Stahl columns – an alternative to molecular sieves?

Case study and independent cost estimations lay out what may someday become the standard way to achieve deep dehydration of produced gas streams

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Gas dehydration is used to remove water vapour from gas streams for applications such as pipeline transportation and cryogenic processing. Absorption into glycols is the favoured dehydration method for pipeline transportation, where typically a moisture content between 80 and 140 ppmv is required, although 7 lb/MMSCF is the often-quoted gas-industry standard.[1]

However, for deep dehydration applications such as LNG processing, where a moisture content of usually less than 0.1 ppmv is required, glycol dehydration for bulk water removal followed by adsorption onto molecular sieves is currently the most common method.[2] However, even though the molecular sieve process can achieve deep dehydration, it is economically expensive.

Disadvantages such as high pressure drop, maintenance due to bed changes, and maintaining switching valves can amount to high costs. On the contrary, the glycol absorption process is economically favourable, but the inability to adequately strip the wet solvent with a reboiled column has until now prevented it from being used in really deep dehydration applications.

Deep water removal

In the glycol process, the achievable moisture content of a gas being dehydrated is almost entirely controlled by the dryness of the lean solvent (glycol) and the temperature of the wet inlet gas. On the solvent side, dried lean solvent is obtained by regeneration of the wet glycol. Concerning the controlling temperature, only a small solvent flow is needed to treat a large gas flow, so the L/V ratio in a dehydration column is usually quite small.

The thermal mass of the solvent flow relative to the gas is therefore too small to affect the gas temperature significantly in most of the absorber. Thus, contrary to popular belief, most of the dehydration column is usually close to the temperature of the entering gas, not the temperature of the lean solvent (except at the very top of the column where the gas rapidly cools or heats the glycol).[3]

From a process standpoint, the conventional reboiled regenerator has a cripplingly serious, inherent weakness in the context of deep water removal. The dehydrating agent is saturated steam, but water is the very component that is desired to be removed from the solvent. There is no carrier or diluent for the removed water. In other words, there is no place for the stripped water to go except into the already saturated steam.

The driving force for stripping out the water is the difference between the equilibrium and actual water content of the vapour. These quantities are nearly equal throughout most of the column; thus, there is little or no driving force for stripping water from the solvent when the vapour is already almost all water. This flaw in the solvent regeneration side of the process can be overcome by providing a diluent gas.

Reboiler inefficiencies

To a limited extent, this diluent is already provided by the gases that dissolved into the glycol in the dehydration column (usually at high operating pressure). However, they are released near the top of the column, where they are swept out immediately. They, therefore, do the least good because they have such a small volume of the column in which to operate. In any case, their concentrations are usually far too low to have a significant dilution effect.

They may also contain components with a significant sales-gas value, so it is desirable to keep them with the sales gas. In addition, there may be components with serious environmental concerns if released into the atmosphere with the stripped water vapour. Incidentally, most glycol regenerators are refluxed. This provides no benefit to dehydration because putting some of the already stripped water back into the column is counterproductive.

Condensate is recycled to recapture glycol from the vapour via a water wash, not to enhance dehydration. The boiling of solvent in the reboiler is chiefly responsible for stripping water from the wet glycol. The column itself contributes very little. What small benefit it has is, to a considerable extent, destroyed by returning reflux water to the top of the regenerator to recover glycol vapour before it escapes from the system.

At best, the reboiler is a single ideal stage of contact. The rest of the regeneration system, mostly the column, is functionally dormant as far as water removal is concerned. To activate the column itself requires use of a stripping gas to dilute the stripped water vapour and encour-

