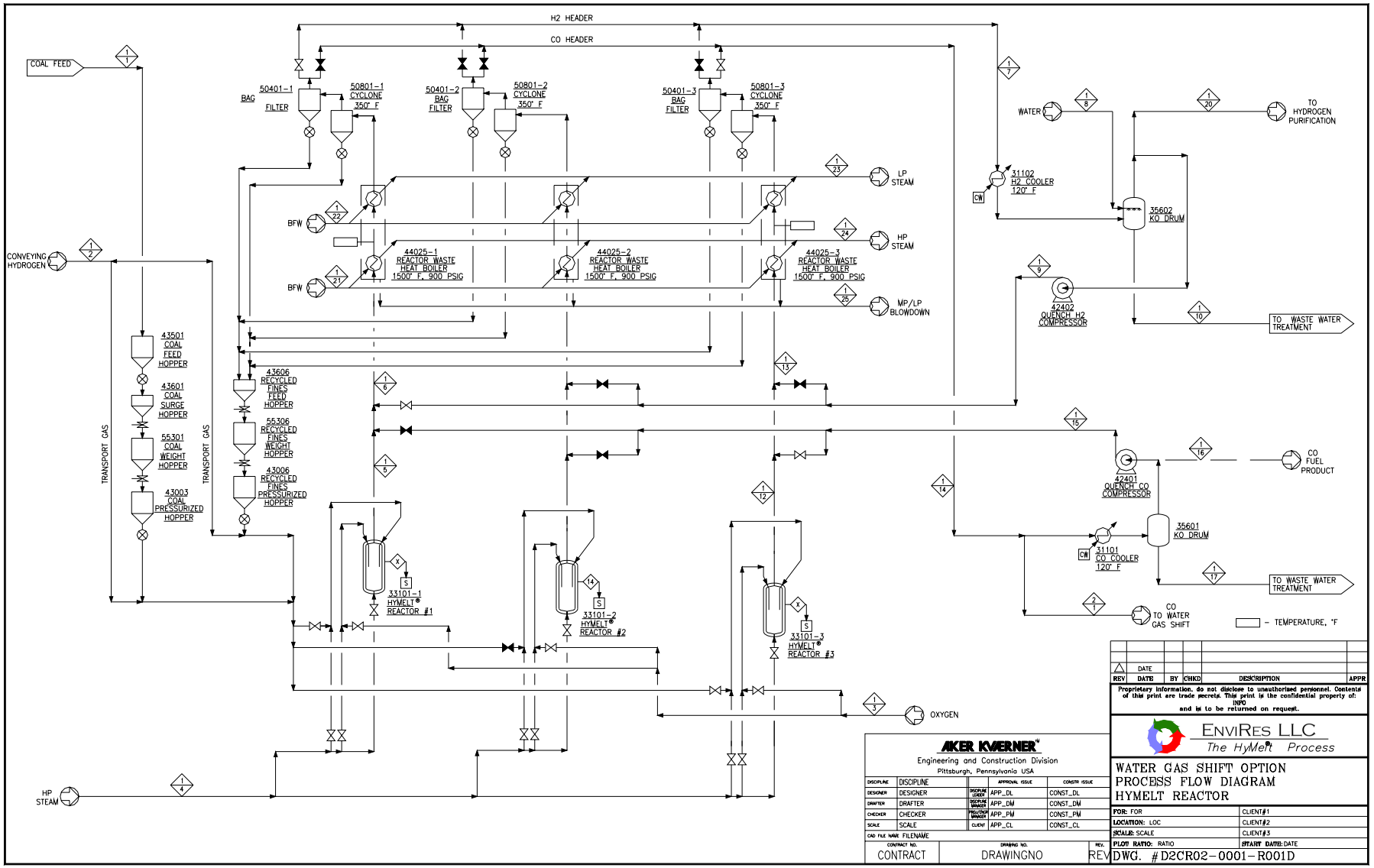
Appendix II

Kvaerner Process Flow, Hydrogen Purification, Amine and CO-Water Gas Shift Studies


H2 HEADER
CO HEADER
COAL FEED
BAG FILTER 50401-1
50801-1 CYCLONE 350° F
50401-2 BAG FILTER
50801-2 CYCLONE 350° F
50401-3 BAG FILTER
50801-3 CYCLONE 350° F
WATER
TO HYDROGEN PURIFICATION
31102 H2 COOLER 120° F
35602 KO DRUM
LP STEAM
HP STEAM
MP/LP BLOWDOWN
BFW
BFW
44025-1 REACTOR WASTE HEAT BOILER 1500° F, 900 PSIG
44025-2 REACTOR WASTE HEAT BOILER 1500° F, 900 PSIG
44025-3 REACTOR WASTE HEAT BOILER 1500° F, 900 PSIG
42402 QUENCH H2 COMPRESSOR
TO WASTE WATER TREATMENT
CONVEYING HYDROGEN
43501 COAL FEED HOPPER
43601 COAL SURGE HOPPER
55301 COAL WEIGHT HOPPER
43003 COAL PRESSURIZED HOPPER
TRANSPORT GAS
TRANSPORT GAS
43606 RECYCLED FINES FEED HOPPER
55306 RECYCLED FINES WEIGHT HOPPER
43006 RECYCLED FINES PRESSURIZED HOPPER
33101-1 HYMELT® REACTOR #1
33101-2 HYMELT® REACTOR #2
33101-3 HYMELT® REACTOR #3
42401 QUENCH CO COMPRESSOR
CO FUEL PRODUCT
35601 KO DRUM
31101 CO COOLER 120° F
TO WASTE WATER TREATMENT
CO TO WATER GAS SHIFT
OXYGEN
HP STEAM
- TEMPERATURE, °F
AKER KVÆRNER
Engineering and Construction Division
Pittsburgh, Pennsylvania USA
WATER GAS SHIFT OPTION
PROCESS FLOW DIAGRAM
HYMELT REACTOR
ENVIRES LLC
The HyMelt Process
DWG. #D2CR02-0001-R001D
CONTRACT
DRAWINGNO
REV
P:\Cnt\C99268\CAD\PROCESSE\R-02-001.DWG
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July 9, 2003

Email: mike.friedrich@akerkvaerner.com

Mr. Mike Friedrich

Aker Kvaerner

1200 Penn Avenue

Pittsburgh, PA 15222

SUBJECT: UOP Polybed PSA Unit

Envires, Kentucky

UOP Proposal P3H038 Rev. 4

Dear Mike,

In reply to your request, two budgetary designs and price estimates are provided for a UOP Polybed PSA Unit that produces a hydrogen product for the Hymelt Process.

Case 1 produces 15.31 MMSCFD of product hydrogen and Case 2 produces 28.39 MMSCFD of product hydrogen.

