1.2.2.1.7.3.2 Products

The product specifications are shown in Table 1.2.2.1.7.3.2(1).

Table 1.2.2.1.7 .3.2(1) Product Specifications

Commodity	Flow Rate	Purity	Conditions
Hydrogen	67,000 Nm^3/h (60 MMSCFD)	99.9 mol% $CO + CO_2 < 10$ ppmv $N_2 + He < 1000$ ppmv	103.5 bara at the Suncor Oil Sands facility
Steam	589,600 kg/hr (1.3 million lb/hr)	--	Saturated steam at 44 barg at user (i.e. Firebag)
Carbon Dioxide (Controlled Baseline Case)	90% carbon capture (Note 1)	97.0 mol% $H_2S < 30$ ppmv $H_2O < 50$ ppmv	80 bara 45°C

Note 1: The capacity of the plant will not be adjusted to produce a specific amount of carbon dioxide for sequestration.

In addition to the products shown in Table 1.2.2.1.7.3.2(1), electrical power is produced at 72 kV voltage for export to the local utility grid.

1.2.2.1.7.3.3 Sparing Philosophy

The plant is designed in order that each unit has an availability of at least 98% for a reliable hydrogen export (excluding major turnarounds that are scheduled on a five-year frequency). No spare gasifier will be provided to increase the availability of the steam export or electrical power production.

All pumps in continuous service are 100% spared. In large capacity services where parallel pumps are required, a common spare is used. With the exception of the large capacity services previously mentioned, a common spare normally does not serve more than two pumps. Spares in critical services are automatic start, with the spare pumps actuated by the loss of discharge pressure or flow rate of the normal operating pump.

Axial and centrifugal compressors are not spared. Reciprocating compressors are spared if required by process considerations.

1.2.2.1.7.3.4 Turndown Requirements

The plant is designed to operate at a turndown of 50%. The requirement to achieve this percentage turndown will not adversely impact the overall cost of the plant. Special turndown considerations for individual products (hydrogen, steam and electrical power) were not considered.

1.2.2.1.7.3.5 Regulations, Codes & Standards

The design is based on fit-for-purpose codes and standards based on Fluor experience. Design methods shall utilize recognized standards, such as ASME, TEMA, NEMA and API as appropriate.

1.2.2.1.7.3.6 Design Criteria

a) Material selection is based on Fluor standards and past experience on similar projects.

b) Electrical start-up requirements of the plant are assumed to be provided by the electrical grid.

c) The electrical design basis is shown in Table 1.2.2.1.7.3.6(1).

Table 1.2.2.1.7.3.6(1) Electrical Design Basis

Services	Voltage
Primary distribution voltage to substations	25 kV
Motors over 7000 HP	13.8 kV, 3 phase, 3-wire resistance grounded
Motors between 250 HP and 7000 HP and secondary distribution to new process units	4,160 volts, 3 phase, 3-wire resistance grounded
Motors between 0.75 and 250 HP, welding receptacles and process building supplies	480 volts, 3 phase, 3-wire resistance grounded
Electric heat tracing and area lighting	277/480 volts, 3 phase, 4 wire solidly grounded
Switchgear control power	125 volts DC, 2 wire, negative ground
Instrumentation	24 volts

1.2.2.1.7.3.7 Make-up Water

Make-up water is Pond Effluent Water (PEW). This water originates from the Athabasca River and has been used in the bitumen extraction process and stored in Suncor's tailings ponds prior to use. The water temperatures are 4.4°C (winter) and 24°C (summer).

1.2.2.1.7.3.8 Environmental Criteria

The level of pollutants in the plant emissions should be below those of the current operating environmental discharges. Environmental limits for the new plant are shown in Table 1.2.2.1.7.3.8 (1).

Table 1.2.2.1.7.3.8(1) Air Environmental Limits
(Note 1)

SOx	98.6% overall sulfur recovery (Note 2)
NOx (for combustion turbines)	15 ppmv (dry) (@15% O_2)

Table 1.2.2.1.7.3.8(1) Air Environmental Limits (Note 1)	
NOx (for sulfur recovery vent)	50 ppmv (dry) (@15% O_2)
PM_{10} (Note 3)	15 kg/hr
CO (for combustion turbines)	25 ppmv
CO (for sulfur recovery vent)	360 ppmv

Notes:
1) Emission limits are based on Best Available Control Technology (BACT) for IGCC plants.
2) SOx concentration emission limits for individual emission sources is governed by overall sulfur recovery.
3) PM_{10} – particles with diameters less than ten micrometers

The plant emission/effluent points are as follows:

- Flue gas
- Sulfur recovery vent
- Air Separation Unit vent
- Cooling tower evaporation/drift
- Waste water
- Sewage
- Storm Drains
- Sulfur product
- Slag
- Fine Slag

1.2.2.1.7.3.9 Utility Information

The following utilities are provided for the plant:

- Steam
- Boiler Feedwater
- Condensate
- Drains and Blowdown
- Demineralized Water
- Cooling Water
- Potable Water
- Plant Water
- Natural Gas
- Nitrogen
- Plant and Instrument Air
- Flare
- Firewater
- Electrical Power

Conditions for selected utilities are shown in Table 1.2.2.1.7.3.9(1).

Table 1.2.2.1.7.3.9(1) Selected Utility Conditions

	Operating		Design	
Commodity (Note 1)	**Pressure, barg**	**Temperature, °C**	**Pressure, barg**	**Temperature, °C**
High Pressure Superheated Steam	113.4	538	120	565
High Pressure Saturated Steam	123	327	130	355
Medium Pressure Superheated Steam	26.5	260	35	290
Medium Pressure Saturated Steam	28	232	35	260
Intermediate Pressure Superheated Steam	13.1	207	20	235
Intermediate Pressure Saturated Steam	13.8	198	20	225
Low Pressure Saturated Steam	6.9	170	10	200
Low Low Pressure Saturated Steam	4.2	153	7	185
Demineralized Water	13.8	15.6	28	125
Cooling Water Supply (Note 2)	3.5	4.4 (winter) 23.9 (summer)	4	95
Cooling Water Return (Note 2)	2.1	48.9 (maximum)	4	95
Potable Water	4.2	15.6	11	20
Utility Water	6.9	18.2 (summer) 1.7 (winter)	15	80
Firewater	6.9	18.2 (summer) 1.7 (winter)	14	30
Natural Gas	40	15.6	49	40
Plant and Instrument Air	6.9	37.8	12	60

Notes:
1) Steam pressure levels and superheat temperatures were set for maximum efficiency for the steam cycle.
2) Cooling water supply is set to match the existing cooling water system.

Existing steam utility information (per Project Millennium at the Suncor site) is shown in Table 1.2.2.1.7.3.9(2).

Table 1.2.2.1.7.3.9(2) Existing Steam Utility Conditions

Commodity	**Operating Pressure, barg***	**Operating Temperature, °C**
High Pressure Superheated Steam	54.5 (51.7)	399
High Intermediate Pressure Steam	41.4	254 – 263
Medium Pressure Superheated Steam	28.6 (27.6)	380
Intermediate Pressure Steam	10.4 (9.7)	182 – 197
Low Pressure Steam	3.5 (3.1)	147 - 204

* Note: Pressures in brackets are estimated delivery pressures to the users.

1.2.2.1.7.3.10 Unit Numbering

The unit numbering for the IGCC plant is shown in Table 1.2.2.1.7.3.10(1).

Table 1.2.2.1.7.3.10(1) Unit Numbering

Unit	Number
Air Separation Unit	101/201/301
Gasification Island	102/202/302
Low Temperature Gas Cooling	103/203
Condensate (Ammonia) Stripper	004
CO_2LDSep^{SM} Unit	005
Sulfur Recovery (Claus) and Tailgas Treating Unit	006
Shift Reactors	107/207
Fuel Gas Saturator	008
Combustion Turbines and Heat Recovery Steam Generators	109/209/309
Steam Turbine and Condensate System	010
Utilities	012

1.2.2.1.7.3.10.1 Equipment Identification

The equipment identification system is based on Fluor standards. The equipment will be numbered using the following system.

AAA-B-CCC D/D

AAA - Unit number
B - Equipment Identification Letter Symbol (See Table 1.2.2.1.7.3.10.1(1))
CCC - Equipment number (starting with 001 for each type of equipment)
D/D - If equipment is spared (i.e. A/B)

Table 1.2.2.1.7.3.10.1(1) Equipment Identification Symbols	
Letter Symbol	**Equipment**
B	Burner
C	Compressor
CT	Combustion Turbine
DA	Deaerator
E	Heat exchanger and cooler
EA	Air Cooler
EX	Expander
F	Filter
G	Eductor
ME	Mechanical package
P	Pump (including motor)
S	Stack
SG	Steam generator
ST	Steam turbine
SU	Sump
TK	Tank
V	Vessel/Column

1.2.2.1.7.3.10.2 Units of Measurement

The design incorporates SI units. The specific units to be used on this project for each type of measurement are shown in Table 1.2.2.1.7.3.10.2(1).

Table 1.2.2.1.7.3.10.2(1) Units of Measurement	
Measurement	**Unit**
Temperature	°C
Pressure	barg, bara
Vacuum	mbar
Mass	kg
Volume, liquids	m^3
Volume, gases (actual)	m^3
Volume, gases (standard)	Nm^3
Density	kg/m^3
Flow, liquids	m^3/h
Flow, gases	Nm^3/h, m^3/h, kg/h
Flow, solids	kg/h, kg/s
Heat	kJ/h
Power	MW, kW
Equipment dimensions and pipe length	m
Nominal pipe diameter	mm
Velocity	m/s

The following prefixes in Table 1.2.2.1.7.3.10.2(2) may be used.

Table 1.2.2.1.7.3.10.2(2) Unit Prefixes

Multiplication Factor	Prefix	Symbol
10^{6}	Mega	M
10^{3}	Kilo	k
10^{-2}	Centi	c
10^{-3}	Milli	m

1.2.2.1.8 Results and Discussion

The deliverables for the Advanced CO_2LDSep^{SM} Case are the following and are contained in this section. Additional deliverables (e.g. process descriptions) for advanced case will be provided later in Phase II.

- Summary Block Flow Diagram
- Preliminary Process Flow Diagrams
- Heat and Material Balances
- Preliminary Equipment Lists with Approximate Sizes
- Cost Estimate with ±40% Accuracy

1.2.2.1.8.1 Summary Block Flow Diagram

The summary block flow diagram for the Advanced CO_2LDSep[SM] Case is shown in Figure 1.2.2.1.8.1(1).

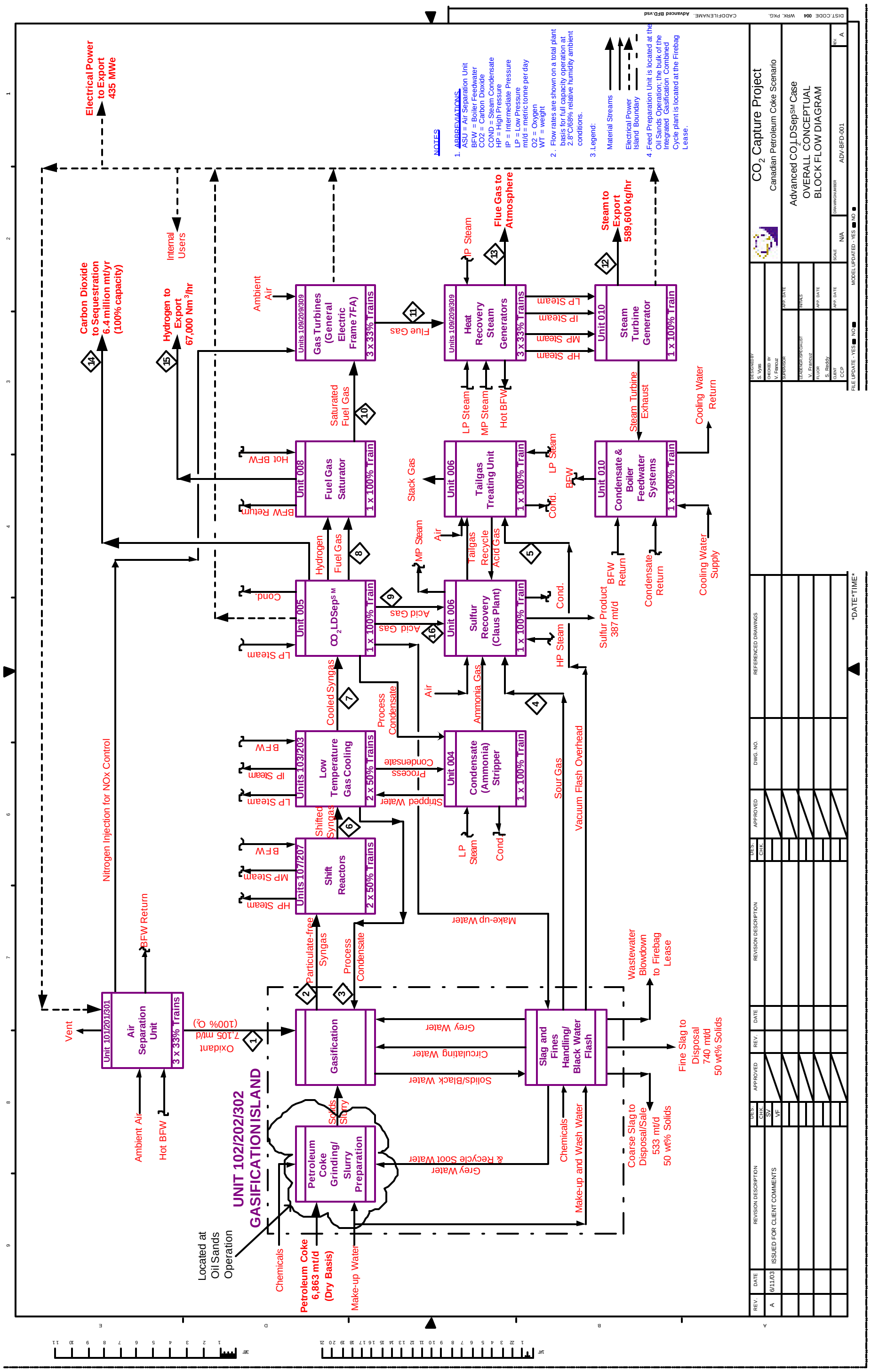

Figure 1.2.2.1.8.1(1) Summary Block Flow Diagram

The overall heat and material balance corresponding to the summary block flow diagram for the Advanced CO_2LDSep[SM] Case is shown in Table 1.2.2.1.8.1(1).

Table 1.2.2.1.8.1(1) Overall Heat and Material Balance

Total Plant Basis unless noted

Overall Heat and Material Balance

Advanced Case

Stream Description		Oxidant from ASU to Gasification Island		Particulate Free Syngas from GI to Shift Reactors (Note 1)		Process Condensate to Syngas Scrubber (Note 1)		Sour Gas from Gasification Island (Note 1)		Vacuum Overhead from Gasification Island (Note 1)	
Stream Number		1		2		3		4		5	
Temperature, °C		88		240		175		133		72	
Pressure, bara		80.3		64.4		70.0		1.7		2.1	
Component Flows	MW	kgmol/hr	mol %	CONFIDENTIAL		kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	0	0.0%			42,952	99.9%	39	37.1%	2	69.5%
CO	28.01	0	0.0%			2	0.0%	19	18.1%	0	1.7%
H2	2.02	0	0.0%			6	0.0%	13	12.4%	0	1.7%
CO2	44.01	0	0.0%			44	0.1%	29	27.6%	0	16.9%
CH4	16.04	0	0.0%			0	0.0%	1	1.0%	0	0.0%
AR	39.95	46	0.5%			0	0.0%	0	0.0%	0	0.0%
N2	28.02	0	0.0%			0	0.0%	0	0.0%	0	0.0%
O2	32.00	9,251	99.5%			0	0.0%	0	0.0%	0	0.0%
NH3	17.03	0	0.0%			5	0.0%	0	0.0%	0	0.0%
H2S	34.08	0	0.0%			4	0.0%	3	2.9%	0	10.2%
COS	60.07	0	0.0%			0	0.0%	1	1.0%	0	0.0%
Total kgmol/hr		9,297	100.0%	71,460	100.0%	43,013	100.0%	105	100.0%	3	100.0%
Total kg/hr		297,870		1,403,773		776,006		2,716		64	
Molecular Weight		32.04		19.64		18.04		25.86		23.95	
Density, kg/m3		85.7		32.0		892.8		6.3		1.7	
Liquid Flow, m3/hr		-		-		869		-		-	
Vapor Flow, m3/hr		3,476		43,868		-		431		38	

Notes: (1) Streams provided for Gasification Island by ChevronTexaco.

