Factors to be considered in design of H_2S Abatement Unit in LNG Project

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OUTLINE

1. INTRODUCTION (PERTAMINA Profile)
2. BACKGROUND (Indonesia LNG Plants)
3. H_2S DESIGN FACTORS
4. EVALUATION
5. CONCLUSION

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I. INTRODUCTION

PERTAMINA PROFILE

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PERTAMINA, AN INTEGRATED OIL AND GAS COMPANY

Government of Indonesia (100%)

Core Business Operations

Division	Upstream (Oil, Gas, Geothermal)	Downstream (Fuel, Non Fuel, Petrochemicals)
Activities	• Exploration • Development • Production	Activities : Refining, Petrochemicals Plant, Distribution, Shipping, Transportation, Terminal. Fuel: • Gasoline • Kerosene • Gasoil • Avtur • LPG Non Fuel: • LSWR • Naphtha • Asphalt • Lube Base • Wax • Lube Oil • Solvent Petrochemicals: • Paraxylene • Benzene • PTA • Propylene • Polypropylene

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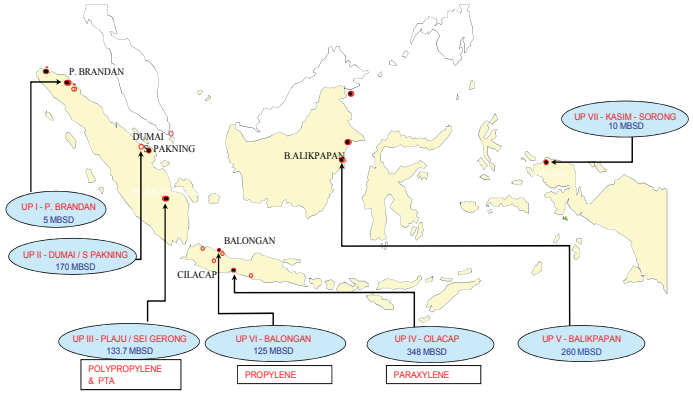
PERTAMINA REFINERIES & PETROCHEMICAL PLANTS PROFILE (2007)



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II. BACKGROUND

INDONESIA LNG PLANTS

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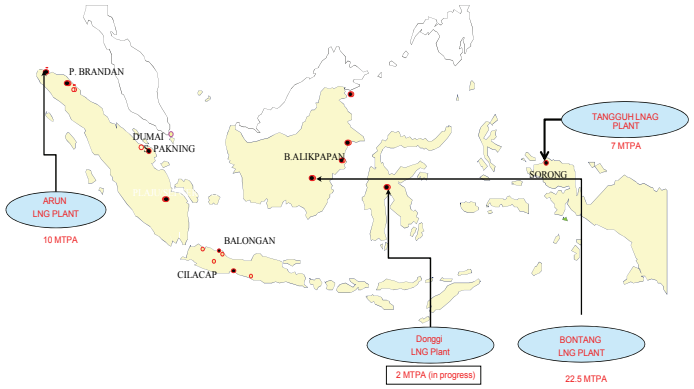
INDONESIA LNG PLANTS



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BONTANG PLANT WITH TRAIN I LOCATION

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III. DESIGN FACTORS

H_2S ABATEMENT UNIT

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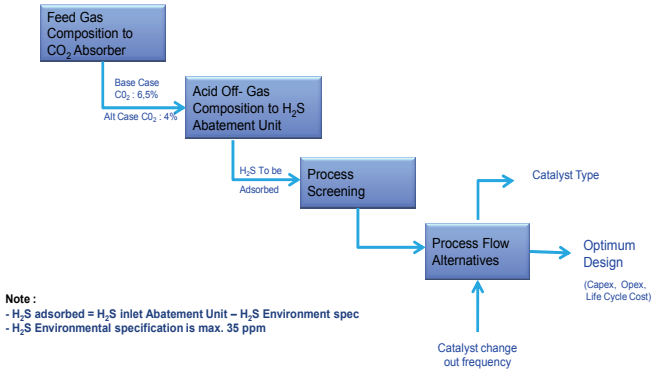
FACTORS TO BE CONSIDERED IN DESIGNING H_2S ABATEMENT UNIT



