Appendix A
Case 1: Texaco gasifier and steam reforming of natural gas (including fugitive emissions study)

CASE 1

The following report gives a brief description of each of the units in the block flow diagram. All capital cost data in this report, except where otherwise specified, has been estimated from similar installations described in the Houston Area Medium-BTU Coal Gasification Project Final Report, published in June 1982 by Union Carbide [1] (All references to material in this report will be referred to as Houston, and all scaling exponents from the Houston report are 0.65). The plant consumes 0.96 million metric tons of coal, 0.82 million metric tons of oxygen, 0.18 billion standard cubic meters of natural gas, and produces 0.50 million metric tons of mixed alcohols per year.

SYNGAS PRODUCTION FROM NATURAL GAS

Compressed natural gas (stream 14) and steam (stream 15) are reacted in the Steam Reformation Block. The cooled output gas (stream 17) goes to the Rectisol Block. The cost for this unit was estimated from data found for a hydrogen production facility, with a scaling exponent of 0.8 [2]. The fuel gas usage for this block is estimated to be 30% of the natural gas feed.

COAL PREPARATION

Coal (stream 10) and water (stream 12), are sent to the Coal Preparation Block. The coal is crushed, mixed with the water, and pumped to the gasifier as a ~60% solids mixture by weight (stream 13). The Coal Preparation Block is composed of four plants from the Houston report. Plant 01 is the Coal Slurry Preparation Plant. The cost of this plant was scaled linearly due to its multiple train format; where each train can handle up to 1,150 tons of coal per day. Plant 61 is the Reclaiming, Transfer, and Crushing Plant. The cost of this plant was scaled exponentially. Plant 22 is the Barge Terminal. This plant was scaled exponentially. Plant 60 is Coal Receiving and Storage and again the cost for this plant was scaled exponentially.

CRYOGENIC OXYGEN PLANT

Compressed air (stream 1) is cooled and sent to the Cryogenic Oxygen Plant Block, and is separated into high purity oxygen (stream 2), nitrogen (stream 3), argon (stream 6), and a water and carbon dioxide waste mixture (stream 28). A small quantity of nitrogen

(stream 19) is sent to the Rectisol Block. The Cryogenic Oxygen Plant Block does not include the inlet air compressors or the outlet oxygen compressors. In the cryogenic system, there are provisions for gaseous and liquid oxygen backups sufficient to maintain downstream plant operation in the event of a shutdown in the cryogenic facility. We also assume that some scale down is possible for this system, so the capital investment has been calculated linearly for the reduction in trains, and exponentially for throughput reduction per train. Each train can produce up to 2,000 tons of oxygen per day. The Houston plants that comprise the Cryoplant Block are 02 and 08.

RECTISOL

The cooled raw gas streams (streams 17 and 18), nitrogen gas (stream 19) for methanol regeneration, and methanol make-up (stream 20) for vapor loss all enter the Rectisol Block. H_2S levels are reduced to the ppb range and CO_2 levels to the ppm range. The clean syngas (stream 22) is sent to the alcohol synthesis loop. A CO_2-N_2 mixture (stream 24) and a CO_2 rich stream (stream 23) are produced as byproducts. Condensed water is also removed (stream 17A). This block is the same as Houston Plant 05. The cost for this plant was estimated by using exponential scaling.

TEXACO GASIFIER

The coal slurry (stream 13) is mixed with compressed oxygen (stream 9) and burned at 1,200-1,400°C and 8,000 kPa in the Texaco Gasifier Block. The hot, raw gas (stream 8) is sent to the Syngas Heat Recovery Block, and the slag (stream 33) is sent to the Slag Handling Block. The equivalent of the Texaco Gasifier Block is Plant 03 in the Houston report, and each train can handle up to 958.3 tons of coal per day.

SLAG HANDLING

Molten slag from the Texaco Gasifier Block (stream 33) is direct quenched with water and sent to slag disposal (stream 37). A small amount of water (stream 36) is purged from the closed loop and is replaced by water make-up (stream 34). This block is the same as Houston Plant 63. The cost for this plant was estimated by exponential scaling.

COS HYDROLYSIS

The sulfide rich stream from the Rectisol Block (stream 25) and steam are sent to the COS Hydrolysis Block where COS is converted to H_2S. The product gas (stream 41) is sent to the Claus Sulfur Recovery Block. The COS Hydrolysis Block cost is assumed to be negligible.

SYNGAS HEAT RECOVERY

The raw gas stream from the Texaco Gasifier Block (stream 8) at 1,300°C and 8,000 kPa enters the Syngas Heat Recovery Block and is cooled against process boiler feed water at 25°C (stream 71). The raw gas stream exits at 300°C (stream 18), and the boiler feed exits as steam at 10,000 kPa and 535°C (stream 68). It is assumed that the raw gas stream is cooled further prior to entering the Rectisol Block. This block is part of Houston Plant 04.

CLAUS PLANT

Hydrogen sulfide rich gas (stream 41) is mixed with air (stream 42) and converted in a two-step reaction to elemental sulfur (stream 46). The unreacted hydrogen sulfide (stream 45) is then sent to the Beavon Plant for further treatment. This block is the same as Houston Plant 06. The cost for this plant was estimated by exponential scaling.

BEAVON PLANT

The Claus tail gas (stream 45) and air (stream 47) go to the Beavon Block. Additional sulfur is made (stream 51), and the gas leaving (stream 50) is sufficiently free from sulfides that it can be vented to the atmosphere. A sour water stream (stream 54) is sent from the plant for treatment. The cost of this block was estimated from data collected from various sources, with a scaling exponent of 0.65 [3].

MoS_2 ALCOHOL SYNTHESIS LOOP

Clean syngas (stream 26) at 140 atmospheres enters the catalytic reactor along with the syngas recycle (stream 56B). The products (stream 26A) are taken to the separations block where the unreacted syngas is removed (stream 59). Part of this stream (stream 27) is sent to power generation while the rest (stream 56) is sent to CO_2 removal. The cost of this block was estimated from the cost of a methanol synthesis loop, with a scaling exponent of 0.565 [4].

CO_2 REMOVAL

This block is very similar to the Rectisol Block. Recycled gas from the alcohol separation block (stream 56) is the only feed. CO_2 free syngas (stream 56A) is then recompressed and sent back to the reactor. CO_2 is taken off as a product (stream 57). The cost of this block is calculated the same way as in the Rectisol block. Its power requirements are included in the Rectisol block.

COMBUSTION GAS TURBINE

The light hydrocarbons extracted from the reactor recycle (stream 27) in the Alcohol Synthesis Loop are sent to a combustion gas turbine with hot gas heat recovery. The power from the combustion gas turbines is assumed to be 35% of the HHV of the fuel in stream 27. This is consistent with recent studies on IGCC plants using medium BTU synthesis gas [9]. The cost for this block was estimated from data taken from an EPRI report, where each train can produce up to 200 MW with a scaling exponent of 0.67 [10].

EXHAUST GAS HEAT RECOVERY

The hot exhaust gas stream from the Gas Turbine Block (stream 70) at 590°C and 101 kPa enters the Exhaust Gas Heat Recovery Block and is cooled against process boiler feed water at 25°C (stream 73). The exhaust gas stream exits at 200°C (stream 75), and the boiler feed exits as steam at 10,000 kPa and 535°C (stream 74). The cost for this block was estimated from data taken from an EPRI report, where each train can generate up to 425 tons of steam per hour with a scaling exponent of 0.67 [10]. This block also supplies the reheat between the high pressure and intermediate pressure steam turbines.

POWER GENERATION

The steam from the Syngas Heat Recovery Block and the Exhaust Gas Heat Recovery Block is let down in the steam turbines for power production. The cost for this block was estimated from data taken from an EPRI report, where each train can produce up to 500 MW with a scaling exponent of 0.67 [10]. This is a 3-stage steam turbine system. The high pressure stage inlet is 535°C, 10,000 kPa steam. The exhaust at 3,000 kPa is reheated to 535°C before entering the intermediate pressure stage. The final stage exhausts to a surface condenser at 7.4 kPa. Each turbine has an assumed efficiency of 75%.

IMPORTANT POINTS OF INFORMATION

Several decisions were made for the creation of this case that should be outlined. Also, there are alternatives that have not been fully considered which will be considered in more detail later. They are listed below along with the reasons behind them.

- Catalytic steam/methane reformation used to adjust the H_2:CO ratio upwards. The ratio from coal gasification is less than 1. Since the optimal ratio for higher alcohol synthesis is approximately 1.1 - 1.2, an additional source of hydrogen was required. The reformer was assumed to operate at equilibrium, as suggested in the literature [8]. Other alternatives to this block are available and will be considered.

- The traditional method for purifying high quantities of pure oxygen is by cryogenics, which is used for this case. However, recent reports suggest that membrane and catalytic processes are becoming economically competitive with cryogenics. Therefore, we will examine these alternatives.

- The Rectisol system was chosen for this case for H_2S and CO_2 removal. The major alternative to Rectisol is Selexol. The literature indicates that Rectisol has a higher installed capital cost, but a lower fixed operating cost than Selexol. Both of these systems are capable of removing H_2S to the ppm level and beyond. However, there is some evidence that quantities of H_2S are beneficial if the reaction involves the MoS_2 catalyst. If this is so, then a system such as the Benfield acid gas removal process might be more suitable. The Benfield system does not remove as much H_2S and has lower capital and operating costs.

- The operating pressure for the Texaco gasifiers has been set at 8,000 kPa. This is the highest pressure indicated in the literature at which a Texaco gasifier has been run. Since the pressure required at the reactor is 14,000 kPa, we would of course like to run the gasifiers at as high a pressure as possible. Another limiting factor is the oxygen feed pressure. According to various sources, the highest pressure available with conventional centrifugal compressors is around 80 atmospheres. It is assumed that, because of the size of this case, a higher cost for the oxygen compressor would be acceptable in return for savings on feed gas compression. In addition, other gasification systems will also be investigated.

TOTAL ESTIMATED CAPITAL INVESTMENT (MM$)

Synthesis Gas via Natural Gas	15.9
Coal Preparation	40.8
Texaco Gasifier	156.7
Slag Handling	3.0
Gas Turbines	45.0
Steam Turbines	22.1
Exhaust Gas Heat Recovery	9.9
Synthesis Gas Heat Recovery	4.6
Cryogenic Oxygen Production	89.3
Rectisol (Acid Gas Separation)	34.9
Claus (Sulfur Recovery)	10.3
Beavon	2.2
Alcohol Synthesis Loop	47.2
CO2 Removal	26.9
Other Compressors	54.1
TOTAL	562.8

(sum of individual block costs does not exactly equal the total due to round-off)

OVERALL ECONOMIC EVALUATION

The following table gives the totals and breakdowns for the yearly operating costs as well as the total installed cost for the plant.

