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Absorption Acid Gas Removal in Liquefied Natural Gas Process

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ABSTRACT

Simulation of fluid mechanic of amine absorber process in removing acid gas from feed sour gas in LNG production plant is presented in this paper. The amine absorption in the Removing Acid Gas Process is designed to remove carbon dioxide (CO_2), hydrogen sulfide (H_2S) and other sulfur compounds from the sour feed gas. The sour gas together with the recycle gas from the Treater unit enters the bottom of Amine Absorber and flows upward and passes through a demister pad to water wash section. In the Amine Absorber, the down-flowing amine solution absorbs H_2S and CO_2 from the up-flowing sour gas to produce a sweetened gas stream as a product and an amine solution rich in the absorbed acid

KEY WORDS: *Liquid Natural Gas; Acid Gas Removal; Amine Absorber; Feed Gas; Carbon Filter; Treater, Sweet Gas; Rich Amine; Water Wash System.*

NOMENCLATURE

H_2S : Hydrogen Sulfide
CO_2 : Carbon Dioxide
MDEA : MethylDiethanolamine
DU : Dehydration Unit
FGS : Flash Gas System
SRU : Sulfur Recovery Unit
AU : Absorption Unit
RU : Regeneration Unit
SU : Supporting Unit
FEED : Front End Engineering Design
USIF : Up-Stream Inlet Facility
FGFS : Feed Gas Filter Separator
FPH : Feed Pre-Heater
PFD : Pre-Flash Drum
AA : Amine Absorber
TU : Treater Unit
RFD : Rich Flash Drum
AHD : Absorber Hydrocarbon Drum
SRD : Solvent Recovery Drum
WWP : Water Wash Pump WWP
WWT : Water Wash Tray
CT : Chimney Tray
CC : Condensate Cooler
OW : Overflow Weir
MWP : Makeup Water Pump
WBT : Water Break Tank
FWC : Flash Wash Column
FGWWP : Flash Gas Water Wash Pump
FGD : Fuel Gas Drum
PF : Pre-Filter
CF : Carbon Filter
AF : After-Filter
LRHE : Lean Rich Heat Exchanger
LSBP : Lean Solvent Booster Pump
DSHS : De-Super Heater Steam
RB : Re-boiler
RP : Reflux Pump
AGAC : Acid Gas Air Cooler
AGTC : Acid Gas Trim Cooler
RD : Reflux Drum
LSAC : Lean Solvent Air Cooler
LSTC : Lean Solvent Trim Cooler
LSP : Lean Solvent Pump
SOP : Skim Oil Pump
SF : Sump Filter
SP : Sump Pump
DPC : Dryer Pre-Cooler

RTU : Regeneration Treating Unit
RG : Re-Generator

1.0 INTRODUCTION

Increasing global energy demand and environment issue have pushed oil and gas players to search the econ-green alternative sources even to the remote area. Energy from natural gas is the major alternative source with less environmental impact which is discovered this century. Chemical properties of the natural gas contains some complex contaminants such as CO_2, H_2S, CO, Mercaptan (Acid Gas). At the atmosphere, these materials constitute great environmental hazards for human body. They are also hindered natural gas processes.

The natural gas is effectively transported through pipelines due the energy content per unit volume is relatively low. As transportation distance increases, the pipelines system becomes inefficient; therefore liquefaction process transform from gas to liquid form is more economical and viable options.

The liquefaction of natural gas process involves operation at a very low Temperature which is about -161 ^{0}C and very low atmospheric pressure. At these conditions CO_2 can freeze out on exchanger surface, plugging lines and reduce plant efficiency. Therefore there is need for removal of CO_2 before liquefaction process, this is done not to overcome the process bottle necks but also to meet the LNG product specifications, prevent corrosion of process equipment and environmental performance.

Amine gas treating is also known as gas sweetening and acid gas removal. The acid gas removal unit in LNG process is designed to remove unnecessary gases such as:$H_2S$and CO_2 and other sulphur compounds from the FEED sour gas by means of chemical absorption. There are many acid gas treating processes available for removal of CO2 from natural gas. These processes include Chemical solvents, Physical solvents, Adsorption Processes Hybrid solvents and Physical separation (Membrane) (Kohl and Nielsen, 1997); The chemical solvents and physical solvents or combination of these two have been used extensively in existing base load LNG facilities (David Coyle et. al 2003).