Note :
- H_2S adsorbed = H_2S inlet Abatement Unit – H_2S Environment spec
- H_2S Environmental specification is max. 35 ppm

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IV. EVALUATION OF DESIGN FACTORS

LNG PROCESSING

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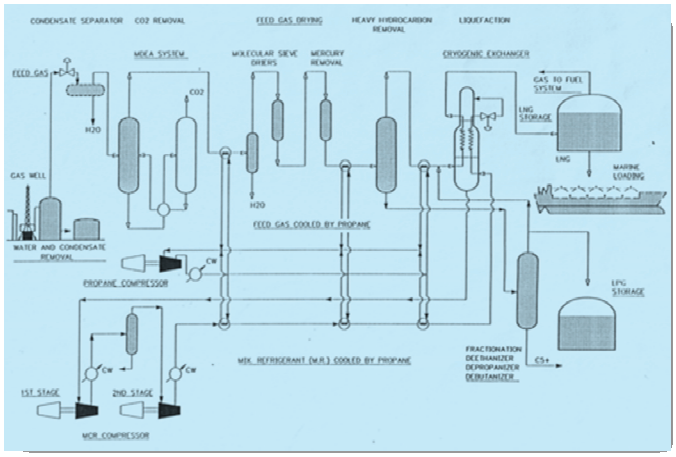
LNG Process Flow Diagram



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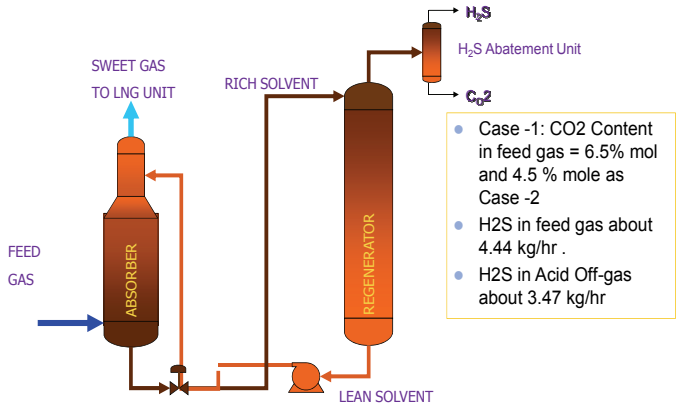
CO2 & H2S ABSORPTION PROCESS



- Case -1: CO2 Content in feed gas = 6.5% mol and 4.5 % mole as Case -2
- H2S in feed gas about 4.44 kg/hr .
- H2S in Acid Off-gas about 3.47 kg/hr

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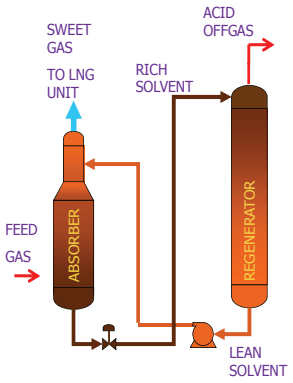
1. Feed Gas Composition to Absorber Unit (dry-mol %)

< Base Feed Gas Case: CO_2 6.5 mol% >

MOLE	Feed Gas	Treated Gas	Flash Gas	Acid Off-gas
Composition [dry-mol%]				
N2	0.083	0.09	0.03	0.00
C1	82.428	88.17	64.91	0.10
C2	5.161	5.52	6.10	0.02
C3	3.446	3.68	3.64	0.01
i-C4	0.711	0.76	0.76	0.00
n-C4	0.815	0.87	0.87	0.00
C5	0.423	0.45	0.45	0.00
C6	0.433	0.46	0.46	0.00
CO2	6.500	0.005	22.78	99.87
H2S	0.0005	0.0003	0.0017	0.0034
Total	100.0	100.0	100.0	100.0



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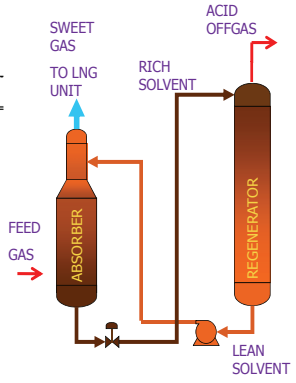
Feed Gas Composition to Absorber Unit (kg/hr)