If there are any questions, please contact me at 713-744-2863 or email: Eugene.kuchta@uop.com.

Sincerely,

Eugene Kuchta

Process Technology & Equipment

EAK:rk

UOP POLYBED™PSA UNIT

for

Kvaerner

Envires / Hymelt Process

Project No: P3H038 July 9, 2003

Case 1 : 15.31 MM SCFD Product

		Feed	Product		Tail Gas	
Flowrate,	MM SCFD	19.08	15.31		3.76	
	lb-mol/hr	2,095	1,681		413	
Pressure,	psig	500	490		5	(Ex ST)
Temperature,	°F	120	130		110	
	°C	49	54		43	
Composition, mol%						
Hydrogen		93.24	99.9		66.15	
Nitrogen		1.13	Balance		5.32	
Carbon Monoxide		3.69	10	ppmv	18.70	
Carbon Dioxide		0.01	--		0.05	
Methane		0.86	Balance		4.36	
Acetylene		0.01	--		0.05	
Water		0.01	--		0.05	

Hydrogen Sulfide	1.00	--	5.07
Hydrogen Cyanide	0.05	--	0.25

Design Hydrogen Recovery: 86%

PSA Price (± 20% FCA USA. Shop): $1,700,000 USD

PSA Approximate Plot Size: 50 ft. x 30 ft.

PSA Utilities:

- Instrument Air: 1,400 SCFH @ 85 psig
- Electric Power: 5.0 kW @ 120 VAC, 1 ph, 60 Hz
- Nitrogen (Startup only)
  - Leak Test: 120,000 SCF @ 500 psig
  - Purge: 60,000 SCF @ 85 psig

UOP POLYBED™PSA UNIT

for

Kvaerner

Envires / Hymelt Process

Project No: P3H038 July 9, 2003

Case 2 : 28.39 MM SCFD Product

		Feed	Product	Tail Gas	
Flowrate,	MM SCFD	46.19	28.39	17.80	
	lb-mol/hr	5,072	3,118	1,954	
Pressure,	psig	491	481	5	(Ex ST)
Temperature,	°F	120	130	110	
	°C	49	54	43	
Composition, mol%					
Hydrogen		71.40	99.9	25.94	
Nitrogen		0.60	Balance	1.40	
Carbon Monoxide		5.20	10 ppmv	13.49	
Carbon Dioxide		21.70	--	56.31	
Methane		0.40	Balance	1.04	
Water		0.20	--	0.52	

Hydrogen Sulfide	0.40	--	1.04
Hydrogen Cyanide	0.10	--	0.26

Design Hydrogen Recovery: 86%

PSA Price (± 20% FCA USA Shop): $2,500,000 USD

PSA Approximate Plot Size: 70 ft. x 40 ft.

PSA Utilities:

- Instrument Air 3,400 SCFH @ 85 psig
- Electric Power 5.0 kW @ 120 VAC, 1 ph, 60 Hz
- Nitrogen (Startup only)
  - Leak Test 360,000 SCF @ 491 psig
  - Purge 180,000 SCF @ 85 psig

UOP POLYBED™PSA UNIT

for

Kvaerner

Envires / Hymelt Process

Project No: P3H038 July 9, 2003

UOP Scope of Supply includes	Adsorber Vessels
	Off-Gas Drum(s)
	Valve and Piping Skid
	Initial Adsorbent Charge
	Engineering
	Control Panel with CRT
	Relief Valves for Adsorber Vessels and Off-Gas Drum
	Block Valves
	Interconnecting Piping from Adsorber Vessels to Skid
Customer Scope of Supply includes	
but is not limited to	Foundation including Anchor Bolts
	Installation of All UOP Supplied Equipment
	Piping from Valve and Piping Skid to Off-Gas Drum
	Adsorbent Loading Under UOP Supervision

Performance Test

Piping To/From PSA Battery Limits

Wiring between Skid and Control Cabinet/CRT

Supply of Utilities

Leak and Pressure Test of the PSA Unit

Design and Supply of Peripheral Controls

- Product Back Pressure Control Valve
- Feed KO Drum
- Feed Flow Control
- Block Valves on All Piping To/From Unit
- Feed and Tail Gas Vent
- Tail Gas Flow/Pressure Control

Analyzer

Finish Paint

Notes:

1. The price is quoted exclusive of taxes, crating, insurance, or freight costs, and is based upon UOP standard fabrication and third quarter, 2003, costs.
2. The typical U.S. installation cost for Polybed™ PSA Units similar to the proposed system has been approximately 15% of UOP's quoted purchase price.

Gas Treating Products

Products, Technology and Service from Dow

AkerKvaerner PSA TGU

Contents: **Page Number**

DOW

SPECIALTY ALKANOLAMINES

AkerKvaerner PSA TGU

Simulation Summary

Absorber Feed Gas Conditions

Gas Flow Rate:	22.09	MM SCFD
Pressure:	5.00	Psig
Temperature:	110.0	Deg F

Composition	Feed Mol %	Feed LB MOL/HR	Product Mol%	Product LB MOL/HR
H2S	0.86%	20.98	0.00%	0.02
CO2	65.29%	1,583.19	60.56%	1,424.87
H2	20.10%	487.47	20.72%	487.44
CO	11.40%	276.52	11.75%	276.50
N2	1.02%	24.69	1.05%	24.69
CH4	0.75%	18.09	0.77%	18.09
C2H6	0.02%	0.58	0.02%	0.58
C3H8	0.05%	1.16	0.05%	1.16
H2O	0.51%	12.32	5.08%	119.47
UCARSOL	0.00%	0.00	0.00%	0.00
TOTAL	100.00%	2,425.00	100.00%	2,352.82

Treated Gas Conditions

GAS FLOW RATE:	21.43	MM SCFD
H2S	10	PPMV
CO2	63.8	%(V/V) DRY
CO2 Slippage	90.0	%

Solvent

Name	UCARSOL HS	103
Lean Solvent Flow	560.0	GPM
Amine Strength	50.00	%(W/W)
Internals - Number of Contact Trays	10	TRAYS

Solution Conditions

Lean Solvent Temperature	100.0	Deg F
Lean Loading	0.005	Mol/Mol
Rich Loading	0.159	Mol/Mol

Regenerator Conditions:

Tower Internals - Number of Trays	20	TRAYS
Rich Amine Feed Temp	213.3	Deg F
Reboiler Press	13.0	Psig
Reflux Flow	31.8	GPM

Exchanger Data:

Lean Cooler Duty	13.681	MM BTU/HR
Lean - Rich Exch'r	27.269	MM BTU/HR
Reflux Cond'r Duty	17.221	MM BTU/HR
Reboiler Duty	32.619	MMBTU/HR