TOTAL ESTIMATED INSTALLED CAPITAL COST (MM$)		562.8
TOTAL ESTIMATED OPERATING COSTS (MM$/YR)		149.6
Coal ($33/metric ton delivered)	31.8	
Natural Gas ($106/1000 cubic meters)	18.7	
Other Expenses	99.2	
TOTAL ESTIMATED CREDITS (EXCLUDING ALCOHOLS) (MM$/YR)		46.6
Power ($0.05/kWh)	39.2	
Slag ($5.5/metric ton) (6)	0.6	
Sulfur ($300/metric ton) (7)	6.9	

Credits for nitrogen, argon, and other rare gases have not been included because prices were not available and potential markets have not yet been identified.

STAND ALONE COMPRESSORS AND POWER SUMMARY

There are 5 compressors that are not included in any of the blocks. Their inlet, outlet, pressure change, power rating, and installed capital cost are listed below. Following that is a summary of the total plant power output/input (5). An efficiency of 70% is assumed for all compressors, with a maximum pressure ratio of 5 for a single stage of compression. Multiple compression stages with intercooling are used for services with pressure ratios greater than 5.

FUNCTION	INLET STREAM	P (kPa)	OUTLET STREAM	P (kPa)	POWER (MW)	COST (MM$)
Air Prep	1A	101	1	500	-31.1	28.3
O2 Prep	2	500	9	8136	-10.8	10.1
Reform Comp	17C	1400	17	8106	-6.4	5.8
Rxtr Prep	22	8106	26	14000	-7.1	6.2
Recy Comp	56A	12666	56B	14000	-3.6	3.6
Total compressor needs					-58.9	
Other in plant needs					-10.1	
Total produced in steam and gas turbines					167.0	
Net power output					98.0	
Total installed compressor costs (1992 dollars)						54.1

REFERENCES

1. *Final Report on the Houston Area Medium-BTU Coal Gasification Project, Volumes 2 and 3.* Prepared by the Linde Division of Union Carbide Corporation, June 1982.

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3. "Beavon Sulfur Removal Process," *Hydrocarbon Processing,* April 1984, p. 78.

4. Frank, Marshall E. "Methanol: Emerging Uses, New Syntheses," *Chemtech,* June 1982, p. 358-362.

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7. *Chemical Marketing Reporter,* August 31, 1992.

8. Rase, Howard F., *Chemical Reactor Design for Process Plants, Volume 2,* John Wiley & Sons, New York, 1977, pp. 133-138.

9. Report TR-101789, Houston Lighting and Power Company's Evaluation of Coal Gasification Coproduction Energy Facilities, EPRI Project 3226-04, 1992.

10. EPRI Report TR-100319, *Evaluation of a 510-MWe Destec GCC Power Plant Fueled With Illinois No. 6 Coal,* Prepared by Fluor Daniel, Inc., EPRI Project 2733-12, 1992.

Figure A.1 : Block Flow Diagram for Case 1

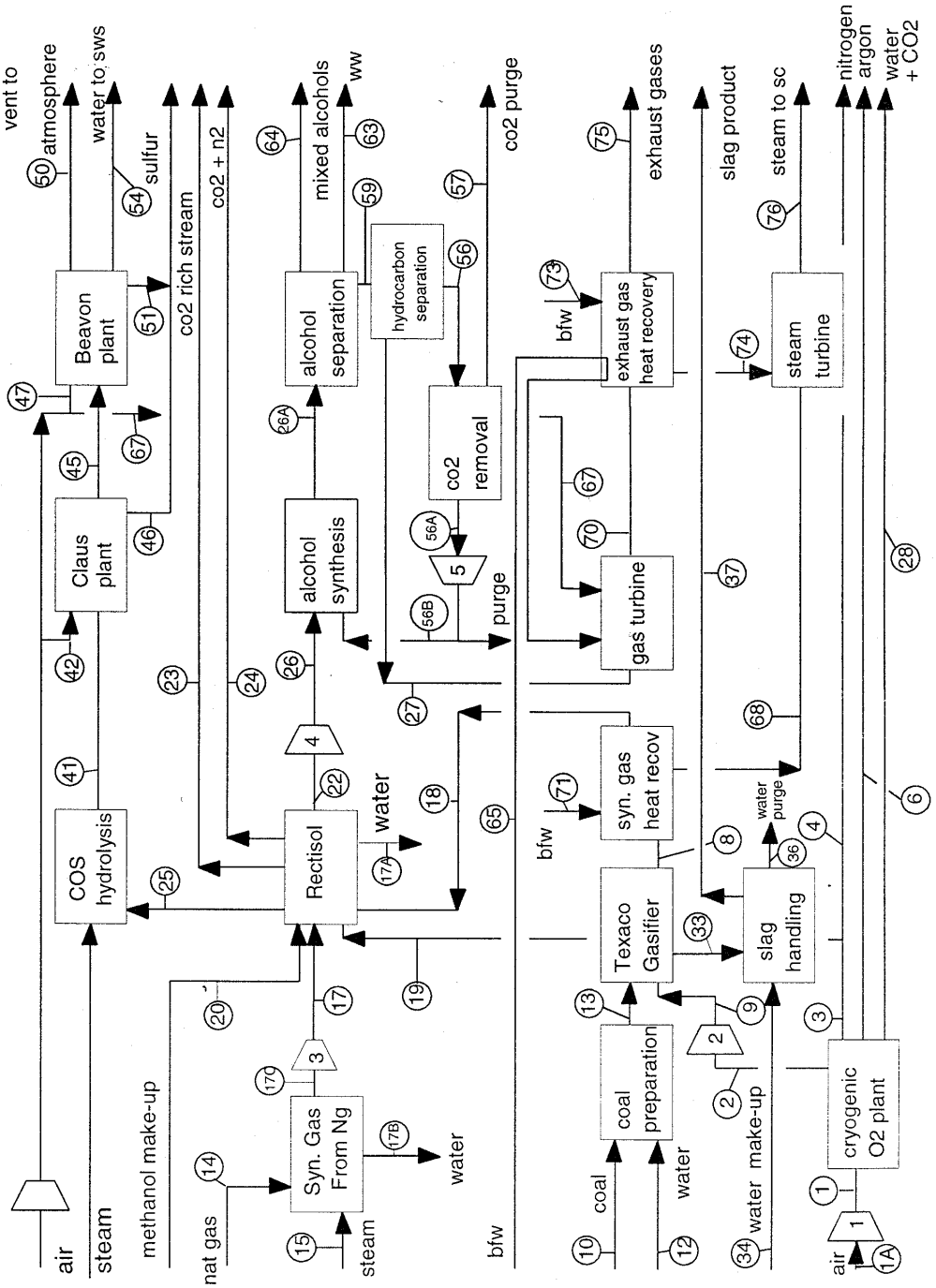

Table A.1 Case 1 Flow Table

	001	001A	002	003	004	006	008	009	010	012
Ar	142.5	142.5				142.5				
C									6646.6	
CH3OH										
C2H5OH										
C3H7OH										
C4H9OH										
C5H11OH										
CO							4770.4			
CO2	4.9	4.9					1861.6			
COS							8.9			
CaCO3										
H2							3649.6		2716.0	
H2O	368.3	368.3					3098.6		76.5	4061.1
H2S							80.4			
N2	11933.5	11933.5		11933.5	11694.5		54.3		58.8	
NH3							9.1			
O2	3208.2	3208.2	3208.2					3208.2	523.5	
S									89.3	
Al2O3									124.4	
C3H6O2										
C4H8O2										
CH4							5.7			
C2H6										
kmol/hr	15657.5	15657.5	3208.2	11933.5	11694.5	142.5	13538.5	3208.2	10235.2	4061.1
kg/hr	449349.1	449349.1	102664.0	334137.8	327447.3	5700.1	283586.3	102664.0	120516.7	73098.9
Temp.(C)	25.0	25.0	25.0	25.0	25.0	25.0	1300.0	225.0	25.0	25.0
Press.(KPA)	500.0	101.3	500.0	500.0	500.0	500.0	8135.8	8135.8	101.3	101.3

Table A.1 Case 1 Flow Table (cont'd)

	013	014	015	017	017A	017B	017C	018	019	020	022
Ar											
C	6646.6										
CH3OH										0.9	
C2H5OH											
C3H7OH											
C4H9OH											
C5H11OH											
CO				611.7			611.7	4770.4			5382.1
CO2				143.1			143.1	1861.6			
COS								8.9			
CaCO3											
H2	2716.0			2407.5			2407.5	3649.6			6057.1
H2O	4137.6		1785.3		3098.6	887.3		3098.6			
H2S								80.4			
N2	58.8							54.3	238.9		
NH3								9.1			
O2	523.5										
S	89.3										
Al2O3	124.4										
C3H6O2											
C4H8O2											
CH4		755.4		0.6			0.6	5.7			5.7
C2H6											
kmol/hr	14296.2	755.4	1785.3	3162.9	3098.6	887.3	3162.9	13538.5	238.9	0.9	11444.9
kg/hr	193615.7	12086.3	32134.7	28248.8	55773.9	15972.2	28248.8	283586.3	6690.6	29.3	162904.7
Temp.(C)	25.0	25.0	300.0	25.0	25.0	25.0	25.0	300.0	25.0	25.0	25.0
Press.(KPA)	8135.8	1480.0	1480.0	8106.0	8106.0	1400.0	1400.0	8106.0	500.0	101.3	8106.0

Table A.1 Case 1 Flow Table (cont'd)