The process scheme selected in the present study is MDEA. In the process scheme, the treated gas is sent to DU, the flash gas is sent to FGS, and the acid gas is sent to SRU.

The MDEA is a tertiary amine and an "activator". The amine reactions occurring in the absorber are:

$$H_2S + R_2CH_3N \rightarrow R_2CH_3NH^+ + HS^- \quad (1)$$

$$CO_2 + R_2CH_3N + H_2O \rightarrow R_2CH_3NH^+ + HCO_3^- \quad (2)$$

The H_2S reacts much faster with the amine than does the CO_2, because the reaction between amine and H_2S appears gas film diffusion-rate limited, whereas the reaction between the amine and CO_2 is kinetically limited. Therefore, if the absorber is designed in such a manner to provide an adequate number of contact stages with sufficient contact time, total absorption of H_2S and CO_2 can be achieved. The trays in the absorber are designed with sufficient contact time such that the CO_2 content of the sweet gas meets the 25 ppmv specification while also achieving the 2 ppmv H_2S specification. The activator present in the solvent enhances the CO_2 reaction kinetics, enabling its essentially complete removal.

To achieve low H_2S and CO_2 slippage in the absorber operating at high pressure, it is necessary to strip the amine to a very low acid gas loading (typical loading is < 0.01 mole acid gas/mole amine). Steam stripping occurs in the regenerator at high temperature and reverses the reactions given above. The steam reduces the partial pressure of H_2S and CO_2 over the amine, thus reducing the equilibrium concentration (or loading) of these components in the amine.

2.0 ABSORPTION ACID GAS PROCESS FLOW

The acid gas removal or amine gas treating process is divided into three main units as follows: AU, RU and SU. In the absorber, the down-flowing amine solution absorbs H_2S and CO_2 from the up-flowing sour gas to produce a sweetened gas stream as a product and an amine solution rich in the absorbed acid gases. Fig.1 shows an absorption unit process flow diagram for acid gas removal. The resultant "rich" amine is then routed into the regenerator to produce regenerated or "lean" amine that is recycled for reuse in the absorber. The stripped overhead gas from the regenerator is concentrated H_2S and CO_2.

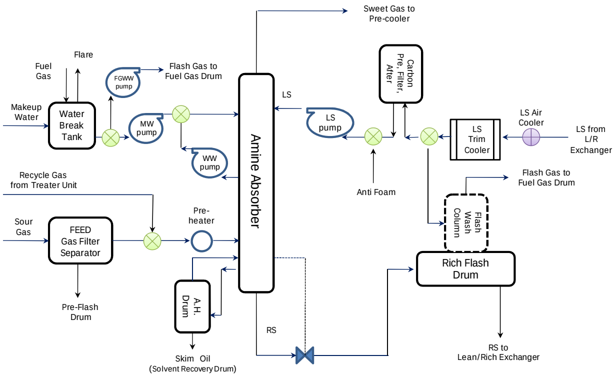

Figure 1: Absorption removing acid gas process flow diagram

2.1 Feed Gas Filtration and Preheating Process

The feed gas filtration and preheating mainly consists of FGFS and FPH. The sour feed gas with composition as shown Table.1 is flown from the USIF to the FGFS. The main task of FGFS eliminates any liquid hydrocarbons droplets and solids. Another task of the FGFS is to handle liquid slugs and shuts down the train when a high liquid level occurs. The liquid from the drum is recycled back to the PFD in the USIF.

In order to avoid liquid hydrocarbon condensing in the AA, the outlet gas from the FGFS is combined with the recycle gas, as shown in Table.1, from TU before entering the FPH to maintain the gas above its saturation temperature (dew point). Normal operating temperature and Pressure is 40.0^0C and 69 bar prior to entering Absorber as shown in Table.2 in In-AA. The FPH uses MP steam as a heating medium.

Table 1: Properties of the feed gas and recycle gasses.

