

TEG DEHYDRATION SYSTEM EVALUATION

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Moving gas from offshore production platforms to onshore processing facilities via a subsea pipeline usually requires that steps are taken to prevent the formation of hydrocarbon and gas hydrates. Preventative measures include (1) the addition of methanol, monoethylene glycol (MEG) or diethylene glycol (DEG) to the gas before transmission, and (2) the removal of water to a concentration outside the hydrate formation region by absorbing water into triethylene glycol (TEG), usually in a packed absorber situated on the production platform. This article presents a case study to determine the cause and remedy for severely reduced capacity of a TEG train in an offshore facility.

As part of the remedy it was suggested to increase the temperature of the lean TEG. However, there were concerns that a hotter lean solvent would fail to produce a dry enough gas. Simulation showed that at this facility contrary to what one might expect from equilibrium charts, drying is affected hardly at all by lean solvent temperature. Instead, it is the temperature of the wet feed gas that has the most significant effect on the dew point of the dry gas. The reason behind this finding is explored here.

GLYCOL SYSTEM EVALUATION

This was a fairly conventional TEG unit for taking a high pressure well-head gas to a -5°C dew point (about 50 ppmv at the operating pressure) for transfer via pipeline to an onshore LNG production facility. Additional stripping of the lean solvent was done by sparging dry stripping gas (98.5% methane, balance water) directly into the regenerator's reboiler.

High liquid-level trips on the flash drum and to some extent the accumulator were occurring at random, but so often that gas production was being seriously compromised. Foaming tests on the lean and rich glycol were all negative—neither appeared to have any foaming tendency. However, water carry-over from the inlet separator would cause the glycol to foam badly. Indeed, even the addition of *distilled* water to the glycol would cause tremendous foaming. Computational Fluid Dynamic (CFD) simulation of the inlet separator showed that there would be elevated velocities through the mesh pads, which would effectively lead to intermittent carry-over through the pads. Level fluctuations in the inlet separator, originally thought to be the normal dumping of fluids via valve opening were found to be taking place even without the dump valve in operation. The level loss in the separator was actually the result of fluid carry-over from the vessel rather than opening of the valve. The real cause of the foaming was never determined but as long as the water content was low, the glycol seemed to be too viscous to foam. Raising the separator pressure lowered the gas volume flow and made foaming more manageable.

The real cause of foaming was never determined; however, carry-over of corrosion inhibitor that was injected upstream was suspected, but as long as the water content was low, the glycol seemed to be too viscous to foam.

Prior to this, plant trips were occurring with such frequency the unit was barely able to process gas at all. Even after getting control of foaming, high liquid-level trips on the accumulator still continued to occur, but now less frequently.

The remaining issue was traced to the inability of the lean glycol charge pump to keep up with the flow from the booster pump which was drawing from the accumulator. One of the pumps happened to be operating in a poor region of the pump curve, and unfortunately, its performance could not be improved. Inadequate pumping ability made the liquid level in the accumulator rise periodically and trip on high level. The bottleneck to pump capacity in this case was the very high viscosity of the stripped solvent at the then-current operating temperature of 42°C. Table 1 shows the temperature dependence of lean-solvent viscosity at the point of entry into the dehydration column.

Table 1 Temperature Dependence of TEG Viscosity

Temperature (°C)	TEG Viscosity (cP)
30	40.0
42	24.5
50	17.6
60	12.1

The only way to allow the second pump to handle the required flow was to lower the viscosity of the glycol, necessitating that the lean glycol be run hotter than desired. The temperature would have to be 50°C. However, running the glycol hotter appears on the surface to be completely counterproductive to meeting the water dew point specification, at least according to the charts.

The lean TEG water content is generally in the range of 0.8 to 0.9 wt% (TEG strength of 99.1 to 99.2 wt%). The rich glycol was in the range of 3.5 to 4.0 wt% water. With no stripping gas to the reboiler, the expected lean water content of TEG is about 1.2 wt% (98.8 wt% TEG). Referring to the GPSA Data Book¹, the chart there shows that 98.8 wt% TEG is quite insufficient to meet the -5°C dew point specification, 99.2 wt% TEG at 42°C could produce a dew point of -12°C, but the same solvent at the temperature of 50°C needed to debottleneck the charge pump would be marginally unable to produce on-specification gas. The dew point would be only -4°C. From the charts it is evident that as the lean glycol temperature increases (no matter the TEG strength), the treated gas water dew point will also rise.