	023	024	025	026	026A	027	028	033	034	036
Ar										
C										
CH3OH			0.9		628.3					
C2H5OH					655.4					
C3H7OH					145.0					
C4H9OH					36.5					
C5H11OH					15.2					
CO				5382.1	7001.9	714.2				
CO2	1202.8	701.6	100.2		1493.7	152.4	4.9			
COS			8.9							
CaCO3										
H2				6057.1	7880.0	803.8				
H2O					140.1		368.3		7689.1	7689.1
H2S			80.4							
N2		293.2								
NH3			9.1							
O2										
S										
Al2O3										
C3H6O2								124.4		
C4H8O2					18.0					
CH4					11.9					
C2H6				5.7	4380.8	446.8				
					171.6	17.5				
kmol/hr	1202.8	994.8	199.5	11444.9	22578.5	2134.7	373.3	124.4	7689.1	7689.1
kg/hr	52923.7	39082.0	7861.0	162904.7	420678.3	35983.3	6847.1	12693.4	138404.0	138404.0
Temp.(C)	25.0	25.0	25.0	98.0	310.0	25.0	25.0	1300.0	25.0	25.0
Press.(KPA)	8106.0	8106.0	8106.0	14000.0	12666.0	12666.0	500.0	101.3	101.3	101.3

Table A.1 Case 1 Flow Table (cont'd)

	037	041	042	045	046	047	050	051	054	056	056A
Ar											
C											
CH3OH		0.9		0.9			0.9				
C2H5OH											
C3H7OH											
C4H9OH											
C5H11OH											
CO										6287.7	6287.7
CO2		109.1		109.1			109.1			1341.4	
COS											
CaCO3											
H2										7076.3	7076.3
H2O				84.8					89.3		
H2S		89.3		4.5							
N2			159.6	159.6		21.1	180.6				
NH3		9.1		9.1			9.1				
O2			42.4			5.6	3.4				
S					84.8			4.5			
Al2O3	124.4										
C3H6O2											
C4H8O2											
CH4										3933.9	3933.9
C2H6										154.1	154.1
kmol/hr	124.4	208.4	202.0	368.0	84.8	26.7	303.1	4.5	89.3	18793.3	17452.0
kg/hr	12693.4	8020.7	5826.1	11131.8	2715.1	768.7	10149.9	142.9	1607.6	316794.0	257773.6
Temp.(C)	25.0	25.0	25.0	200.0	125.0	25.0	100.0	125.0	50.0	25.0	25.0
Press.(KPA)	101.3	101.3	101.3	101.3	101.3	101.3	101.3	101.3	101.3	12666.0	12666.0

Table A.1 Case 1 Flow Table (cont'd)

	056B	057	059	063	064	065	067	068	070	071
Ar										
C										
CH3OH					628.3					
C2H5OH					655.4					
C3H7OH					145.0					
C4H9OH					36.5					
C5H11OH					15.2					
CO	6287.7		7001.9							
CO2		1341.4	1493.7						1348.4	
COS										
CaCO3										
H2	7076.3		7880.0							
H2O				140.1		967.2		10615.6	2717.1	10615.6
H2S										
N2							20422.1		20422.1	
NH3										
O2							5428.7		3714.7	
S										
Al2O3										
C3H6O2				18.0						
C4H8O2				11.9						
CH4	3933.9		4380.8							
C2H6	154.1		171.6							
kmol/hr	17452.0	1341.4	20928.0	170.1	1480.4	967.2	25850.8	10615.6	28202.4	10615.6
kg/hr	257773.6	59020.4	352777.2	4905.1	62996.0	17409.0	745536.0	191080.1	798928.2	191080.1
Temp.(C)	45.0	25.0	25.0	25.0	25.0	25.0	25.0	535.0	590.0	25.0
Press.(KPA)	14000.0	12666.0	12666.0	12666.0	12666.0	10000.0	101.3	10000.0	101.3	10000.0

Table A.1 Case 1 Flow Table (cont'd)

	073	074	075	076	077	078
Ar						
C						
CH3OH						
C2H5OH						
C3H7OH						
C4H9OH						
C5H11OH						
CO						
CO2			1348.4			
COS						
CaCO3						
H2						
H2O	3600.0	3600.0	2717.1	14215.6	14215.6	14215.6
H2S						
N2			20422.1			
NH3						
O2			3714.7			
S						
Al2O3						
C3H6O2						
C4H8O2						
CH4						
C2H6						
kmol/hr	3600.0	3600.0	28202.4	14215.6	14215.6	14215.6
kg/hr	64800.6	64800.6	798928.2	255880.7	255880.7	255880.7
Temp.(C)	25.0	535.0	200.0	40.0	380.0	535.0
Press.(KPA)	10000.0	10000.0	101.3	7.4	3000.0	3000.0

Table A.2 Case 1 Energy Analysis

ELECTRICITY		
Plant	Electricity Used (MW)	Electricity Produced (MW)
Coal Preparation Plant	2.0	0.0
Cryogenic Oxygen Plant	4.3	0.0
Rectisol Plant	2.3	0.0
Texaco Gasifier	0.6	0.0
Syn. Gas Heat Recovery	0.9	0.0
Claus Plant	0.1	0.0
Gas Turbine	0.0	80.7
Steam Turbine	0.0	86.3
Compressor 1	31.1	0.0
Compressor 2	10.8	0.0
Compressor 3	6.4	0.0
Compressor 4	7.1	0.0
Compressor 5	3.6	0.0
Total	**69.1**	**167.0**

EMISSIONS FROM THE SULFUR REMOVAL PROCESS
BASE CASE 1

Base Case 1 is primarily a model of a process that will turn coal into an alcohol based fuel additive. This plant is very large, and will have a production of roughly 0.5 million metric tons of mixed alcohols per year. In order to properly design this Plant, it is important to compare the emissions of this facility with the Threshold Emission levels allowed by the government before Best Available Control Technology (BACT) is required. If BACT is required it will significantly affect the cost of our plant. The emissions were estimated from the Sulfur Removal portion of the plant because all of the sulfur compounds, along with a major part of the plant's CO, ozone producing compounds (VOC's that are precursors to ozone formation), and two Hazardous Air Pollutants (HAP's), methanol and COS, are found in this part of the process. After the estimations were completed, it was found that the H_2S, Total Reduced Sulfur (including H_2S), Reduced Sulfur Compounds (including H_2S and COS), Ozone producing VOC's, and the HAP's were all above the Threshold Values.

If the size of the plant increases, the total emissions will also increase. The stack emissions will go up with any raise in production. However, the fugitive emissions will grow only if the amount of equipment increases, for example, more trains are added.

The estimation of emissions for the sulfur removal process, which includes four blocks from Base Case 1 ; the Rectisol, COS Hydrolysis, Claus, and Beavon blocks (see Figure A.1), includes stack emissions and an estimation of the fugitive emissions for the blocks. The stack emissions were taken from the Base Case 1 flowsheet (see Figure A.1 and Tables A.1), while the fugitive emissions had to be estimated.

The fugitive emissions were estimated by using average emission factors.

$$E_{ij} = m_j F_i N_i$$

i = a type of equipment
j = a component
E_{ij} = Emissions of component j in equip. i (kg/hr)
m_j = mass fraction of component i
F_i = SOCMI Emission Factor for equipment i (kg/hr/source)
N_i = number of equipment i

The average emission factors (F_i) were taken from the Average Emission Factors for Synthetic Organic Chemical Manufacturing Industry (SOCMI) Fugitive Emissions (see Table A.1), which was taken from the U.S. Environmental Protection Agency, Emission Factors for Equipment Leaks of VOC and HAP, EPA-450/3-86-002, Research Triangle Park, NC, 1986.

Table A.3

EQUIPMENT	SERVICE	EMISSIONS FACTOR, kg/hr/source
Valves	Gas	0.0056
	Light Liquid	0.0071
	Heavy Liquid	0.00023
Pumps	Light Liquid	0.0494
	Heavy Liquid	0.0214
Compressors	Gas	0.228
Pressure Relief Valves	Gas	0.104
Flanges and Other Connectors	All	0.00083
Open-Ended Lines	All	0.0017
Sampling Connectors	All	0.015

A "light liquid " is defined by SOCMI as any fluid that is a liquid at the operating conditions and that either:

(1) Has a vapor pressure greater than 0.3 kPa at 20°C, or

(2) Contains at least 20% (by weight) of any component that has a vapor pressure greater than 0.3 kPa at 20°C.

A "heavy liquid" is any fluid that is a liquid at the operating conditions and that is not a "light liquid."

The mass fractions for each component in every stream were estimated from actual flowsheets and process specifications. The last estimation made was the quantity of each type of equipment that released fugitive emissions. This estimation involved a classification of each piece of equipment. For example, a reactor would be classified as a vertical vessel (see Table A.4). From these classifications, the total number of valves could be calculated, by using the Valve Estimations provided by the Chemical

Manufacturers Association, Improving Air Quality: Guidance for Estimating Fugitive Emissions from Equipment, p. 25, Washington, DC, January 1989, along with a correlation of the quantity of valves to the number of open-ended lines and flanges.

Table A.4

VALVE ESTIMATION	
Flow Sheet Predicting Item	Estimating Factor Valves per Item
Pressure Relief Valves	3
Flow Transmitter	6
Storage	13
Pump	11
Turbine Meter and Prover Connection	14
Vertical Vessel (reactor)	23
Horizontal Vessel (settler)	21
Heat Exchanger-Heated Side	8
Heat Exchanger-Cooled Side	17
Loading or Unloading Point	4

Number of open ended lines = 50% of the number of valves

Number of flanges = 420% of the number of valves

After the estimations and calculations were completed, the total emissions for the sulfur removal process were compared to the West Virginia Administrative Regulations, Air Pollution Control Commission, Chapter 16-20, Series 14, p. 14-5, 1984. If the quantity of a substance released is above its threshold value, then BACT applies. Table A.5 shows the comparison.

Table A.5

SIGNIFICANT EMISSIONS FROM THE SULFUR REMOVAL PROCESS

CLASSIFICATION	COMPONENTS EMITTED	THRESHOLD VALUES (ton/yr)	TOTAL EMISSIONS (ton/yr)
CO	CO	100	42.8
NOx	n/a	40	0
SOx	SO2	40	3.52
H2S	H2S	10	20.49
Total Reduced Sulfur Including H2S	H2S	10	20.49
Reduced Sulfur Compounds Including H2S	H2S, COS	10	21.39
Ozone (VOC excluding non-reactives)	CH3OH	40	73.69

The total emissions for the sulfur removal process were compared to the 1990 Clean Air Act Amendment, Section 301. Any plant that emits 25 tons per year of any combination of HAP's, or more than 10 tons per year of any HAP compound is classified as a "major source" and is subject to stringent air pollution control. This portion of the plant has two HAP's: methanol and COS. The COS emitted is 0.9 tons per year, which is well below the limit. However, the methanol is well above the limit, 73.69 tons per year, which pushes the plant over the combined 25 tons per year limit by 49.59 tons per year. Thus, the plant is a major source of HAP's.