AkerKvaerner PSA TGU

Major Equipment Summary

Absorber

Absorber Internals	10	TRAYS
Absorber Diameter	7.6	FT
Lean Loading	0.005	Mol/Mol
Rich CO2 Loading	0.141	Mol/Mol
Rich H2S Loading	0.019	Mol/Mol
Atmospheric Pressure	14.7	Psia
Treated Gas H2S	10.0	PPMV
Treated Gas CO2	63.8	%(V/V) DRY

Regenerator

Regenerator Internals	20	TRAYS
Regenerator Diameter	6.3	FT
O/H Reflux Ratio	5.00	Mol H2O/Mol AG
Regenerator Heat to Acid Gas Ratio	181.954	M BTU/Mol Acid Gas
Steam to Feed Ratio	1.077	LB/GAL

Reboiler

Heat Duty	32.619	MMBTU/HR	**U**	145.0	BTU/HR-FT2-DEGF
Steam Rate	35.8	M LB/HR	**LMTD**	41.8	Deg F
Reboiler Temperature	253.3	Deg F	**Fn**	1.00	
Reboiler Steam Pressure	50.0	Psig	**Area**	5,384	SQFT

Lean/Rich Exchanger

			U	120	BTU/HR-FT2-DEGF
Heat Duty	27.269	MM BTU/HR	**LMTD**	41.6	Deg F
Rich Inlet Temp	110.0	Deg F	**Fn**	0.80	
Rich Outlet Temp	213.3	Deg F	**Area**	6,836	SQFT
Lean Inlet Temp	253.3	Deg F			
Lean Outlet Temp	153.1	Deg F			

Lean Solvent Cooler

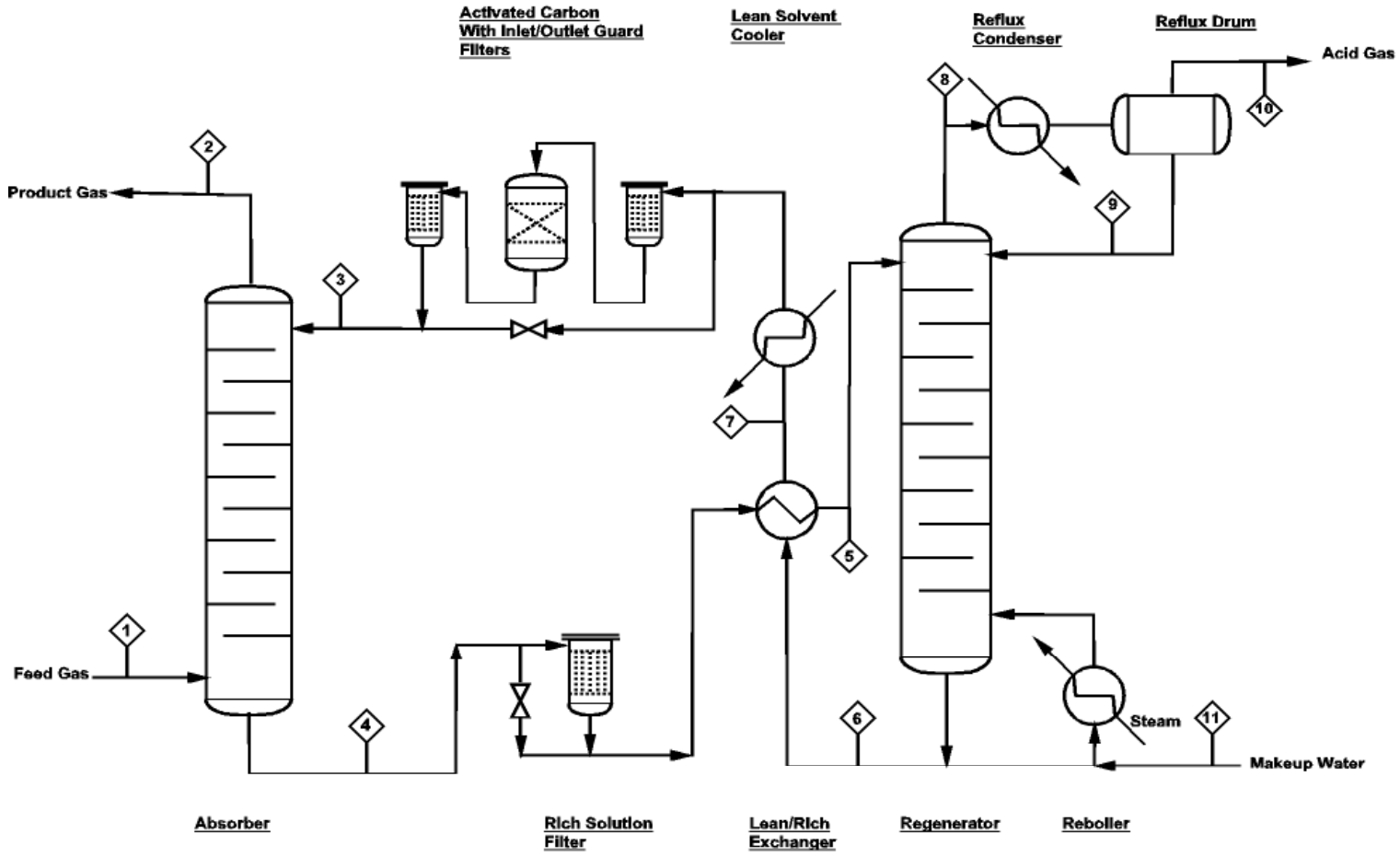
			U	90	BTU/HR-FT2-DEGF
Type	AIR		**LMTD**	15.4	Deg F
Heat Duty	13.681	MM BTU/HR	**Fn**	0.80	
Lean Inlet Temp	153.1	Deg F	**Area**	12,309	SQFT
Lean Outlet Temp	100.0	Deg F			

Reflux Condenser

			U	64	BTU/HR-FT2-DEGF
Type	AIR		**LMTD**	49.7	Deg F
Heat Duty	17.221	MM BTU/HR	**Fn**	0.80	
Inlet Temp	231.6	Deg F	**Area**	6,759	SQFT
Outlet Temp	120.0	Deg F			
Reflux Flow Rate	31.8	GPM			

