmp Pwr @TPL2	Cnd Pmp Pwr @TPL2	LP Trb Pwr @TPL2	HP Trb Pwr @TPL2	LP Cmp Pwr @TPL2
Heat Flow	(kW)	4931	133.1	9.644e+004	9.883e+004	5.053e+004
Name		Intercooler Q @TPL2	HP Cmp Pwr @TPL2	Cooler Q @TPL2	Electric Power Out @	
Heat Flow	(kW)	4.997e+004	5.315e+004	6.824e+004	2.467e+005	

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
High Pressure Turbine @TPl	Expander	Steam Generator Out @TPL	4 @TPL2 HP Trbn Pwr @TPL2	No	500.0 *
Intermdiate Pressure Turbine	Expander	8 @TPL2	13 @TPL2 IT Trbn Stg 1 Pwr @TPL2	No	500.0 *
Intermediatte Pressure Turbi	Expander	15 @TPL2	18 @TPL2 ITTrbn Stg 2 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	21 @TPL2	24 @TPL2 LP Trb Stg 1 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	25 @TPL2	43 @TPL2 LP Trbn Stg 2 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	44 @TPL2	47 @TPL2 LP Trbn Stg 3 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	51 @TPL2	53 @TPL2 LP Trbn Stg 4 Pwr @TPL2	No	500.0 *
Low Pressure Turbine Stage	Expander	54 @TPL2	64 @TPL2 LP Trg Stg 5 Pwr @TPL2	No	500.0 *
HP Turbine @TPL2	Expander	9 @TPL2	19 @TPL2 HP Trb Pwr @TPL2	No	500.0 *
LP Turbine @TPL2	Expander	32 @TPL2	33 @TPL2 LP Trb Pwr @TPL2	No	500.0 *
T4 @TPL2	Tee	4 @TPL2	To Reheater @TPL2 To FW Heater 7 @TPL2	No	500.0 *
T6 @TPL2	Tee	13 @TPL2	14 @TPL2 15 @TPL2	No	500.0 *
T7 @TPL2	Tee	18 @TPL2	21 @TPL2 22 @TPL2	No	500.0 *
T8 @TPL2	Tee	24 @TPL2	25 @TPL2 26 @TPL2	No	500.0 *
T9 @TPL2	Tee	43 @TPL2	44 @TPL2 45 @TPL2	No	500.0 *
T10 @TPL2	Tee	47 @TPL2	51 @TPL2 52 @TPL2	No	500.0 *
T11 @TPL2	Tee	53 @TPL2	54 @TPL2	No	500.0 *

* Specified by user.

	INL Calgary, Alberta CANADA	Case Name:	C:\Documents and Settings\mgq\Desktop\NGNP\FY 09 Report\750 C I
		Unit Set:	NGNP
		Date/Time:	Wed May 12 11:37:15 2010