This analysis uses the *temperature of the lean solvent feed* to the tower as the basis for determining the best possible moisture level in the dried gas. Using this temperature has the implicit assumption that the temperature inside the top of the tower is equal to the entering temperature of the lean TEG. How valid is this assumption, and what does a mass transfer rate based simulation tell us? The simulator used has a mass and heat transfer rate-based glycol dehydration module and, as will become apparent, it is an excellent tool to answer this question.

SIMULATION STUDY

The flowsheet was laid out for simulation as shown in Figure 1. Stripping gas (relatively dry methane, although not bone dry) is sparged into the reboiler by admixing with stripped solvent from the regenerator bottom. The Booster and Charge pumps are also shown in the Figure. The temperature of the lean solvent is set by the conditions in the Trim Cooler. The contactor contains 3.4 meters of a fine crimp structured packing. The Stripper contains a random packing. The pressure in the absorber is quite high at 10.6 MPa (106 bara) and the gas is mostly methane with small amounts of C₂+ hydrocarbons and a few mol% CO₂.

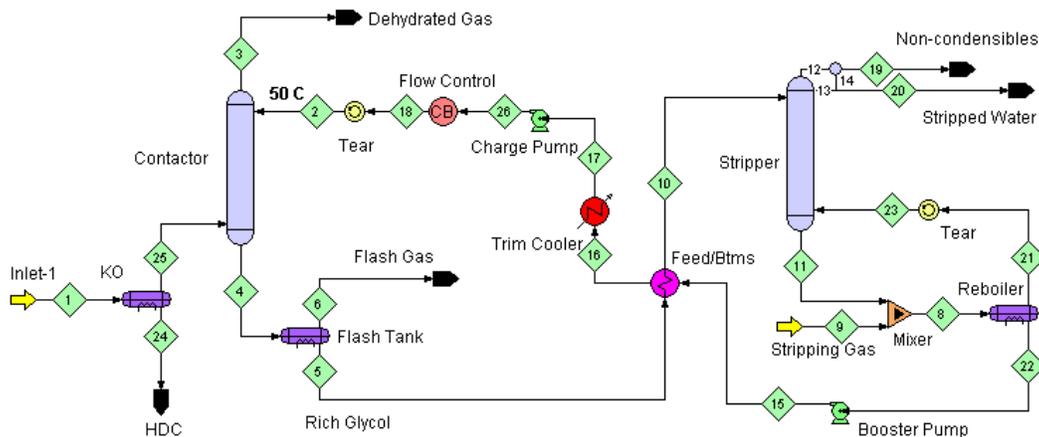


Figure 1 Schematic of TEG Unit

At the initial 42°C lean TEG temperature, simulation predicted the lean solvent should be 99.21 wt% TEG, in perfect agreement with the measured value of 99.1 to 99.2 wt%. The dehydrated gas was predicted to contain 1.907 lb of water per MMscf. At the operating pressure of 106 bara, this corresponds to a dew point of -15°C (5°F), quite a bit better than requirements.

The simulation was rerun with a lean TEG temperature of 50°C. The results were nearly identical to the 42°C case. *Increasing the lean solvent temperature by 8°C caused virtually no change in the dry case water content!* This was quite a surprise! The simulator then was used to do further experimentation over the solvent temperature range from 30 to 60°C. The results were much the same—the dried gas moisture level was unresponsive to lean TEG temperature. So what was the determining parameter?

The actual temperature of the inlet gas was 38°C. Simulations were run in 5°C steps from 30 to 45°C. The results are summarised in Figure 2. The wt% TEG shown above or below each line correlates with the temperature of the wet feed gas shown in the legend. The astonishing observations are that:

- The moisture content of the dried gas depends on the *wet gas* temperature.
- It is almost completely *independent from the lean glycol temperature*.

This runs counter to conventional wisdom and it suggests that, at least in this case (and in most dehydration units as will be shown), estimating the likely dry gas moisture content on the basis of lean glycol temperature can be quite inaccurate. If one inlet stream or the other must be used, the estimate can be made using the *lean glycol water* content and the *wet feed gas temperature*. To understand why this is so, consider the mass flow rates of glycol versus gas. In the present case, the gas-to-glycol (G/L) mass flow rate ratio was 40:1, so the gas phase completely dominates. The temperature throughout the column, including the glycol phase, is set mainly by the inlet gas temperature, moderated slightly by allowing for gas heating by the small glycol flow.