AkerKvaerner PSA TGU

Stream Summary		Feed Gas 1	Product Gas 2	Lean UCARSOL 3	Cool Rich UCARSOL 4	Hot Rich UCARSOL 5	Hot Lean UCARSOL 6	Warm Lean UCARSOL 7	Stripper Overhead 8	Reflux Liquid 9
Temperature	Deg F	110.0	100.0	100.0	110.0	213.3	253.3	153.1	231.6	120.0
Pressure	Psig	5.0	4.0	4.0	5.0	.0	13.0		11.0	10.0
Gas Flow	MM SCFD	22.1	21.4						9.80	
Liquid Flow	GPM			560.0	573.2	-	594.4	570.4		31.8
Lean Solution Density	LB/GAL			8.8	8.7	8.4	8.3	8.6		8.7
Lean Solution Viscosity	cP			5.35			0.96	2.25		
Lean Solution Specific Heat	BTU/LB-F			0.858			0.956	0.889		
Lean Solution Surface Tension	DYNE/CM			38.8			30.3	35.9		
Lean Solution Thermal Conductivity	BTU/HR-FT-F			0.27			0.328	0.298		
H2S	LB MOL/HR	20.98	0.02	0.68	21.63	21.63	0.68	0.68	20.95	
CO2	LB MOL/HR	1,583.19	1,424.87	5.13	163.45	163.45	5.13	5.13	158.32	
H2	LB MOL/HR	487.47	487.44		0.03	0.03			0.03	
CO	LB MOL/HR	276.52	276.50		0.02	0.02			0.02	
N2	LB MOL/HR	24.69	24.69		0.00	0.00			0.00	
CH4	LB MOL/HR	18.09	18.09		0.00	0.00			0.00	
C2H6	LB MOL/HR	0.58	0.58		0.00	0.00			0.00	
C3H8	LB MOL/HR	1.16	1.16		0.00	0.00			0.00	
H2O	LB MOL/HR	12.32	119.47	8,184.82	8,077.67	8,077.67	8,184.82	8,184.82	896.36	883.17
UCARSOL HS	LB MOL/HR		0.003	1,161.02	1,161.02	1,161.02	1,161.02	1,161.02	0.379	0.379
TOTAL	LB MOL/HR	2,425.00	2,352.82	9,351.64	9,423.82	9,423.82	9,351.64	9,351.64	1,076.07	883.55
TOTAL	LB/HR	80,391.4	74,640.1	295,147.8	300,899.1	300,899.1	295,147.8	295,147.8	23,830.3	15,958.5
M/H A.G.	LB MOL/HR	1,604.16	1,424.89	5.81	185.08	185.08	5.81	5.81	179.27	



The Dow Chemical Company
Process Flow Diagram

AkerKvaerner PSA TGU

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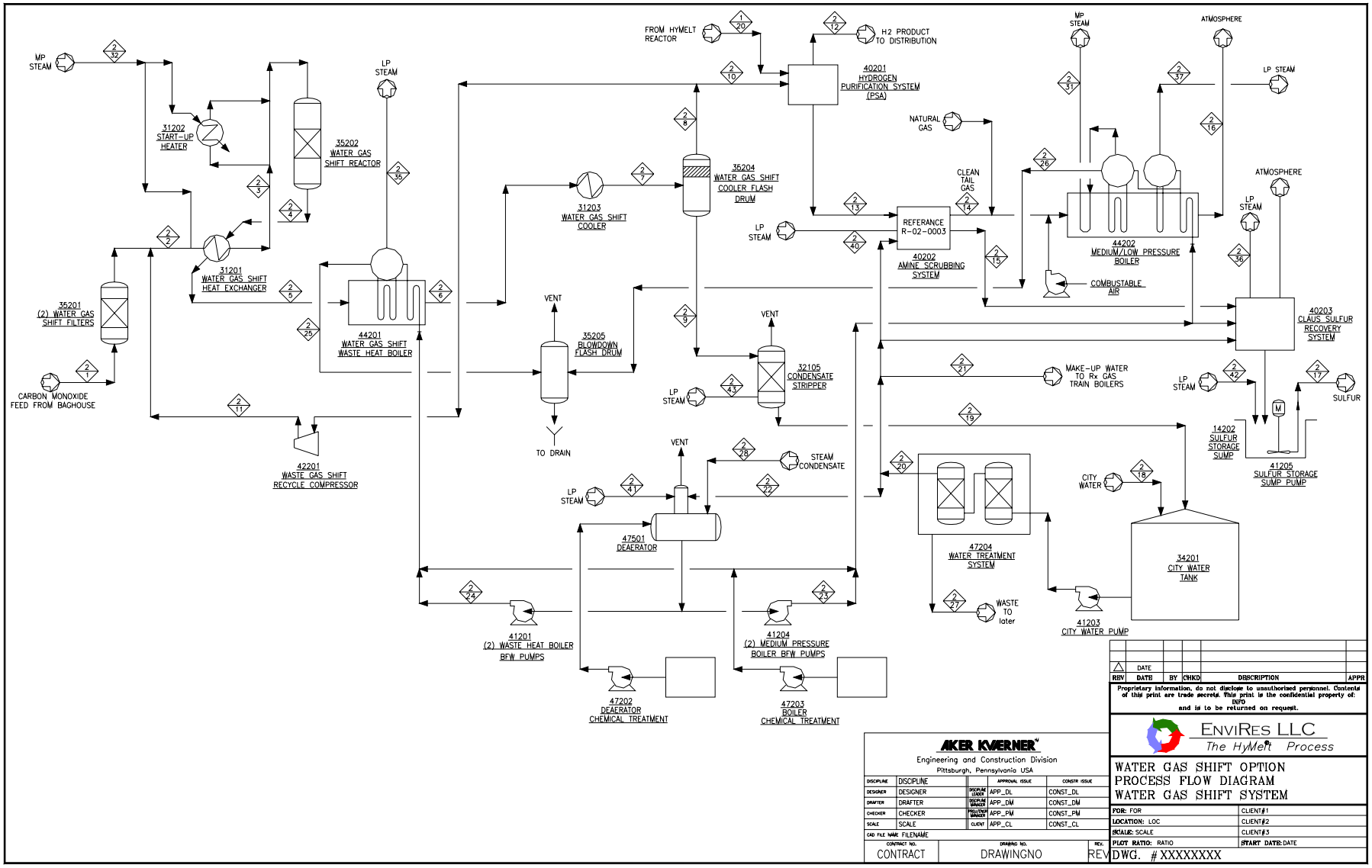
MP STEAM
31202 START-UP HEATER
35202 WATER GAS SHIFT REACTOR
LP STEAM
31201 WATER GAS SHIFT HEAT EXCHANGER
35201 (2) WATER GAS SHIFT FILTERS
CARBON MONOXIDE FEED FROM BAGHOUSE
44201 WATER GAS SHIFT WASTE HEAT BOILER
42201 WASTE GAS SHIFT RECYCLE COMPRESSOR
FROM HYMELT REACTOR
H2 PRODUCT TO DISTRIBUTION
40201 HYDROGEN PURIFICATION SYSTEM (PSA)
31203 WATER GAS SHIFT COOLER
35204 WATER GAS SHIFT COOLER FLASH DRUM
VENT
35205 BLOWDOWN FLASH DRUM
TO DRAIN
LP STEAM
32105 CONDENSATE STRIPPER
STEAM CONDENSATE
47501 DEAERATOR
41201 (2) WASTE HEAT BOILER BFW PUMPS
47202 DEAERATOR CHEMICAL TREATMENT
41204 (2) MEDIUM PRESSURE BOILER BFW PUMPS
47203 BOILER CHEMICAL TREATMENT
NATURAL GAS
CLEAN TAIL GAS
REFERANCE R-02-0003
40202 AMINE SCRUBBING SYSTEM
MP STEAM
ATMOSPHERE
LP STEAM
44202 MEDIUM/LOW PRESSURE BOILER
COMBUSTABLE AIR
40203 CLAUS SULFUR RECOVERY SYSTEM
MAKE-UP WATER TO Rx GAS TRAIN BOILERS
SULFUR
14202 SULFUR STORAGE SUMP
41205 SULFUR STORAGE SUMP PUMP
CITY WATER
47204 WATER TREATMENT SYSTEM
WASTE TO later
34201 CITY WATER TANK
41203 CITY WATER PUMP
AKER KVAERNER
Engineering and Construction Division
Pittsburgh, Pennsylvania USA
DISCIPLINE
DESIGNER
DRAFTER
CHECKER
SCALE
CAD FILE NAME FILENAME
CONTRACT NO. CONTRACT
DRAWING NO. DRAWINGNO
REV. REV
REV DATE BY CHKD DESCRIPTION APPR
Proprietary information, do not disclose to unauthorized personnel. Contents of this print are trade secrets. This print is the confidential property of: INFO and is to be returned on request.
ENVIRES LLC
The HyMelt Process
WATER GAS SHIFT OPTION
PROCESS FLOW DIAGRAM
WATER GAS SHIFT SYSTEM
FOR: FOR
LOCATION: LOC
SCALE: SCALE
PLOT RATIO: RATIO
CLIENT#1
CLIENT#2
CLIENT#3
START DATE: DATE
DWG. # XXXXXXXX
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Balance14Jul03.xls