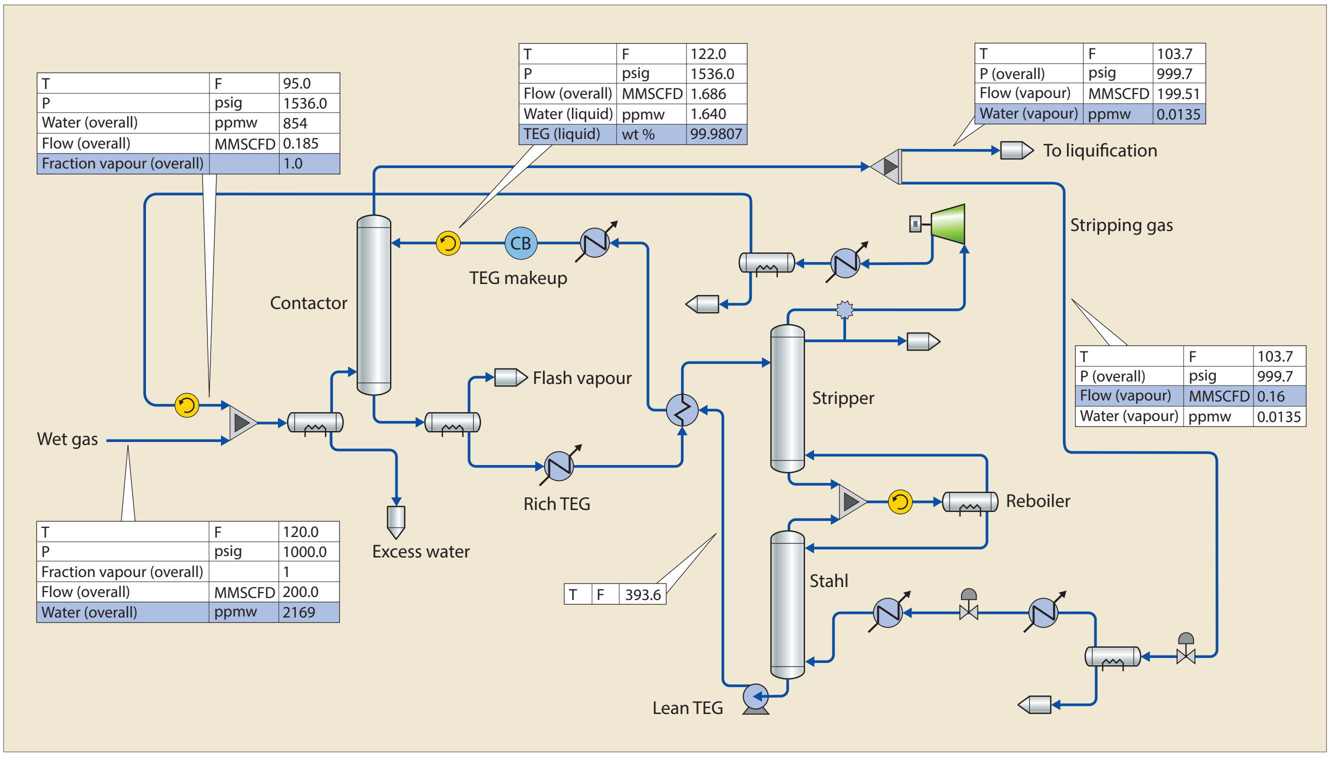

Figure 1 Flowsheet for gas dehydration using TEG and a Stahl column

age further evaporation. This is the principle behind the Stahl column.

Case study

The following case study focuses on whether it is possible in principle to regenerate triethylene glycol (TEG) to a moisture level capable of drying methane to below 0.1 ppmv H_2O, the generally accepted maximum moisture level recommended for gas entering the liquefaction section of an LNG train. It goes without saying that this is not possible using only a reboiled regenerator.

Our contention, substantiated via simulation, is that a Stahl column can enable reaching the same low water content while keeping temperatures below TEG's decomposition limit. Recently, Carmody[4] presented an interesting paper in which he suggested using the approach being described here. However, without access to a mass transfer rate based simulator, his analysis could not connect ideal stages to actual towers with real internals. Here we show that a TEG system alone can achieve dehydration very satisfactorily for gas liquefaction in an LNG plant without using molecular sieves.

To test this idea, a plant was designed with specifications similar to existing TEG plants. A Stahl column was added to the regeneration section immediately below the reboiler of the conventional regenerator. A small slipstream, 0.08% of the fully dehydrated gas, was fed to the bottom of the Stahl column, where it acts as very dry stripping gas. The contactor contains 10m of MellapakPlus 452.Y, the stripper contains 3m of 1in metal Pall rings, and the Stahl column contains 10m of Mellapak 250X. None of these columns is particularly tall, and all are well within reasonable flooding levels. The L/G ratios are typical for glycol dehydration units, so an unusual hydraulic situation in any of the columns is not expected.