Overall Heat and Material Balance

Advanced Case

Stream Description		Shifted Gas from Shift Reactor Unit to LTGC Unit		Cooled Syngas from LTGC to CO_2LDSep[SM] Unit		Fuel Gas from CO_2LDSep[SM] Unit to Fuel Gas Saturator		Acid Gas from CO_2LDSep[SM] Unit to Sulfur Recovery Plant		Saturated Fuel Gas to Gas Turbines	
Stream Number		6		7		8		9		10	
Temperature, °C		259		35		34		35		288	
Pressure, bara		61.5		58.2		28.3		2.4		26.7	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	27,894	39.0%	64	0.1%	0	0.0%	7	1.0%	8,834	28.4%
CO	28.01	726	1.0%	720	1.7%	649	2.9%	0	0.0%	649	2.1%
H2	2.02	23,712	33.2%	23,702	54.5%	20,403	91.6%	0	0.0%	20,403	65.6%
CO2	44.01	18,382	25.7%	18,290	42.0%	1,019	4.6%	369	52.5%	1,019	3.3%
CH4	16.04	22	0.0%	22	0.1%	15	0.1%	0	0.0%	15	0.0%
AR	39.95	42	0.1%	42	0.1%	36	0.2%	0	0.0%	36	0.1%
N2	28.02	158	0.2%	158	0.4%	142	0.6%	0	0.0%	142	0.5%
O2	32.00	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NH3	17.03	10	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
H2S	34.08	514	0.7%	506	1.2%	0	0.0%	327	46.5%	0	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		71,460	100.0%	43,504	100.0%	22,264	100.0%	703	100.0%	31,098	100.0%
Total kg/hr		1,403,786		897,749		109,815		27,506		268,959	
Molecular Weight		19.64		20.64		4.93		39.14		8.65	
Density, kg/m3		28.6		48.4		5.4		3.7		5.0	
Liquid Flow, m3/hr		-		-		-		-			
Vapor Flow, m3/hr		49,083		18,549		20,336		7,434		53,792	

Overall Heat and Material Balance

Advanced Case

Stream Description		Gas Turbine Exhaust		Process Steam Export for Bitumen Recovery		Flue Gas from HRSGs to Atmosphere		Carbon Dioxide to Sequestration		Hydrogen to Export	
Stream Number		11		12		13		14		15	
Temperature, °C		558		474		96		45		35	
Pressure, bara		1.0		121.6		1.0		80.0		103.5	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	30,051	16.0%	32,732	100.0%	30,051	16.0%	0	0.0%	0	0.0%
CO	28.01	0	0.0%	0	0.0%	0	0.0%	70	0.4%	0	0.0%
H2	2.02	0	0.0%	0	0.0%	0	0.0%	299	1.7%	2,995	100.0%
CO2	44.01	1,683	0.9%	0	0.0%	1,683	0.9%	16,722	97.6%	0	0.0%
CH4	16.04	0	0.0%	0	0.0%	0	0.0%	7	0.0%	0	0.0%
AR	39.95	1,701	0.9%	0	0.0%	1,701	0.9%	6	0.0%	0	0.0%
N2	28.02	134,136	71.3%	0	0.0%	134,136	71.3%	16	0.1%	0	0.0%
O2	32.00	20,529	10.9%	0	0.0%	20,529	10.9%	0	0.0%	0	0.0%
NH3	17.03	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
H2S	34.08	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%	11	0.1%	0	0.0%
Total kgmol/hr		188,100	100.0%	32,732	100.0%	188,100	100.0%	17,131	100.0%	2,995	100.0%
Total kg/hr		5,098,811		589,667		5,098,811		739,960		6,038	
Molecular Weight		27.11		18.02		27.11		43.19		2.02	
Density, kg/m3		0.4		39.9		2.3		225.4		7.8	
Liquid Flow, m3/hr		-		-		-		-		-	
Vapor Flow, m3/hr		12,747,028		14,779		2,216,874		3,283		774	

Overall Heat and Material Balance

Advanced Case

Stream Description		CONFIDENTIAL
Stream Number		[redacted]
Temperature, °C		
Pressure, bara		
Component Flows	MW	
H2O	18.02	
CO	28.01	
H2	2.02	
CO2	44.01	
CH4	16.04	
AR	39.95	
N2	28.02	
O2	32.00	
NH3	17.03	
H2S	34.08	
COS	60.07	
Total kgmol/hr		
Total kg/hr		
Molecular Weight		
Density, kg/m3		
Liquid Flow, m3/hr		
Vapor Flow, m3/hr		

1.2.2.1.8.2 Process Flow Diagrams

The process flow diagrams for the Advanced CO_2LDSep^{SM} Case are shown in the following figures.

Advanced CO_2LDSep^{SM} Case		
Figure Number	**Drawing Number**	**Title**
1.2.2.1.8.2(1)/(2)	003-PFD-001/002	Low Temperature Gas Cooling
1.2.2.1.8.2(3)	004-PFD-001	Condensate (Ammonia) Stripper Unit
1.2.2.1.8.2(4)	005-PFD-001	CO_2LDSep^{SM} Unit
1.2.2.1.8.2(5)	006-PFD-001	Sulfur Recovery and Tail Gas Treating Unit
1.2.2.1.8.2(6)	007-PFD-001	Shift Reactors
1.2.2.1.8.2(7)	008-PFD-001	Fuel Gas Saturator
1.2.2.1.8.2(8)/(9)	109-PFD-001/002	Combustion Turbines and Heat Recovery Steam Generator
1.2.2.1.8.2(10)	010-PFD-001	Steam Turbine and Condensate
1.2.2.1.8.2(11)		Steam Balance

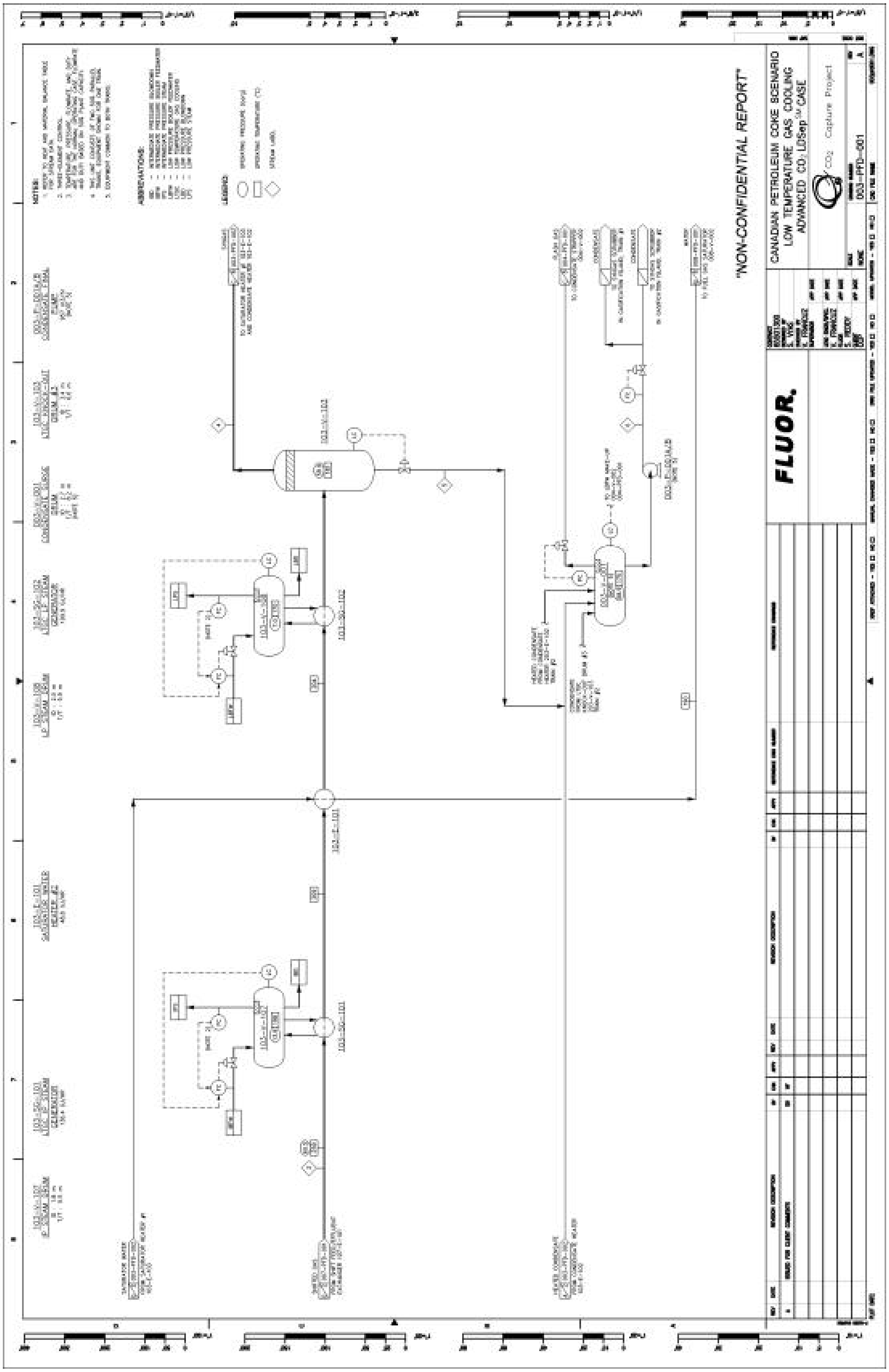

Figure 1.2.2.1.8.2(1) Low Temperature Gas Cooling (Sheet 1 of 2)

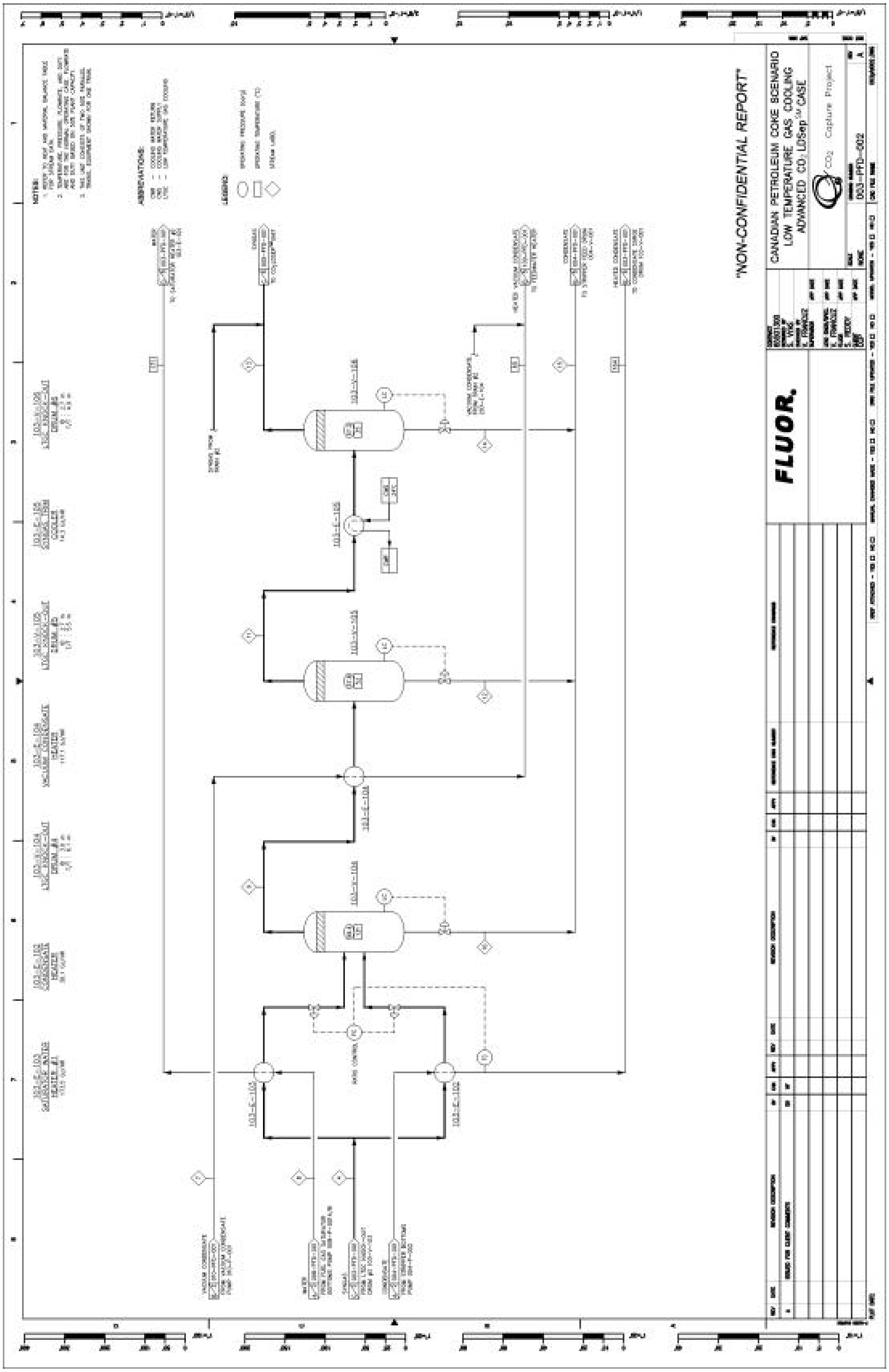

Figure 1.2.2.1.8.2(2) Low Temperature Gas Cooling (Sheet 2 of 2)