C99168 PRELIMINARY MATERIAL BALANCE - Water Gas Shift Option

Stream Number	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2-10	2-11	2-12	2-13				
Description	COFEED	HTRIN1	COFEED2	WGOUT	WHBIN	WGWHB OUT	FLASHIN	FLASHOUT	FLCOND	WGSOUT	REC	PSAPROD	TAILGAS			Convey. H2	H2 PRODUCT
Temperature F	350	192.4	600	842.5	694.9	390.3	120	120	120	119.9	126.1	130	110			130	130
Pressure psia	500	500	497	496	493	490	487	486	486	485	500	475	19.7			475	475
Vapor Frac	1	1	1	1	1	1	0.646	1	0	1	1	1	1			1	1
Mole Flow lbmol/hr	1816.315	5537.209	10912.55	10912.55	10912.55	10912.55	10912.553	7045.592	3866.961	3324.701	3720.891	2994.447	2424.883			1400	1594.447
Mass Flow lb/hr	51524.224	139485.15	236323.5	236323.5	236323.5	236323.5	236323.49	166555.9	69767.546	78595.05	87960.9	6038.129	80368.87			2823.019	3215.111
Volume Flow cuft/hr	32111.641	77404.455	245686	307933	273443.6	197321.5	89632.643	88311.34	1503.461	41755.83	45844.97	40665.93	750683.8			19012.626	21653.31
Enthalpy MMBtu/hr	-91.849	-402.652	-921.167	-921.125	-936.191	-966.694	-1065.708	-588.848	-476.859	-277.868	-310.803	1.136	-282.267			0.531	0.605
Mole Flow lbmol/hr																	
CO	1702.668	1925.713	1925.713	422.348	422.348	422.348	422.348	422.347	0.001	199.299	223.048	0.028	276.508			0.013	0.015
H2	25.356	1736.241	1736.241	3239.606	3239.606	3239.606	3239.606	3239.594	0.012	1528.712	1710.882	2994.375	487.456			1399.966	1594.409
H2O	3.051	16.546	5391.891	3888.525	3888.525	3888.525	3888.525	25.552	3862.973	12.058	13.495	0	12.326			0	0
CH4	0.163	0.346	0.346	0.346	0.346	0.346	0.346	0.346	0	0.163	0.183	0.018	18.098			0.008	0.01
C2H2	0.272	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0	0.272	0.305	0	0.584			0	0
N2	1.108	2.348	2.348	2.348	2.348	2.348	2.348	2.348	0	1.108	1.24	0.025	24.673			0.012	0.013
CO2	83.55	1855.13	1855.13	3358.495	3358.495	3358.495	3358.495	3354.521	3.974	1582.944	1771.577	0	1583.099			0	0
H2S	0.031	0.065	0.065	0.065	0.065	0.065	0.065	0.064	0.001	0.03	0.034	0.002	20.974			0.001	0.001
COS	0.114	0.242	0.242	0.242	0.242	0.242	0.242	0.242	0	0.114	0.128	0	0.12			0	0
HCN	0	0	0	0	0	0	0	0	0	0	0	0	1.043			0	0
HG	0	0	0	0	0	0	0	0	0	0	0	0	0.001			0	0
*** VAPOR PHASE ***																	
Enthalpy Btu/lb	-1782.636	-2886.704	-3897.905	-3897.728	-3961.479	-4090.553	-3535.439	-3535.439		-3535.446	-3533.423	188.158	-3512.138			188.158	188.158
Heat Cap Btu/lb-R	0.261	0.327	0.415	0.436	0.429	0.421	0.36	0.36		0.36	0.361	3.448	0.254			3.448	3.448
Conductivity Btu-ft/hr-sqf	0.022	0.035	0.041	0.065	0.058	0.042	0.039	0.039		0.039	0.04	0.112	0.021			0.112	0.112
Density lb/cuft	1.605	1.802	0.962	0.767	0.864	1.198	1.89	1.886		1.882	1.919	0.148	0.107			0.148	0.148
Viscosity cP	0.024	0.019	0.024	0.029	0.027	0.02	0.017	0.017		0.017	0.017	0.01	0.016			0.01	0.01
VVSTDMX @ 60 F MMcuft/day	16.543	50.432	99.389	99.389	99.389	99.389	99.389	64.170		30.281	33.889	27.273	22.085			12.751	14.522
*** LIQUID PHASE ***																	
Enthalpy Btu/lb							-6834.935		-6834.971								
Heat Cap Btu/lb-R							1.146		1.146								
Conductivity Btu-ft/hr-sqf							0.335		0.335								
Density lb/cuft							46.404		46.405								
Viscosity cP							0.564		0.564								
Surface Ten dyne/cm							68.034		68.036								
Flowrate gpm																	