< Base Feed Gas Case: CO_2 6.5 mol% >

MOLE	Feed Gas	Treated Gas	Flash Gas	Acid Off-gas
Weight Flow [kg/h]				
N2	604.3	612.1	0.2	0.0
C1	343675.9	343409.4	283.6	27.0
C2	40332.6	40297.5	50.0	10.1
C3	39492.4	39397.0	43.7	7.4
i-C4	10740.2	10724.4	12.0	0.0
n-C4	12311.2	12276.7	13.8	0.0
C5	7931.8	7882.4	8.8	0.0
C6	9697.8	9624.1	10.8	0.0
CO2	74345.3	53.4	273.1	74021.3
H2S	4.4	2.5	0.0	2.0
Total	539135.9	464279.5	696.1	74067.9



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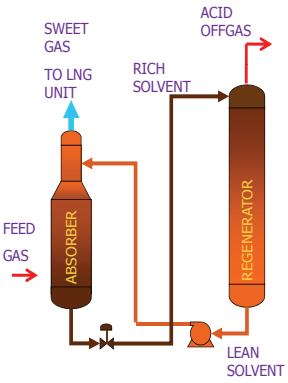
Feed Gas Composition to Absorber Unit (dry-mol %)

< Base Feed Gas Case: CO_2 4.0 mol% >

MOLE	Feed Gas	Treated Gas	Flash Gas	Acid Off-gas
Composition [dry-mol%]				
N2	0.085	0.089	0.033	0.000
C1	84.632	88.158	71.428	0.167
C2	5.299	5.517	6.713	0.033
C3	3.538	3.684	4.006	0.017
i-C4	0.730	0.760	0.836	0.000
n-C4	0.836	0.871	0.957	0.000
C5	0.435	0.453	0.496	0.000
C6	0.444	0.462	0.506	0.000
CO2	4.000	0.0050	15.024	99.778
H2S	0.0005	0.00030	0.002	0.0053
Total	100.0	100.0	100.0	100.0



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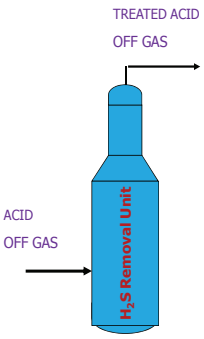
2. Acid Off-Gas Composition (H_2S Removal Unit Design Condition)

		<Case-1>	<Case-2> Bypass = 41.1%	
MOLE	Acid Off-gas	Treated Acid Off-gas (35 PPMY)	Treated Acid Off-gas (4 PPMY)	Overall Acid Off-gas (35 PPMY)
Composition [dry-mol%]				
N2	0.00	0.00	0.00	0.00
C1	0.17	0.17	0.17	0.17
C2	0.03	0.03	0.03	0.03
C3	0.02	0.02	0.02	0.02
i-C4	0.00	0.00	0.00	0.00
n-C4	0.00	0.00	0.00	0.00
C5	0.00	0.00	0.00	0.00
C6	0.00	0.00	0.00	0.00
CO2	99.78	99.78	99.78	99.78
H2S	**0.00550**	**0.00250**	**0.00040**	**0.00250**
Total	100.01	100.00	100.00	100.00
Mole Flow [kgmol/h]				
N2	0.00	0.00	0.00	0.00
C1	3.15	3.15	1.85	3.15
C2	0.56	0.56	0.33	0.56
C3	0.37	0.37	0.22	0.37
i-C4	0.00	0.00	0.00	0.00
n-C4	0.00	0.00	0.00	0.00
C5	0.00	0.00	0.00	0.00
C6	0.00	0.00	0.00	0.00
CO2	1845.93	1845.93	1087.25	1845.93
H2S	0.1018	0.0463	0.0044	0.0462
Total	1850.0	1850.05	1089.65	1850.05



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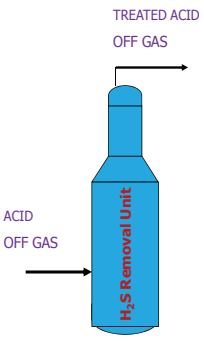
3. H_2S to be Removed (2 kg/hr or 48 kg/day)