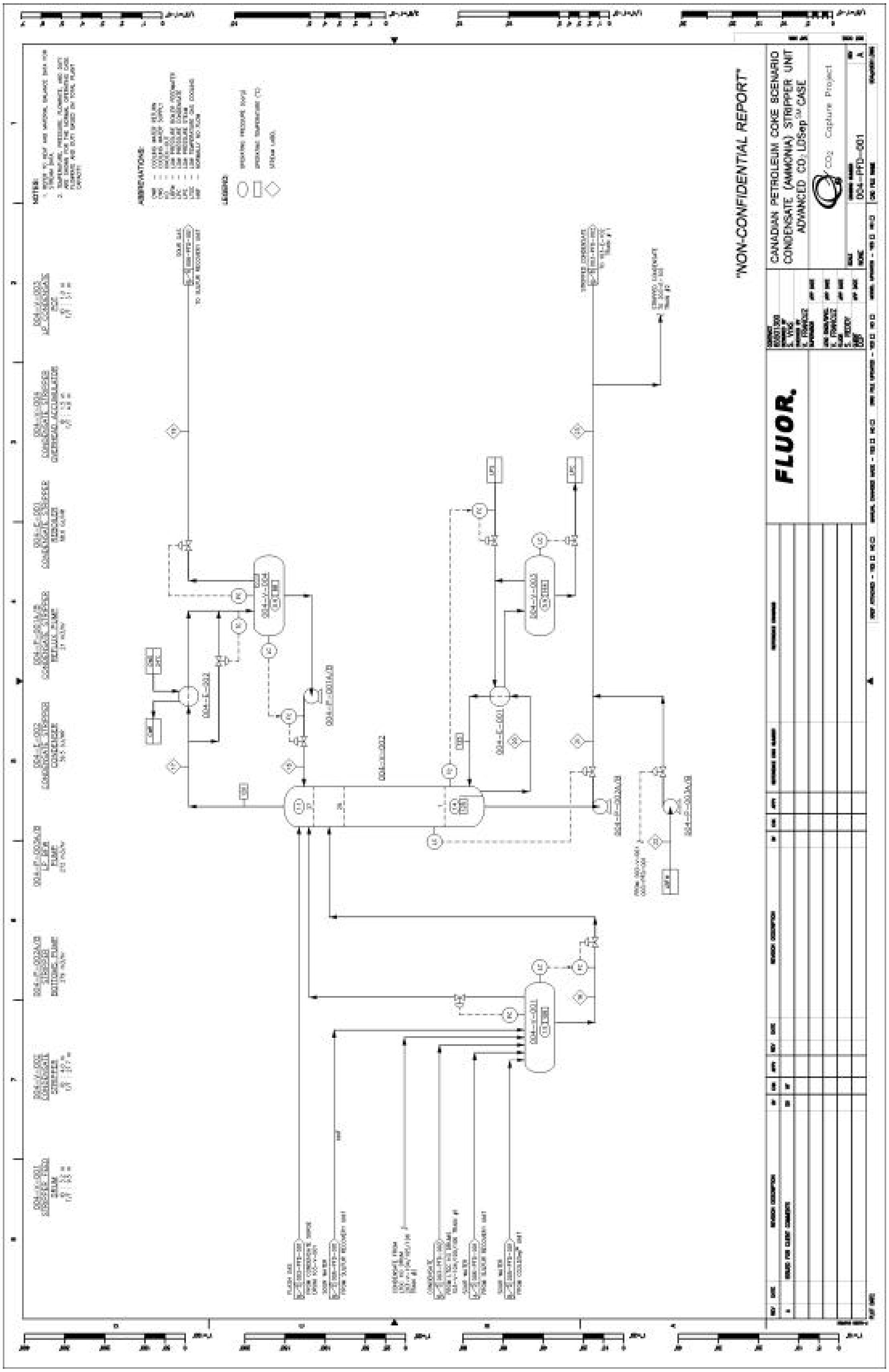

Figure 1.2.2.1.8.2(3) Condensate (Ammonia) Stripper Unit

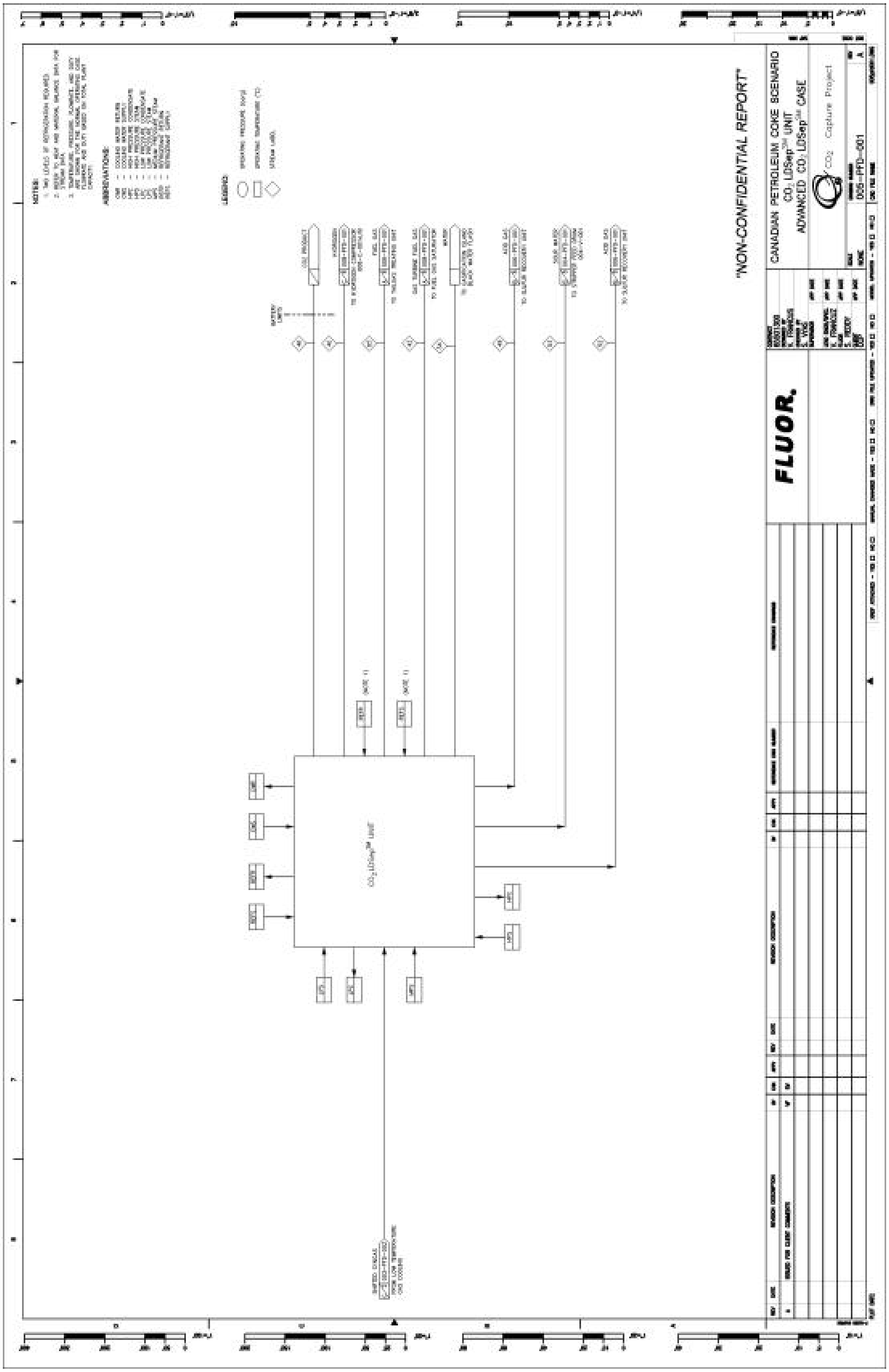

Figure 1.2.2.1.8.2(4) CO_2LDSep^{SM} Unit

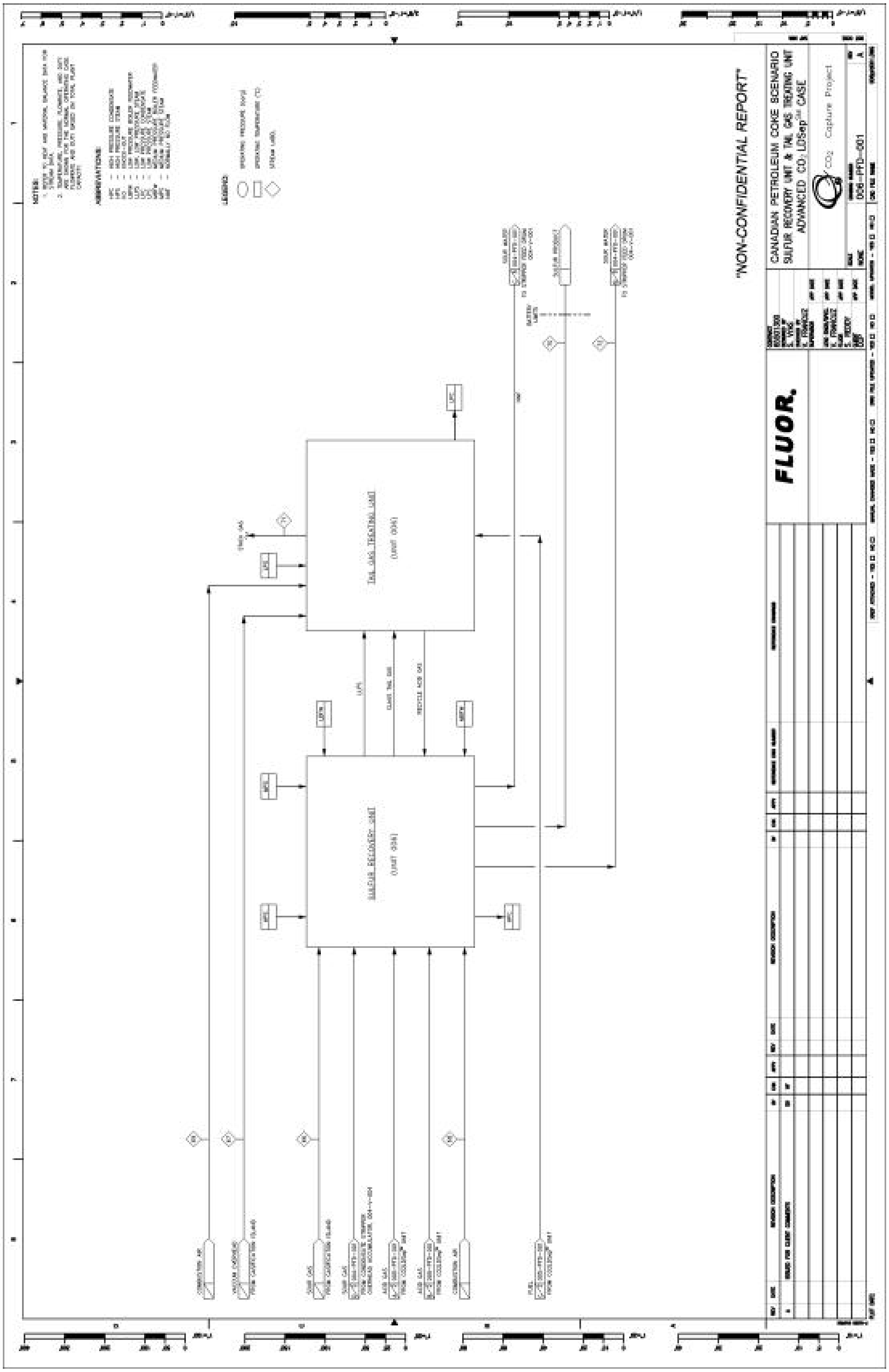

Figure 1.2.2.1.8.2(5) Sulfur Recovery and Tail Gas Treating Unit

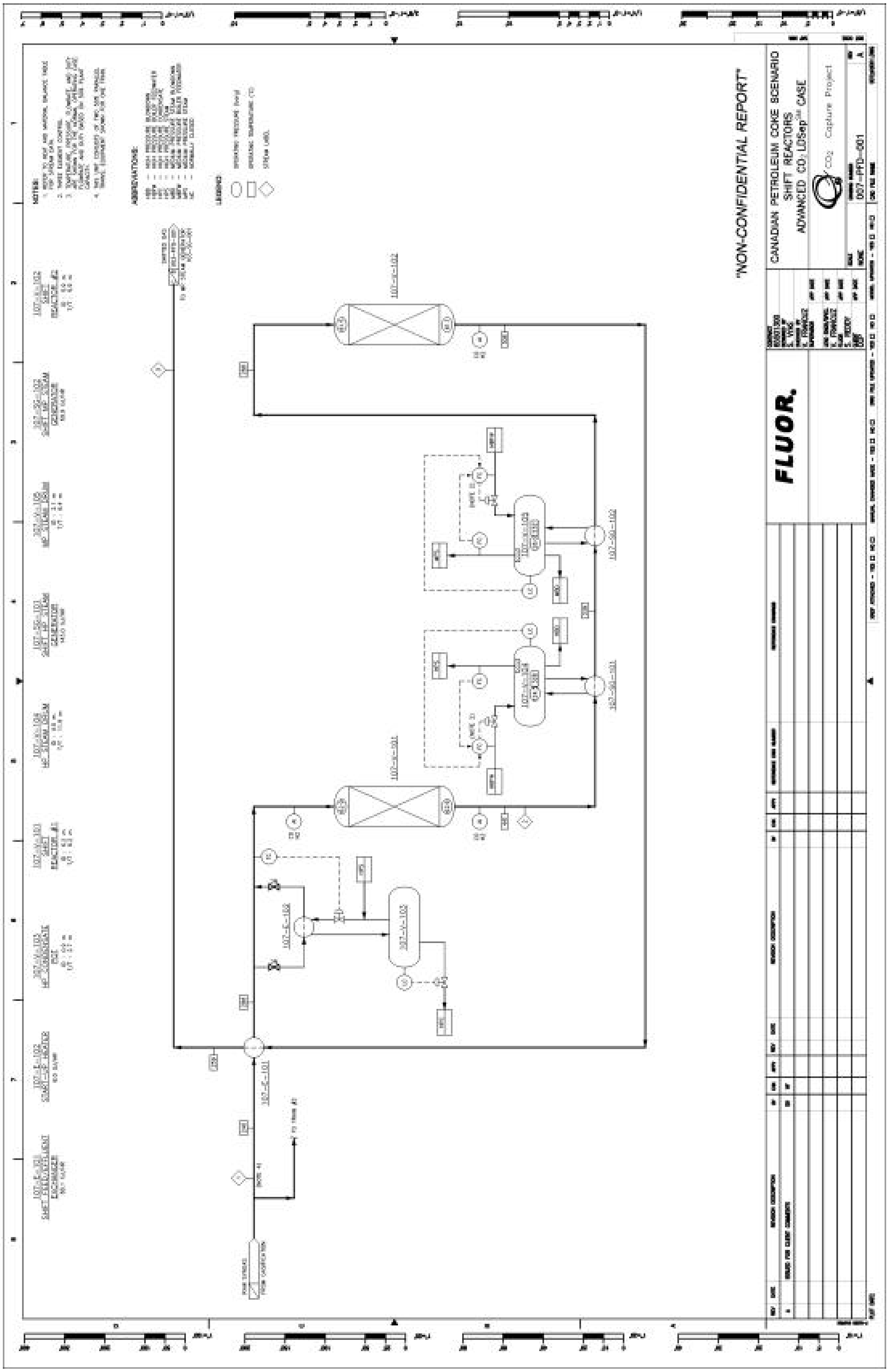

Figure 1.2.2.1.8.2(6) Shift Reactors

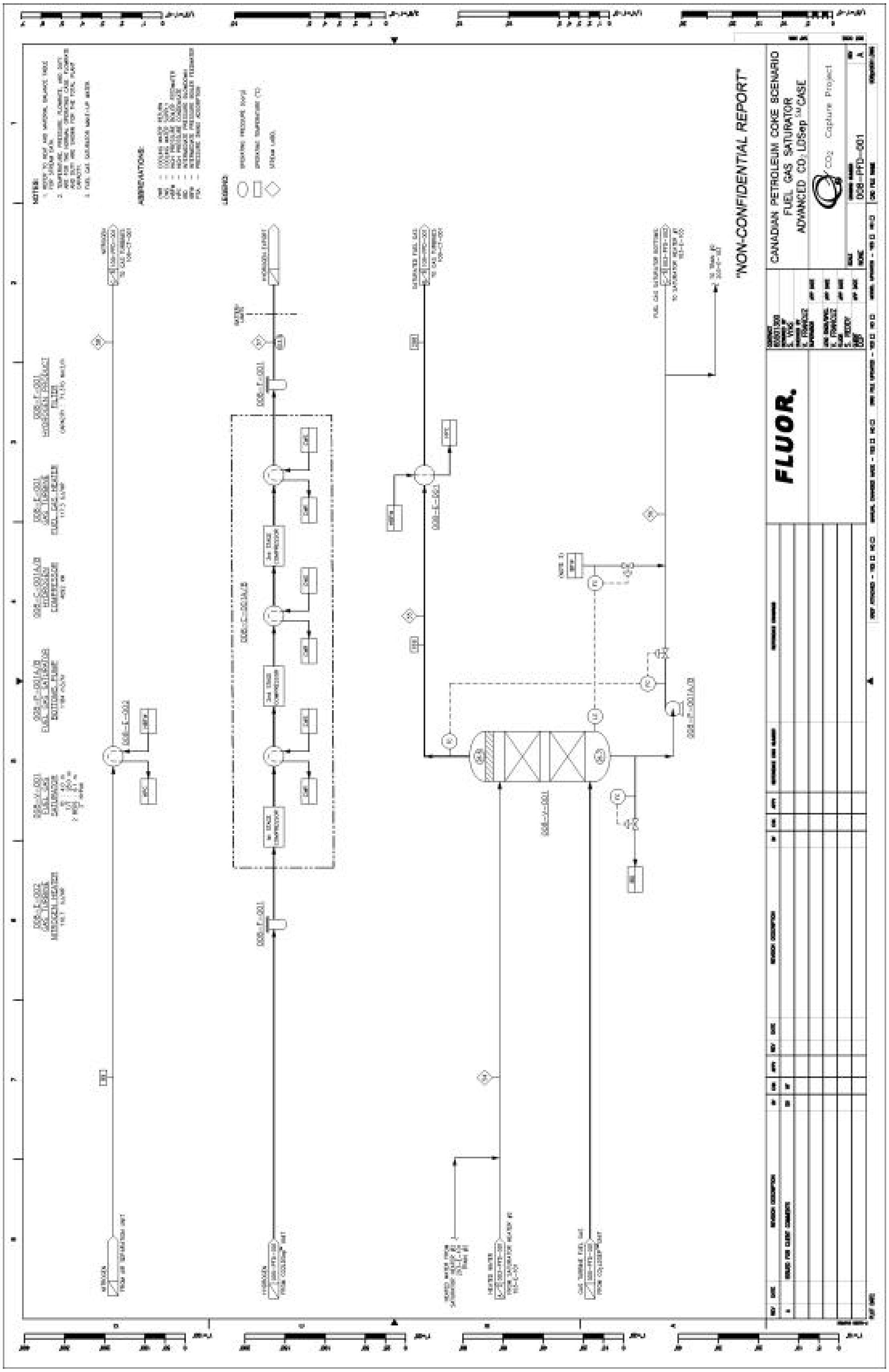

Figure 1.2.2.1.8.2(7) Fuel Gas Saturator

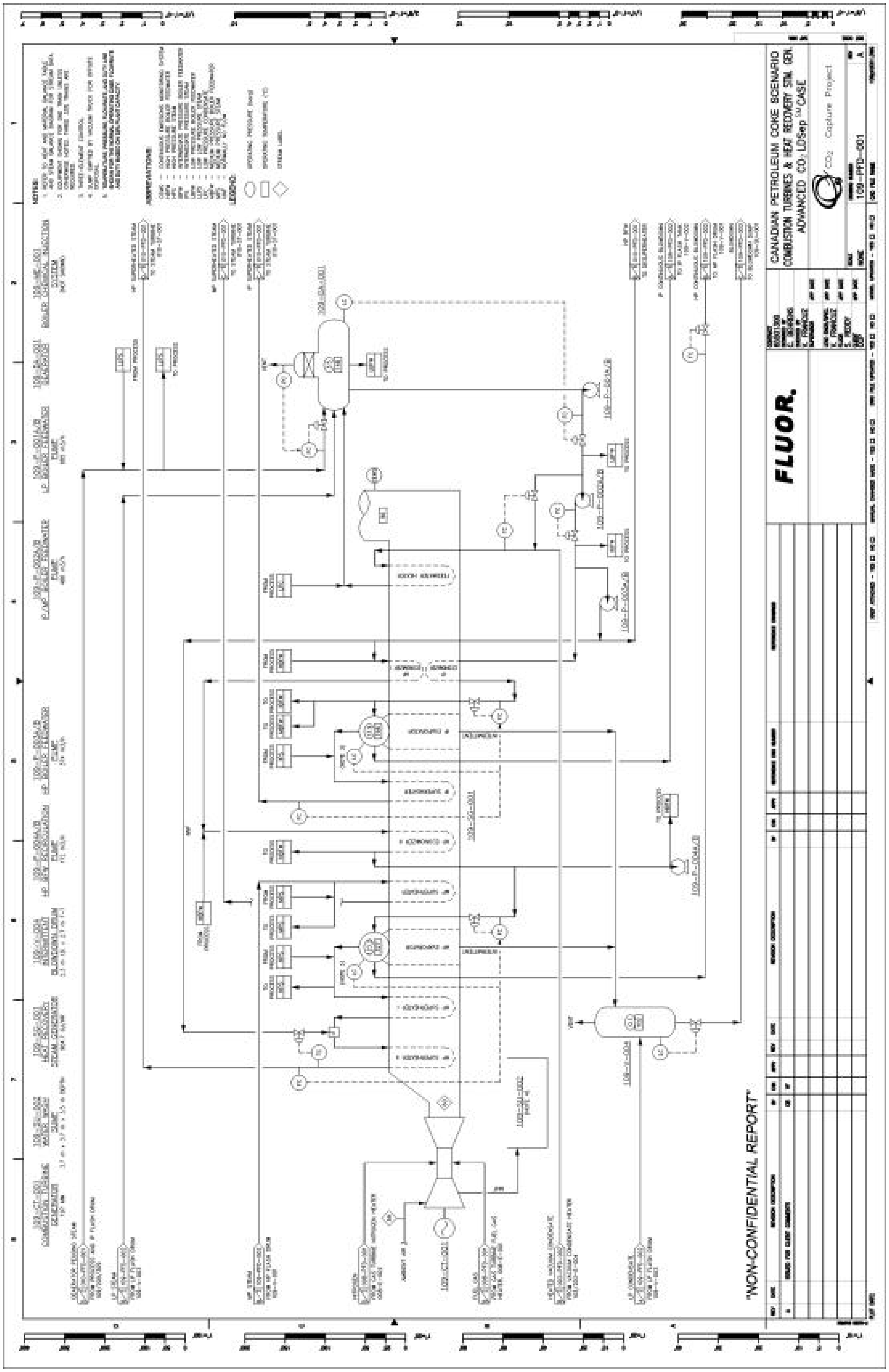

Figure 1.2.2.1.8.2(8) Combustion Turbine and Heat Recovery Steam Generator (Sheet 1 of 2)