Component	Mol%
Water	0.217 (2169 ppmv)
CO_2	4.989E-3 (50 ppmv)
Methane	89.299
Ethane	5.684
Propane	2.108
N-Butane	0.589
Isobutane	0.340
N-Pentane	0.200
Isopentane	0.200
N-Hexane	0.549
Nitrogen	0.809

Table 1

The feed gas composition (see **Table 1**) was assumed to be primarily wet methane with small amounts of other hydrocarbons at 120°F (49°C) and 120 psig (827 kPa). The VLE model used for the simulation was that of Bestani and Shing.[5]

Figure 1 shows a schematic of the process flowsheet. The callouts on the flowsheet display OGT | ProTreat simulated results for key streams. Results show that the TEG coming from the regenerator is only 0.0193 wt% water (99.9807 wt% TEG), which at 50°C (122°F) can produce 0.0125 ppmv water in the dry gas. The tiny stripping gas stream (only 0.16 MMSCFD of the 199.67 MMSCFD dry gas flow) enables the Stahl column to produce extremely dry solvent.

To test the sensitivity of dehydration level to process variables, the VLE model, stripping gas flow rate, and Stahl column height were varied. In the first test, the stripping gas flow rate to the Stahl column was changed between 0.05 and 0.3 MMSCFD with a constant Stahl column packing height of 10m. In addition to the Bestani-Shing model, the Parrish VLE model was also tested.

The results in **Figure 2** show that the Parrish-Margules model pre-

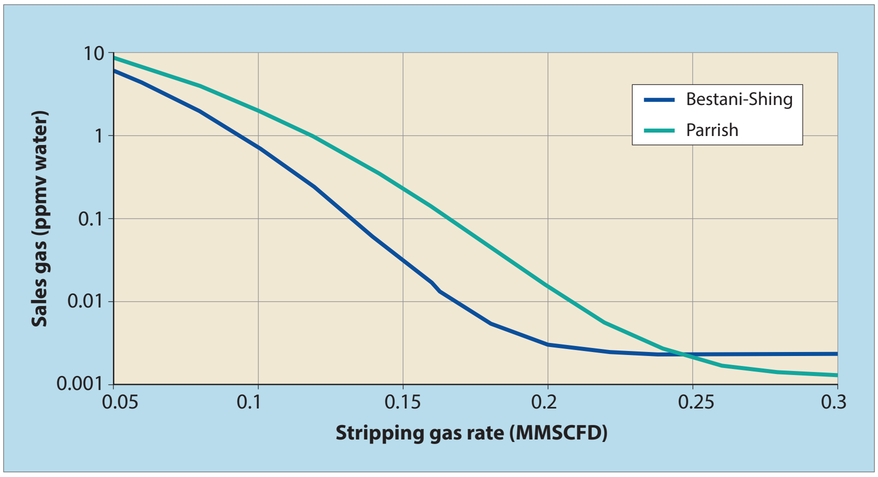

Figure 2 Effect of stripping gas flow rate and VLE model

	Typical TEG	Stahl TEG	Molecular sieve
Total price, million USD	2.32	2.75	10.89

Table 2

dicts a higher water content by a factor of 10 than the Bestani-Shing model at the original simulation stripping gas flow rate of 0.16 MMSCFD. However, it has a lower predicted water content at higher stripping gas flow rates.

In the second test (see **Figure 3**), the Stahl column packed depth was varied at a constant stripping gas flow rate of 0.25 MMSCFD, as both VLE models showed a similar dry gas water content at this value. This test shows that at greater column heights, a very low water content, below 0.01 ppmv, can be achieved. The Parrish-Margules model predicts a lower water content at higher packing depths but a higher water content at lower packing depths.

These results show how modifying the stripping gas rate and the Stahl column's packed height affect the dehydration level significantly. Furthermore, there is a difference between VLE models that can make dehydration levels differ by an order of magnitude. When designing a Stahl column dehydration unit, the difference between models might be viewed as a rough measure of the margin of error.