WEIGHT	Acid Off-gas	Treated Acid Off-gas (35 PPMY)	Treated Acid Off-gas (4 PPMY)	Overall Acid Off-gas (35 PPMY)
Composition [dry-wt%]				
N2	0.000	0.000	0.000	0.000
C1	0.062	0.062	0.062	0.062
C2	0.021	0.021	0.021	0.021
C3	0.020	0.020	0.020	0.020
i-C4	0.000	0.000	0.000	0.000
n-C4	0.000	0.000	0.000	0.000
C5	0.000	0.000	0.000	0.000
C6	0.000	0.000	0.000	0.000
CO2	99.893	99.895	99.897	99.895
H2S	0.00426	0.00194	0.00031	0.00194
Total	100.0	100.0	100.0	100.0
Weight Flow [kg/h]				
N2	0.00	0.00	0.00	0.00
C1	50.46	50.46	29.72	50.46
C2	16.69	16.69	9.83	16.69
C3	16.32	16.32	9.61	16.32
i-C4	0.00	0.00	0.00	0.00
n-C4	0.00	0.00	0.00	0.00
C5	0.00	0.00	0.00	0.00
C6	0.00	0.00	0.00	0.00
CO2	81239.38	81239.38	47849.99	81239.38
H2S	3.47	1.58	0.15	1.57
Total	81326.3	81324.4	47899.3	81324.4



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4. PROCESS SCREENING

NO	H_2S TO BE REMOVED	PROCESS TYPE
01.	10-30 TON SULFUR /DAY	REGENERABLES SOLVENT SOLVENT/CLAUS PROCESS
02.	LOWER SULFUR RATES	REDOX PROCESS
03.	VERY LOW SULFUR	SIMPLER NON REGENERATIVES PROCESS

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Summary on Non Regenerable H_2S Scavenging Technologies

Category	Catalyst/Solution	Representative Process	Supplier
Solid-based	Iron Oxide	Iron Sponze	
		SulfaTreat (R)	SulfaTreat Co.
	Zinc Oxide	conventional	
		PURASPEC (R)	ICI Katalco (Synetix)
	Sodium and Calcium Hydroxides	Sofnolime RG (R)	Molecular Products Ltd.
Slurry Process	Iron Oxide	Slurrysweet (R)	
	Zinc Oxide	Chemsweet (R)	Natco
Liquid-based	Nitrite-based Solutions	SULFA-CHECK (R)	Nalco/Exxon
		Hondo HS	Hondo Chemical Inc.
	Non-regenerable Amines (Triazines/amine aldehyde)	GAS TREA (R)	Champion Technologies
		SULFA-GUARD (R)	Coastal Co.
		SULFA-SCRUB (R)	Petrolite Corporation
	Others	caustic, formaldehyde, etc.	

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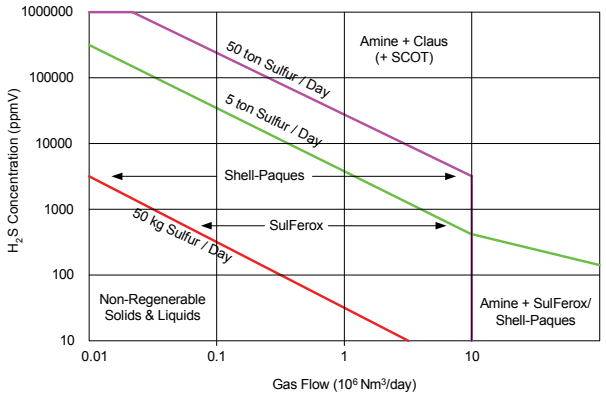
Sulfur Recovery Process Selection



Source : Shell, 2009

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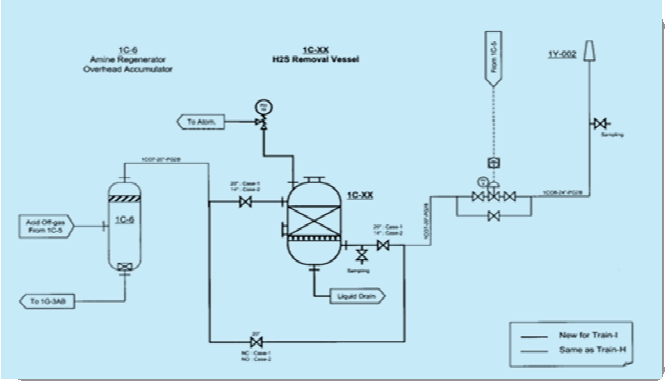
5. Conceptual Flow Scheme for H_2S Abatement Unit (Case – 1: Full Flow; Case – 2: Bypass Flow to H_2S Removal Vessel)