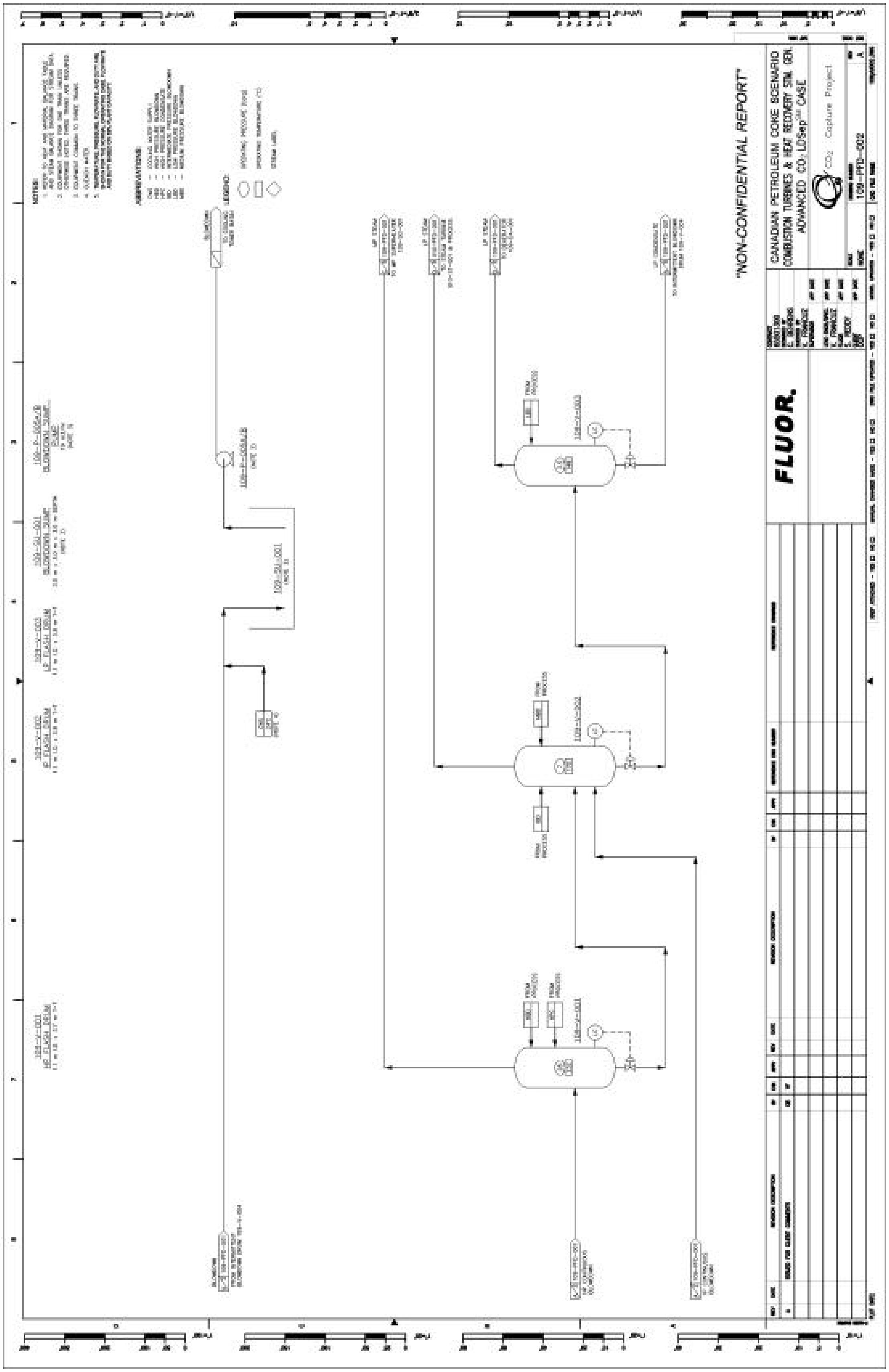

Figure 1.2.2.1.8.2(9) Combustion Turbine and Heat Recovery Steam Generator (Sheet 2 of 2)

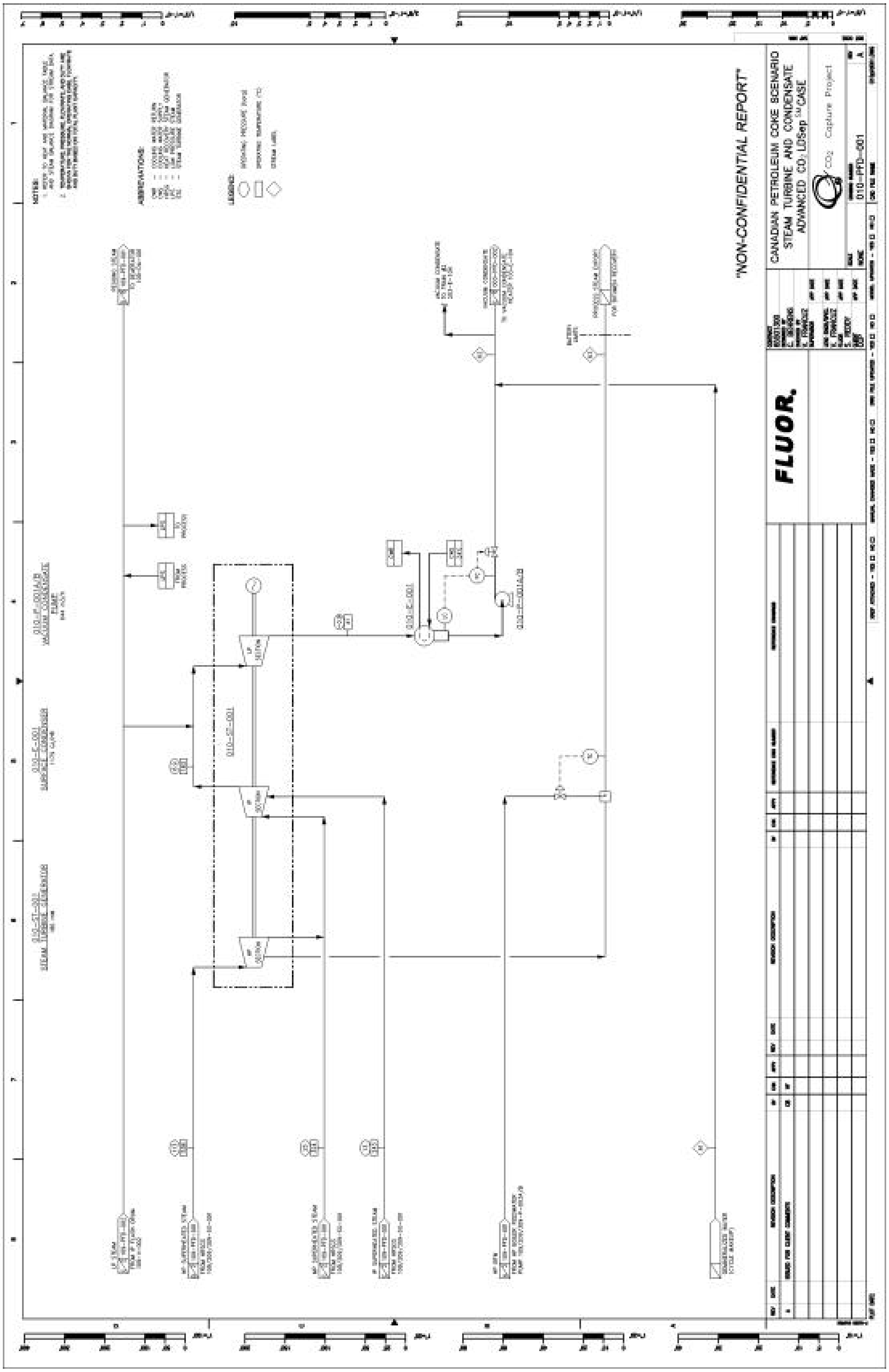

Figure 1.2.2.1.8.2(10) Steam Turbine and Condensate

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SEMI-ANNUAL TECHNICAL REPORT.

Figure 1.2.2.1.8.2(11) Steam Balance

1.2.2.1.8.2 Heat and Material Balances

The heat and material balances corresponding to the Process Flow Diagrams for the Advanced CO_2LDSep[SM] Case is shown in Table 1.2.2.1.8.3(1).

Table 1.2.2.1.8.3(1) Heat and Material Balances

Total Plant Basis unless noted

Heat and Material Balance

Advanced Case

Stream Description		Raw Syngas from Gasification (Notes 1 & 2)		Shifted Gas from Shift Reactor #1 (Note 2)		Shifted Gas from Shift Reactor #2 (Note 2)		LTGC KO Drum #3 Overhead (Note 2)		LTGC KO Drum #3 Bottoms (Note 2)	
Stream Number		1		2		3		4		5	
Temperature, °C		240		441		259		181		181	
Pressure, bara		64.4		63.5		61.5		59.9		59.9	
Component Flows	MW	[redacted] CONFIDENTIAL		kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02			14,689	41.1%	13,947	39.0%	5,442	20.0%	8,505	99.6%
CO	28.01			1,104	3.1%	363	1.0%	362	1.3%	1	0.0%
H2	2.02			11,115	31.1%	11,856	33.2%	11,853	43.6%	3	0.0%
CO2	44.01			8,449	23.6%	9,191	25.7%	9,169	33.7%	22	0.3%
CH4	16.04			11	0.0%	11	0.0%	11	0.0%	0	0.0%
AR	39.95			21	0.1%	21	0.1%	21	0.1%	0	0.0%
N2	28.02			79	0.2%	79	0.2%	79	0.3%	0	0.0%
O2	32.00			0	0.0%	0	0.0%	0	0.0%	0	0.0%
NH3	17.03			5	0.0%	5	0.0%	3	0.0%	2	0.0%
H2S	34.08			256	0.7%	257	0.7%	255	0.9%	2	0.0%
COS	60.07			1	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		35,730	100.0%	35,730	100.0%	35,730	100.0%	27,195	100.0%	8,535	100.0%
Total kg/hr		701,887		701,892		701,893		547,571		154,322	
Molecular Weight		19.64		19.64		19.64		20.13		18.08	
Density, kg/m3		32.0		21.0		28.6		32.8		881.9	
Liquid Flow, m3/hr		-		-		-		-		175	
Vapor Flow, m3/hr		21,934		33,423		24,542		16,694		-	

Notes: (1) Streams provided for Gasification Island by ChevronTexaco.
(2) Flow provided for one 50% capacity train.

Heat and Material Balance

Advanced Case

Stream Description		Condensate to Syngas Scrubber (Note 1)		Vacuum Cond. from Vacuum Cond. Pump (Note 2)		Water from Fuel Gas Saturator Bottoms Pump (Note 2)		LTGC KO Drum #4 Overhead (Note 2)		LTGC KO Drum #4 Bottoms (Note 2)	
Stream Number		6		7		8		9		10	
Temperature, °C		175		38		102		132		132	
Pressure, bara		70.0		5.2		33.6		59.3		59.3	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	42,952	99.9%	46,369	100.0%	32,806	100.0%	1,342	5.8%	4,100	99.5%
CO	28.01	2	0.0%	0	0.0%	0	0.0%	361	1.6%	1	0.0%
H2	2.02	6	0.0%	0	0.0%	0	0.0%	11,851	51.4%	2	0.0%
CO2	44.01	44	0.1%	0	0.0%	0	0.0%	9,154	39.7%	15	0.4%
CH4	16.04	0	0.0%	0	0.0%	0	0.0%	11	0.0%	0	0.0%
AR	39.95	0	0.0%	0	0.0%	0	0.0%	21	0.1%	0	0.0%
N2	28.02	0	0.0%	0	0.0%	0	0.0%	79	0.3%	0	0.0%
O2	32.00	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NH3	17.03	5	0.0%	0	0.0%	0	0.0%	1	0.0%	2	0.0%
H2S	34.08	4	0.0%	0	0.0%	0	0.0%	254	1.1%	1	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		43,013	100.0%	46,369	100.0%	32,806	100.0%	23,074	100.0%	4,121	100.0%
Total kg/hr		776,006		835,338		591,000		472,949		74,622	
Molecular Weight		18.04		18.02		18.02		20.50		18.11	
Density, kg/m3		892.8		966.5		962.2		36.6		926.8	
Liquid Flow, m3/hr		869		864		614		-		81	
Vapor Flow, m3/hr		-		-		-		12,922		-	

Notes: (1) Streams provided for Gasification Island by ChevronTexaco.

(2) Flow provided for one 50% capacity train.

Heat and Material Balance

Advanced Case

Stream Description		LTGC KO Drum # 5 Overhead (Note 1)		LTGC KO Drum #5 Bottoms (Note 1)		LTGC KO Drum #6 Overhead (Note 1)		LTGC KO Drum #6 Bottoms (Note 1)		Condensate to Stripper Feed Drum (Note 1)	
Stream Number		11		12		13		14		15	
Temperature, °C		52		52		35		35		112	
Pressure, bara		58.8		58.8		58.2		58.2		58.2	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	71	0.3%	1,271	99.1%	32	0.1%	39	100.0%	5,410	99.4%
CO	28.01	360	1.7%	1	0.1%	360	1.7%	0	0.0%	2	0.0%
H2	2.02	11,851	54.4%	0	0.0%	11,851	54.5%	0	0.0%	2	0.0%
CO2	44.01	9,145	42.0%	9	0.7%	9,145	42.0%	0	0.0%	24	0.4%
CH4	16.04	11	0.1%	0	0.0%	11	0.1%	0	0.0%	0	0.0%
AR	39.95	21	0.1%	0	0.0%	21	0.1%	0	0.0%	0	0.0%
N2	28.02	79	0.4%	0	0.0%	79	0.4%	0	0.0%	0	0.0%
O2	32.00	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NH3	17.03	0	0.0%	1	0.1%	0	0.0%	0	0.0%	3	0.1%
H2S	34.08	253	1.2%	1	0.1%	253	1.2%	0	0.0%	2	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		21,791	100.0%	1,283	100.0%	21,752	100.0%	39	100.0%	5,443	100.0%
Total kg/hr		449,577		23,372		448,874		703		98,697	
Molecular Weight		20.63		18.22		20.64		18.02		18.13	
Density, kg/m3		46.0		966.1		48.4		964.1		939.6	
Liquid Flow, m3/hr		-		24		-		0.73		105	
Vapor Flow, m3/hr		9,773		-		9,274		-		-	

Note: (1) Flow provided for one 50% capacity train.

Heat and Material Balance

Advanced Case

Stream Description		Stripper Feed Drum Bottoms to Condensate Stripper		Condensate Stripper Overhead to Overhead Condenser		Condensate Stripper Reflux		Sour Gas from Condensate Stripper to Sulfur Recovery SWS KO Drum		Condensate Stripper Boilup	
Stream Number		16		17		18		19		20	
Temperature, °C		97		120		88		88		125	
Pressure, bara		2.4		2.1		2.1		2.1		2.3	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	13,548	99.9%	917	86.5%	877	94.5%	40	30.3%	1,739	98.7%
CO	28.01	1	0.0%	4	0.4%	0	0.0%	4	3.0%	0	0.0%
H2	2.02	0	0.0%	4	0.4%	0	0.0%	4	3.0%	0	0.0%
CO2	44.01	7	0.1%	70	6.6%	15	1.6%	55	41.7%	0	0.0%
CH4	16.04	1	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
AR	39.95	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
N2	28.02	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
O2	32.00	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
NH3	17.03	7	0.1%	37	3.5%	32	3.4%	5	3.8%	18	1.0%
H2S	34.08	3	0.0%	28	2.6%	4	0.4%	24	18.2%	5	0.3%
COS	60.07	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		13,567	100.0%	1,060	100.0%	928	100.0%	132	100.0%	1,762	100.0%
Total kg/hr		244,641		21,305		17,141		4,164		31,805	
Molecular Weight		18.03		20.10		18.47		31.55		18.05	
Density, kg/m3		959.8		1.2		958.7		2.2		938.7	
Liquid Flow, m3/hr		255		-		18		-		34	
Vapor Flow, m3/hr		-		17,754		-		1,893		-	

Heat and Material Balance

Advanced Case

Stream Description		Stripped Condensate from Stripper Bottoms Pump		LP BFW to LP BFW Pump		Stripped Condensate to Saturator Water Heater #1	
Stream Number		21		22		23	
Temperature, ^{o}C		126		138		133	
Pressure, bara		61.4		8.0		61.4	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	13,550	100.0%	12,392	100.0%	25,942	100.0%
CO	28.01	0	0.0%	0	0.0%	0	0.0%
H2	2.02	0	0.0%	0	0.0%	0	0.0%
CO2	44.01	0	0.0%	0	0.0%	0	0.0%
CH4	16.04	0	0.0%	0	0.0%	0	0.0%
AR	39.95	0	0.0%	0	0.0%	0	0.0%
N2	28.02	0	0.0%	0	0.0%	0	0.0%
O2	32.00	0	0.0%	0	0.0%	0	0.0%
NH3	17.03	1	0.0%	0	0.0%	1	0.0%
H2S	34.08	0	0.0%	0	0.0%	0	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		13,551	100.0%	12,392	100.0%	25,943	100.0%
Total kg/hr		244,120		223,242		467,362	
Molecular Weight		18.01		18.02		18.01	
Density, kg/m3		938.4		927.5		935.4	
Liquid Flow, m3/hr		260		241		500	
Vapor Flow, m3/hr		-		-		-	

[redacted]

CONFIDENTIAL

Heat and Material Balance

Advanced Case

Stream Description		
Stream Number		[redacted]
Temperature, °C		
Pressure, bara		
Component Flows	MW	
H2O	18.02	
CO	28.01	
H2	2.02	
CO2	44.01	
CH4	16.04	
AR	39.95	
N2	28.02	
O2	32.00	
NH3	17.03	
H2S	34.08	
COS	60.07	
Total kgmol/hr		
Total kg/hr		
Molecular Weight		
Density, kg/m3		
Liquid Flow, m3/hr		
Vapor Flow, m3/hr		

CONFIDENTIAL

Heat and Material Balance

Advanced Case

Stream Description			Water from CO_2LDSep[SM] Unit		
Stream Number		CONFIDENTIAL	34		CONFIDENTIAL
Temperature, °C			35		
Pressure, bara			27.6		
Component Flows	MW		kgmol/hr	mol %	
H2O	18.02		570	100.0%	
CO	28.01		0	0.0%	
H2	2.02		0	0.0%	
CO2	44.01		0	0.0%	
CH4	16.04		0	0.0%	
AR	39.95		0	0.0%	
N2	28.02		0	0.0%	
O2	32.00		0	0.0%	
NH3	17.03		0	0.0%	
H2S	34.08		0	0.0%	
COS	60.07		0	0.0%	
Total kgmol/hr			570	100.0%	
Total kg/hr			10,269		
Molecular Weight			18.02		
Density, kg/m3			1,001.0		
Liquid Flow, m3/hr			10		
Vapor Flow, m3/hr			-		

Note: (1) Streams provided for Gasification Island by ChevronTexaco.