The conclusion is that for SO_X compounds, we will have no trouble meeting regulations because no other place in our plant has any SO_X. However, H_2S, Total Reduced Sulfur Including H_2S, Reduced Sulfur Compounds Including H_2S, and Ozone (VOC excluding non-reactives) are above the thresholds for BACT. The threshold value is not just for a particular part of the plant, it is a cumulative valve that includes the entire plant. Therefore it is a possibility that CO emissions will surpass the threshold, along with an increase in the Ozone (VOC) emissions because all of the alcohols (which are VOC's) are produced in the other portion of the plant. Also the plant is well over the HAP's limit, due to the large amount of methanol going up the stack.

The following tables (A.6-A.8) contain a summary of the emissions from the Stack, the fugitive emissions, and the total emissions for the sulfur removal process.

Table A.6

STACK EMISSIONS FROM THE SULFUR REMOVAL PROCESS

COMPONENT	STACK EMISSIONS FROM:		TOTAL STACK EMISSIONS	TOTAL STACK EMISSIONS
	Rectisol Plant (kgmol/hr)	Beavon Plant (kgmol/hr)	(kgmol/hr)	(ton/yr)
CO2	1535	84.2	1619	560983
N2	247.5	152.8	400	88255
CH3OH	0	0.19	0.19	48
NH3	0	8	8	1111

Table A.7

ESTIMATED FUGITIVE EMISSIONS FROM THE SULFUR REMOVAL PROCESS

COMPONENT	SULFUR REMOVAL EMISSIONS FROM :				TOTAL SULFUR REMOVAL EMISSIONS
	Rectisol (kg/hr)	COS Hydrolysis (kg/hr)	Claus (kg/hr)	Beavon (kg/hr)	(ton/yr)
CH3OH	3.28	0	0	0	25.82
CH4	0.03	0	0	0	0.21
CO	4.06	1.37	0	0	42.80
CO2	4.54	0.77	2.65	1.76	76.50
COS	0.07	0.05	0	0	0.90
H2	0.33	0	0	0	2.58
H2O	1.28	0	0.48	4.66	50.52
H2S	0.81	0.53	0.79	0.48	20.49
N2	0.65	0.08	2.31	3.31	49.99
NH3	0.01	0.03	0.1	0.06	1.63
O2	0	0.02	0	0.07	0.74
SO2	0	0	0.45	0	3.52

Table A.8

TOTAL (stack plus fugitive) EMISSIONS FROM THE SULFUR REMOVAL PROCESS

CLASSIFICATION	COMPONENTS EMITTED	THRESHOLD VALUES (ton/yr)	TOTAL EMISSIONS (ton/yr)
CO	CO	100	42.8
NOx	n/a	40	0
SOx	SO2	40	3.52
H2S	**H2S**	**10**	**20.49**
Total Reduced Sulfur Including H2S	**H2S**	**10**	**20.49**
Reduced Sulfur Compounds Including H2S	**H2S, COS**	**10**	**21.39**
Ozone (VOC excluding non-reactives)	**CH3OH**	**40**	**73.69**

RECTISOL PLANT

The flowsheet for the Rectisol Plant was taken from the Houston Area Medium-BTU Coal Gasification Project Final Report, published in June 1982 by Union Carbide (Further references to this will be referred to as Houston). The information needed for the flow estimations was taken from Houston as well as the Gas Process Handbook '92, Hydrocarbon Processing, April 1992, p. 125.

Table A.9

RECTISOL PLANT OVERALL FUGITIVE EMISSIONS
FOR TWO TRAINS

COMPONENT	EMISSIONS FROM :						TOTAL
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open-Ended Lines (kg/hr)	EMISSIONS (kg/hr)
CO	2.02E+ 00	0	4.22E-01	1.76E-01	1.16E+ 00	2.83E-01	4.06
CO2	2.45E+ 00	0	0	4.56E-01	1.32E+ 00	3.21E-02	4.54
COS	4.02E-02	2.79E-03	0	1.34E-03	2.01E-02	4.90E-03	0.07
H2	1.63E-01	0	3.42E-02	1.42E-02	9.37E-02	2.28E-02	0.33
H20	6.80E-01	0	0	1.48E-01	3.65E-01	8.89E-02	1.28
H2S	4.67E-01	3.24E-02	0	1.55E-02	2.33E-01	5.69E-02	0.81
N2	3.67E-01	0	0	8.17E-03	2.25E-01	5.48E-02	0.65
NH3	8.42E-03	0	0	9.02E-04	4.36E-03	1.06E-03	0.01
CH4	1.43E-02	0	0	2.78E-03	7.73E-03	1.88E-03	0.03
CH3OH	1.87E+ 00	2.61E-01	0	9.13E-03	9.18E-01	2.24E-01	3.28

The following tables (A.10-A.25) are the actual estimations made for the Rectisol Plant in Base Case 1.

Table A.10

ESTIMATION OF FUGITIVE EMISSIONS FOR THE RECTISOL PLANT

RECTISOL PLANT	
QUANTITY	EQUIPMENT TYPE
3	Pumps
7	Vertical Vessles
0	Horizontal Vessles
0	Storage Tanks
4	Pressure Relief Valves
3	Heat - Exchangers (Heating Side)
6	Heat - Exchangers (Cooling Side)
0	Loading or Unloading Point
37	Flow Transmitters
0	Turbine Meter and Prover Connection

QUANTITY	ACTUAL EQUIPMENT
3	Separators (Knockout Drums)
4	Towers
4	Heat Exchangers
3	Pumps
1	Compressor
4	Pressure Relief Valves
37	Flow Transmitters

QUANTITY	ESTIMATED EQUIPMENT
623	Valves
312	Open - Ended Lines
2617	Flanges

QUANTITY	EQUIPMENT WITH FUGITIVES
623	Valves
3	Pumps
1	Compressors
4	Pressure Relief Valves
2617	Flanges
312	Open - Ended Lines

Table A.11

INLET STREAM (gas)

ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	4673	130830	4.56E-01
CO2	1619	71245	2.48E-01
COS	4	210	7.31E-04
H2	5260	10520	3.66E-02
H20	3893	70074	2.44E-01
H2S	72	2448	8.52E-03
N2	46	1277	4.45E-03
NH3	8	141	4.91E-04
CH4	27	434	1.51E-03
CH3OH	1	22	7.80E-05
TOTAL FLOW	15602	287201	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	12	0	0	0	50	6

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	3.06E-02	0	0	0	1.91E-02	4.65E-03	5.43E-02
CO2	1.67E-02	0	0	0	1.04E-02	2.53E-03	2.96E-02
COS	4.91E-05	0	0	0	3.06E-05	7.46E-06	8.72E-05
H2	2.46E-03	0	0	0	1.53E-03	3.74E-04	4.37E-03
H20	1.64E-02	0	0	0	1.02E-02	2.49E-03	2.91E-02
H2S	5.73E-04	0	0	0	3.57E-04	8.69E-05	1.02E-03
N2	2.99E-04	0	0	0	1.86E-04	4.53E-05	5.30E-04
NH3	3.30E-05	0	0	0	2.06E-05	5.01E-06	5.86E-05
CH4	1.01E-04	0	0	0	6.32E-05	1.54E-05	1.80E-04
CH3OH	5.24E-06	0	0	0	3.26E-06	7.96E-07	9.30E-06

Table A.12

FEED HEAT EXCHANGER AND KNOCKOUT VESSEL (gas)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	3071	85991	5.19E-01
CO2	810	35622	2.15E-01
COS	2	105	6.33E-04
H2	3425	6850	4.13E-02
H20	1947	35037	2.11E-01
H2S	36	1224	7.38E-03
N2	23	638	3.85E-03
NH3	4	71	4.26E-04
CH4	14	217	1.31E-03
CH3OH	0	11	6.76E-05
TOTAL FLOW	9331	165766	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	52	0	0	0	218	26

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	1.51E-01	0	0	0	9.40E-02	2.29E-02	2.68E-01
CO2	6.26E-02	0	0	0	3.90E-02	9.50E-03	1.11E-01
COS	1.84E-04	0	0	0	1.15E-04	2.80E-05	3.27E-04
H2	1.20E-02	0	0	0	7.49E-03	1.83E-03	2.14E-02
H20	6.15E-02	0	0	0	3.83E-02	9.34E-03	1.09E-01
H2S	2.15E-03	0	0	0	1.34E-03	3.26E-04	3.82E-03
N2	1.12E-03	0	0	0	6.98E-04	1.70E-04	1.99E-03
NH3	1.24E-04	0	0	0	7.71E-05	1.88E-05	2.20E-04
CH4	3.81E-04	0	0	0	2.37E-04	5.78E-05	6.76E-04
CH3OH	1.97E-05	0	0	0	1.22E-05	2.99E-06	3.49E-05

Table A.13

GAS ABSORBER WASH TOWER (gas)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	1
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	4673	130830	4.56E-01
CO2	1619	71245	2.48E-01
COS	4	210	7.31E-04
H2	5260	10520	3.66E-02
H20	3893	70074	2.44E-01
H2S	72	2448	8.52E-03
N2	46	1277	4.45E-03
NH3	8	141	4.91E-04
CH4	27	434	1.51E-03
CH3OH	1	22	7.80E-05
TOTAL FLOW	15602	287201	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	29	0	0	0	122	15

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	7.40E-02	0	0	0	4.61E-02	1.12E-02	1.31E-01
CO2	4.03E-02	0	0	0	2.51E-02	6.11E-03	7.15E-02
COS	1.19E-04	0	0	0	7.39E-05	1.80E-05	2.11E-04
H2	5.95E-03	0	0	0	3.70E-03	9.03E-04	1.06E-02
H20	3.96E-02	0	0	0	2.47E-02	6.01E-03	7.03E-02
H2S	1.38E-03	0	0	0	8.62E-04	2.10E-04	2.46E-03
N2	7.22E-04	0	0	0	4.49E-04	1.10E-04	1.28E-03
NH3	7.98E-05	0	0	0	4.97E-05	1.21E-05	1.42E-04
CH4	2.45E-04	0	0	0	1.53E-04	3.72E-05	4.35E-04
CH3OH	1.27E-05	0	0	0	7.88E-06	1.92E-06	2.25E-05