Balance14Jul03.xls

C99168 PRELIMINARY MATERIAL BALANCE - Water Gas Shift Option

Stream Number	2-14	2-15	2-16	2-17 *	1-20		2-18	2-19	2-20	2-21	2-22	2-23	2-24	2-25	2-26	2-27	2-28
Description	CLEAN TAIL GAS	CLAUS FEED	BOILER FLUE	SULFUR PRODUCT	H2FEED		CITY WATER	STRIPPED COND	DEMIN MAKE-UP	DEMIN TO Rx GAS TRAIN BOILERS	DEMIN TO WGS BOILERS	MED PRES BFW	WATER GAS SHIFT WHB BFW	WATER GAS SHIFT WHB BDOWN	MED PRES BDOWN	DEMIN PLANT WASTE	STEAM COND RETURN
Temperature F	100	120	465		120		60	212	100	100	100	250	250	308	474	100	298
Pressure psia	18.7	24.7	14.7		500		90	15	65	65	65	715	215	75	535	65	65
Vapor Frac	1	1	1		1		0	0	0	0	0	0	0	0	0	0	0
Mole Flow lbmol/hr	2352.714	192.502	6520		2094.63		2006.97	4219.37	6164.08	856.73	5187.01	6097.81	1772.97	17.76	120.34	62.26	1985.57
Mass Flow lb/hr	74618	7919	204170	670	7811.948		36155	76012	111046	15434	93444	109852	31940	320	2168	1122	35770
Volume Flow cuft/hr					26584.86												
Enthalpy MMBtu/hr					-3.749												
Mole Flow lbmol/hr																	
CO	276.489	0.019			77.237												
H2	487.427	0.029			1953.119												
H2O	119.470	13.190	928.77		0.268		2006.97	4219.37	6164.08	856.73	5187.01	6097.81	1772.97	17.76	120.34	62.26	1985.57
CH4	18.098	0.000			17.953												
C2H2	0.584	0.000			0.312												
N2	24.673	0.000	3505.48		23.59												
CO2	1424.789	158.310	1872.48		0.155												
H2S	0.021	20.953	SO2 - 22 ppmv		20.946												
COS	0.120	0.000			0.006												
HCN	1.043	0.000			1.043												
HG	0.001	0.000			0.001												
*** VAPOR PHASE ***																	
Enthalpy Btu/lb					-479.868												
Heat Cap Btu/lb-R					1.877												
Conductivity Btu-ft/hr-sqf					0.099												
Density lb/cuft					0.294												
Viscosity cP					0.011												
VVSTDMX @ 60 F MMcuft/day	21.428	1.753	59.383		19.077												
*** LIQUID PHASE ***																	
Enthalpy Btu/lb																	
Heat Cap Btu/lb-R																	
Conductivity Btu-ft/hr-sqf																	
Density lb/cuft							62.37	59.81	62	62	62	58.8	58.8	50.2	55	62	55.6
Viscosity cP																	
Surface Ten dyne/cm																	
Flowrate gpm							72.3	158.6	223.5	31.1	188.1	233.2	67.8	0.8	4.9	2.3	80.3

Balance14Jul03.xls

C99168 PRELIMINARY MATERIAL BALANCE - Water Gas Shift Option

Stream Number		2-31	2-32		2-35	2-36 *		2-37		2-40 *	2-41	2-42 *	2-43				
Description		SUPHT MPSTM	MPSTM TO PROCESS		LPSTM from WHB	LPSTM from Claus	LPSTM from Rx gas trains	LPSTM from Med Pres Boiler		LPSTM to Amine Plant	LPSTM to Deaerator	LPSTM to Sulfur Pit	LPSTM to Condensate Stripper	LPSTM to Rx gas train deaerator		NG to BOILER	
Temperature F		700	700		308	308	308	308		298	298	298	298	298		20	
Pressure psia		520	520		75	75	75	75		65	65	65	65	65		50	
Vapor Frac		1	1		1	1	1	1		1	1	1	1	1		1	
Mole Flow lbmol/hr		5375.41	5375.43		1755.20	194.28	814.99	407.77		1985.57	720.40	83.26	360.81	22.20		142.63	
Mass Flow lb/hr		96838	96838.34		31620	3500	14682	7346		35770	12978	1500	6500	400		2580	
Volume Flow cuft/hr			121088														
Enthalpy MMBtu/hr			-533.581														
Mole Flow lbmol/hr																	
CO			0														
H2			0														
H2O		5375.41	5375.43		1755.20	194.28	814.99	407.77		1985.57	720.40	83.26	360.81	22.20			
CH4			0														
C2H2			0														
N2			0														
CO2			0														
H2S			0														
COS			0														
HCN			0														
HG			0														
*** VAPOR PHASE ***																	
Enthalpy Btu/lb			-5510.013														
Heat Cap Btu/lb-R			0.566														
Conductivity Btu-ft/hr-sqf			0.032														
Density lb/cuft			0.8														
Viscosity cP			0.023														
VVSTDMX @ 60 F MMcuft/day																1.299	
*** LIQUID PHASE ***																	
Enthalpy Btu/lb																	
Heat Cap Btu/lb-R																	
Conductivity Btu-ft/hr-sqf																	
Density lb/cuft																	
Viscosity cP																	
Surface Ten dyne/cm																	
Flowrate gpm																	