Heat and Material Balance

Advanced Case

Stream Description		[redacted] CONFIDENTIAL	Hydrogen to Hydrogen Compressor	
Stream Number			40	
Temperature, °C			35	
Pressure, bara			28.3	
Component Flows	MW		kgmol/hr	mol %
H2O	18.02		0	0.0%
CO	28.01		0	0.0%
H2	2.02		2,995	100.0%
CO2	44.01		0	0.0%
CH4	16.04		0	0.0%
AR	39.95		0	0.0%
N2	28.02		0	0.0%
O2	32.00		0	0.0%
NH3	17.03		0	0.0%
H2S	34.08		0	0.0%
COS	60.07		0	0.0%
Total kgmol/hr			2,995	100.0%
Total kg/hr			6,038	
Molecular Weight			2.02	
Density, kg/m3			2.2	
Liquid Flow, m3/hr			-	
Vapor Flow, m3/hr			2,745	

Heat and Material Balance

Advanced Case

Stream Description		[redacted] CONFIDENTIAL	Syngas from CO_2LDSep[SM] Unit		[redacted] CONFIDENTIAL
Stream Number		[redacted]	42		[redacted]
Temperature, °C		[redacted]	34		[redacted]
Pressure, bara		[redacted]	28.3		[redacted]
Component Flows	MW	[redacted]	kgmol/hr	mol %	[redacted]
H2O	18.02	[redacted]	0	0.0%	[redacted]
CO	28.01	[redacted]	649	2.9%	[redacted]
H2	2.02	[redacted]	20,403	91.6%	[redacted]
CO2	44.01	[redacted]	1,019	4.6%	[redacted]
CH4	16.04	[redacted]	15	0.1%	[redacted]
AR	39.95	[redacted]	36	0.2%	[redacted]
N2	28.02	[redacted]	142	0.6%	[redacted]
O2	32.00	[redacted]	0	0.0%	[redacted]
NH3	17.03	[redacted]	0	0.0%	[redacted]
H2S	34.08	[redacted]	0	0.0%	[redacted]
COS	60.07	[redacted]	0	0.0%	[redacted]
Total kgmol/hr		[redacted]	22,264	100.0%	[redacted]
Total kg/hr		[redacted]	109,815		[redacted]
Molecular Weight		[redacted]	4.93		[redacted]
Density, kg/m3		[redacted]	5.4		[redacted]
Liquid Flow, m3/hr		[redacted]	-		[redacted]
Vapor Flow, m3/hr		[redacted]	20,336		[redacted]

Note: (1) Flow provided for one 33% capacity train.

Heat and Material Balance

Advanced Case

Stream Description		CO2 Product	
Stream Number		46	
Temperature, °C		45	
Pressure, bara		80.0	
Component Flows	MW	kgmol/hr	mol %
H_2O	18.02	0	0.0%
CO	28.01	70	0.4%
H_2	2.02	299	1.7%
CO_2	44.01	16,722	97.6%
CH_4	16.04	7	0.0%
AR	39.95	6	0.0%
N_2	28.02	16	0.1%
O_2	32.00	0	0.0%
NH_3	17.03	0	0.0%
H_2S	34.08	0	0.0%
COS	60.07	11	0.1%
Total kgmol/hr		17,131	100.0%
Total kg/hr		739,960	
Molecular Weight		43.19	
Density, kg/m3		225.4	
Liquid Flow, m3/hr		-	
Vapor Flow, m3/hr		3,283	

[redacted]

CONFIDENTIAL

Heat and Material Balance

Advanced Case

Stream Description			Acid Gas to Sulfur Recovery Plant		Sour Water to Stripper Feed Drum		Heated Water from Saturator Heater #2 to Fuel Gas Saturator		Saturated Fuel Gas to Gas Turbines	
Stream Number		[redacted] CONFIDENTIAL	52		53		54		55	
Temperature, ^{o}C			35		54		102		169	
Pressure, bara			2.4		19.6		27.6		27.4	
Component Flows	MW		kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02		7	1.0%	2,419	98.9%	65,612	100.0%	8,834	28.4%
CO	28.01		0	0.0%	0	0.0%	0	0.0%	649	2.1%
H2	2.02		0	0.0%	0	0.0%	0	0.0%	20,403	65.6%
CO2	44.01		369	52.5%	7	0.3%	0	0.0%	1,019	3.3%
CH4	16.04		0	0.0%	0	0.0%	0	0.0%	15	0.0%
AR	39.95		0	0.0%	0	0.0%	0	0.0%	36	0.1%
N2	28.02		0	0.0%	0	0.0%	0	0.0%	142	0.5%
O2	32.00		0	0.0%	0	0.0%	0	0.0%	0	0.0%
NH3	17.03		0	0.0%	0	0.0%	0	0.0%	0	0.0%
H2S	34.08		327	46.5%	20	0.8%	0	0.0%	0	0.0%
COS	60.07		0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr			703	100.0%	2,446	100.0%	65,612	100.0%	31,098	100.0%
Total kg/hr			27,506		44,568		1,182,000		268,959	
Molecular Weight			39.14		18.22		18.02		8.65	
Density, kg/m3			3.7		984.6		877.5		6.5	
Liquid Flow, m3/hr			-		45		1,347		-	
Vapor Flow, m3/hr			7,434		-		-		41,378	

Heat and Material Balance

Advanced Case

Stream Description		Fuel Gas Saturator Bottoms to Saturator Heater #1		Hydrogen Export		Nitrogen from Gas Turbine Nitrogen Heater to Gas Turbines		Ambient Air to Gas Turbine (Note 1)		Gas Turbine Exhaust (Note 1)	
Stream Number		56		57		58		59		60	
Temperature, °C		102		35		288		3		558	
Pressure, bara		33.6		103.5		22.1		1.0		1.0	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	65,612	100.0%	0	0.0%	0	0.0%	262	0.5%	10,017	16.0%
CO	28.01	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
H2	2.02	0	0.0%	2,995	100.0%	0	0.0%	0	0.0%	0	0.0%
CO2	44.01	0	0.0%	0	0.0%	0	0.0%	0	0.0%	561	0.9%
CH4	16.04	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
AR	39.95	0	0.0%	0	0.0%	228	1.2%	479	1.0%	567	0.9%
N2	28.02	0	0.0%	0	0.0%	18,962	98.1%	38,344	77.6%	44,712	71.3%
O2	32.00	0	0.0%	0	0.0%	139	0.7%	10,315	20.9%	6,843	10.9%
NH3	17.03	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
H2S	34.08	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total kgmol/hr		65,612	100.0%	2,995	100.0%	19,329	100.0%	49,400	100.0%	62,700	100.0%
Total kg/hr		1,182,000		6,038		544,872		1,428,335		1,699,604	
Molecular Weight		18.02		2.02		28.19		28.91		27.11	
Density, kg/m3		962.2		7.8		13.2		1.2		0.4	
Liquid Flow, m3/hr		1,228		-		-		-		-	
Vapor Flow, m3/hr		-		774		41,278		1,190,279		4,249,009	

Note: (1) Flow provided for one 33% capacity train.

Heat and Material Balance

Advanced Case

Stream Description		Demineralized Water (cycle makeup)		Vacuum Condensate to Vacuum Condensate Heaters		Process Steam Export for Bitumen Recovery		CONFIDENTIAL	Fuel Gas to Tail Gas Treating Unit	
Stream Number		61		62		63		[redacted]	65	
Temperature, °C		105		105		474			32	
Pressure, bara		5.2		5.2		121.6			28.3	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %		kgmol/hr	mol %
H2O	18.02	62,182	100.0%	92,739	100.0%	32,732	100.0%		0	0.0%
CO	28.01	0	0.0%	0	0.0%	0	0.0%		1	14.2%
H2	2.02	0	0.0%	0	0.0%	0	0.0%		5	59.4%
CO2	44.01	0	0.0%	0	0.0%	0	0.0%		2	22.2%
CH4	16.04	0	0.0%	0	0.0%	0	0.0%		0	0.3%
AR	39.95	0	0.0%	0	0.0%	0	0.0%		0	0.8%
N2	28.02	0	0.0%	0	0.0%	0	0.0%		0	3.1%
O2	32.00	0	0.0%	0	0.0%	0	0.0%		0	0.0%
NH3	17.03	0	0.0%	0	0.0%	0	0.0%		0	0.0%
H2S	34.08	0	0.0%	0	0.0%	0	0.0%		0	0.0%
COS	60.07	0	0.0%	0	0.0%	0	0.0%		0	0.0%
Total kgmol/hr		62,182	100.0%	92,739	100.0%	32,732	100.0%		8	100.0%
Total kg/hr		1,120,209		1,670,693		589,667			129	
Molecular Weight		18.02		18.02		18.02			16.18	
Density, kg/m3		61.9		61.9		39.9			17.9	
Liquid Flow, m3/hr		18,097		26,990		-			-	
Vapor Flow, m3/hr		-		-		14,779			7	

Heat and Material Balance

Advanced Case

Stream Description		Sour Gas from Gasification Island (Note 1)		Vacuum Overhead from Gasification Island (Note 1)		Combustion Air to Sulfur Recovery Unit		Combustion Air to Tail Gas Treating Unit		Sulfur Product	
Stream Number		66		67		68		69		70	
Temperature, °C		133		72		Ambient		Ambient		Ambient	
Pressure, bara		1.7		2.1		1.0		1.0		1.0	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	39	37.1%	2	69.5%	11	0.9%	0	0.8%	0	0.0%
CO	28.01	19	18.1%	0	1.7%	0	0.0%	0	0.0%	0	0.0%
H2	2.02	13	12.4%	0	1.7%	0	0.0%	0	0.0%	0	0.0%
CO2	44.01	29	27.6%	0	16.9%	0	0.0%	0	0.0%	0	0.0%
CH4	16.04	1	1.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
AR	39.95	0	0.0%	0	0.0%	12	0.9%	0	0.9%	0	0.0%
N2	28.02	0	0.0%	0	0.0%	983	77.4%	18	77.4%	0	0.0%
O2	32.00	0	0.0%	0	0.0%	264	20.8%	5	20.8%	0	0.0%
NH3	17.03	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
H2S	34.08	3	2.9%	0	10.2%	0	0.0%	0	0.0%	0	0.0%
COS	60.07	1	1.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
S	32.07	0	0.0%	0	0.0%	0	0.0%	0	0.0%	502	100.0%
Total kgmol/hr		105	100.0%	3	100.0%	1,270	100.0%	23	100.0%	502	0.0%
Total kg/hr		2,716		64		36,669		666		16,115	
Molecular Weight		25.86		23.95		28.87		28.88		32.07	
Density, kg/m3		6.3		1.7		-		-		-	
Liquid Flow, m3/hr		-		-		-		-		-	
Vapor Flow, m3/hr		431		38		-		-		-	

Note: (1) Streams provided for Gasification Island by ChevronTexaco.

Heat and Material Balance

Advanced Case

Stream Description		Stack Gas from Tail Gas Treating Unit		Sour Water to Condensate Stripper	
Stream Number		71		72	
Temperature, °C		69		38	
Pressure, bara		1.0		4.4	
Component Flows	MW	kgmol/hr	mol %	kgmol/hr	mol %
H2O	18.02	148	0.2%	351	100.0%
CO	28.01	1	0.0%	0	0.0%
H2	2.02	28	0.0%	0	0.0%
CO2	44.01	640	1.0%	0	0.0%
CH4	16.04	0	0.0%	0	0.0%
AR	39.95	13	0.0%	0	0.0%
N2	28.02	1,025	1.6%	0	0.0%
O2	32.00	7	0.0%	0	0.0%
NH3	17.03	0	0.0%	0	0.0%
H2S	34.08	0	0.0%	0	0.0%
COS	60.07	0	0.0%	0	0.0%
SO2	64.06	0	0.0%	0	0.0%
Total kgmol/hr		1,863	3.0%	351	100.0%
Total kg/hr		60,420		6,320	
Molecular Weight		32.44		18.02	
Density, kg/m3		1.1		1,000.0	
Liquid Flow, m3/hr		-		6	
Vapor Flow, m3/hr		54,927		-	

1.2.2.1.8.3 Preliminary Equipment List

The preliminary equipment list with approximate sizes for the Advanced CO_2LDSep[SM] Case is shown in Table 1.2.2.1.8.4(1).

Table 1.2.2.1.8.4(1) Preliminary Equipment List with Approximate Sizes

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	SIZE/MATERIAL
AIR SEPARATION UNIT (101/201/301)			
No tag	Cryogenic Air Separation Unit	3/0	TIC = $178,576,170 (total for three trains) Budgetary Quote provided by Air Products and Chemicals. Instantaneous price basis (US dollars), February 2003, Gulf Coast location. Excludes spare parts.
GASIFICATION ISLAND (102/202/302)			
No tag	Gasification Island	3/0	TIC = $211,079,570 (total for three trains) Total Installed Cost Estimate provided by ChevronTexaco. Instantaneous price basis (US dollars), March 2002, Canada location.
LOW TEMPERATURE GAS COOLING UNIT (103/203)			
103/203-E-101	Saturator Water Heater #2	2/0	Shell & Tube Shell: 64.1 barg DP @ 224°C DT, 209 °C OT, SS 316L Tube: 42.7 barg DP @ 204°C DT, 190 °C OT, SS 316L
103/203-E-102	Condensate Heater	2/0	Shell & Tube Shell: 64.1 barg DP @ 196°C DT, 181 °C OT, SS 316L Tube: 64.1 barg DP @ 179°C DT, 164 °C OT, SS 316L
103/203-E-103	Saturator Water Heater #1	2/0	Shell & Tube Shell: 64.1 barg DP @ 196°C DT, 181 °C OT, SS 316L Tube: 42.7 barg DP @ 185°C DT, 172 °C OT, SS 316L
103/203-E-104	Vacuum Condensate Heater	2/0	Shell & Tube Shell: 64.1 barg DP @ 146°C DT, 131 °C OT, SS 316L Tube: 42.7 barg DP @ 122°C DT, 65 °C OT, SS 316L
103/203-E-105	Syngas Trim Cooler	2/0	Shell & Tube Shell: 64.1 barg DP @ 122°C DT, 52°C OT, SS 316L Tube: 42.7 barg DP @ 122°C DT, 41°C OT, SS 316L
003-P-001A/B	Condensate Final Pump	1/0	Horizontal Centrifugal: Rated Flow: 957 m^3/h Differential Pressure: 17.1 bar, Differential Head: 194 m Discharge Pressure: 75.8 barg Brake Power: 567 kW Casing: CS, Impeller: CS
103/203-SG-101	LTGC MP Steam Generator	2/0	Shell & Tube Shell: 42.7 barg DP @ 213°C DT, 199 °C OT, CS, 3 mm CS Tube: 64.1 barg DP @ 263°C DT, 249 °C OT, SS 316L
103/203-SG-102	LTGC LP Steam Generator	2/0	Shell & Tube Shell: 42.7 barg DP @ 185°C DT, 170 °C OT, CS, 3 mm CA Tube: 64.1 barg DP @ 218°C DT, 204 °C OT, SS 316L

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	**SIZE/MATERIAL**
003-V-001	Condensate Surge Drum	1/0	Horizontal: 2.7 m ID x 8.2 m T/T Design Conditions: 62.4 barg/FV @ 204°C Operating Temperature: 175°C Shell: CS with SS 316L clad
103/203-V-103	LTGC Knock-Out Drum #3	2/0	Vertical: 3.4 m ID x 6.6 m T/T Design Conditions: 63.4 barg/FV DP @ 210°C DT Operating Temperature: 181°C Shell: CS with 316L SS Clad, Internals: 316L SS
103/203-V-104	LTGC Knock-Out Drum #4	2/0	Vertical: 3.0 m ID x 6.1 m T/T Design Conditions: 63.4 barg/FV DP @ 160°C DT Operating Temperature: 131°C Shell: CS with 316L SS Clad, Internals: 316L SS
103/203-V-105	LTGC Knock-Out Drum #5	2/0	Vertical: 2.7 m ID x 5.5 m T/T Design Conditions: 63.4 barg/FV DP @ 122°C DT Operating Temperature: 52°C Shell: CS with 316L SS Clad, Internals: 316L SS
103/203-V-106	LTGC Knock-Out Drum #6	2/0	Vertical: 2.7 m ID x 4.9 m T/T Design Conditions: 63.4 barg/FV DP @ 122°C DT Operating Temperature: 35°C Shell: CS with 316L SS Clad, Internals: 316L SS
103/203-V-107	LTGC MP Steam Drum	2/0	Horizontal: 1.8 m ID x 5.5 m T/T Design Conditions: 15.9 barg/FV DP @ 227°C DT Operating Temperature: 198°C Shell: CS, 3 mm CA, Internals: CS, 3mm CA
103/203-V-108	LTGC LP Steam Drum	2/0	Horizontal: 2.0 m ID x 5.9 m T/T Design Conditions: 9.0 barg/FV DP @ 199°C DT Operating Temperature: 170°C Shell: CS, 3 mm CA, Internals: CS, 3 mm CA
CONDENSATE (AMMONIA) STRIPPER UNIT (004)			
004-E-001	Condensate Stripper Reboiler	1/0	Shell & Tube Shell: 7.9 barg DP @ 179°C DT, 164°C OT, CS, 3 mm CA Tube: 5.5 barg DP @ 141°C DT, 125°C OT, CS, 3 mm CA Surface Area: 371 m^2
004-E-002	Condensate Stripper Condenser	1/0	Shell & Tube Shell: 5.2 barg DP @ 122°C DT, 50°C OT, CS, 3 mm CA Tube: 3.4 barg DP @ 135°C DT, 120°C OT, Titanium Surface Area: 472 m^2
004-P-001A/B	Condensate Stripper Reflux Pump	1/1	Horizontal Centrifugal Rated Flow: 20 m^3/h Differential Pressure: 4.4 bar, Differential Head: 46 m Discharge Pressure: 6.0 barg Brake Power: 3.0 kW Casing: SS 304L, Impeller: SS 304L