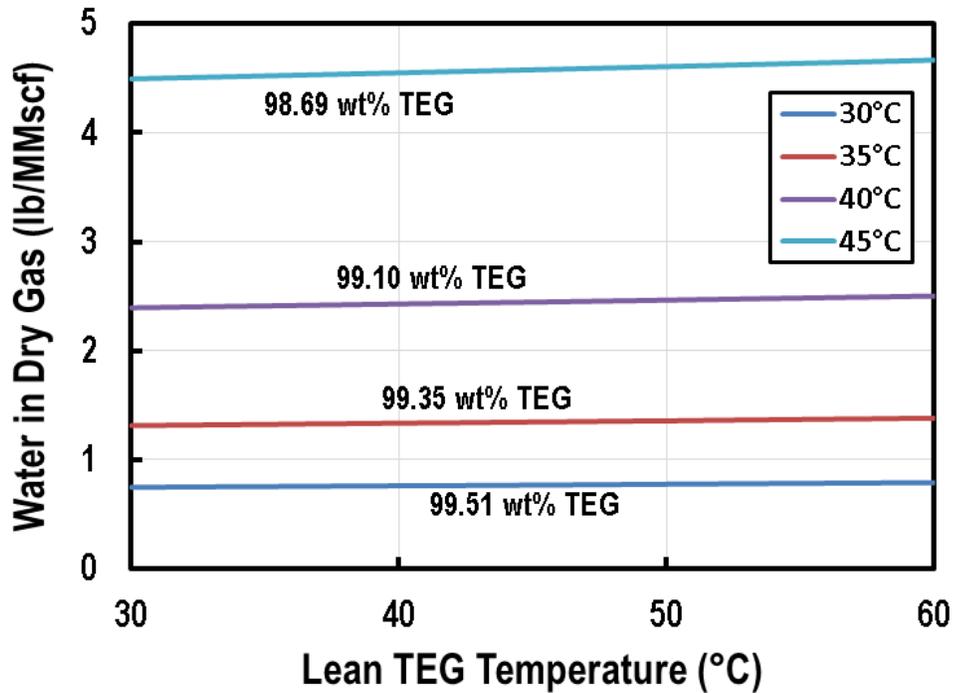


Figure 2 Dependence of Dried Gas Moisture Content on Lean TEG Temperature. Parameter is Wet Feed Gas Temperature and the Corresponding Lean TEG Strength

In the extremely hot case of the gas at 40°C and the glycol at 60°C, the profiles in Figure 3 show that within less than one meter from the bottom of the bed, the gas has reached a temperature of 40.8°C and it stays at that temperature through the remainder of the packed bed. The liquid enters at 60°C and reaches 40.8°C within 60–70 mm after entering the top of the bed.

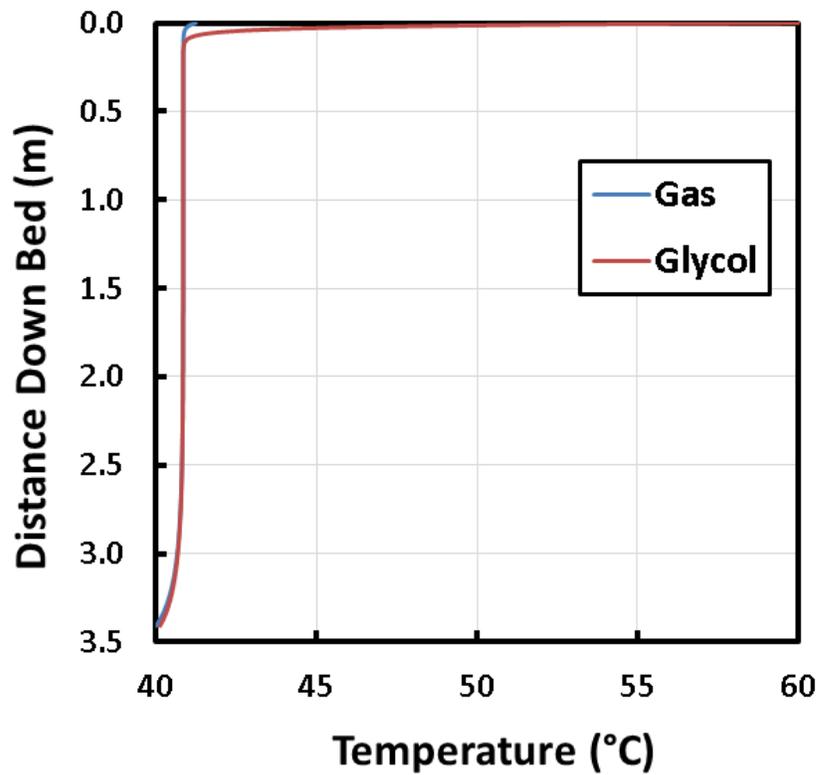


Figure 3 How Gas and Glycol Temperatures Change across the Column

Figure 4 shows that water removal occurs over at least the bottom 2 meters of the bed, where the tower temperature is not changing. The average tower temperature is certainly a lot closer to the inlet gas temperature than to that of the lean glycol. The upper part of the bed might be called design margin. It makes good sense then to use the inlet gas temperature as a first approximation, and the temperature found by combining the two inlet streams to find the mixture temperature for a more accurate assessment. But to use just the lean glycol temperature is possibly the worst approximation of all.