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6. CHANGE OUT FREQUENCY

Case	Case-1				Case-2			
Feed Gas	Full Flow				Bypass Flow			
Catalyst	A		B		A		B	
Time to Change out (Year)	0.5	1	0.5	1	0.5	1	0.5	1

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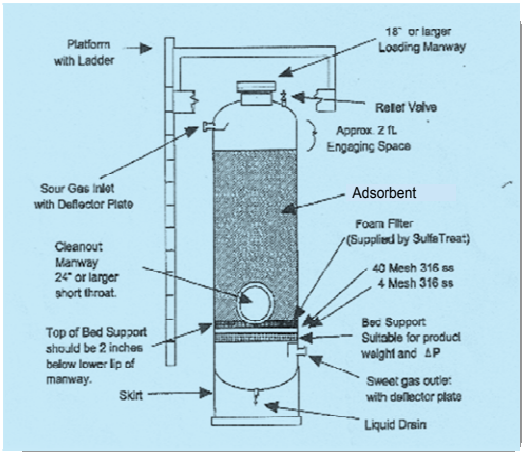
TYPICAL OF H_2S VESSEL CONFIGURATION



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7. Total H_2S adsorbed, Catalyst Required and Equipment Sizing, Case-1: Full Flow and 0.5 years Catalyst Change out (or 0.5 year continuous operation)

		Catalyst- A	Catalyst-B
<CATALYST Information>			
Total H2S Adsorbed	[lb]	25,508	
	[ton]	11.57 (*1)	
Required Catalyst Quantity	[lb]	240,290 (*3)	68,618
	[ton]	109.0	31.3
	[ft3]	3,881	1,011 (*4)
	[m3]	109.9	28.3
Catalyst Type		A	B
Bed Size	[mm]	Dia. 7,000 (*5) Height 2,900	Dia. 3,800 Height 2,500
Operating Pressure	[Kg/cm2A]	2.12 (*3)	1.50
Pressure Drop	[Kg/cm2]	0.11	< 0.1
<Vessel Information>			
Vessel Size	[mm]	I.D. 7,000 TL-TL 5,300	I.D. 3,800 TL-TL 4,900
Design Pressure	[Kg/cm2G]	3.5 & FV	3.5 & FV
Design Temperature	[°C]	135	135
Material		304L	304L

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7a. Cost Required (estimated) for Point 7

	Catalyst-A	Catalyst-B
<INITIAL INVESTMENT>		
Equipment Cost (Vessel)	550,000	215,000
Bulk/Construction Cost (*6)	275,000	107,500
Indirect Cost (*7)	275,000	107,500
1E-5 Cost Impact (*8)	402,000	0
Catalyst Initial Filling	96,200	151,000
Total Capital Cost	**1,598,200**	**581,000**
<Operating Cost / Year>		
Catalyst (*9)	192,400	302,000
Changeout Cost	Nil	Nil
Total Operating Cost / Year	**192,400**	**302,000**

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8. Total H_2S adsorbed, Catalyst Required and Equipment Sizing, Case-1: Full Flow and 1 years Change out (or 1 year continuous operation)

		Catalyst-A	Catalyst-B
<CATALYST Information>			
Total H2S Adsorbed	[lb]	51,017	
	[ton]	23.14 (*1)	
Required Catalyst Quantity	[lb]	480580 (*3)	137,236
	[ton]	218.0	62.2
	[ft3]	7,761	2,002 (*4)
	[m3]	219.8	56.7
Catalyst Type		A	B
Bed Size	[mm]	Dia. 7,000 (*5) Height 5,800	Dia. 3,800 Height 5,000
Operating Pressure	[Kg/cm2A]	2.12 (*3)	1.50
Pressure Drop	[Kg/cm2]	0.23	< 0.1
<Vessel Information>			
Vessel Size	[mm]	I.D. 7,000 TL-TL 8,200	I.D. 3,800 TL-TL 7,400
Design Pressure	[Kg/cm2G]	3.5 & FV	3.5 & FV
Design Temperature	[°C]	135	135
Material		304L	304L