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	**SIZE/MATERIAL**
004-P-002A/B	Stripper Bottoms Pump	1/1	Horizontal Centrifugal Rated Flow: 279 m^3/h Differential Pressure: 61.5 bar, Differential Head: 668 m Discharge Pressure: 63.3 barg Brake Power: 596 kW Casing: CS, Impeller: CS
004-P-003A/B	LP BFW Pump	1/1	Horizontal Centrifugal Rated Flow: 272 m^3/h Differential Pressure: 56.6 bar, Differential Head: 622 m Discharge Pressure: 63.3 psig Brake Power: 536 kW Casing: CS, Impeller: CS
004-V-001	Stripper Feed Drum	1/0	Horizontal: 3.2 m ID x 9.5 m T/T Design Conditions: 3.5 barg/FV @ 124°C Operating Temperature: 97°C Shell: CS with SS 316L clad
004-V-002	Condensate Stripper	1/0	Vertical: 4.0 m ID x 28.7 m T/T Design Conditions: 3.5 barg/FV @ 154°C Operating Temperature: 125°C Shell: CS, 5 mm CA, Internals: CS, 6 mm CA
004-V-003	LP Condensate Pot	1/0	Horizontal: 1.0 m ID x 3.1 m T/T Design Conditions: 6.9 barg/FV @ 193°C Operating Temperature: 164°C Shell: CS, 3 mm CA
004-V-004	Condensate Stripper Overhead Accumulator	1/0	Horizontal: 1.5 m ID x 4.6 m T/T Design Conditions: 3.4 barg/FV @ 122°C Operating Temperature: 88°C Shell: CS, 5mm CA, Internals: CS, 6 mm CA
CO_2LDSep[SM] UNIT (005)			
	Equipment List for Unit 005 is **CONFIDENTIAL**.		
SULFUR RECOVERY (CLAUS) AND TAILGAS TREATING UNIT (006)			
No tag	Sulfur Recovery and Tail Gas Treating Unit		TIC = $43,000,000 ROM Estimate, 1st qtr 2003, Gulf Coast location, excluding location adjustment, contingency, and forward escalation.
006-V-009	HP Condensate Pot #1	1/0	Horizontal, 0.9 m ID x 2.7 m T/T Design Conditions: 127.6 barg/FV @ 354°C Operating Temperature: 326°C Shell: CS, 3 mm CA
006-V-010	HP Condensate Pot #2	1/0	Horizontal, 0.8 m ID x 2.3 m T/T Design Conditions: 127.6 barg/FV @ 354°C Operating Temperature: 326°C Shell: CS, 3 mm CA

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	**SIZE/MATERIAL**
006-V-011	HP Condensate Pot #3	1/0	Horizontal, 0.9 m ID x 2.7 m T/T Design Conditions: 127.6 barg/FV @ 354°C Operating Temperature: 326°C Shell: CS, 3 mm CA
006-V-012	HP Condensate Pot #4	1/0	Horizontal, 0.9 m ID x 2.7 m T/T Design Conditions: 127.6 barg/FV @ 354°C Operating Temperature: 326°C Shell: CS, 3 mm CA
SHIFT REACTORS (107/202)			
107/207-E-101	Shift Feed/Effluent Exchanger	2/0	Shell & Tube Shell: 67.2 barg DP @ 302°C DT, 288°C OT, SS 316L Tube: 64.8 barg DP @ 324°C DT, 315°C OT, SS 316L Surface Area: 4,032 m^2
107/207-E-102	Start Up Heater	2/0	Shell & Tube Shell: 129.6 barg DP @ 357°C DT, 327°C OT, CS, 3mm CA Tube: 86.9 barg DP @ 302°C DT, 288°C OT, SS 316L Surface Area: 69 m^2
107/207-SG-101	Shift HP Steam Generator	2/0	Shell & Tube Shell: 128.2 barg DP @ 357°C DT, 328°C OT, CS, 3 mm CA Tube: 87.6 barg DP @ 471°C DT, 441°C OT, SS 316L Surface Area: 763 m^2
107/207-SG-102	Shift MP Steam Generator	2/0	Shell & Tube Shell: 58.6 barg DP @ 246°C DT, 232°C OT, CS, 3 mm CA Tube: 87.6 barg DP @ 368°C DT, 339°C OT, SS 316L Surface Area: 207 m^2
107/207-V-101	Shift Reactor #1	2/0	Vertical: 6.2 m ID x 6.2 m T/T Design Conditions: 67.6 barg/FV DP @ 488°C DT Shell: CS, 3 mm CA Internals: CS, 4.5 mm CA, Catalyst: Sud-Chemie C25-1-02 HTS
107/207-V-102	Shift Reactor #2	2/0	Vertical: 5.9 m ID x 5.9 m T/T Design Conditions: 66.2 barg/FV DP @ 343°C DT Shell: CS, 3 mm CA Internals: CS, 4.5 mm CA, Catalyst: Sud-Chemie C25-1-02 HTS
107/207-V-103	HP Condensate Pot	2/0	Horizontal, 0.9 m ID x 2.7 m T/T Design Conditions: 131.0 barg/FV @ 357°C Operating Temperature: 328°C Shell: CS, 3 mm CA
107/207-V-104	HP Steam Drum	2/0	Horizontal: 4.0 m ID x 11.9 m T/T Design Conditions: 131 barg/FV DP @ 357°C DT Operating Temperature: 328°C Shell: CS, 3mm CA, Internals: CS, 3mm CA

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	**SIZE/MATERIAL**
107/207-V-105	MP Steam Drum	2/0	Vertical: 2.1 m ID x 6.4 m T/T Design Conditions: 31.0 barg/FV DP @ 260°C DT Operating Temperature: 232°C Shell: CS, 3mm CA, Internals: CS, 3mm CA
FUEL GAS SATURATOR UNIT (008)			
008-C-001A/B	Hydrogen Compressor	1/1	Reciprocating Compressor Rated Flow: 74,243 Nm^3/h Inlet Actual Flow Rate: 4,130 m^3/h Discharge Pressure: 102.5 barg Differential Pressure: 69.6 bar Materials: CS, 3 mm CA Brake Power: 4,013 kW
008-E-001	Gas Turbine Fuel Gas Heater	1/0	Shell & Tube Shell: 112.7 barg DP @ 302°C DT, 288°C OT, CS, 3 mm CA Tube: 168.9 barg DP @ 349°C DT, 319°C OT, CS, 3 mm CA Surface Area: 2,362 m^2
008-E-002	Gas Turbine Nitrogen Heater	1/0	Shell & Tube Shell: 112.7 barg DP @ 302°C DT, 288°C OT, CS, 3 mm CA Tube: 168.9 barg DP @ 349°C DT, 319°C OT, CS, 3 mm CA Surface Area: 2,936 m^2
008-F-001	Hydrogen Product Filter	1/0	Rated Flow: 71,371 Nm^3/h Material: CS, 3 mm CA Design Conditions: 36.5 barg DP @ 122°C DT Includes filter/charcoal contactor/afterfilter
008-P-001A/B	Fuel Gas Saturator Bottoms Pump	1/1	Horizontal Centrifugal Rated Flow: 1,184 m^3/h Differential Pressure: 6.1 bar, Differential Head: 66 m Discharge Pressure: 32.6 barg Brake Power: 252 kW Casing: CS, Impeller: SS 316L
008-V-001	Fuel Gas Saturator	1/0	Vertical: 4.0 m ID x 28.0 m T/T Design Conditions: 31.0 barg/FV DP @ 121°C DT Operating Temperature: 97°C Shell: CS with SS 316L clad, Internals: SS 316 L
COMBUSTION TURBINES AND HEAT RECOVERY STEAM GENERATORS (109/209/309)			
109/209/309-CT-001	Combustion Turbine Generator	3/0	GE PG7241(FA) with IGCC Combustor Output: 197 MW
109-DA-001	Deaerator	1/0	Shell: CS, 3 mm CA, Internals: SS 304L Included with HRSG Common to all 3 trains

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	SIZE/MATERIAL
109/209/309-ME-001	Boiler Chemical Injection Skid	3/0	Metering Pump Skid 2 Oxygen Scavenger Pumps per train (4 total), 0.6 kW motor 2 Phosphate Pumps per train (4 total), 0.6 kW motor 2 Amine Pumps per train (4 total), 0.6 kW motor Storage Totes
109/209/309-P-001A/B	LP Boiler Feedwater Pump	3/3	Horizontal Centrifugal Rated Flow: 885 m^3/h Differential Pressure: 3.3 bar, Differential Head: 37 m Discharge Pressure: 9.1 barg Brake Power: 103 kW Casing: 12 Chrome, Impeller: 12 Chrome
109/209/309-P-002A/B	MP/IP Boiler Feedwater Pump	3/3	Horizontal Centrifugal Rated Flow: 486 m^3/h Differential Pressure: 24.2 bar, Differential Head: 269 m Discharge Pressure: 32.1 barg Brake Power: 409 kW Casing: 12 Chrome, Impeller: 12 Chrome
109/209/309-P-003A/B	HP Boiler Feedwater Pump	3/3	Horizontal Centrifugal Rated Flow: 374 m^3/h Differential Pressure: 105.5 bar, Differential Head: 1,167 m Discharge Pressure: 136.4 barg Total Brake Power: 1369 kW Casing: 12 Chrome, Impeller: 12 Chrome
109/209/309-P-004A/B	HP BFW Recirculation Pump	3/3	Horizontal Centrifugal Rated Flow: 172 m^3/h Differential Pressure: 6.3 bar, Differential Head: 95 m Discharge Pressure: 142.8 barg Brake Power: 37 kW Casing: 12 Chrome, Impeller: 12 Chrome
109-P-005A/B	Blowdown Sump Pump	1/1	Common to all 3 trains Vertical Sump Pump Rated Flow: 19 m^3/h Differential Pressure: 3.4 bar, Differential Head: 36.4 m Discharge Pressure: 3.4 barg Brake Power: 3 kW Casing: Ductile Iron, Impeller: CS
109/209/309-SG-001	Heat Recovery Steam Generator	3/0	3 Pressure Level HRSG 858 MMBtu/hr Heat Recovered per HRSG Shell: Refractory lined CS HP Superheated tubes: 5A-213-T91, All other tubes: CS Includes inlet duct, stack, and stack damper
109-SU-001	Blowdown Sump	1/0	3.0 m x 3.0 m x 3.0 m Depth Concrete sump Common to all 3 trains
109/209/309-SU-002	Water Wash Sump	3/0	3.7 m x 3.7 m x 3.5 m Depth Epoxy lined concrete sump

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	**SIZE/MATERIAL**
109/209/309-V-001	HP Flash Drum	3/0	Vertical: 1.1 m ID x 3.7 m T/T Design Conditions: 31.0 barg/FV @ 260°C Operating Temperature: 232 °C Shell: CS, 3 mm CA
109/209/309-V-001	HP Flash Drum	3/0	Vertical: 1.1 m ID x 3.7 m T/T Design Conditions: 31.0 barg/FV @ 260°C Operating Temperature: 232 °C Shell: CS, 3 mm CA
109/209/309-V-002	IP Flash Drum	3/0	Vertical: 1.1 m ID x 3.8 m T/T Design Conditions: 9.0 barg/FV @ 199°C Operating Temperature: 170°C Shell: CS, 3 mm CA
109/209/309-V-003	LP Flash Drum	3/0	Vertical: 1.1 m ID x 3.8 m T/T Design Conditions: 4.8 barg/FV @ 177°C Operating Temperature: 148°C Shell: CS, 3 mm CA
109/209/309-V-004	Intermittent Blowdown Drum	3/0	Vertical: 2.3 m ID x 2.7 m T/T Design Conditions: 3.4 barg/FV @413°C Operating Temperature: 103.6°C Shell: CS, 3 mm CA, Internals: CS, 3 mm CA
STEAM TURBINE AND CONDENSATE (010)			
010-E-001	Surface Condenser	1/0	Surface Condenser w/ Steam Jet Air Ejector Duty: 1,179 GJ/h Estimated Area = 7,716 m^2 Shell: 1 barg/FV DP @ 122°C DT, CS, 3 mm CA Tubes: 8.6 barg DP @ 122°C DT, SS 317L
010-P-001A/B	Vacuum Condensate Pump	1/1	Vertical Rated Flow: 644 m^3/h Differential Pressure: 8.8 bar, Differential Head: 90.5 Discharge Pressure: 8.1 barg Brake Power: 198 kW Casing: Cast Iron, Impeller: Bronze
010-ST-001	Steam Turbine Generator	1/0	Condensing Steam Turbine HP Steam Inlet Flow: 1,766,800 kg/h @113.5 barg & 538°C Extraction Steam: 1,095,942 kg/h @ 45.9 barg & 410°C Discharge Pressure: 56.89 mm Hg Materials: CS, 3 mm CA Output: 180.4 MW
UTILITIES (012)			

TAG NO.	EQUIPMENT NAME	NUMBER REQ'D	EQUIPMENT
		Oper/Spare	**SIZE/MATERIAL**
012-ME-004	Wastewater Treatment Package	1/0	Reference: Texaco Enhancement Study (Case U-4), Unit 75 - General Waste Water. Include the following equipment: Floating Oil Skimmer (75-ME-001B/C), Storm Water Basin Pump (75-P-004A/B), Collection Sump Pump (75-P-006A/B), Sanitary Waste Water Treating Unit (75-PKG-001), Stormwater Pump (75-SU-001B/C), Collection Sump (75-SU-002), Basin Oil Sump (75-SU-006), Basin Water Sump (75-SU-007), Diversion Box (75-SU-010), Storm Water/Area Drainage, Sediment Control and U/G Piping for Sanitary Sewer. Increase capacity of reference by 1.95 (3 x 7FA plus hydrogen production).
012-ME-005	Backup Plant/Instrument Air Package	1/0	Oil flood rotary screw compressor package with receiver vessel 7,226 Nm^3/h @ 6.9 barg Dual Tower Dryer Package: -40°C dewpoint. Electric regeneration with moisture analyzer (8 hr cycle)

Abbreviations:
DP = Design Pressure
CA = Corrosion Allowance
DT = Design Temperature
FV = Full Vacuum
ID = Inside Diameter
OT = Operating Temperature
TIC = Total Installed Cost
TR = Tons of Refrigerant
T/T = Tangent to Tangent Length

1.2.2.1.8.4 Cost Estimate

1.2.2.1.8.5.1 Cost Estimate Purpose and Basis

The purpose of this estimate is to produce a capital cost for the Integrated Gasification Combined Cycle (IGCC) plant based on ChevronTexaco's (CVX) high pressure, total quench, petroleum coke gasification technology. The Advanced CO_2LDSep^{SM} Case and the Controlled Baseline Case both generate electrical power, hydrogen, steam and carbon dioxide for export.

Both estimates are for new grassroots IGCC plants (greenfield). The level of the estimates represent a Class 4 type category (feasibility type estimate) (As defined in The Association for the Advancement of Cost Engineering (AACE) International Recommended Practice No. 18R-97.) with an accuracy range of approximately ±40% (for the Advanced Case) and +30%/-15% (for the Controlled Baseline Case).

The capital costs are based upon the documents produced during conceptual engineering and have the following basis/assumptions:

- Costs are for an instantaneous 2nd quarter 2003 timeframe.
- The cost is based on an Alberta, Canadian site.
- The site is flat and level, grubbed and ready for construction, and with no interferences.
- An adequate supply of qualified, skilled craftsman/workforce is available to support construction of the plant.
- The construction labor workweek is based on 40 hours a week.
- There is sufficient laydown and parking areas for construction.
- The purchase of the direct field materials is based on worldwide procurement.

1.2.2.1.8.5.2 Estimate Methodology

The capital cost estimate or Total Installed Cost (TIC) includes all items necessary for a full and complete installation of materials and equipment and was prepared using the Icarus 2000 cost estimating program. The TIC includes the following:

- Direct field costs (includes direct field materials, subcontracts & labor)
- All-in wage rate (fully burdened) for direct hire union shop labor, adjusted for the site
- Labor productivity adjusted to the site from Fluor standard base manhours
- Scaffolding, winterization and freight (included as allowances)
- Indirect field costs including:
  - Construction management (included as allowance)
  - Construction camp (included as allowance)
  - Heavy haul/heavy lift (estimated on a labor rate basis)
- Home office costs
- Contractor's risk and profit as a percent (included as allowance)
- Contingency as a percent (included as allowance)

The direct field costs (DFC) were developed by using an equipment model estimating program as the primary tool to model, price and collect the various estimate components. Mechanical equipment design data was inputted to the estimating program to produce the bulk material and labor costs and equipment pricing (not priced by vendor or in-house) based on equipment sizing, temperature, pressure, metallurgy, type, etc. provided by an equipment list from Process.

