

Floating LNG unit

Drying

or

CO2 removal

**How molecular sieve designs can
answer to Amine unit performance?**

**Peter. B. Chr. Meyer
CECA SA**

**Paper presented at the GPA Europe Conference
in London on Feb 19th 2009.**

Abstract

FLNG - Drying or CO₂-removal How molecular sieve designs can answer to Amine unit performance ?

Floating LNG are the present challenge for a compact and competitive design. The below paper discusses the impact of Amine unit setup causing fluctuations of the CO₂ concentration in the treated gas and how the design of a molecular sieve unit will be changed in order to compensate these fluctuations.

Designs for drying only and drying and CO₂-removal are shown based on 250 MMSCFD feed flow (1 – 1.5 MMtpa LNG unit).

It is assumed that there is no H₂S in the gas to be removed by the Amine unit and that the fluctuations of the CO₂ content are 50 ppmV in the drying case (Amine unit on spec for CO₂) and 400 ppmV in the drying and CO₂ removal case.

Different solutions for the unit arrangement of the CO₂ removal and drying package (Amine and molecular sieves) are proposed.

Presented by Peter Meyer, Business Manager Dynamic Applications, Molecular sieves business unit, CECA SA.

Biography

Peter Bernd Christian MEYER is Business Manager Dynamic Applications and head of the O&G team for the molecular sieves of CECA in the headquarter in Paris.

The O&G team covers adsorbent applications for Natural Gas, Petrochemistry, Refinery and Bioethanol. He has 10 years experience in the adsorbent business. He worked previously 5 years as Process and Project Engineer in an engineering company Salzgitter Anlagenbau in Germany and in a process department of a ARKEMA (former name ATOFINA).

He holds a diploma of the Technical University of Karlsruhe, Germany in Chemical Engineering and second diploma from the Ecole National Supérieure du Pétrole et des Moteurs (known as IFP school), France in Refinery, Engineering and Gas Technology.

He has already given several presentations about molecular sieves at the GPA Europe and on internal company seminars such as PEATEM (Aramco). The most recent one was a training session about molecular sieves in the Natural Gas Industry in Feb 2007 at the GPA Europe in Paris.

FLNG - Drying or CO₂-removal

How molecular sieve designs can answer to Amine unit performance ?

Introduction

Molecular sieve designs for Natural Gas Drying prior to its liquefaction are pretty much standard designs. Depending on the inlet flow rate the design is done with adsorption times of 16-24 hrs, 2 to 3 vessels in adsorption and 1 in regeneration. The treated gas is used for regeneration and fed back to the inlet of the drying unit after being cooled down by an air cooler or a chiller. 4A is the most often used molecular sieve allowing rather high regeneration temperatures going up to 280-300 °C. The principal reason for this is the high regeneration pressure and the lower regeneration gas quantity needed to regenerate the sieves.

On a FLNG (floating LNG unit) there are different constraints. Only a certain number of utilities are available for space or security reasons. Even if the molecular sieve unit itself is not subject to upsets due to hull motion there are other units where two phases, liquid and gas, are present, which may face at least temporarily off spec production or malfunction.

Taking into account a typical scheme of a gas treatment plant an Amine unit could be subject to such upsets. The below paper treats different upset conditions and proposes different designs in order to meet the specification of the Natural Gas before liquefaction (CO₂ below 50 ppmV, water below 1 ppmV).

The goal of the paper is to show a couple of solutions and to give a starting point for a technical discussion. The reader will see that the most important point is to well define the different cases the molecular sieve unit has to cope with and that one design can not easily fit to all the cases.

Focusing in drying case only a particularly optimized design for CAPEX and OPEX will be shown, too.

Design basis

A typical gas treatment unit for LNG production consist of an

- Amine unit for the removal of CO₂ and probably H₂S
- Chiller to reduce the gas water content before the drying unit
- Molecular sieve drying unit
- Liquefaction unit (not detailed as not subject of this paper)

As the FLNG units are rather for small or mid size gas fields the production capacity is about 1-1.5 MMtpy LNG which corresponds to a feed flow (sweet gas) of about 250 MMSCFD.