Table A.14

GAS ABSORBER WASH TOWER (liquid)

ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	1
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	0	0	0
COS	0	0	0
H2	0	0	0
H20	0	0	0
H2S	0	0	0
N2	0	0	0
NH3	0	0	0
CH4	0	0	0
CH3OH	50	1600	1
TOTAL FLOW	50	1600	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0	0.00083	0.0017
QUANTITY	29	0	0	0	122	15

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	0	0	0	0	0	0	0
COS	0	0	0	0	0	0	0
H2	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0
H2S	0	0	0	0	0	0	0
N2	0	0	0	0	0	0	0
NH3	0	0	0	0	0	0	0
CH4	0	0	0	0	0	0	0
CH3OH	0.21	0	0	0	0.10	0.02	3.32E-01

Table A.15

H2, CO RECLAIMER #1 (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	350	9811	4.30E-01
CO2	270	11876	5.21E-01
COS	0	0	0.00E+00
H2	398	795	3.49E-02
H20	0	0	0.00E+00
H2S	0	0	0.00E+00
N2	8	213	9.34E-03
NH3	1	23	1.03E-03
CH4	5	72	3.17E-03
CH3OH	0	0	0.00E+00
TOTAL FLOW	1031	22790	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0.104	0.00083	0.0017
QUANTITY	61	0	0	1	256	31

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	1.86E-01	0	0	4.48E-02	9.15E-02	2.23E-02	3.45E-01
CO2	2.26E-01	0	0	5.42E-02	1.11E-01	2.70E-02	4.18E-01
COS	0	0	0	0	0	0	0
H2	1.51E-02	0	0	3.63E-03	7.42E-03	1.81E-03	2.80E-02
H20	0	0	0	0	0	0	0
H2S	0	0	0	0	0	0	0
N2	4.04E-03	0	0	9.71E-04	1.99E-03	4.84E-04	7.48E-03
NH3	4.46E-04	0	0	1.07E-04	2.19E-04	5.34E-05	8.25E-04
CH4	1.37E-03	0	0	3.30E-04	6.75E-04	1.65E-04	2.54E-03
CH3OH	0	0	0	0	0	0	0

Table A.16

H2, CO RECLAIMER #2 (liquid)

ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	350	9811	4.14E-01
CO2	270	11876	5.02E-01
COS	1	70	2.96E-03
H2	398	795	3.36E-02
H20	0	0	0
H2S	24	816	3.45E-02
N2	8	213	8.99E-03
NH3	1	23	9.91E-04
CH4	5	72	3.05E-03
CH3OH	0	0	0
TOTAL FLOW	1056	23677	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0.104	0.00083	0.0017
QUANTITY	61	0	0	1	256	31

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	1.79E-01	0	0	4.31E-02	8.81E-02	2.15E-02	3.32E-01
CO2	2.17E-01	0	0	5.22E-02	1.07E-01	2.60E-02	4.02E-01
COS	1.28E-03	0	0	3.08E-04	6.30E-04	1.54E-04	2.38E-03
H2	1.45E-02	0	0	3.49E-03	7.14E-03	1.74E-03	2.69E-02
H20	0	0	0	0	0	0	0
H2S	1.49E-02	0	0	3.58E-03	7.33E-03	1.79E-03	2.76E-02
N2	3.89E-03	0	0	9.35E-04	1.91E-03	4.66E-04	7.20E-03
NH3	4.29E-04	0	0	1.03E-04	2.11E-04	5.14E-05	7.94E-04
CH4	1.32E-03	0	0	3.18E-04	6.50E-04	1.58E-04	2.45E-03
CH3OH	0	0	0	0	0	0	0

Table A.17

H2, CO RECYCLE STREAM (gas)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	5
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	701	19622	9.25E-01
CO2	0	0	0
COS	0	0	0
H2	795	1590	7.50E-02
H20	0	0	0
H2S	0	0	0
N2	0	0	0
NH3	0	0	0
CH4	0	0	0
CH3OH	0	0	0
TOTAL FLOW	1496	21212	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0.228	0	0.00083	0.0017
QUANTITY	47	0	1	0	197	24

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	2.43E-01	0	2.11E-01	0	1.52E-01	3.70E-02	6.43E-01
CO2	0	0	0	0	0	0	0
COS	0	0	0	0	0	0	0
H2	1.97E-02	0	1.71E-02	0	1.23E-02	2.99E-03	5.21E-02
H20	0	0	0	0	0	0	0
H2S	0	0	0	0	0	0	0
N2	0	0	0	0	0	0	0
NH3	0	0	0	0	0	0	0
CH4	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.18

PURIFIED GAS STREAM

ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	2
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	2336	65416	9.26E-01
CO2	0	0	0
COS	0	0	0
H2	2630	5260	7.44E-02
H20	0	0	0
H2S	0	0	0
N2	0	0	0
NH3	0	0	0
CH4	0	0	0
CH3OH	0	0	0
TOTAL FLOW	4966	70676	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	28	0	0	0	118	14

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	1.45E-01	0	0	0	9.03E-02	2.20E-02	2.58E-01
CO2	0	0	0	0	0	0	0
COS	0	0	0	0	0	0	0
H2	1.17E-02	0	0	0	7.26E-03	1.77E-03	2.07E-02
H20	0	0	0	0	0	0	0
H2S	0	0	0	0	0	0	0
N2	0	0	0	0	0	0	0
NH3	0	0	0	0	0	0	0
CH4	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.19

UNSHIFTED GAS METHANOL - WATER SEPARATION TOWER (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	540	23747	2.41E-01
COS	1	70	7.12E-04
H2	0	0	0
H20	3900	70200	7.12E-01
H2S	24	816	8.27E-03
N2	15	426	4.31E-03
NH3	3	47	4.77E-04
CH4	9	144	1.46E-03
CH3OH	100	3214	3.26E-02
TOTAL FLOW	4592	98665	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0.104	0.00083	0.0017
QUANTITY	44	0	0	1	185	22

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	7.52E-02	0	0	2.50E-02	3.69E-02	9.00E-03	1.46E-01
COS	2.22E-04	0	0	7.40E-05	1.09E-04	2.66E-05	4.32E-04
H2	0	0	0	0	0	0	0
H20	2.22E-01	0	0	7.40E-02	1.09E-01	2.66E-02	4.32E-01
H2S	2.58E-03	0	0	8.60E-04	1.27E-03	3.09E-04	5.02E-03
N2	1.35E-03	0	0	4.49E-04	6.62E-04	1.61E-04	2.62E-03
NH3	1.49E-04	0	0	4.96E-05	7.32E-05	1.79E-05	2.90E-04
CH4	4.57E-04	0	0	1.52E-04	2.25E-04	5.48E-05	8.89E-04
CH3OH	1.02E-02	0	0	3.39E-03	5.00E-03	1.22E-03	1.98E-02

Table A.20

UNSHIFTED GAS STRIPPING COLUMN (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	540	23756	8.84E-01
COS	1	70	2.61E-03
H2	0	0	0.00E+00
H20	0	0	0
H2S	24	816	3.04E-02
N2	15	426	1.58E-02
NH3	3	47	1.75E-03
CH4	9	145	5.39E-03
CH3OH	50	1600	5.96E-02
TOTAL FLOW	642	26859	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0	0.00083	0.0017
QUANTITY	35	0	0	0	147	18

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	2.20E-01	0	0	0	1.08E-01	2.63E-02	3.54E-01
COS	6.49E-04	0	0	0	3.19E-04	7.78E-05	1.05E-03
H2	0.00E+00	0	0	0	0.00E+00	0.00E+00	0.00E+00
H20	0	0	0	0	0	0	0
H2S	7.55E-03	0	0	0	3.71E-03	9.04E-04	1.22E-02
N2	3.94E-03	0	0	0	1.93E-03	4.71E-04	6.34E-03
NH3	4.34E-04	0	0	0	2.13E-04	5.20E-05	6.99E-04
CH4	1.34E-03	0	0	0	6.57E-04	1.60E-04	2.16E-03
CH3OH	1.48E-02	0	0	0	7.27E-03	1.77E-03	2.38E-02

Table A.21

UNSHIFTED GAS STRIPPING COLUMN (gas)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	1
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	0	0	0
COS	0	0	0
H2	0	0	0
H20	0	0	0
H2S	0	0	0
N2	101	2828	1
NH3	0	0	0
CH4	0	0	0
CH3OH	0	0	0
TOTAL FLOW	101	2828	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	29	0	0	0	122	15

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	0	0	0	0	0	0	0
COS	0	0	0	0	0	0	0
H2	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0
H2S	0	0	0	0	0	0	0
N2	1.62E-01	0	0	0	1.01E-01	2.47E-02	2.88E-01
NH3	0	0	0	0	0	0	0
CH4	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.22

UNSHIFTED METHANOL REGENERATION TOWER (gas feed)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	270	11876	9.30E-01
COS	1	35	2.77E-03
H2	0	0	0
H20	0	0	0
H2S	12	408	3.19E-02
N2	8	213	1.67E-02
NH3	1	23	1.84E-03
CH4	5	72	5.66E-03
CH3OH	5	145	1.13E-02
TOTAL FLOW	301	12772	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0.104	0.00083	0.0017
QUANTITY	61	0	0	1	256	31

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	3.18E-01	0	0	9.67E-02	1.98E-01	4.82E-02	6.60E-01
COS	9.47E-04	0	0	2.88E-04	5.89E-04	1.44E-04	1.97E-03
H2	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0
H2S	1.09E-02	0	0	3.32E-03	6.79E-03	1.66E-03	2.27E-02
N2	5.69E-03	0	0	1.73E-03	3.54E-03	8.64E-04	1.18E-02
NH3	6.27E-04	0	0	1.91E-04	3.91E-04	9.52E-05	1.30E-03
CH4	1.93E-03	0	0	5.89E-04	1.20E-03	2.94E-04	4.02E-03

Table A.23

UNSHIFTED METHANOL REGENERATION TOWER (liquid feed)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	1
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	0	0	0
COS	1	70	2.82E-02
H2	0	0	0
H20	0	0	0
H2S	24	816	3.28E-01
N2	0	0	0
NH3	0	0	0
CH4	0	0	0
CH3OH	50	1600	6.44E-01
TOTAL FLOW	75	2486	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0.0494	0	0	0.00083	0.0017
QUANTITY	69	1	0	0	290	35