Mechanical Engineering provided budgetary pricing for selected equipment. This pricing is based on either in-house historical data from recent projects or budgetary quotes from equipment vendors.

Contingency is defined (per Fluor's standards) as:

"Contingency is defined as a special monetary provision in the project budget and TIC of a project, to cover uncertainties or unforeseeable elements of time/cost within the scope of the project under Fluor's control."

Material takeoff allowances and design allowances for engineered equipment are provided for predictable occurrences and are therefore not contingency items. In addition to allowances for predictable occurrences, costs associated with the following are excluded from the contingency: escalation, changes in scope, catastrophic events and labor strikes.

Costs associated with the following items are included in contingency: material cost changes, labor rate changes, labor productivity changes, design changes (other than scope changes), errors and omissions, schedule slippages (engineering, material delivery, construction), construction problems (including weather), estimating inaccuracies and impact of Government regulations.

The contingency of 15% chosen for this project is based on the contingency analysis recently performed for a similar project. The estimated contingency is based on meeting an 85% probability of under run assigned to the estimate. Note that additional contingency was not added to the LSTK prices for the Gasification Island (GI) and Air Separation Unit as it is assumed that the costs already include an allowance for contingency (12% for GI provided by CVX).

1.2.2.1.8.5.3 Estimate Exclusions

The following are exclusions to the TIC:

- Engineering and material costs for any new pipelines (e.g. feed slurry, hydrogen export) from the Oil Sands Operations to the Firebag Lease, and also the carbon dioxide and steam export pipelines.
- Facilities for water make-up (water is provided from the Oil Sands Operation)
- Removal of obstructions (above/below ground), contaminated soils or hazardous materials
- Piling
- Working capital/Inventory
- Scope changes
- Canadian federal/sales taxes and import duties
- Escalation beyond instantaneous 2nd Quarter, 2003

- Interest during construction period
- Lost or damaged materials
- Infrastructure upgrades – except for those items required to support the current project
- Mobile equipment for permanent plant operations
- Owner's Costs - Owner's costs are the normal developmental costs for a project that are part of the owner's responsibility to provide. The type of costs include:
  - owner's project management representatives
  - initial start-up of the plant facility
  - government taxes for the project
  - project permitting costs
  - land acquisition costs
  - governmental fees, if required
  - financing fees
  - royalties
  - licensor fees
  - owner's contingency
  - initial chemical/catalyst fill
  - spare parts inventory
  - project insurance, etc.

1.2.2.1.8.5.4 Disclaimer

In arriving at estimates contained herein, specialized estimating techniques may have been applied to information not within Fluor's control. While it is believed that the estimates contained herein will be reliable under the conditions and subject to the qualifications set forth herein, Fluor does not warrant or guarantee the accuracy of such estimates or other information contained herein. The use of such estimates and information shall be at the user's risk and shall constitute a release and agreement to defend and indemnify Fluor from and against any liability in connection therewith (including, but not limited to incidental, indirect and consequential damages), whether arising out of Fluor's negligence or otherwise.

1.2.2.1.8.5.5 Total Installed Cost Summary

The total installed cost summary for the Advanced CO_2LDSep^{SM} Case is shown in Table 1.2.2.1.8.5.5(1).

Table 1.2.2.1.8.5.5(1) Cost Estimate

Cost to be provided later.

1.2.2.1.9 Conclusion

The Advanced CO_2LDSep^{SM} Case has a "better" performance and produces approximately 40 MWe more than that produced by the baseline case. A small natural gas fired combined cycle plant producing 40 MWe (based on a Rolls Royce RB211-6562 combustion turbine) costs ~$665/kWe. Therefore, a "credit" could be taken for the additional 40 MWe produced in the Advanced Case. The total installed cost with a ±40% accuracy for phase I will be determined. This advanced case will also be evaluated further in Phase II of the project to result in a cost estimate with a ±30 accuracy.

1.2.2.1.10 References

No references were required for this study.

1.2.2.1.11 List of Acronyms and Abbreviations

ASU – Air Separation Unit

bara – bar absolute
barg – bar gauge
BFW – Boiler Feedwater
BL – Blower
BTU – British Thermal Unit

C – Compressor
°C – Degrees Celsius
CA – Corrosion Allowance
CCP – CO_2 Capture Project
CEMS – Continuous Emissions Monitoring System
CO – Carbon monoxide
CO_2 – Carbon dioxide
Cond – Steam condensate
COS – Carbonyl sulfide
CT – Combustion Turbine
CVX - ChevronTexaco

DA – Deaerator
DCS – Distributed Control System
DOE – Department of Energy
DP – Design Pressure
DT – Design Temperature

E – Heat exchanger or cooler
EOR – Enhanced Oil Recovery

F – Filter
FV – Full Vacuum

GE – General Electric
GI – Gasification Island
gpm – Gallons per minute

h or hr – Hour
H2 – Hydrogen
H2O – Water
H2S – Hydrogen sulfide
HCN – Hydrocyanic acid
HP – High Pressure
HRSG – Heat Recovery Steam Generator
HVAC – Heating, Ventilation and Air Conditioning

ID – Inside Diameter
IGCC – Integrated Gasification Combined Cycle
IP – Intermediate Pressure

kg – Kilogram
kgmol – Kilogram moles
kJ – Kilojoules
km – Kilometers
KO – Knock-out
kV – Kilovolts
kW – Kilowatt

lb – Pound
LHV – Lower Heating Value
LP – Low Pressure
LSTK – Lump Sum Turnkey
LTGC – Low Temperature Gas Cooling

m – Meter
m3 – Cubic meters
mbar – Millibar
ME – Mechanical package
mm – Millimeter
MMlb/hr – Million pounds per hour
MMSCFD – Million Standard Cubic Feet per Day
MP – Medium Pressure
Mol% – Molar percent
mt/d – Metric Tons per Day
MW – Molecular Weight
MW – Megawatt
MWe – Megawatt electric

N2 – Nitrogen
NH3 – Ammonia
Ni – Nickel
Nm3 – Normal cubic meter

O2 – Oxygen
OPER – Operating
OT – Operating Temperature

P – Pump
P&I – Plant and Instrument
PFD – Process flow diagram
PM10- particles with diameters less than ten micrometers
ppmv – Parts Per Million (volume basis)
ppmvd – Parts Per Million (volume and dry basis)

s or sec – Second
SAGD – Steam Assisted Gravity Drainage
SRU – Sulfur Recovery Unit
ST – Steam Turbine
SU – Sump
SWS – Sour Water Stripper

TGTU – Tailgas Treating Unit
TIC – Total Installed Cost

TK – Tank
TR – Tons of Refrigerant
T/T – Tangent to Tangent Length

UPS – Uninterruptible Power Supply
US – United States

V – Vessel/Column

Wt% – Weight percent

1.2.3 Integration and Scale-Up Studies

1.2.3.1 Study of Gas Turbine Retrofit Requirements to Burn Decarbonized Fuel (Hydrogen)

Report Title

CO_2 Capture Project - An Integrated, Collaborative Technology Development Project for Next Generation CO_2 Separation, Capture and Geologic Sequestration

Study of Gas Turbine Retrofit Requirements to Burn Decarbonized Fuel (Hydrogen)

Report Reference

1.2.3.1

Type of Report:	Semi-Annual Report
Reporting Period Start Date:	February 2003
Reporting Period End Date:	July 2003
Principal Author(s):	Peter Middleton
Date Report was issued:	August 2003
DOE Award Number:	DE-FC26-01NT41145
Submitting Organization:	BP
Address:	BP Exploration & Production Technology Group Chertsey Road, Sunbury on Thames Middlesex UK

1.2.3.1.1 Abstract

The Gas Turbine Retrofit Study is an activity proposed to commence in the latter half of calendar year 2003. It will evaluate the performance and costs of modifying gas turbines of the type used in the CCP Alaska scenario for firing a decarbonized (hydrogen rich) fuel. No work has yet commenced on this activity beyond defining the objectives of the work and development of a statement of work, which is outlined in the report.

1.2.3.1.2 Table of Contents

1.2.3.1.3 Introduction

One of the scenarios which the CCP is using to evaluate decarbonisation technologies includes facilities on the North Slope of Alaska which includes four Frame 6 and three Frame 5 gas turbines in gas compression service.

Application of any pre-combustion capture technology to this scenario assumes that the gas turbines can be modified to burn the hydrogen fuel and this can be accomplished at an acceptable cost and without adversely affecting the key performance characteristics such as power output, turndown, emissions and reliability.

The retrofit study will evaluate a range of hydrogen fuel mixtures for use on generic Frame 5 and Frame 6 Gas Turbines. The compositions will be selected to cover the composition range anticipated for the PCDC capture technologies.

The study will cover issues of feasibility of hydrogen firing, effects on the performance and emissions from the machine. Key considerations in the design of the overall capture scheme such as the fuel temperature and steam content will be studied. It is anticipated that some of the hydrogen fuel compositions available will enable significant reductions in the NO_X emissions from the existing machines, and all PCDC schemes will totally eliminate sulphur oxide emissions.

Engineering modifications required to accommodate the change to hydrogen fuel will be evaluated and a scope of engineering work together with cost for implementation will be estimated. This will provide a basis for costing the overall implementation of a pre-combustion capture scheme in the scenario.

1.2.3.1.4 Executive Summary

The objectives of the Gas Turbine Retrofit Study as follows

1. Establish feasibility of principle of firing a carbon free hydrogen rich fuel on generic Frame 5 and Frame 6 type Gas Turbines.
2. Evaluate alternate hydrogen fuel mixtures for gas turbine firing
3. Predict the performance of the gas turbines on the same range of fuels.
4. Determine the costs of retrofitting an existing machine to permit hydrogen firing

This study will be combined with the individual CO_2 capture development programmes to provide a complete picture of the costs and feasibility of the pre-combustion decarbonisation approach to CO_2 capture from the CCP Alaska scenario.

A statement of requirements has been prepared for the study and this will be used as the basis for the contract scope of work.

1.2.3.1.5 Experimental

A statement of work is being developed for the study describing the tasks and approach to be used, this is described below.

1.2.3.1.5.1 Task 1 Requirements Definition

This task will identify requirements and criteria for evaluation of candidate gas turbines and processes and ensure that these are consistent with the top-level requirements of both the CCP project and the Prudhoe site.

The Technology Provider (TP) will coordinate with CCP to identify and agree on the top-level requirements and/or assumptions to be used for evaluating candidate gas turbines for the CCP study. This will include environmental emission requirements in terms of criteria pollutants, load requirements and characteristics, fuel and fuel conditions, hydrogen safety and operating requirements, available utilities, de-carbonization process operating characteristics, process streams and potential process upset conditions that must be reflected in the gas turbine hardware and controls.

1.2.3.1.5.2 Task 2 Condition Assessment

TP will assess the current configuration and status for each of the candidate machines. This assessment will include documentation of the base configuration, combustor type, fuels, control system type and capability, operations and maintenance history, hot gas path inspections, component modifications and uprates, scheduled maintenance and prior recommendations that TP has provided.

1.2.3.1.5.3 Task 3 Combustion Screening

A combustion feasibility evaluation will be completed for each of the proposed de-carbonized fuels. Evaluations will be specific to the candidate machines and based on the data provided from Task 2. Combustor operating conditions will be predicted from cycle-deck evaluations. Feasibility criteria will include combustion stability, turndown capability combustor life, expected emissions at full and part load, and potential control strategies or combustor modifications to meet the emission goals defined in Task 1. This evaluation will provide input required for Tasks 4 and 6.

1.2.3.1.5.4 Task 4 Performance Evaluations

Cycle deck runs will be completed for prediction of expected performance changes from current natural gas firing for Frame 5 and 6B machines using each of the de-carbonized fuels provided in Table 2. In those cases where TP evaluates that changes or modifications to fuel or process can significantly improve performance, it is expected that CCP and TP will confer to evaluate and adopt such changes. The minimum turndown load will be estimated. Performance will consist of gross output, heat rate (HHV and LHV) and expected emissions of NOx and CO. Performance estimates will be provided in at full load, minimum turndown and at an intermediate load. CCP will advise whether fuel conditions or compositions will change at part-load conditions. Expected performance changes will be provided for and referenced to 6B and Frame 5 machine fired on natural gas. Performance will be computed using control of firing temperature to maintain hot gas path part life equivalent to natural gas operation. These results will be documented in a summary table of results.

1.2.3.1.5.5 Task 5 Conversion Options

Based on the results of performance, CCP will identify a single process fuel to be used for the basis of recommended conversion options. Each candidate gas turbine will be examined in terms of suitability of retrofitting for high hydrogen fuel. TP will provide a listing of recommended modifications or component replacements to each machine, fuel and controls system and sub-systems as needed to accommodate hydrogen firing. Where it is deemed necessary for implementation of hydrogen conversion, costs and schedule will also be identified for development.. Budgetary estimates will be developed for the CCP to complete its cost evaluation. TP's recommendations will be provided in the form of a prioritization of the candidate modifications and description.

1.2.3.1.6 Results and Discussion

This activity has not yet started and so no results are available at this stage, it is anticipated that the results and full report of the study findings will be available during the second half of calendar year 2003.

1.2.3.1.7 Conclusion

This contract has not yet been placed and not conclusions can be drawn at this stage.

1.2.3.1.8 References

No contract has been placed and no material published to date.

1.3 Oxyfuel Technologies

1.3.1 Study of Advanced Boiler

Report Title

CO_2 Capture Project - An Integrated, Collaborative Technology Development Project for Next Generation CO_2 Separation, Capture and Geologic Sequestration

Study of Advanced Boiler

Report Reference

1.3.1

Type of Report:	Semi-Annual Report
Reporting Period Start Date:	February 2003
Reporting Period End Date:	July 2003
Principal Author(s):	Mark Simmonds
Date Report was issued:	August 2003
DOE Award Number:	DE-FC26-01NT41145
Submitting Organization:	BP Exploration Operating Company Ltd.
Address:	Chertsey Road Sunbury on Thames Middlesex TW16 7LN

1.3.1.1 Abstract

The CO_2 Capture Project (CCP) is a joint program of eight energy companies (BP, ChevronTexaco, EnCana, ENI, Norsk Hydro, Shell, Statoil and Suncor) aimed at reducing the cost of capture and storage of carbon dioxide from stationary combustion sources. Elements of the program are co-funded by the US Department of Energy, the European Union and Norway's Klimatek program.

The CCP is supporting the development of a number of technologies and evaluating their costs for CO_2 capture against four scenarios, one of which is an oil refinery in Europe. The CCP is also interested in comparing the economics of these processes against promising technologies being developed for the same purpose by others.

Praxair, Inc, is leading a consortium supported by the US Department of Energy to develop a novel Advanced Boiler which incorporates a membrane to separate oxygen from the air, which is then used for combustion. The flue gas will consist essentially of CO_2 and water from which the CO_2 can easily be separated. The technology promises to reduce the cost of capturing CO_2 from new boilers and potentially also process heaters.

1.3.1.2 Table of Contents

1.3.1.3 Executive Summary

The CO_2 Capture Project (CCP) is a joint program of eight energy companies (BP, ChevronTexaco, EnCana, ENI, Norsk Hydro, Shell, Statoil and Suncor) aimed at reducing the cost of capture and storage of carbon dioxide from stationary combustion sources. Elements of the program are co-funded by the US Department of Energy, the European Union and Norway's Klimatek program.

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A contract for this work has been submitted to Praxair for signature, but has not yet been signed.

1.3.1.4 Experimental

In executing this study, Praxair will produce an outline design and feasibility study and provide conceptual capital and operating cost estimates for a plant incorporating a Praxair Advanced Boiler designed to:

(i) match the performance of a specified boiler within the CCP's Refinery Scenario (Grangemouth, Scotland) and

(ii) to capture the CO_2 emissions, delivering them with a specified product quality for storage.

The study will also provide cost and performance data for a new conventional boiler with the same output and air as oxidant, without CO_2 capture. This is required so that a net capture cost per ton of CO_2 can be derived.

1.3.1.5 Results and Discussion

1.3.1.5.1 Deliverables

The Final Report will cover the following:

- Summary.
- Description of the technology.
- Decription of the current status of the development program and the anticipated forward schedule to commercialisation.
- Heat and mass balances for the conventional boiler and for the Advanced Boiler and CO_2 treatment plant.
- Block Process flow diagrams for the conventional boiler and for the Advanced Boiler and CO_2 treatment plant.
- Overall Layout diagram with dimensions of the main units (length, breadth, height) for the conventional boiler and for the Advanced Boiler and CO_2 treatment plant.
- CO_2 emitted from the conventional plant. CO_2 produced by the Advanced Boiler together with the proportion of CO_2 captured and the composition of the delivered CO_2 product.
- Estimated capital costs for the conventional boiler and for the Advanced Boiler and CO_2 treatment plant, broken down by plant unit. These should be the contractor's installed costs with a clear definition of scope.
- Power, fuel gas and other utility consumptions, broken down by plant usage, for the conventional and Advanced systems.
- Other operating costs for both systems with the bases for estimation.

Notes on the deliverables:

- Costs should be on a US Gulf Coast basis. Sufficient information on utility, power and fuel costs for the study will be provided by the CCP at the start of the work.

o It is recognised that the Advanced Boiler is new technology at a relatively early stage in its development. Please indicate the main sources of uncertainty in the cost and other data and give an indication of the likely accuracy of each type of data.

o The data will be used by the CCP to develop a costing on a standardised basis for the complete refinery scenario, and therefore it is important that the basis of the costs presented is fully broken down and explained.

1.3.1.6 Conclusion

No contract placed as yet.

1.3.1.7 References

No contract placed as yet.