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8.a. Cost Required (estimated) for Point 8

	Catalyst-A	Catalyst-B
<INITIAL INVESTMENT>		
Equipment Cost (Vessel)	846,000	325,000
Bulk/Construction Cost (*6)	423,000	162,500
Indirect Cost (*7)	423,000	162,500
1E-5 Cost Impact (*8)	402,000	0
Catalyst Initial Filling	192,400	302,000
Total Capital Cost	**2,286,400**	**952,000**
<Operating Cost / Year>		
Catalyst (*9)	192,400	302,000
Changeout Cost	Nil	Nil
Total Operating Cost / Year	**192,400**	**302,000**

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9. Total H_2S Adsorbed, Catalyst Required and Equipment Sizing, Case-2: Bypass Flow and 0.5 years Catalyst Change out (or 0.5 year continuous operation)

		Catalyst-A	Catalyst-B
<CATALYST Information>			
Total H2S Adsorbed	[lb]	18,736	
	[ton]	8.50 (*2)	
Required Catalyst Quantity	[lb]	176,490 (*3)	50,399
	[ton]	80.1	22.9
	[ft3]	2,850	735 (*4)
	[m3]	80.7	20.8
Catalyst Type		A	B
Bed Size	[mm]	Dia. 6,600 (*5) Height 2,400	Dia. 3,000 Height 3,000
Operating Pressure	[Kg/cm2A]	1.50	1.50
Pressure Drop	[Kg/cm2]	0.10	< 0.1
<Vessel Information>			
Vessel Size	[mm]	I.D. 6,600 TL-TL 4,800	I.D. 3,000 TL-TL 5,400
Design Pressure	[Kg/cm2G]	3.5 & FV	3.5 & FV
Design Temperature	[°C]	135	135
Material		304L	304L

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9.a. Cost Required for Point 9

	Catalyst-A	Catalyst-B
<INITIAL INVESTMENT>		
Equipment Cost (Vessel)	470,000	190,000
Bulk/Construction Cost (*6)	235,000	95,000
Indirect Cost (*7)	235,000	95,000
1E-5 Cost Impact	402,000	0
Catalyst Initial Filling	70,600	111,000
Total Capital Cost	**1,412,600**	**491,000**
<Operating Cost / Year>		
Catalyst (*9)	141,200	222,000
Changeout Cost	Nil	Nil
Total Operating Cost / Year	**141,200**	**222,000**

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10. Total H_2S adsorbed, Catalyst required and Equipment Sizing, Case-2: Bypass Flow and 1 years Catalyst Change out (or 1 year continuous operation)

		Catalyst-A	Catalyst-B
<CATALYST Information>			
Total H2S Adsorbed	[lb]	37,471	
	[ton]	17.00 (*2)	
Required Catalyst Quantity	[lb]	352,980 (*3)	100,798
	[ton]	160.1	45.7
	[ft3]	5,701	1,471 (*4)
	[m3]	161.4	41.6
Catalyst Type		A	B
Bed Size	[mm]	Dia. 7,000 (*5) Height 4,200	Dia. 3,000 Height 5,900
Operating Pressure	[Kg/cm2A]	1.50	1.50
Pressure Drop	[Kg/cm2]	0.14	< 0.1
<Vessel Information>			
Vessel Size	[mm]	I.D. 7,000 TL-TL 6,600	I.D. 3,000 TL-TL 8,300
Design Pressure	[Kg/cm2G]	3.5 & FV	3.5 & FV
Design Temperature	[°C]	135	135
Material		304L	304L

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11. Cost Required for point 10