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	0	0	0	0	0	0	0
COS	1.38E-02	1.39E-03	0	0	6.79E-03	1.66E-03	2.37E-02
H2	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0
H2S	1.61E-01	1.62E-02	0	0	7.89E-02	1.92E-02	2.75E-01
N2	0	0	0	0	0	0	0
NH3	0	0	0	0	0	0	0
CH4	0	0	0	0	0	0	0
CH3OH	3.15E-01	3.18E-02	0	0	1.55E-01	3.77E-02	5.40E-01

Table A.24

METHANOL RECYCLE STREAM (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	2
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	1
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	4
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	0	0	0
COS	0	0	0
H2	0	0	0
H20	0	0	0
H2S	0	0	0
N2	0	0	0
NH3	0	0	0
CH4	0	0	0
CH3OH	100	3200	1
TOTAL FLOW	100	3200	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0.0494	0	0	0.00083	0.0017
QUANTITY	54	2	0	0	227	27

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	0	0	0	0	0	0	0
COS	0	0	0	0	0	0	0
H2	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0
H2S	0	0	0	0	0	0	0
N2	0	0	0	0	0	0	0
NH3	0	0	0	0	0	0	0
CH4	0	0	0	0	0	0	0
CH3OH	3.83E-01	9.88E-02	0	0	1.88E-01	4.59E-02	7.16E-01

Table A.25

H2S , COS RICH STREAM (gas)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE UNSHIFTED RECTISOL TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	81	3555	5.59E-01
COS	4	210	3.30E-02
H2	0	0	0
H20	0	0	0
H2S	72	2448	3.85E-01
N2	0	0	0
NH3	8	141	2.22E-02
CH4	0	0	0
CH3OH	0	6	9.56E-04
TOTAL FLOW	165	6360	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0	0.00083	0.0017
QUANTITY	12	0	0	0	50	6

COMPONENT	EMISSIONS (kg/hr) FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	0	0	0	0	0	0	0
CO2	4.76E-02	0	0	0	2.34E-02	5.70E-03	7.67E-02
COS	2.81E-03	0	0	0	1.38E-03	3.37E-04	4.53E-03
H2	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0
H2S	3.28E-02	0	0	0	1.61E-02	3.93E-03	5.28E-02
N2	0	0	0	0	0	0	0
NH3	1.89E-03	0	0	0	9.28E-04	2.26E-04	3.04E-03
CH4	0	0	0	0	0	0	0
CH3OH	8.14E-05	0	0	0	4.00E-05	9.75E-06	1.31E-04

COS HYDROLYSIS PLANT

The flowsheet for the COS hydrolysis along with the information needed for the stream estimations were taken from the Gas Process Handbook '84, Hydrocarbon Processing, April 1984, p. 78.

Table A.26

COS HYDROLYSIS PLANT OVERALL FUGITIVE EMISSIONS

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open-Ended Lines (kg/hr)	
CO	6.65E-01	0	0	1.93E-01	4.14E-01	1.01E-01	1.37
CO2	3.74E-01	0	0	1.08E-01	2.33E-01	5.67E-02	0.77
COS	2.21E-02	0	0	6.40E-03	1.37E-02	3.50E-03	0.05
H2	7.36E-04	0	0	2.13E-04	4.58E-04	1.12E-04	0
H2S	2.57E-01	0	0	7.47E-02	1.60E-01	3.91E-02	0.53
N2	3.65E-02	0	0	1.06E-02	2.27E-02	5.54E-03	0.08
NH3	1.48E-02	0	0	4.30E-03	9.23E-03	2.25E-03	0.03
CH3OH	6.39E-04	0	0	1.85E-04	3.98E-04	9.70E-05	0
O2	1.11E-02	0	0	3.22E-03	6.91E-03	1.68E-03	0.02

The following tables (A.27-A.29) are the actual estimations made for the COS Hydrolysis Plant in Base Case 1.

Table A.27

ESTIMATION OF FUGITIVE EMISSIONS FOR THE COS HYDROLYSIS PLANT

COS HYDROLYSIS	
QUANTITY	EQUIPMENT TYPE
0	Pumps
1	Vertical Vessles
0	Horizontal Vessles
0	Storage Tanks
1	Pressure Relief Valves
1	Heat - Exchangers (Heating Side)
0	Heat - Exchangers (Cooling Side)
0	Loading or Unloading Point
5	Flow Transmitters
0	Turbine Meter and Prover Connection

QUANTITY	ACTUAL EQUIPMENT
1	Preheater
1	Hydrolysis Reactor
1	Pressure Relief Valves
5	Flow Transmitters

QUANTITY	ESTIMATED EQUIPMENT
64	Valves
32	Open - Ended Lines
269	Flanges

QUANTITY	EQUIPMENT WITH FUGITIVES
64	Valves
0	Pumps
0	Compressors
1	Pressure Relief Valves
269	Flanges
32	Open - Ended Lines

Table A.28

MIXER - PREHEATER

ESTIMATION OF FUGITIVE EMISSIONS FOR COS HYDROLYSIS

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	1
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	3.5	98	9.28E-01
CO2	81	3555	5.21E-01
COS	4	210	3.08E-02
H2	4	7	1.03E-03
H2S	72	2448	3.59E-01
N2	12	347	5.09E-02
NH3	8	141	2.07E-02
CH3OH	0	6	8.91E-04
O2	3	106	1.55E-02
TOTAL FLOW	184	6820	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	26	0	0	0	109	13

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	1.35E-01	0	0	0	8.41E-02	2.05E-02	2.40E-01
CO2	7.59E-02	0	0	0	4.72E-02	1.15E-02	1.35E-01
COS	4.48E-03	0	0	0	2.79E-03	6.80E-04	7.95E-03
H2	1.49E-04	0	0	0	9.30E-05	2.27E-05	2.65E-04
H2S	5.23E-02	0	0	0	3.25E-02	7.93E-03	9.27E-02
N2	7.41E-03	0	0	0	4.61E-03	1.13E-03	1.32E-02
NH3	3.01E-03	0	0	0	1.88E-03	4.57E-04	5.34E-03
CH3OH	1.30E-04	0	0	0	8.08E-05	1.97E-05	2.30E-04
O2	2.25E-03	0	0	0	1.40E-03	3.42E-04	4.00E-03

Table A.29

HYDROGENATION / HYDROLYSIS REACTOR
ESTIMATION OF FUGITIVE EMISSIONS FOR COS HYDROLYSIS

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO	0	0	0
CO2	87	3846	5.57E-01
COS	0	0	0
H2	0	0	0
H2S	76	2567	3.72E-01
N2	12	347	5.03E-02
NH3	8	141	2.04E-02
CH3OH	0	6	8.80E-04
O2	0	0	0
TOTAL FLOW	184	6907	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0.104	0.00083	0.0017
QUANTITY	38	0	0	1	160	19

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO	1.97E-01	0	0	9.65E-02	1.23E-01	3.00E-02	4.47E-01
CO2	1.11E-01	0	0	5.42E-02	6.91E-02	1.68E-02	2.51E-01
COS	6.55E-03	0	0	3.20E-03	4.08E-03	9.95E-04	1.48E-02
H2	2.18E-04	0	0	1.07E-04	1.36E-04	3.32E-05	4.94E-04
H2S	7.64E-02	0	0	3.73E-02	4.75E-02	1.16E-02	1.73E-01
N2	1.08E-02	0	0	5.29E-03	6.74E-03	1.64E-03	2.45E-02
NH3	4.40E-03	0	0	2.15E-03	2.74E-03	6.68E-04	9.96E-03
CH3OH	1.90E-04	0	0	9.27E-05	1.18E-04	2.88E-05	4.29E-04
O2	3.29E-03	0	0	1.61E-03	2.05E-03	5.00E-04	7.46E-03

CLAUS PLANT

The flowsheet for the Claus Plant was taken from Houston. The information needed for the flow estimations was taken from Houston as well as the Gas Process Handbook '84, Hydrocarbon Processing, April 1984, p. 74.

Table A.30

CLAUS PLANT OVERALL FUGITIVE EMISSIONS FOR TWO TRAINS

COMPONENT	EMISSIONS FROM:						TOTAL EMISSIONS
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open-Ended Lines (kg/hr)	(kg/hr)
CO2	1.33E+ 00	0	0	2.93E-01	8.25E-01	2.01E-01	**2.65**
H2O	2.33E-01	0	0	6.51E-02	1.45E-01	3.54E-02	**0.48**
H2S	4.07E-01	0	0	6.44E-02	2.53E-01	6.18E-02	**0.79**
N2	1.12E+ 00	0	0	3.23E-01	6.97E-01	1.70E-01	**2.31**
CH3OH	2.10E-03	0	0	4.65E-04	1.31E-03	3.19E-04	**0.00**
S	3.39E-03	0	0	2.77E-03	2.11E-02	5.15E-03	**0.06**
SO2	2.11E-01	0	0	7.21E-02	1.32E-01	3.21E-02	**0.45**
O2	0	0	0	0	0	0	**0.00**
NH3	4.87E-02	0	0	1.08E-02	3.03E-02	7.39E-03	**0.10**

The following tables (A.31-A.37) are the actual estimations made for the Claus Plant in Base Case 1.