2. Storage Monitoring and Verification Studies

2.1 Risk Analysis

2.1.1 Safety Assessment Methodology Assessment for CO_2 Sequestration (SAMCARDS)

Report Title

CO_2 Capture Project - An Integrated, Collaborative Technology Development Project for Next Generation CO_2 Separation, Capture and Geologic Sequestration

Safety Assessment Methodology Assessment for CO_2 Sequestration (SAMCARDS)

Report Reference

2.1.1

Type of Report:	Semi-Annual Report
Reporting Period Start Date:	February 2003
Reporting Period End Date:	July 2003
Principal Author(s):	A. Leijnse, A.F.B. Wildenborg, E. Kreft, A. Obdam, M. Nepveu & L. Wipfler
Date Report was issued:	August 2003
DOE Award Number:	DE-FC26-01NT41145
Submitting Organization:	TNO-NITG
Address:	P.O. Box 80.015 3508 TA UTRECHT The Netherlands

2.1.1.1 Abstract

2.1.1.1.1 FEP analysis and scenario formation

The FEP analysis and scenario formation have been further developed in the period reported here. A number of tools have been developed that allow for a simple analysis of FEP interactions, grouping of scenario defining FEP's and construction of influence diagrams for these FEP's. In conjunction with the existing FEP database, the tools were tested during a workshop in June 2003. The general conclusion was, that the tools were very useful, but need some further refinement. Working with the tools also showed that there is a need for further screening of the FEP's, especially in relation to the differences in abstraction levels. Clearer definitions of the FEP's and the actions required in the analysis of the FEP database are also necessary.

2.1.1.1.2 Process modeling

Monte Carlo simulations to feed the probabilistic Performance Assessment model have been carried out for the reservoir-seal model. Based on the sensitivity analysis reported in the Phase 1 status report (Wildenborg et al, 2003), and expert guesses on the distribution of the uncertain parameters in the system, some 1,000 combinations of parameter values were generated, and the CO_2 fluxes at a depth of 300 m below ground level were calculated. For the shallow subsurface, including the atmospheric compartment, the simulations will be carried out by LBNL. The conceptual model has been defined, and the first simulation results are now being evaluated. It seems that the main problem that needs to be resolved is the dependence of the results on the grid resolution.

The probalistic tool, based on Parzen densities has been completed, and has been tested on the results of the Monte Carlo simulation with the reservoir-seal model. The results of this test are promising.

2.1.1.2 Table of Contents

2.1.1.3 List(s) of Graphical Materials

2.1.1.4 Introduction

2.1.1.4.1 FEP analysis and scenario formation

The FEP database consists of a large number of FEPs, that have different levels of abstraction. Screening and analyzing these FEPs and their interaction is required to arrive at a set of scenario defining FEPs. Given the large number of FEPs such an analysis is not easy to carry out. Tools are required that can help in analyzing the interactions between FEPs and the influences FEPs have on other (groups of) FEPs in a consistent way. But even with the presence of these tools, expert judgement is still the basis for the development of sets of scenario defining FEPs.

Within the framework of the SAMCARDS project, a number of these tools have been developed. They have been tested during a workshop in June 2003, where a number of experts made a first attempt to analyse the FEP database, define interactions between FEPs and finally group FEP into scenario elements. The results will be reported in the following chapters.

2.1.1.4.2 Process modeling

A comprehensive description of the physical, chemical and mechanical modeling that will form the basis of the probabilistic performance assessment (PA) model has been given by Wildenborg et al, 2003.

Most of the parameters in the models will have a high level of uncertainty associated with them. Basically, these parameters (like permeabilities, porosities, relative permeabilities, capillary pressures, etc.) can only be measured for a very limited number of locations. Given the heterogeneity of the subsurface system, it will be virtually impossible to predict the parameter values in locations that have not been measured.

Treating the uncertainties in the parameter values requires a stochastic approach. Monte Carlo simulations are required because of the non-linearity of the response of the models. This in turn requires the definition of the probability distributions of the parameters. In general, these will be based on expert judgment.
For the reservoir-seal model, such a Monte Carlo simulation has been carried out, using 1,000 realizations of parameter values. Subsequent Monte Carlo simulations with the shallow subsurface model have as yet not been carried out.

The probabilistic PA model has been tested on the data generated by the Monte Carlo simulation with the reservoir-seal model. Because these results form a multi-dimensional probability distribution, visualizing this distribution is not a trivial problem. However, it is easy to generate probabilities of certain events, like e.g. the probability that the CO_2 flux exceeds a certain limit.

Results of the process modeling will be reported in detail in the next chapters.

2.1.1.5 Executive Summary

2.1.1.5.1 FEP analysis and scenario formation

The FEP database that has been set up in the framework of the SAMCARDS project consists of some 665 different FEPs. Analyzing this comprehensive set of FEPs in terms of interactions, relations and grouping will require, apart from expert judgment, a lot of effort. In fact, such an analysis is virtually impossible without the aid of a number of tools that allow for a consistent treatment of these FEPs. These tools have been developed within the project. They allow visualization of interactions between FEPs and relations between the different FEPs. They also allow the grouping of FEPs based on information available in the database. However, even though these tools are a necesscity, analysis of the FEPs and grouping them into scenario defining elements cannot be done without expert judgment.

During a two-day workshop held in June 2003, a number of experts were requested to work with these tools and analyze the FEPs that were previously screened (Wildenborg et al, 2003), and, if possible, define groups of FEPs that form scenario elements. Although the general conclusion of the workshop was that, working with the tools, it would certainly be possible to define scenario elements by grouping the FEPs, a number of problems still need to be addressed. These problems adhere to both the definition of the FEPs and the possibilities of the tools.

In principle, the completely different abstraction levels of different FEPs makes it in some cases difficult to define interactions between the FEPs. The fact that definitions are not always clear, and that there sometimes still is considerable overlap between the FEPs does not help either.

Definitions and rules with respect to the screening of the FEPs are not always clear and need further documentation. Apart from small adjustments in the tools, the possibility to show circular relations in the influence diagrams should certainly be implemented. With these adjustments and developments the definition of scenario should follow.

Integration with the Quintesse IEA FEP database is still waiting for financial support from the IEA Greenhouse Gas R&D Program.

2.1.1.5.2 Process modeling

The process models for the different compartments all suffer from the fact that the physical/chemical/ mechanical parameters that are required for these models are in general highly uncertain. In order to address the problem of parameter uncertainty, a stochastic approach has to be taken. Because of the non-linearities of the models, this will require Monte Carlo simulations with the different compartment models. This in turn will require definition of the probability distributions of the different parameters. For a specific site, these will be based on available data in combination with expert judgment.

Based on the sensitivity analysis reported in the Phase 1 report (Wildenborg et al, 2003), Monte Carlo simulations have been carried out for the reservoir-seal model. Some 1,000 combinations of parameter values were generated, and CO_2 fluxes that must serve as boundary conditions for the shallow subsurface model have been calculated for these different combinations.

Simulations for the shallow subsurface compartment, including the atmosphere, are being carried out by LBNL. The first results are now being discussed and evaluated at the moment. They seem to indicate that the spatial resolution of the model still plays a role, i.e. that no grid converged solution was obtained with a course grid. This problem needs to be resolved in order to make Monte Carlo simulations with the shallow subsurface model possible.

The development of the probabilistic Performance Assessment model has been finalized. Documentation, both of the scientific background and the computer program are available (Wojcik and Torfs, 2003a, 2003b). One of the important parameters in the probabilistic model is the globality parameter, that in effect determines how far the influence of the different data points reaches. How sensitive results of the probabilistic model are for values of the globality parameter needs to be tested further.

The model was tested with the results of the Monte Carlo simulations of the reservoir-seal model. The test showed that the probabilistic tool is easy to work with. Although it is almost impossible to visualize the multi-dimensional (in this case four dimensional) probability density functions, it is easy to generate individual probabilities, e.g. the probability that the CO_2 flux exceeds a certain limit. These probabilities are generated by Monte Carlo type simulations with the multi-dimensional probability density function, and these can easy and fast be carried out.

2.1.1.6 Experimental

2.1.1.6.1 FEP analysis and scenario formation

2.1.1.6.1.1 Concept

The core of the long term safety assessment is the systematic development of a limited number of scenarios that describe the future behaviour of the sequestration facility with respect to HS&E. The basic elements for the development of scenarios are the FEPs. FEPs are all possible Features, Events and Processes that may have a risk impact on the future evolution or state of the sequestration facility. FEP analysis is the process of evaluating FEPs. Scenarios are constructed subsequently during the scenario formation process.

During the FEP analysis the relevance of each FEP is evaluated with respect to the assessment basis. The assessment basis specifies the criteria for risks, the sequestration concept, site characterization and other boundary conditions. FEP analysis depends on the input of expert opinion and is therefore subjective by nature. A method is being developed to structure and rationalize the FEP analysis process in order to reduce the subjectivity as much as possible.

The FEP analysis and scenario formation method will be screened by an external and independent review committee, as part of the safety assessment procedure. Prerequisites and main test parameters are:
comprehensiveness: the list of FEPs relevant to the safety assessment should be complete;
transparency: the FEP descriptions and analysis procedure should be transparent to a wider audience;
tractability: all decisions made during the FEP analysis and scenario formation should be traceable.
The FEP analysis and scenario formation procedure have been described in the SAMCARDS annual report 2002 (Wildenborg et al, 2003) and are included in Appendix A.

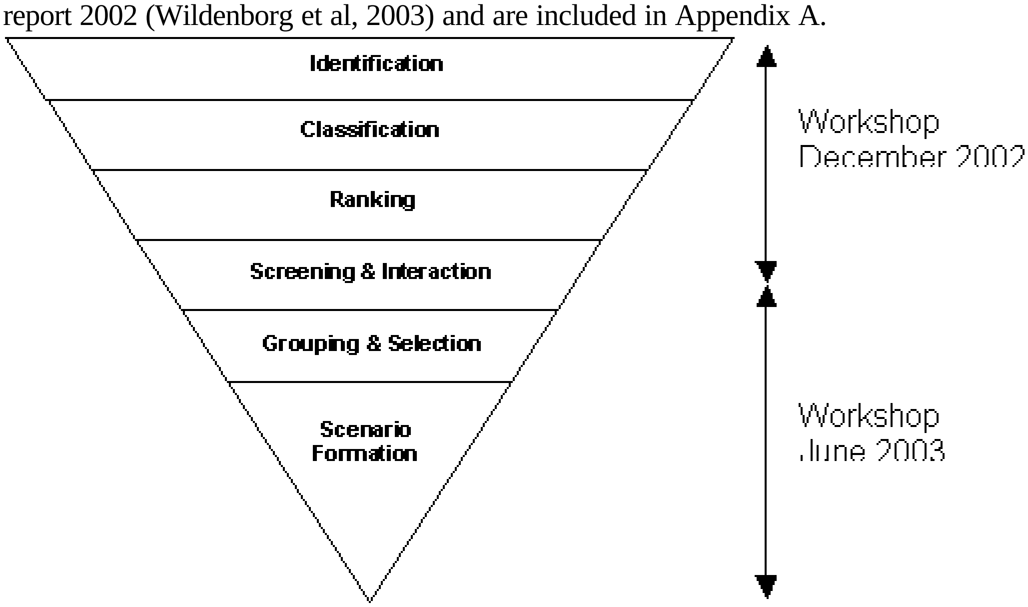

Figure 1 Stages of the FEP analysis procedure

2.1.1.6.1.2 Developments

In 2002, 665 FEPs were identified and were implemented in a FEP database to support the FEP analysis process. During a workshop in December 2002 (TNO-NITG, 2002) the database and FEP analysis methodology were tested and the FEPs were screened for relevance with respect to two field specific cases: CO_2 sequestration in an on-shore depleted gas field and in an off-shore aquifer. At that time the methodology and database tool were developed halfway (Figure 1).

In 2003 the methodology and tool(s) supporting the FEP analysis process have been developed further. The time schedule of the main activities is given in table 1 .

Table 1 Time schedule of FEP analysis process

		Year 2003											
		1	2	3	4	5	6	7	8	9	10	11	12
Activity							Phase 2						
2100	Scenario development												
							T	WS		M210			
A	Interaction Matrix												
B	FEP Grouping Procedure												
C	Scenario Construction												
D	Tool Development												

M210 Milestone with due date 31/08/03
T Internal test methodology
WS Scenario workshop

So far the activities focused mainly on the procedures of interaction and grouping of FEPs. The objective has been to develop a transparent methodology supported by tools that are capable of recording all the steps and decisions during the interaction, grouping and scenario formation process. At this time, no tools have been developed to support the scenario formation.

2.1.1.6.1.3 Examples of tools

In 2003 the screening and interaction procedure has been implemented within the MS-Access database tool that was developed in 2002 and that already covered the first three steps of the FEP analysis procedure (Fig. 1). The interaction between FEPs is supported by the identification of mutual features (parameters) that are affected by two or more FEPs. Once all FEPs are screened for features that could be potentially affected (Fig. 2), the interaction matrix (Fig. 3) can be generated. In case two FEPs affect a similar feature, the interaction matrix is automatically filled in. The syntax of the matrix is as follows: fields within the matrix present the likelihood that the FEP on the (top) horizontal axis could initiate the FEP on the vertical axis. The order of likelihood can be expressed by different magnitudes.

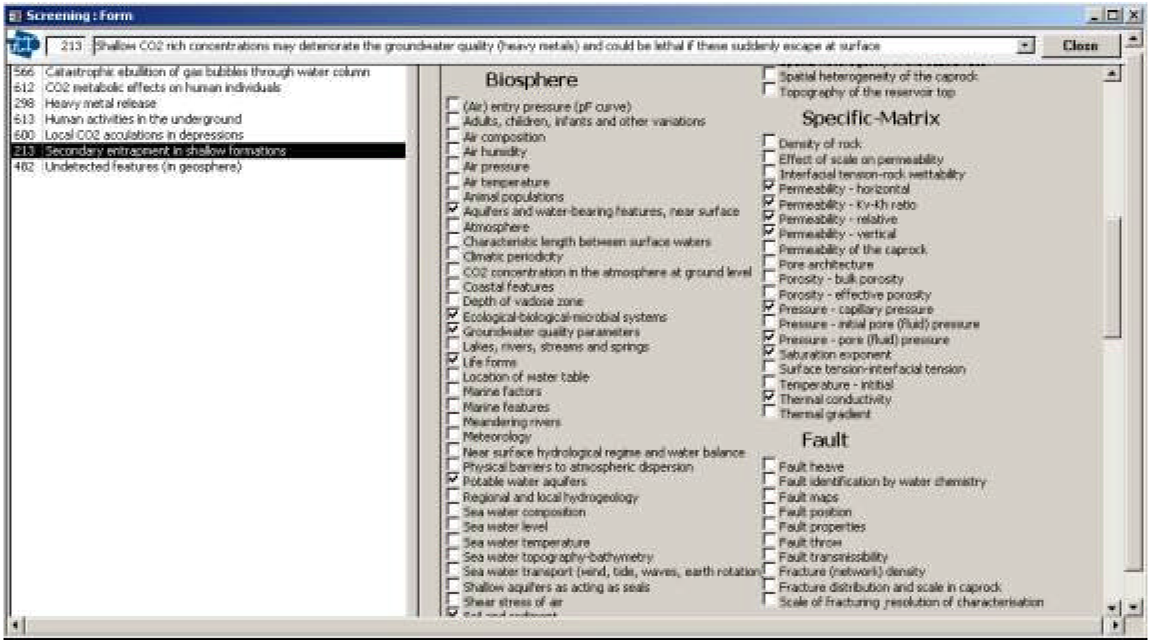

Figure 2 Example of the tool that records which features (right) may be affected by which FEP (left).

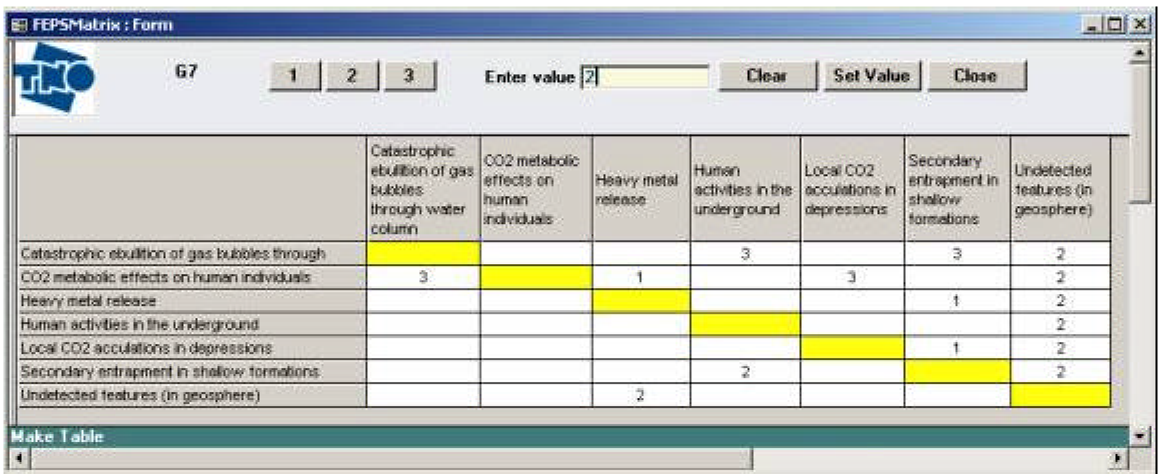

Figure 3 Example of the interaction matrix tool (biosphere compartment).

The results of the interaction matrix can be exported to an influence diagram (Fig. 4). The influence diagram tool visually, and more intuitively, presents the cause-effect relationships between FEPs.

The grouping of FEPs has been implemented within the MS-Access database tool, similar to the screening and interaction procedures. Grouping of FEPs is based on spatial and temporal consistency in combination with the interactions that have been previously defined. Fig. 5 shows an example of the tool that supports the grouping process.