For the design the following other operating conditions are assumed

- Chiller outlet temperature 25 °C, in case of chiller upset the temperature is 40 °C
- Pressure 56 bar
- Gas composition 99.2% C₁, 0.25% C₂, 0.05% C₃, 0.5% CO₂
- Water saturated
- Impurities: no H₂S, RSH, sulfides, disulfides ... only water and CO₂ to be removed

Process options

Looking more in detail on the design of the molecular sieve unit, there are several options for the regeneration gas and the vessel design.

Regeneration

There are two general options. Either the treated gas is used directly at the outlet of the adsorption unit or boil off gas from the liquefaction train could be used.

A material balance can indicate the possibility of using the boil-off gas as regeneration gas. Taking into account its availability at a lower pressure than adsorption pressure a depressurization and repressurization step has to be taken into account in the molsieve design.

Depending on the available utilities the regeneration temperature could be between 240-290 °C. This temperature level will have a strong influence on the design.

Different solutions are possible for the use of the regeneration gas:

- Option 1: the regeneration gas (treated gas) could be cooled by a seawater cooler, the liquids separated from the gas and then the gas recycled to the inlet of the adsorption unit. The gas would in this case only be water saturated during the heating phase of the regeneration. For seawater cooling it was assumed that 40 °C gas temperature might be obtained.
- Option 2: the regeneration gas (treated gas) could be cooled by a seawater cooler, the liquids separated from the gas and then the gas recycled to the inlet of the chiller. The gas would in this case be water saturated all the time but with a lower water content (25 °C).
- Option 3: the regeneration is not recycled in the case of CO₂ removal by molecular sieve. It could be possibly flared or used as fuel gas. If treated gas is used this would significantly reduce production if the regeneration gas flow rate is higher than the fuel gas consumption.

Vessel

Two options for the vessel design should be considered: internal or external heat insulation.

Design philosophy - questions

A huge number of possible cases for the drying and CO₂ removal could be imagined.

In the drying only scenario the case that the chiller does not work (during start-up) should be considered. In this case the feed temperature could be between 25 and 40 °C. In terms of water load the difference is more than the double.

What happens in the case of Amine unit upset? Which CO₂ content should be taken: 100, 200, 400ppmV, more? Is there only a peak with a limited duration or shall the molsieve design be for a constantly high CO₂ content.

Shall the higher CO₂ case been taken into account with the chiller failure? In this case, high water content, high CO₂ content and at the same time a lower adsorption capacity due to higher adsorption temperature have to be considered.

Shall the regeneration gas be recycled? Shall it be recycled to the inlet of the Amine unit to possibly remove the adsorbed CO₂?

The above mentioned questions, a certainly incomplete list, show that the base design for the molsieve unit should be well defined to prevent installing an over designed unit.

In order to illustrate the different options, two cases were studied showing the two limits. Both were considered as grassroot units. This means that for both designs the best design options in terms of the above mentioned constraints have been chosen.

CASE 1 Water removal only – standard design

Inlet conditions to molecular sieve unit

Feed flow 250 MMSCFD

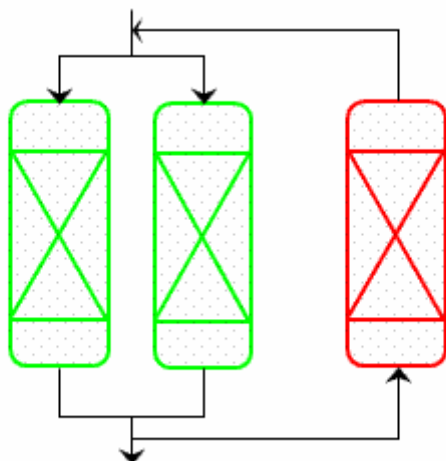
Temperature 25°C

Pressure 56 bar

Water saturated

Regeneration gas recycled to inlet of adsorption unit, cooled down by seawater cooler to 40°C

Regeneration at same pressure as adsorption



t ads	16 hrs
Pressure drop SOR	0.3 bar
Int. vessel diameter	2.5 m
Bed height	4 m
T-T height	5 m
Regen. temp.	240 °C
Regen. flow	22 MMSCFD
Product flow	250 MMSCFD

This case is named standard design as a standard molecular sieve has been considered for the design, and this concerns particularly the density of the product.