Water Gas Shift Equipment List
C99268
EnviRes LLC HyMelt Process

Equipment Number	Quantity	Operating/Standby	Description	Capacity/Size	Motor Hp operating/ connected
14202	1	1/0	Sulfur Storage Pit	10,000 gallon	
31201	1	1/0	WGS Heat Exchanger	15.1 MM Btu/h; Shell: 0.5 Mo; Tube: 316 SS	
31202	1	1/0	Start-up Heater	5 MM Btu/h; Shell: CS; Tube: CS	
31203	1	1/0	WGS Cooler	99.0 MM Btu/h; Shell&Tube: 316 SS	
32105	1	1/0	Condensate Stripper	3 ft dia. X 20' T/T; 10' packed section; Shell SS	
34201	1	1/0	City Water Storage Tank	400,000 gallons, CS	
35201	2	1/1	WGS Filter	2 ft dia. X 10 ft high, 500 psig, 120 F	
35202	1	1/0	Water Gas Shift Reactor	10 ft dia x 20 ft high, 1.0 Cr, 0.5 Mo	
35204	1	1/0	WGS Cooler Flash Drum	9 ft.x 18 ft high	
35205	1	1/0	Blowdown Flash Drum	1.5 ft.dia X 3 ft. high	
35212	1	1/0	WGS Reactor Catalyst	1050 ft3 each reactor bed	
40201	1	1/0	H2 Purification System	28 million SCFD H2 Product	
40202	1	1/0	Amine Scrubbing System	22 MM SCFD feed	
40202.01	1	1/0	Absorber	7.6 ft dia. X 35' T/T; 10 SS trays; Shell CS	
40202.02	1	1/0	Regenerator	6.5 ft dia. X 55' T/T; 20 SS trays; Shell CS	
40202.03	1	1/0	Lean/ Rich Exchanger	27.3 MM Btu/hr; Plate&Frame: 316 SS	
40202.04	1	1/0	Lean Solvent Cooler	13.7 MM Btu/h; Plate&Frame: 316 SS	
40202.05	1	1/0	Reflux Condenser	17.2 MM Btu/h; Tubes: 316SS; Shell: CS	
40202.06	1	1/0	Reboiler	32.6 MM Btu/h; Tubes: SS; Shell: CS	
40202.07	1	1/0	Reflux Drum	3 ft dia. X 6' T/T; SS	
40202.08	1	1/0	Activated Carbon Bed	8 ft dia. X 14' T/T; CS; 530 cu ft activated carbon	
40202.09	1	1/0	Rich Solution Filter	650 gpm; 50 micron; 8" line	
40202.10	1	1/0	Activated Carbon Inlet Guard Bed	200 gpm; 10 micron; 4" line	
40202.11	1	1/0	Activated Carbon Outlet Guard Bed	200 gpm; 10 micron; 4" line	
40202.12	2	1/1	Lean Solvent Pump	700 gpm @ 50 psi; Shaft: SS	40 / 80
40202.13	2	1/1	Rich Solvent Pump	650 gpm @ 50 psi; Shaft: SS	30 / 60
40202.14	2	1/1	Reflux Pump	40 gpm @ 100 ft TDH ; SS	2 / 4
40202.15	2	1/1	Make-up Pump	150 gpm @ 100 ft TDH	7.5 / 15
40202.16	1	1/0	Amine Storage Tank	20,000 gal; underground	
40203	1	1/0	Claus Sulfur Recovery Plant	8 tons/day skid mounted	
40203.01	1	1/0	Claus Plant Incinerator	Operation at 1000 F w/ recuperator; 0.83 MM Btu/h fuel	
40205	1	1/0	CO Power Generation Plant	Not included in this option as produce 14.5 MM SCFD Hydrogen (9.5 MM SCFD more than base case)	
41201	2	1/1	WH Boiler Feedwater Pump	80 gpm x 200 psi TDH	20 / 40
41203	2	1/1	City Water Pump	300 gpm x 100 ft. TDH	15 / 30
41204	2	1/1	MP BFW Pump	250 gpm x 700 psi TDH	150 / 300
41205	2	1/1	Sulfur Storage Pump	100 gpm x 30 psi TDH	5 / 10
41501	2	1/1	Cooling Tower Pump	13,000 gpm x 50 psi TDH	500 / 1000
42201	1	1/0	Water Gas Shift Recycle Compressor	800 acfm x 25 psi pressure rise, 500 psig discharge	150 / 150
44201	1	1/0	WGS Waste Heat Boiler	31,600 lbs/hr (60 psig)	
44202	1	1/0	Medium/ Low Pressure Boiler	97,000 lbs/hr (505 psig/700 F) & 7,300 lbs/hr (60 psig) Est. one 75 Hp comb air fan	75 / 75
44301	1	1/0	Cooling Tower	130 MM Btu/hr; 13,000 gpm circulation Est. three fans @ 125 Hp ea.	375 / 375
47202	1	1/0	Deaerator Chemical Treatment System	Est. two 1/2 Hp metering pumps	0.5 / 1
47203	1	1/0	Boiler Chemical Treatment System	Est. two 1/2 Hp metering pumps	0.5 / 1
47204	1	1/0	Water Treatment System	250 gpm demin plant w/ inlet filter, regeneration Est. two 15 Hp demin pumps, two 20 Hp blowers; two 15 Hp pumps for regen,etc.	35 / 100
47501	1	1/0	Deaerator	350 gpm; Storage Section - 6.5 ft dia. X 21 ft T/T	

Water Gas Shift Equipment List
C99268
EnviRes LLC HyMelt Process

Project Direct Cost Comparison to Base Case

Equipment, Material Costs & Field labor			
Areas	Base Case	WGS Cost	WGS Delta
Feed Prep			$0
Reactor Area			$0
WGS Area	----	3113700	$3,113,700
Hydrogen Purification	1998200	2961400	$963,200
Amine Scrubbing	1593000	2371500	$778,500
Claus Plant	2888500	3247000	$358,500
Steam Generation			$3,511,700
Power Generation		----	$0
Utilities			$2,800,000
			$11,525,600

Results:

1.) WGS option ---> $22,083,050 Project Total
Produce 9.5 MM SCFD more of hydrogen than base.

2.) Base Power Options (from CO)
Simple Cycle: Generate 17.8 MW for $15,200,000
Combined Cyc: Generate 27 MW for $30,600,000

Water Gas Shift Equipment List
C99268
EnviRes LLC HyMelt Process

Preliminary Economics of Water Gas Shift Option (Differential to Base Case)

Capital Cost Multiplier	**1**		
Basis:			
Avg. On-stream Factor	**90%**		
Amortization Parameters			
Annual Interest Rate	**10%**		
Payoff Period	**20**	years	

Labor Rates (all-up):

Engineering	**80**	$/hr
Field Labor	**70**	$/hr
Constr. Mgt	**85**	$/hr

Estimated Differential Capital Costs:

Major Equipment Cost		6,206,000
Installed Equipment Cost		5,319,800
Direct Totals		11,525,800
Constr Equip & Indirects		$2,305,160
Constr. Mgt. Staff Supv		$794,100
Freight		$366,520
Taxes & Permits		$504,830
Engineering		$2,545,600
Other Project Costs (Ovhd & GA)		$1,342,339
Contingency		$3,420,768
Indirect Totals		$11,279,317
Total Capital Cost		$22,805,117

Field Hrs	**49300**		
% Directs	**20%**		
% Field Hrs	**18.95%**	9342	
% Directs	**3.18%**		
% Directs	**4.38%**		
Manhours	**31820**		
% Above Indirects	**20.60%**		
% Total	**15.00%**		

Differential Operating & Maintenance Costs, $ per year:

Natural Gas @ $ / MM Btu	**5**	$2,135,250	MM SCFD	**1.3**	Btu/SCF	**1000**
Electricity @ cents / kwh	**0.04**	$443,081	kwh	**1405**		
Cooling Water Chem @ cents/kgal	**0.02**	$122,990	gpm	**13000**		
BFW Chem @ cents/kgal	**0.08**	$12,488	gpm	**330**		
LP Stm (from Reactor) @ $ / k lb	**0**	$0	lb/hr consumed	**14300**		
Operation/ Maint @ $ / manhr	**50000**	$150,000	No. of addnl	**3**		
Insur & Taxes @ 1% Capital/yr		$228,051				
O & M Mgt Fees		**$400,000**				
Spare Parts @ 5% Major Equip/yr		$310,300				
Total O & M Cost		$3,802,161				
Amortization Cost @ % capital/ yr	11.75	$2,678,680				
Total Yearly Costs		6,480,841				

Differential Sales, $ per year:

CO Fuel Lost @ $ / MM Btu	**2.5**	-$4,142,960	MM SCFD	**-16.54**	Btu/SCF	**305**
PSA TailGas Fuel Lost @ $ / MM Btu	**1.5**	-$648,459	MM SCFD	**-3.76**	Btu/SCF	**350**
Total Sales		-$4,791,419				

Net Hydrogen Production Cost, $ per year		$11,272,260
Net Hydrogen Production Cost, $ per k scf	$	2.86

MM SCFD	**12**

Appencix III
Siemens Westinghouse Power Corporation

Selection issues for the DF-42 and catalytic burners are compared in Table AIII 1.