Workbook: Combined Cycle (TPL2) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
T11 @TPL2	Tee		55 @TPL2	No	500.0 *
T13 @TPL2	Tee	29 @TPL2	79 @TPL2 63 @TPL2	No	500.0 *
TEE-100 @TPL2	Tee	In @TPL2	6 @TPL2 7 @TPL2	No	500.0 *
Feedwater Heater 7 @TPL2	Heat Exchanger	11 @TPL2 To FW Heater 7 @TPL2	Steam Generator In @TPL2 10 @TPL2	No	500.0 *
Feedwater Heater 6 @TPL2	Heat Exchanger	35 @TPL2 16 @TPL2	17 @TPL2 28 @TPL2	No	500.0 *
Feedwater Heater 5 @TPL2	Heat Exchanger	27 @TPL2 20 @TPL2	35 @TPL2 38 @TPL2	No	500.0 *
Feedwater Heater 3 @TPL2	Heat Exchanger	48 @TPL2 45 @TPL2	39 @TPL2 46 @TPL2	No	500.0 *
Feedwater Heater 2 @TPL2	Heat Exchanger	57 @TPL2 36 @TPL2	48 @TPL2 56 @TPL2	No	500.0 *
Feedwater Heater 1 @TPL2	Heat Exchanger	62 @TPL2 74 @TPL2	57 @TPL2 60 @TPL2	No	500.0 *
IHX 1 @TPL2	Heat Exchanger	30 @TPL2 6 @TPL2	9 @TPL2 67 @TPL2	No	500.0 *
IHX 2 @TPL2	Heat Exchanger	19 @TPL2 7 @TPL2	32 @TPL2 12 @TPL2	No	500.0 *
Boiler Feed Pump @TPL2	Pump	17 @TPL2 BF Pmp Pwr @TPL2	11 @TPL2	No	500.0 *
Booster Pump @TPL2	Pump	40 @TPL2 Bstr Pmp Pwr @TPL2	27 @TPL2	No	500.0 *
Condensate Pump @TPL2	Pump	58 @TPL2 Cnd Pmp Pwr @TPL2	62 @TPL2	No	500.0 *
M3 @TPL2	Mixer	34 @TPL2 14 @TPL2	16 @TPL2	No	500.0 *
M4 @TPL2	Mixer	22 @TPL2 23 @TPL2	20 @TPL2	No	500.0 *
Deaerating Heater @TPL2	Mixer	39 @TPL2 41 @TPL2 26 @TPL2	40 @TPL2	No	500.0 *
M11 @TPL2	Mixer	55 @TPL2 37 @TPL2	74 @TPL2	No	500.0 *
M13 @TPL2	Mixer	52 @TPL2 49 @TPL2	36 @TPL2	No	500.0 *
M14 @TPL2	Mixer	59 @TPL2 78 @TPL2	58 @TPL2	No	500.0 *
M7 @TPL2	Mixer	81 @TPL2 82 @TPL2	Out @TPL2	No	500.0 *
MIX-100 @TPL2	Mixer	67 @TPL2 12 @TPL2	29 @TPL2	No	500.0 *
VLV 8 @TPL2	Valve	38 @TPL2	41 @TPL2	No	500.0 *
VLV 10 @TPL2	Valve	46 @TPL2	49 @TPL2	No	500.0 *
VLV 11 @TPL2	Valve	56 @TPL2	37 @TPL2	No	500.0 *
VLV 18 @TPL2	Valve	10 @TPL2	34 @TPL2	No	500.0 *
VLV 17 @TPL2	Valve	28 @TPL2	23 @TPL2	No	500.0 *
VLV 13 @TPL2	Valve	60 @TPL2	59 @TPL2	No	500.0 *
Condenser @TPL2	Cooler	64 @TPL2	78 @TPL2 Cond Q @TPL2	No	500.0 *
Intercooler @TPL2	Cooler	50 @TPL2	61 @TPL2 Intercooler Q @TPL2	No	500.0 *

* Specified by user.

Workbook: Combined Cycle (TPL2) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc. Level
Cooler @TPL2	Cooler	42 @TPL2	66 @TPL2 Cooler Q @TPL2	No	500.0 *
Steam Generator @TPL2	LNG	63 @TPL2 Steam Generator In @TPL2	81 @TPL2 Steam Generator Out @TPL	No	500.0 *
Reheater @TPL2	LNG	79 @TPL2 To Reheater @TPL2	82 @TPL2 8 @TPL2	No	500.0 *
Brayton Recup @TPL2	LNG	65 @TPL2 33 @TPL2	30 @TPL2 42 @TPL2	No	500.0 *
LP Compressor @TPL2	Compressor	66 @TPL2 LP Cmp Pwr @TPL2	50 @TPL2	No	500.0 *
HP Compressor @TPL2	Compressor	61 @TPL2 HP Cmp Pwr @TPL2	65 @TPL2	No	500.0 *
ADJ-1 @TPL2	Adjust			No	3500 *
ADJ-2 @TPL2	Adjust			Yes	3500 *
ADJ-3 @TPL2	Adjust			No	3500 *
SET-1 @TPL2	Set			No	500.0 *
SET-2 @TPL2	Set			No	500.0 *
Efficiency Calculations @TP	Spreadsheet			No	500.0 *
Pressure Drops @TPL2	Spreadsheet			No	500.0 *
Pressure Drops Brayton @T	Spreadsheet			No	500.0 *
Brayton Efficiency @TPL2	Spreadsheet			No	500.0 *

* Specified by user.