CASE 2 Water and CO2 removal

Inlet conditions to molecular sieve unit

Feed flow 250 MMSCFD

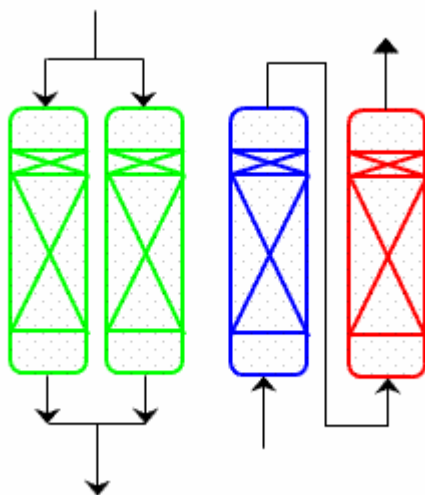
Temperature 25°C

Pressure 56 bar

Water saturated

CO2 content 400 ppmV, arbitrarily chosen, supposed to be constant

Regeneration gas not recycled, treated gas used for regeneration, Regeneration at same pressure as adsorption



t ads	4 hrs
Pressure drop SOR	0.35 bar
Int. vessel diameter	3.8 m
Bed height	5.6 m
T-T height	6.5 m
Regen. temp.	290 °C
Regen. flow	22 MMSCFD
Product flow	228 MMSCFD

The most important difference between the two designs is that the vessel for case 2 has an internal heat insulation and a regeneration temperature of 290°C in order to economize on regeneration gas flow and quantity.

As the treated gas is not recycled the product flow is only 228 MMSCFD.

The below table shows the main differences between the two designs.

	CASE 1 Drying only	CASE 2 Drying and CO2 removal
Water	Saturated at 25 °C	Saturated at 25 °C
CO2	50 ppmV	400 ppmV
Internal vessel diameter	2500 mm	3800 mm
System	2 + 1	2 + 2
Total bed volume all adsorbers	59 m3	255 m3
Regeneration gas flow	22 MMSCFD	22 MMSCFD
Adsorption time	16 hrs	4 hrs
Product flow	250 MMSCFD	228 MMSCFD

Case 1 is the standard drying case and could not handle any additional CO2 to be adsorbed. Case 2 can do this up to 400 ppmV and with the low adsorption temperature (chiller still working) but this case would definitively be over designed for the usual drying application.

It is important to note that case 2 is done with a regeneration temperature of 290°C and internal heat insulation. The reason is to economize on the regeneration gas flow rate and to improve the CO2 adsorption capacity.

As the regeneration gas for case 2 is not recycled the product flow is only 91% of the case 1 product flow.

Last but not least, taking into account the lower adsorption time for case 2 the life time of the molecular sieves will be lower as it is essentially determined by the number of regeneration cycles. In order to get the same life time out of case 2 the adsorption time should be increased and this could only be reached by adding further vessels. Instead of working with 4 vessels probably 3 trains with a total of 12 vessels should be used.

Parameters influencing the CO2 adsorption capacity

As mentioned above a regeneration temperature of 290°C has been used in order to improve the CO2 adsorption capacity. The higher temperature will lead to a lower residual water content which influences directly CO2 adsorption capacity.

Another factor than the usual parameters such as temperature, pressure and CO2 concentration would be the heavy hydrocarbon content in the Natural Gas. The heavier the feed the lower the CO2 adsorption capacity.

CASE 3 Complete CO2 removal and drying

Taking into account the possibility for a FLNG to choose the gas to be treated by selection of the gas field one could imagine treating a gas containing only little CO₂, as it is the case for the proposed gas composition. Assuming the full CO₂ concentration of 0.5% what would be the design for the molecular sieve unit?

Inlet conditions to molecular sieve unit

Feed flow 250 MMSCFD

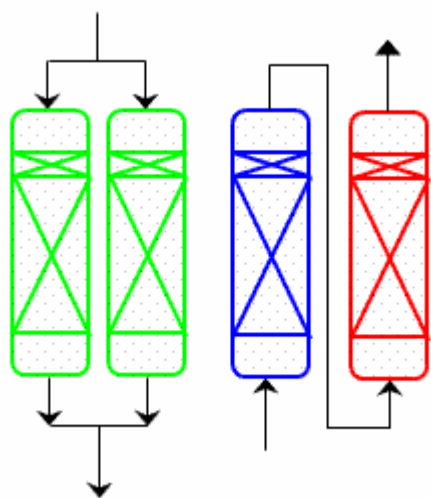
Temperature 25 °C

Pressure 56 bar

Water saturated

CO₂ content 0.5%,

Regeneration gas not recycled, treated gas used for regeneration, Regeneration at same pressure as adsorption



t ads	4 hrs
Pressure drop SOR	0.31 bar
Int. vessel diameter	4.3 m
Bed height	8.7 m
T-T height	10 m
Regen. temp.	290 °C
Regen. flow	44 MMSCFD
Product flow	206 MMSCFD

The design is again with internal heat insulation.