Table A III 1
Candidate Burner Comparison

	DF-42	Catalytic
Technical Areas		
Commercial fleet	(+) Many running units	(-) None running
Proven on CO/H_2 fuel?	(-) No	(-) No
NOx control	(-) Burner designed for 42 ppm with diesel fuel (DF). May get 25 ppm with syngas. Needs steam or water injection, plus SCR	(+) Lowest NOx emission. Catalytic burner has tested capability to achieve around 2 ppm NOx without SCR (but not with this fuel). SCR may not be needed.
Dual-fuel capability (natural gas and high-CO syngas)	(+) Dual-fuel capable	(-) Dual-fuel capability may be complicated.
Programmatic Areas		
Technology advancement	(-) Mainly adaptation of an existing design	(+) Development of new type of burner
Scalability	(-) ~1/250 scale testing	(+) ~full-scale testing
Burner geometry model	(-) Model needed	(+)STC has model
Transition geometry model	(-) Model needed	(-)Model needed
Kinetics model	All by CS&E	Catalytic partial reactions by STC, downstream combustion by CS&E
Test burner design	(-) Design needed	(+) Design complete
Test burner fabrication	(-) Hardware needed	(?) Hardware may be needed
Commercial Areas		
GT (w/burner) capital cost	(+) Slightly less?	(-) Slightly more?
SCR capital cost	(-) SCR needed	(?) SCR may not be needed
SCR operating cost	(-) SCR needed	(+) less than for DF-42, maybe zero.
Development needed	(+) Basic burner is developed, may need modification	(-) Burner development needed
Commercial Availability	(+) Sooner	(-) Later

EnviRes High-CO Gas Turbine Study Specification

This document describes the key parameters that form the boundary conditions, for the conceptual design of a gas turbine operating with HyMelt off-gas. This is intended to be a working document that can be updated throughout the project by Siemens Westinghouse.

Contents

7 Revisions

Rev.	Date	Description of Change
A	22 Oct 03	Original Issue

8 Syngas Composition

The composition, temperature, and pressure of HyMelt syngas from Illinois #6 Coal are shown in Table 2. The syngas from petroleum coke will be virtually identical to that from coal. The contaminants listed in Table 2 are all expected to be less than 1 ppmv.

Table A III 2
Illinois #6 Coal Syngas Composition

Composition

CH_4	0.07	%(vol)
CO	75.72	%(vol)
CO_2	3.92	%(vol)
COS [1]	-	%(vol)
H_2	19.96	%(vol)
H_2O	0.30	%(vol)
H_2S [1]	-	%(vol)
N_2	0.03	%(vol)
Total	100.00	%(vol)

Properties

Temperature	160 or lower	°F	71 or lower	°C
Pressure	365 to 415	psia	25 to 29	bar
HHV	309	Btu/scf	12.16	MJ/Nm^3
HHV	4,995	Btu/lb	11.61	MJ/kg
LHV	298	Btu/scf	11.76	MJ/Nm^3
LHV	4,832	Btu/lb	11.23	MJ/kg

Contaminants

Barium (Ba)	ppm(w)
Calcium (Ca)	ppm(w)
Chlorides (Cl)	ppm(w)
Copper (Cu)	ppm(w)
Iron (Fe)	ppm(w)
Lead (Pb)	ppm(w)
Magnesium (Mg)	ppm(w)
Manganese (Mn)	ppm(w)
Nickel (Ni) [1]	ppm(w)
Phosphorus (P) [1]	ppm(w)
Potassium (K)	ppm(w)
Silica (SiO2)	ppm(w)
Silicon (Si)	ppm(w)
Sodium (Na)	ppm(w)
Vanadium (V)	ppm(w)
Zinc (Zn)	ppm(w)
Other trace metals	ppm(w)

[1] These constituents may be harmful to catalysts.

9 Gas Turbine Size

The original proposal assumed that the HyMelt® process module would produce about 1157 million Btu/hr of CO-rich gas, which was slightly less than the fuel requirements of a W501D5A gas turbine. The actual gasification module may produce more gas, which would match the fuel requirements of a larger turbine or turbines.

Table 3 lists the approximate syngas consumption of the three W-class gas turbines in 1x1 and 2x1 combined cycle arrangements. More detailed calculations performed during the project will determine the actual syngas requirements.

Table A III 3
Estimated Gas Turbine Syngas Consumption

Combined Cycle Plant Designation	Gas fuel, Million Btu/h	Syngas, Million scf/h[1]	Gas Turbine Power, MW	Combined Cycle Power, MW
1x1.W501D5A	1,169	3.9	121	173
1x1.W501FD	1,726	5.8	190	283
1x1.W501G	2,146	7.2	253	365
2x1.W501D5A	2,338	7.8	241	346
2x1.W501FD	3,452	11.6	379	567
2x1.W501G	4,292	14.4	506	730

[1] Estimated consumption of syngas with an LHV of 298 Btu/scf.

10 Use of Natural Gas

Natural gas is the preferred fuel for start-up and, if necessary during shutdown.

11 Emission Limits

The two tentative plant sites are

A. East St. Louis, Illinois

B. Decatur, Illinois

In the absence of specific information about emission limits at these sites, the values of 2 ppmv for both CO and NOx seem to be the best choice. In the near future, stack emissions are projected to be as low as 2 ppmv NOx and 2 ppmv CO when corrected to 0% moisture and 15% oxygen. These projections are based on (1) current limits in California, Massachusetts, New York, and New Hampshire of 2.5 to 3.5 ppmv NOx, and (2) the current best available emission control technology (BACT) can achieve 2-3 ppmv for both NOx and CO. These limits are not expected to be relaxed during the next 15 years.

If the gas turbine exhaust contains NOx and CO emissions higher than the target levels, some exhaust gas treatment, such as selective catalytic reduction, will have to be added.