Items	Feed Gas to FGFS	Recycle Gas from TU
State	Vapor	Vapor
H_2S $(mol\,\%\,dry)$	0.8	0.0
CO_2 $(mol\,\%\,dry)$	2.5	0.0
$Sulfur\ (mol\,\%\,dry)$	0.04	0.02
$Molecular\ (Wet)$	19.0	18.0
$Density\ (kg/m^3)$	57.0	48.0
Normal Operating Temperature (C)	40^0	60^0
Normal Operating Pressure (Bar)	73	70
$Total\ flow\ kg/h\ (wet)$	1460000	32000

Table 2: Mechanical properties of feed gas enters and Rich Solvent leaves the Amine Absorber

Items	Feed Gas from FGFS to AA
State	Vapor
H_2S $(mol\,\%\,dry)$	0.8
CO_2 $(mol\,\%\,dry)$	2.40
$Sulfur\ (mol\,\%\,dry)$	0.04
$Molecular\ (Wet)$	19.0
$Density\ (kg/m^3)$	57.0
Normal Operating Temperature (C)	40^0
Normal Operating Pressure (Bar)	69
$Total\ flow\ kg/h\ (wet)$	1490000

2.2 Amine Absorption System

The absorption process mainly consists of the following equipments: Amine Absorber, Flash Wash Column, Lean Solvent Pump, Water Wash Pump, Makeup Water Pump, Flash Gas Water Wash Pump, Absorber Hydrocarbon Drum, Rich Flash Drum and Water Break Tank.

The feed gas with mechanical properties as shown in Table.2 enters the bottom of AA and flows upward and passes through a demister pad to water wash section. Amine Absorber is equipped with 30 absorption trays, where the gas is counter-currently contacted with the solvent. The lean solvent enters the tower at a controlled temperature of 45^0C through a liquid distributor and flows down through the trays, absorbing H_2S and CO_2 to the required product specifications. Only a small amount of mercaptans and other sulfur compounds are absorbed by the solvent.

As the solvent flows down through absorber, the heat of absorption liberated by the acid gases reacting with the solvent is removed by the solvent. Thus, the rich solvent leaves the bottom of the column at an elevated temperature around 66^0C as shown in Table.2.

A solvent reservoir is maintained in the bottom of AA by liquid level control with an automatic level control valves in the rich solvent line between AA and RFD. Pressure differential indicators are also available so that the pressure drop and hydraulic performance of AA can be monitored.

AHD is provided adjacent to the bottom of AA to allow liquid hydrocarbon skimming capabilities in AA, when necessary, to the SRD.

The top section of AA contains three WWT and an OW above the lean solvent feed point to minimize solvent losses. A pump-around loop is used for the wash water to provide good gas or liquid contacting. A portion of the makeup water enters at the pump-around pump discharge.

The makeup water at 45^0C and 3.5 bar from the CC and fuel gas are stored in the WBT. The water streams enter above the top WWT, and then, the make-up water is flown to MWP and FGWWP. Mechanical properties of the makeup water are shown in Table.3.

Table 3: Mechanical properties of make-up water from WBT to MWP and FGWWP

Items	Make-up water from WBT to MWP	Make-up water from WBT to FGWWP
State	Liquid	Liquid
H_2S $(mol\,\%\,dry)$	0.0	0.0
CO_2 $(mol\,\%\,dry)$	0.0	0.0
$Sulfur\ (mol\,\%\,dry)$	0.00	0.00
$Molecular\ (Wet)$	18.0	18.0
$Density\ (kg/m^3)$	997.0	997.0
Normal Operating Temperature (C)	45^0	45^0
Normal Operating Pressure (Bar)	1.2	1.2
$Total\ flow\ kg/h\ (wet)$	3800	1130

WWP draws water from the CT and pumps the water to combine with a portion of the makeup water from MWP. The mechanical properties of the waters are shown in Table.4. The makeup water entering at this location reduces the build-up of solvent in the water wash loop. The water wash minimizes the losses of solvent with the sweet gas. Water level above the chimney tray is maintained with an automatic level control valve, which sends excess water to RFD

The sweet gas from top of AA is flown to DPC in RTU with expected parameters as shown in Table.5

Table 4: Mechanical properties of water withdrawn from the chimney tray

Items	Water from CT-AA to WWP	Combination water from WWP-MWP to WWT-AA
State	Liquid	Liquid
H_2S $(mol\,\%\,dry)$	1.1	1.15
CO_2 $(mol\,\%\,dry)$	2.8	2.8
$Sulfur\ (mol\,\%\,dry)$	0.00	0.00
$Molecular\ (Wet)$	18.0	18.0
$Density\ (kg/m^3)$	990.0	991.0
Normal Operating Temperature (C)	47^0	46^0
Normal Operating Pressure (Bar)	69	69
$Total\ flow\ kg/h\ (wet)$	67800	68000