[US$]	Catalyst-A	Catalyst-B
<INITIAL INVESTMENT>		
Equipment Cost (Vessel)	685,000	290,000
Bulk/Construction Cost (*6)	342,500	145,000
Indirect Cost (*7)	342,500	145,000
1E-5 Cost Impact	402,000	0
Catalyst Initial Filling	141,200	222,000
Total Capital Cost	**1,913,200**	**802,000**
<Operating Cost / Year>		
Catalyst (*8)	141,200	222,000
Changeout Cost	Nil	Nil
Total Operating Cost / Year	**141,200**	**222,000**

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12. CHANGE OUT / DISPOSAL PROCEDURES

Description	Catalyst-A	Catalyst-B
Waste quantity for 20 years operation (estimated)	3200 ton	915 ton
Required Area for 20 years operation (estimated) <assuming 2 m waste layer depth>	40 m X 40 m 1600 m2	20 m x 20 m 400 m2

Catalyst A requires the use of more land area than Catalyst B.

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13. PLANT LAY OUT

NOT A BIG DIFFERENCE FOR PLANT LAY OUT OF CATALYST A AND B.

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13. Study Summary for H_2S Abatement Unit

			Case-1 (Full Flow)				Case-2 (Bypass Flow)			
			A		B		A		B	
Changeout Period		[year]	0.5	1	0.5	1	0.5	1	0.5	1
Vessel	Dia	[mm]	7,000	7,000	3,800	3,800	6,600	7,000	3,000	3,000
	Bed Height	[mm]	2,900	5,800	2,500	5,000	2,400	4,200	3,000	5,900
	TL-TL	[mm]	5,300	8,200	4,900	7,400	4,800	6,600	5,400	8,300
CAPEX (*1)		[US$]	1,599,000	2,287,000	581,000	952,000	1,413,000	1,914,000	**491,000**	802,000
OPEX		[US$]	193,000	193,000	302,000	302,000	142,000	142,000	222,000	222,000

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14. Life Cycle Cost Estimation H_2S Abatement Unit (Case 1)

			A (1 Year)	B (1 Year)	A (0.5 Year)	B (0.5 Year)
CAPEX	Vessel	[US$]	846,000	325,000	550,000	215,000
	Others	[US$]	846,000	325,000	550,000	215,000
	Impact to Existing	[US$]	402,000	0	402,000	0
	Catalyst	[US$]	192,400	302,000	96,200	151,000
	Total	[US$]	2,286,400	952,000	1,598,200	581,000
OPEX	Catalyst	[US$/Year]	192,400	302,000	192,400	302,000
	Replace MH Cost	[US$/Year]	0	0	0	0
	Total	[US$/Year]	192,400	302,000	192,400	302,000

Life Cycle Cost	Year	A (1 Year)	B (1 Year)	A (0.5 Year)	B (0.5 Year)
	0	2,286,400	952,000	1,598,200	581,000
	1	2,478,800	1,254,000	1,790,600	883,000
	2	2,671,200	1,556,000	1,983,000	1,185,000
	3	2,863,600	1,858,000	2,175,400	1,487,000
	4	3,056,000	2,160,000	2,367,800	1,789,000
	5	3,248,400	2,462,000	2,560,200	2,091,000
	6	3,440,800	2,764,000	2,752,600	2,393,000
	7	3,633,200	3,066,000	2,945,000	2,695,000
	8	3,825,600	3,368,000	3,137,400	2,997,000
	9	4,018,000	3,670,000	3,329,800	3,299,000
	10	4,210,400	3,972,000	3,522,200	3,601,000
	11	4,402,800	4,274,000	3,714,600	3,903,000
	12	4,595,200	4,576,000	3,907,000	4,205,000
	13	4,787,600	4,878,000	4,099,400	4,507,000
	14	4,980,000	5,180,000	4,291,800	4,809,000
	15	5,172,400	5,482,000	4,484,200	5,111,000

Life Cycle *Cost for Catalyst A lower* than Catalyst B

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15. Life Cycle Cost Estimation H_2S Abatement Unit (Case 2)

			A (1 Year)	B (1 Year)	A (0.5 Year)	B (0.5 Year)
CAPEX	Vessel	[US$]	685,000	290,000	470,000	190,000
	Others	[US$]	685,000	290,000	470,000	190,000
	Impact to Existing	[US$]	402,000	0	402,000	0
	Catalyst	[US$]	141,200	222,000	70,600	111,000
	Total	[US$]	1,913,200	802,000	1,412,600	491,000
OPEX	Catalyst	[US$/Year]	141,200	222,000	141,200	222,000
	Replace MH Cost	[US$/Year]	0	0	0	0
	Total	[US$/Year]	141,200	222,000	141,200	222,000