Economic evaluation

To evaluate the economics of the Stahl column process compared to a typical molecular sieve dehydration unit, an independent cost estimation quote was obtained from Reset Energy LP. Reset provided three different quotes: a typical TEG plant, a TEG plant with a Stahl column, and a traditional molecular sieve dehydration process. All three processes were based on the same feed used in the ProTreat simulation. Prices are quoted with a West Texas freight-on-board basis of current prices. The final cost estimation of each process is shown in **Table 2.**

Analysis shows that the typical TEG and Stahl processes have similar cost estimates. The main equipment difference in the quoted processes was that the TEG reboiler and BTEX condenser in the Stahl process were actually sized smaller. However, the Stahl process had a slightly larger column diameter. Since the Stahl process had an extra (Stahl) column, the final cost was slightly higher than the typical TEG process. However, the molecular sieve process was much more expensive than either TEG based process.

Overcoming pitfalls

In this study, the ProTreat simulator clearly demonstrated the possibility of achieving very deep dehydration using a Stahl column. Through modifying the stripping gas flow rate and Stahl packing depth, it was found that the dehydration level was sensitive to design. Despite these encouraging results, there exist several pitfalls. When designing these systems, the dry gas and hydrate equilibrium curve must be evaluated because very low water concentrations can be conducive to hydrate formation.

Additionally, TEG tends to absorb chemicals besides water, such as BTEX, amines, and oil, which can each lead to fouling. Keeping the Stahl column packing free from fouling is important to prevent long-term maldistribution, which is known to be a problem in at least one facility. There are also the normal process risks of entrainment, leading to the potential presence of TEG in the dry gas and other issues such as excessive reboiler temperatures causing thermal decomposition and vaporisation of TEG. Aerosol and even vapour tail TEG can also form an epoxy-like material, leading downstream to process disruptions.

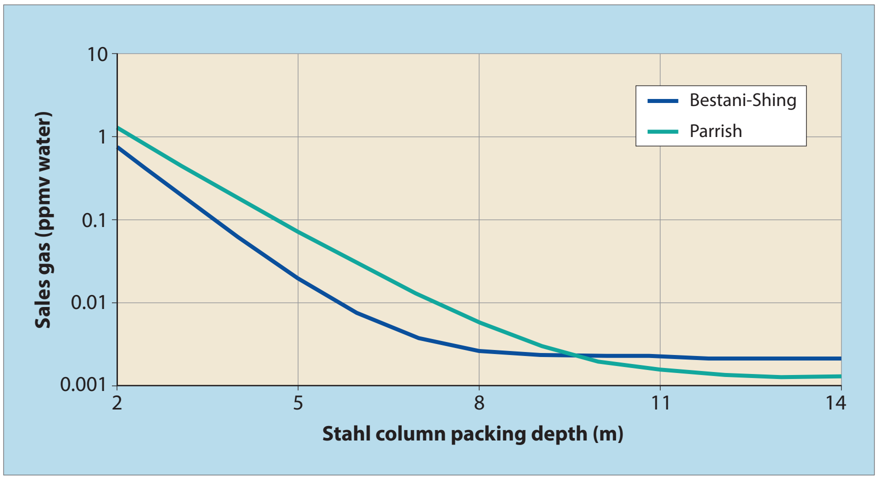

Figure 3 Effect of Stahl column height and VLE model

Lastly, operating at turndown with structured packing in the Stahl column can negatively impact column performance since the dehydration level is sensitive to packing depth (primarily wetted interfacial area). This can be engineered around with larger sales gas percentage losses at turndown and some energy expense to maintain sufficient solvent circulation to properly irrigate the packing.

Upside

However, if these design flaws are recognised and accounted for, there is significant economic upside in favour of using a TEG Stahl process over molecular sieves, as shown by the independent cost estimation. Therefore, Stahl columns as an alternative to molecular sieves offer significant upside potential that demands further investigation. To perform this investigation, there should be a further analysis of the practical pitfalls inherent in the Stahl column process.

Additionally, while this study focused on the same feed gas rate, composition, and design specs, these variables should be investigated. Comparison of the Stahl column method with alternative enhanced glycol dehydration technology such as stripping gas injection into the regenerator reboiler, the DRIZO process, and coldfinger technology, would be beneficial to allow production facilities to select the best option.

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