Table 5: Mechanical properties of sweet sour gas from Amine Absorber

Items	Sweet Gas from AA
State	Vapor
H_2S $(mol\ \%\ dry)$	0.0
CO_2 $(mol\ \%\ dry)$	0.0
$Sulfur\ (mol\ \%\ dry)$	0.035
$Molecular\ (Wet)$	18.4
$Density\ (kg/m^3)$	52.0
Normal Operating Temperature (C)	47^0
Normal Operating Pressure (Bar)	68.0
$Total\ flow\ kg/h\ (wet)$	1385000

The rich solvent flows from the bottom of AA to RFD with mechanical properties of the rich solvent are shown in Table.6. The RFD serves two purposes:

i. Degassing of volatile, dissolved hydrocarbons; and
ii. Separation of heavier liquid hydrocarbons.

Table 6: Mechanical properties of feed gas enters and Rich Solvent leaves the Amine Absorber

Items	Rich Solvent from AA to RFD	Foam Water to FWC
State	Liquid	Liquid
H_2S $(mol\ \%\ dry)$	7.0	7.1
CO_2 $(mol\ \%\ dry)$	21.9	21.8
$Sulfur\ (mol\ \%\ dry)$	0.0	0.0
$Molecular\ (Wet)$	29.0	29.0
$Density\ (kg/m^3)$	1055.0	1055.0
Normal Operating Temperature (C)	66^0	45^0
Normal Operating Pressure (Bar)	69	7.0
$Total\ flow\ kg/h\ (wet)$	1680000	8200

Hydrocarbon skimming is provided to allow liquid hydrocarbon withdrawal when necessary to the SRD. A small water flow from FGWWP enters above the top packed bed of FWC to wash the flash gas and minimize solvent losses. Also the water stream has a Chemical Injection Point to allow the introduction of antifoam when required.

The flashed gas exiting FWC is water saturated at 42^0C and 6.8 Bar and is routed to the FGD. The Flash Gas exits the RFD through a three bed packed FWC. Since the flashed gas contains too much H_2S for the fuel system, the gas is contacted with a slipstream of the lean solvent to meet the requirement of less than 50 ppmv H_2S. The cooled lean solvent enters above the middle packed bed to re-absorb most of the H_2S and a portion of the CO_2 flashed out of the solvent in the drum.

2.3 Carbon Filtration Process

Filtration section consists of the following equipments: Pre-Filter, Carbon-Filter and After-Filter as shown in Fig.2. A 25% slipstream is routed to a filtration section. The mechanical properties are shown in the Table.7. PF removes any solid materials which may be in the system and protects CF from plugging. CF will remove surface active contaminants that promote foaming such as heavy hydrocarbons, surfactants, compressor oils, etc. Downstream of CF is AF to ensure that carbon fines from CF do not contaminate the system. Such carbon fines could be the result of improper CF operation, such as inadequate carbon defining, aging of the carbon, or improper installation. PF and AF are cartridge filters, rated at 10 micron.

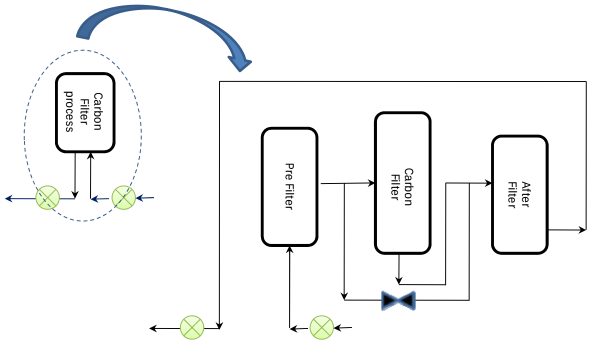

Figure 2: Carbon filter flow diagram.

Table.7 Mechanical properties of sweet sour gas to Carbon filter section.

Items	Stream to CF section
State	Liquid
H_2S $(mol\ \%\ dry)$	0.15
CO_2 $(mol\ \%\ dry)$	0.60
$Sulfur\ (mol\ \%\ dry)$	0.00
$Molecular\ (Wet)$	29.0
$Density\ (kg/m^3)$	1009.0
Normal Operating Temperature (C)	45^0
Normal Operating Pressure (Bar)	8.0
$Total\ flow\ kg/h\ (wet)$	398,000

3.0 CONCLUSION

Absorption acid gas removal of Liquefied Natural Gas process has been discussed. The process includes FEED gas filtration and preheating process, amine absorption system and carbon filtration process**.**

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