As the table below indicates, the vessel size and adsorbent volume has increased by a lot but on the other side there is no Amine unit anymore.

	CASE 1 Drying only	CASE 2 Drying and CO₂ removal	CASE 3 Complete CO₂ removal
Water	Saturated at 25 °C	Saturated at 25 °C	Saturated at 25 °C
CO ₂	50 ppmV	400 ppmV	0.5%
Internal vessel diameter	2500 mm	3800 mm	4300 mm
System	2 + 1	2 + 2	2 + 2
Total bed volume all adsorbers	59 m³	255 m³	505 m³
Regeneration gas flow	22 MMSCFD	22 MMSCFD	44 MMSCFD
Adsorption time	16 hrs	4 hrs	4 hrs
Product flow	250 MMSCFD	228 MMSCFD	206 MMSCFD

The CO₂ removal and drying solution for this gas treatment plant would be much less sensitive to hull motion.

On the other hand, for case 3 only 82% of the case 1 flow rate are available for production of LNG.

Having studied a couple of other CO₂ removal design it is important to notice that the regeneration gas flow rate is an important design factor for the design of the vessels. This means that it should be well clarified for the basic design if the regeneration gas flow rate has to meet the fuel gas balance or if certain upset cases could allow temporarily flaring of excess regeneration gas.

We come back to the point mentioned at the beginning of the paper: everything is in the definitions of the project.

SPACE IS MONEY

Coming back to another important issue and this time for the drying option only. Can we imagine a design using less space?

Indeed the use of high density molecular sieve with a high dynamic volume adsorption capacity can allow to economize on CAPEX and OPEX.

Inlet conditions to molecular sieve unit

Feed flow 250 MMSCFD

Temperature 25°C

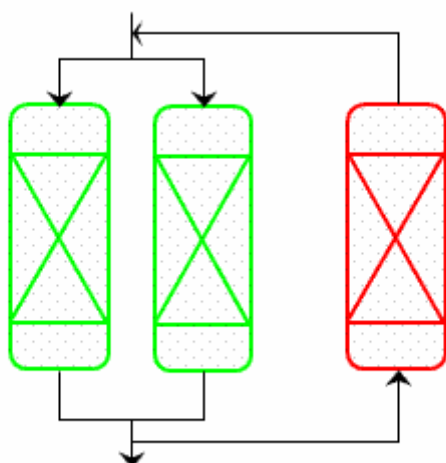
Pressure 56 bar

Water saturated

Regeneration gas recycled to inlet of adsorption unit, cooled down by seawater cooler to 40 °C

Regeneration at same pressure as adsorption

HIGH DENSITY molecular sieves



t ads	16 hrs
Pressure drop SOR	0.3 bar
Int. vessel diameter	2.3 m
Bed height	4 m
T-T height	5 m
Regen. temp.	240 °C
Regen. flow	21 MMSCFD
Product flow	250 MMSCFD

Compared to the standard drying design the above design offers a smaller footprint (2.3 m int diameter instead of 2.5 m), less weight and a slightly lower regeneration gas flow rate.

The total bed volume decreases from 59 to 50 m³.

CHILLER UPSET or START UP CASE

In order to cover the most important cases a further indication.

Supposing the normal temperature (25°C) as design case the drying cases could treat about 118 MMSCFD by keeping the adsorption cycle and regeneration procedure the same. This corresponds to a start-up case with maximum 47% feed flow at 40°C.

CONCLUSIONS

- Drying Natural Gas with molecular sieves is not an issue as well known
- Drying and CO₂ removal with molecular sieves gives very huge vessels and regeneration gas issues
- For small CO₂ contents molecular sieves could be a stand alone solution for drying and CO₂ removal, not sensitive to hull motion

⇒ The design case should be well defined (water and CO₂ upset conditions)

⇒ Question: can we allow temporarily CO₂ peaks in the upstream liquefaction process and go for an optimized drying unit only?

⇒ Space is money: think about high density sieves for small vessel designs.