Life Cycle Cost	Year	A (1 Year)	B (1 Year)	A (0.5 Year)	B (0.5 Year)
	0	1,913,200	802,000	1,412,600	491,000
	1	2,054,400	1,024,000	1,553,800	713,000
	2	2,195,600	1,246,000	1,695,000	935,000
	3	2,336,800	1,468,000	1,836,200	1,157,000
	4	2,478,000	1,690,000	1,977,400	1,379,000
	5	2,619,200	1,912,000	2,118,600	1,601,000
	6	2,760,400	2,134,000	2,259,800	1,823,000
	7	2,901,600	2,356,000	2,401,000	2,045,000
	8	3,042,800	2,578,000	2,542,200	2,267,000
	9	3,184,000	2,800,000	2,683,400	2,489,000
	10	3,325,200	3,022,000	2,824,600	2,711,000
	11	3,466,400	3,244,000	2,965,800	2,933,000
	12	3,607,600	3,466,000	3,107,000	3,155,000
	13	3,748,800	3,688,000	3,248,200	3,377,000
	14	3,890,000	3,910,000	3,389,400	3,599,000
	15	4,031,200	4,132,000	3,530,600	3,821,000

Life Cycle *Cost for Catalyst A lower* than Catalyst B

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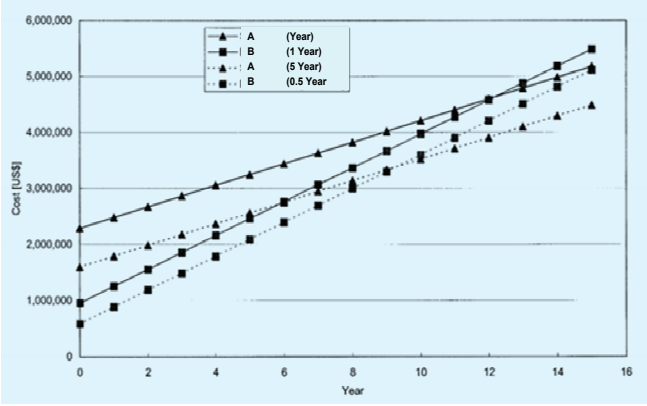
16. Life Cycle Cost for H_2S Abatement Unit (Case 1)



Catalyst A has a lower life cycle cost than Catalyst B

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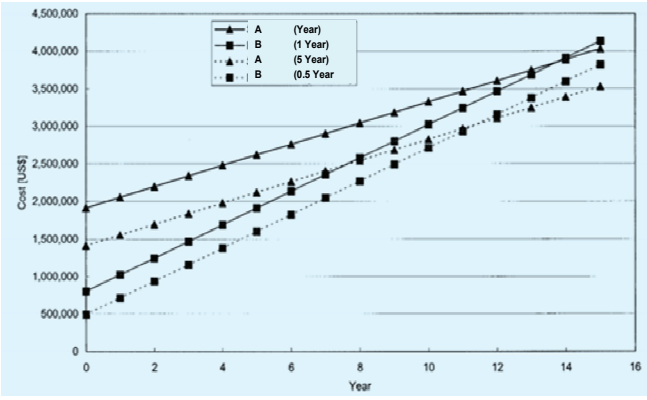
17. Life Cycle Cost for H_2S Abatement Unit (Case 2)



Life Cycle Cost for Catalyst A is lower than Catalyst B

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CONCLUSION

From this study, it could be concluded that the following factors need to be considered in designing the H_2S Abatement Unit:

1) feed gas composition to Absorber Unit
2) acid off-gas composition to H_2S Abatement Unit
3) catalyst type
4) change out of catalyst frequency
5) process flow alternatives
6) cost analysis of Capex and Opex
7) life cycle cost of the system
8) the plant lay out factors and change out/disposal procedure

Catalyst type A is recommendable from the aspect of overall life cycle cost along with consideration of factors such as Capex, Opex.

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