Table A.31

ESTIMATION OF FUGITIVE EMISSIONS FOR THE CLAUS PLANT

CLAUS PLANT	
QUANTITY	EQUIPMENT TYPE
0	Pumps
6	Vertical Vessles
6	Horizontal Vessles
0	Storage Tanks
8	Pressure Relief Valves
8	Heat - Exchangers (Heating Side)
0	Heat - Exchangers (Cooling Side)
0	Loading or Unloading Point
28	Flow Transmitters
0	Turbine Meter and Prover Connection

QUANTITY	ACTUAL EQUIPMENT
2	Separators (Knockout Drums)
2	Thermal Incinerators
2	Boilers
6	Reheaters
2	3 - Staged Catalytic Reactors
2	Sulfur Condensers
8	Pressure Relief Valves
28	Flow Transmitters

QUANTITY	ESTIMATED EQUIPMENT
520	Valves
260	Open - Ended Lines
2184	Flanges

QUANTITY	EQUIPMENT WITH FUGITIVES
520	Valves
0	Pumps
0	Compressors
8	Pressure Relief Valves
2184	Flanges
260	Open - Ended Lines

Table A.32

SEPARATOR

ESTIMATION OF FUGITIVE EMISSIONS FOR ONE CLAUS TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	1
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	5
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	87	3846	5.57E-01
H2O	0	0	0
H2S	76	2567	3.72E-01
N2	12	347	5.03E-02
CH3OH	0	6	8.80E-04
S	0	0	0
SO2	0	0	0
O2	0	0	0
NH3	8	141	2.04E-02
TOTAL FLOW	184	6907	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	51	0	0	0	214	26

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	1.59E-01	0	0	0	9.90E-02	2.41E-02	2.82E-01
H2O	0	0	0	0	0	0	0
H2S	1.06E-01	0	0	0	6.61E-02	1.61E-02	1.88E-01
N2	1.44E-02	0	0	0	8.94E-03	2.18E-03	2.55E-02
CH3OH	2.51E-04	0	0	0	1.56E-04	3.82E-05	4.46E-04
S	0	0	0	0	0	0	0
SO2	0	0	0	0	0	0	0
O2	0	0	0	0	0	0	0
NH3	5.83E-03	0	0	0	3.63E-03	8.86E-04	1.04E-02

Table A.33

THERMAL INCINERATOR AND BOILER
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE CLAUS TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	1
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	0
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	29	1282	2.81E-01
H2O	12	222	4.86E-02
H2S	11	385	8.43E-02
N2	67	1883	4.12E-01
CH3OH	0	2	4.49E-04
S	2	61	1.33E-02
SO2	11	685	1.50E-01
O2	0	0	0.00E+00
NH3	3	47	1.03E-02
TOTAL FLOW	135	4566	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0.104	0.00083	0.0017
QUANTITY	41	0	0	1	172	21

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	6.45E-02	0	0	2.92E-02	4.01E-02	9.78E-03	1.44E-01
H2O	1.12E-02	0	0	5.06E-03	6.95E-03	1.69E-03	2.49E-02
H2S	1.94E-02	0	0	8.77E-03	1.20E-02	2.94E-03	4.31E-02
N2	9.47E-02	0	0	4.29E-02	5.89E-02	1.44E-02	2.11E-01
CH3OH	1.03E-04	0	0	4.66E-05	6.41E-05	1.56E-05	2.29E-04
S	3.06E-03	0	0	1.38E-03	1.90E-03	4.64E-04	6.81E-03
SO2	3.44E-02	0	0	1.56E-02	2.14E-02	5.23E-03	7.67E-02
O2	0.00E+00	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	2.37E-03	0	0	1.07E-03	1.47E-03	3.59E-04	5.27E-03

Table A.34

FIRST REHEATER AND FIRST REACTOR STAGE
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE CLAUS TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	1
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	3.40E-01
H2O	12	222	3.92E-02
H2S	24	813	1.44E-01
N2	69	1940	3.43E-01
CH3OH	0	3	5.37E-04
S	0	0	0
SO2	11	685	1.21E-01
O2	0	0	0.00E+00
NH3	4	71	1.25E-02
TOTAL FLOW	164	5656	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0.104	0.00083	0.0017
QUANTITY	52	0	0	1	218	26

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	9.90E-02	0	0	3.54E-02	6.16E-02	1.50E-02	2.11E-01
H2O	1.14E-02	0	0	4.08E-03	7.11E-03	1.73E-03	2.44E-02
H2S	4.18E-02	0	0	1.49E-02	2.60E-02	6.35E-03	8.92E-02
N2	9.99E-02	0	0	3.57E-02	6.22E-02	1.52E-02	2.13E-01
CH3OH	1.57E-04	0	0	5.59E-05	9.74E-05	2.38E-05	3.34E-04
S	0	0	0	0	0	0	0
SO2	3.53E-02	0	0	1.26E-02	2.19E-02	5.35E-03	7.51E-02
O2	0.00E+00	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	3.63E-03	0	0	1.30E-03	2.26E-03	5.51E-04	7.74E-03

Table A.35

SECOND REHEATER AND SECOND REACTOR STAGE
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE CLAUS TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	1
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	3.93E-01
H2O	28	509	1.04E-01
H2S	8	271	5.55E-02
N2	69	1940	3.97E-01
CH3OH	0	3	6.21E-04
S	0	0	0
SO2	3	175	3.58E-02
O2	0	0	0.00E+00
NH3	4	71	1.44E-02
TOTAL FLOW	156	4893	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0.104	0.00083	0.0017
QUANTITY	46	0	0	1	193	23

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	1.01E-01	0	0	4.09E-02	6.30E-02	1.54E-02	2.20E-01
H2O	2.68E-02	0	0	1.08E-02	1.67E-02	4.07E-03	5.84E-02
H2S	1.43E-02	0	0	5.77E-03	8.89E-03	2.17E-03	3.11E-02
N2	1.02E-01	0	0	4.12E-02	6.36E-02	1.55E-02	2.23E-01
CH3OH	1.60E-04	0	0	6.46E-05	9.96E-05	2.43E-05	3.49E-04
S	0	0	0	0	0	0	0
SO2	9.23E-03	0	0	3.73E-03	5.75E-03	1.40E-03	2.01E-02
O2	0.00E+00	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	3.71E-03	0	0	1.50E-03	2.31E-03	5.64E-04	8.09E-03

Table A.36

THIRD REHEATER AND REACTOR STAGE
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE CLAUS TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	1
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	1
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	3.97E-01
H2O	33	585	1.21E-01
H2S	4	128	2.63E-02
N2	69	1940	4.01E-01
CH3OH	0	3	6.28E-04
S	0	0	0
SO2	3	192	3.97E-02
O2	0	0	0.00E+00
NH3	4	71	1.46E-02
TOTAL FLOW	156	4841	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0.104	0.00083	0.0017
QUANTITY	67	0	0	1	281	34

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	1.49E-01	0	0	4.13E-02	9.28E-02	2.26E-02	3.06E-01
H2O	4.53E-02	0	0	1.26E-02	2.82E-02	6.88E-03	9.30E-02
H2S	9.88E-03	0	0	2.74E-03	6.15E-03	1.50E-03	2.03E-02
N2	1.50E-01	0	0	4.17E-02	9.36E-02	2.28E-02	3.09E-01
CH3OH	2.36E-04	0	0	6.53E-05	1.47E-04	3.58E-05	4.83E-04
S	0	0	0	0	0	0	0
SO2	1.49E-02	0	0	4.12E-03	9.26E-03	2.26E-03	3.05E-02
O2	0.00E+00	0	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	5.47E-03	0	0	1.52E-03	3.40E-03	8.30E-04	1.12E-02

Table A.37

SULFUR CONDENSER

ESTIMATION OF FUGITIVE EMISSIONS FOR ONE CLAUS TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	1
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	4
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	160	7050	3.58E-01
H2O	95	1714	8.71E-02
H2S	28	939	4.77E-02
N2	275	7704	3.91E-01
CH3OH	0	11	5.67E-04
S	34	1086	5.52E-02
SO2	14	924	4.69E-02
O2	0	0	0.00E+00
NH3	15	259	1.31E-02
TOTAL FLOW	622	19687	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	45	0	0	0	189	23

COMPONENT	EMISSIONS FROM :						**TOTAL EMISSIONS (kg/hr)**
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	9.02E-02	0	0	0	5.62E-02	1.37E-02	1.60E-01
H2O	2.19E-02	0	0	0	1.37E-02	3.33E-03	3.89E-02
H2S	1.20E-02	0	0	0	7.48E-03	1.82E-03	2.13E-02
N2	9.86E-02	0	0	0	6.14E-02	1.50E-02	1.75E-01
CH3OH	1.43E-04	0	0	0	8.90E-05	2.17E-05	2.54E-04
S	1.39E-02	0	0	0	8.65E-03	2.11E-03	2.47E-02
SO2	1.18E-02	0	0	0	7.36E-03	1.80E-03	2.10E-02
O2	0.00E+00	0	0	0	0.00E+00	0.00E+00	0.00E+00
NH3	3.31E-03	0	0	0	2.06E-03	5.03E-04	5.88E-03

BEAVON PLANT

The flowsheet for the Beavon Plant along with the information needed for the stream estimations were taken from the Gas Process Handbook '84, Hydrocarbon Processing, April 1984, p. 88.

Table A.38

BEAVON PLANT OVERALL FUGITIVE EMISSIONS

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open-Ended Lines (kg/hr)	(kg/hr)
CO2	9.91E-01	8.12E-02	0	0	5.53E-01	1.35E-01	**1.76**
O2	3.77E-02	0	0	1.00E-02	1.85E-02	4.51E-03	**0.07**
S	1.46E-01	0	0	2.56E-02	7.17E-02	1.75E-02	**0.26**
H2O	2.61E+ 00	2.58E-02	0	4.06E-01	1.30E+ 00	3.17E-01	**4.66**
H2S	2.65E-01	5.39E-03	0	4.00E-02	1.35E-01	3.29E-02	**0.48**
N2	1.86E+ 00	8.20E-02	0	1.42E-01	9.82E-01	2.39E-01	**3.31**
NH3	3.64E-02	2.98E-03	0	0	2.03E-02	4.95E-03	**0.06**
CH3OH	1.57E-03	1.28E-04	0	0	8.75E-04	2.13E-04	**0.00**

The following tables (A.39-A.48) are the actual estimations made for the Beavon Plant in Base Case 1.

Table A.39

ESTIMATION OF FUGITIVE EMISSIONS FOR THE BEAVON PLANT

BEAVON PLANT	
QUANTITY	EQUIPMENT TYPE
4	Pumps
16	Vertical Vessles
6	Horizontal Vessles
2	Storage Tanks
6	Pressure Relief Valves
2	Heat - Exchangers (Heating Side)
2	Heat - Exchangers (Cooling Side)
0	Loading or Unloading Point
42	Flow Transmitters
0	Turbine Meter and Prover Connection

QUANTITY	ACTUAL EQUIPMENT
2	Preheater
2	Hydrolysis Reactor
4	Boilers
4	Pumps
2	Desuperheater Contact Condenser
2	Venturi Scrubber-Stripper
8	Pressure Relief Valves
4	Oxidizer Tanks
2	Slurry Tank
2	Balance Tank
2	Separation Wash and Reslurry
2	Sulfur Collector Drum
46	Flow Transmitters

QUANTITY	ESTIMATED EQUIPMENT
442	Valves
221	Open - Ended Lines
1856	Flanges

QUANTITY	EQUIPMENT WITH FUGITIVES
442	Valves
4	Pumps
0	Compressors
8	Pressure Relief Valves
1856	Flanges
221	Open - Ended Lines

Table A.40

FEED COOLER
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	1
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	4.11E-01
O2	0	0	0.00E+00
S	0	0	0
H2O	34	611	1.31E-01
H2S	4	128	2.73E-02
N2	69	1942	4.15E-01
NH3	4	71	1.51E-02
CH3OH	0	3	6.50E-04
TOTAL FLOW	155	4677	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	29	0	0	0	122	15

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	6.68E-02	0	0	0	4.16E-02	1.01E-02	1.18E-01
O2	0.00E+00	0	0	0	0.00E+00	0.00E+00	0.00E+00
S	0	0	0	0	0	0	0
H2O	2.12E-02	0	0	0	1.32E-02	3.22E-03	3.77E-02
H2S	4.43E-03	0	0	0	2.76E-03	6.72E-04	7.86E-03
N2	6.74E-02	0	0	0	4.20E-02	1.02E-02	1.20E-01
NH3	2.45E-03	0	0	0	1.53E-03	3.72E-04	4.35E-03
CH3OH	1.06E-04	0	0	0	6.57E-05	1.60E-05	1.87E-04

Table A.41

DESUPERHEATER CONTACT CONDENSER (liquid lines)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	2
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	1
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	5
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	4.11E-01
O2	0	0	0.00E+00
S	0	0	0
H2O	34	611	1.31E-01
H2S	4	128	2.73E-02
N2	69	1942	4.15E-01
NH3	4	71	1.51E-02
CH3OH	0	3	6.50E-04
TOTAL FLOW	155	4677	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0.0494	0	0	0.00083	0.0017
QUANTITY	83	2	0	0	349	42

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	2.42E-01	4.06E-02	0	0	1.19E-01	2.90E-02	4.31E-01
O2	0.00E+00	0.00E+00	0	0	0.00E+00	0.00E+00	0.00E+00
S	0	0	0	0	0	0	0
H2O	7.70E-02	1.29E-02	0	0	3.78E-02	9.22E-03	1.37E-01
H2S	1.61E-02	2.69E-03	0	0	7.89E-03	1.92E-03	2.86E-02
N2	2.45E-01	4.10E-02	0	0	1.20E-01	2.93E-02	4.35E-01
NH3	8.89E-03	1.49E-03	0	0	4.36E-03	1.06E-03	1.58E-02
CH3OH	3.83E-04	6.42E-05	0	0	1.88E-04	4.59E-05	6.81E-04

Table A.42

DESUPERHEATER CONTACT CONDENSER (vapor lines)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	1
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	4.11E-01
O2	0	0	0.00E+00
S	0	0	0
H2O	34	611	1.31E-01
H2S	4	128	2.73E-02
N2	69	1942	4.15E-01
NH3	4	71	1.51E-02
CH3OH	0	3	6.50E-04
TOTAL FLOW	155	4677	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	35	0	0	0	147	18

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	8.06E-02	0	0	0	5.02E-02	1.22E-02	1.43E-01
O2	0.00E+00	0	0	0	0.00E+00	0.00E+00	0.00E+00
S	0	0	0	0	0	0	0
H2O	2.56E-02	0	0	0	1.59E-02	3.89E-03	4.54E-02
H2S	5.34E-03	0	0	0	3.33E-03	8.11E-04	9.48E-03
N2	8.14E-02	0	0	0	5.07E-02	1.24E-02	1.44E-01
NH3	2.96E-03	0	0	0	1.84E-03	4.49E-04	5.26E-03
CH3OH	1.27E-04	0	0	0	7.93E-05	1.93E-05	2.26E-04

Table A.43

VENTURI SCRUBBER / STRIPPER (vapor line)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	2
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	0
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	44	1923	4.11E-01
O2	0	0	0.00E+00
S	0	0	0
H2O	34	611	1.31E-01
H2S	4	128	2.73E-02
N2	69	1942	4.15E-01
NH3	4	71	1.51E-02
CH3OH	0	3	6.50E-04
TOTAL FLOW	155	4677	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0056	0	0	0	0.00083	0.0017
QUANTITY	46	0	0	0	193	23

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	1.06E-01	0	0	0	6.59E-02	1.61E-02	1.88E-01
O2	0.00E+00	0	0	0	0.00E+00	0.00E+00	0.00E+00
S	0	0	0	0	0	0	0
H2O	3.37E-02	0	0	0	2.10E-02	5.11E-03	5.97E-02
H2S	7.02E-03	0	0	0	4.37E-03	1.07E-03	1.25E-02
N2	1.07E-01	0	0	0	6.66E-02	1.62E-02	1.90E-01
NH3	3.89E-03	0	0	0	2.42E-03	5.90E-04	6.89E-03
CH3OH	1.67E-04	0	0	0	1.04E-04	2.54E-05	2.97E-04

Table A.44

VENTURI SCRUBBER / STRIPPER (liquid lines)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	2
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	5
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	0	0	0
O2	0	0	0
S	0	0	0
H2O	20	360	5.81E-01
H2S	1	34	5.49E-02
N2	8	225	3.64E-01
NH3	0	0	0
CH3OH	0	0	0
TOTAL FLOW	29	619	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0	0.00083	0.0017
QUANTITY	76	0	0	0	319	38

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	0	0	0	0	0	0	0
O2	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
H2O	3.14E-01	0	0	0	1.54E-01	3.75E-02	5.06E-01
H2S	2.96E-02	0	0	0	1.45E-02	3.55E-03	4.77E-02
N2	1.96E-01	0	0	0	9.64E-02	2.35E-02	3.16E-01
NH3	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.45

OXIDIZER TANK (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	2
Horizontal Vessles	0
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	1
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	0	0	0
O2	2	69	4.82E-02
S	0	0	0
H2O	54	971	6.81E-01
H2S	5	162	1.13E-01
N2	8	225	1.58E-01
NH3	0	0	0
CH3OH	0	0	0
TOTAL FLOW	69	1427	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0.104	0.00083	0.0017
QUANTITY	55	0	0	1	231	28

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	0	0	0	0	0	0	0
O2	1.88E-02	0	0	5.01E-03	9.25E-03	2.25E-03	3.53E-02
S	0	0	0	0	0	0	0
H2O	2.66E-01	0	0	7.08E-02	1.30E-01	3.18E-02	4.99E-01
H2S	4.42E-02	0	0	1.18E-02	2.17E-02	5.29E-03	8.30E-02
N2	6.17E-02	0	0	1.64E-02	3.03E-02	7.39E-03	1.16E-01
NH3	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.46

SLURRY TANK AND WASH (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	1
Storage Tanks	1
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	2
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	0	0	0
O2	0	0	0
S	5	173	1.23E-01
H2O	54	971	6.92E-01
H2S	1	34	2.42E-02
N2	8	225	1.61E-01
NH3	0	0	0
CH3OH	0	0	0
TOTAL FLOW	68	1403	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0.104	0.00083	0.0017
QUANTITY	49	0	0	1	206	25

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	0	0	0	0	0	0	0
O2	0	0	0	0	0	0	0
S	4.28E-02	0	0	1.28E-02	2.10E-02	5.13E-03	8.18E-02
H2O	2.41E-01	0	0	7.20E-02	1.18E-01	2.88E-02	4.60E-01
H2S	8.43E-03	0	0	2.52E-03	4.14E-03	1.01E-03	1.61E-02
N2	5.59E-02	0	0	1.67E-02	2.74E-02	6.69E-03	1.07E-01
NH3	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.47

BALANCE TANK (liquid)
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	1
Storage Tanks	0
Pressure Relief Valves	1
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	1
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	0	0	0
O2	0	0	0
S	0	0	0
H2O	20	360	5.81E-01
H2S	1	34	5.49E-02
N2	8	225	3.64E-01
NH3	0	0	0
CH3OH	0	0	0
TOTAL FLOW	29	619	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0.104	0.00083	0.0017
QUANTITY	30	0	0	1	126	15

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	0	0	0	0	0	0	0
O2	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
H2O	1.24E-01	0	0	6.04E-02	6.08E-02	1.48E-02	2.60E-01
H2S	1.17E-02	0	0	5.71E-03	5.74E-03	1.40E-03	2.45E-02
N2	7.75E-02	0	0	3.78E-02	3.81E-02	9.28E-03	1.63E-01
NH3	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0

Table A.48

WATER - SULFUR SEPARTOR
ESTIMATION OF FUGITIVE EMISSIONS FOR ONE BEAVON TRAIN

EQUIPMENT TYPE	QUANTITY
Pumps	0
Vertical Vessles	0
Horizontal Vessles	1
Storage Tanks	0
Pressure Relief Valves	0
Heat - Exchangers (Heating Side)	0
Heat - Exchangers (Cooling Side)	0
Loading or Unloading Point	0
Flow Transmitters	3
Turbine Meter and Prover Connection	0

FLOW SUMMARY	kgmol/hr	kg/hr	mass fraction
CO2	0	0	0
O2	0	0	0
S	5	173	1.09E-01
H2O	64	1151	7.27E-01
H2S	1	34	2.16E-02
N2	8	225	1.42E-01
NH3	0	0	0
CH3OH	0	0	0
TOTAL FLOW	78	1583	

EQUIPMENT WITH FUGITIVES	Valves	Pumps	Compressors	Pressure Relief Valves	Flanges	Open - Ended Lines
EMISSION FACTOR	0.0071	0	0	0	0.00083	0.0017
QUANTITY	39	0	0	0	164	20

COMPONENT	EMISSIONS FROM :						TOTAL EMISSIONS (kg/hr)
	Valves (kg/hr)	Pumps (kg/hr)	Compressors (kg/hr)	Pressure Relief Valves (kg/hr)	Flanges (kg/hr)	Open - Ended Lines (kg/hr)	
CO2	0	0	0	0	0	0	0
O2	0	0	0	0	0	0	0
S	3.02E-02	0	0	0	1.48E-02	3.62E-03	4.87E-02
H2O	2.01E-01	0	0	0	9.88E-02	2.41E-02	3.24E-01
H2S	5.95E-03	0	0	0	2.92E-03	7.12E-04	9.58E-03
N2	3.94E-02	0	0	0	1.94E-02	4.72E-03	6.35E-02
NH3	0	0	0	0	0	0	0
CH3OH	0	0	0	0	0	0	0