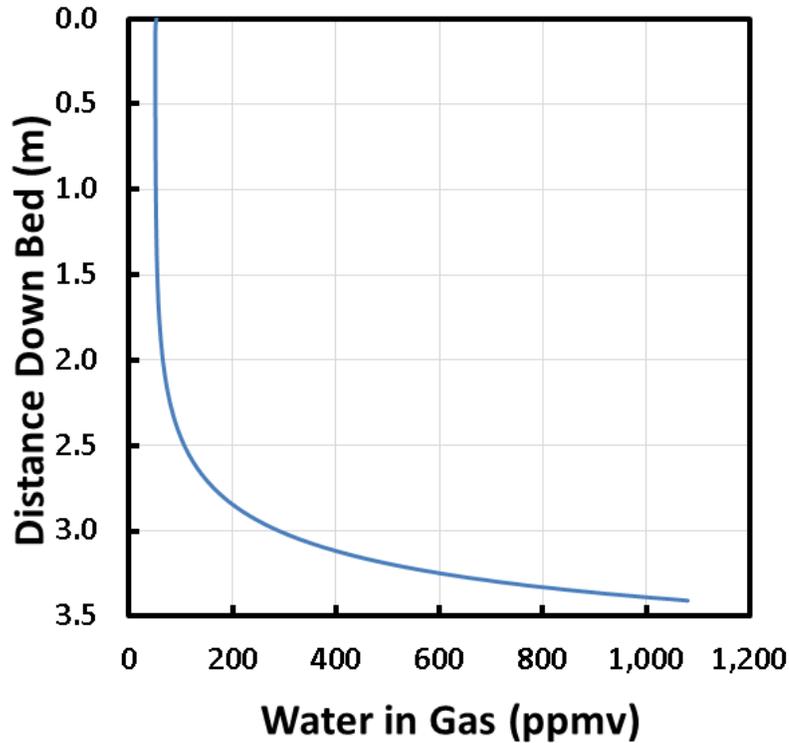


Figure 4 Water Profile in Gas across the Column when the Inlet Gas is at 40°C and the lean TEG is at 60°C

CONCLUSION

Theoretically, the plant should have gone off-specification with the rise in lean glycol temperature but when the process is properly simulated with a mass and heat transfer rate-based model, the effect of the lean glycol temperature increase is found to be far less troublesome than first thought.

Glycol dehydration efficiency is based on the concept of dew point depression. Dew point depression is usually measured from the *lean glycol* temperature, not the feed gas temperature, so the lean glycol temperature has always been considered very important for plant performance. According to the simulation work, the treated gas dew point should change minimally (perhaps only within a single degree) between the 42 or 50°C lean TEG temperatures. The reason for the miniscule effect is seen through the gas and glycol temperature profiles across the structured packing in the absorber. These values are completely identical except for the upper 60–70 mm of packing, which is effectively operating as a heat exchanger. The liquid is cooled within the first 10s of millimeters of packing, giving a profile in which variability of the lean glycol temperature is barely visible in the graphs.

In this case study, even though the lean TEG temperatures differ by 20°C, the much higher mass flow of colder gas cools the TEG dramatically to a constant, nearly feed-gas temperature almost immediately, so, in effect, the tower is dehydrating at essentially the temperature of the gas regardless of the lean glycol temperature.

It should also be noted that the higher the gas pressure, the lower will be the water content at saturation, and the less glycol per unit volume of gas will be needed for dehydration. High G/L ratios mean the inlet gas will dominate and determine the absorber temperature. Dehydration is usually (but not always) done on gases at high pressure. The higher the pressure, the less water per unit of standard gas volume there is at saturation. On the other hand, warm gases at low pressure can have quite high water content so the G/L ratio needed to dehydrate to a high level of dryness may not be large at all. How well the feed gas temperature predicts the maximum possible extent of dehydration depends on the G/L ratio, but lean glycol temperature is probably not the best basis for doing such a calculation. The right temperature to use is undoubtedly the mixing cup temperature of the combined wet gas and lean glycol streams. Using the wrong temperature can have significant consequences in terms of deciding what the right strategy is to overcome operational problems. Beyond estimating however, the best tool for deciding the best way forward is mass transfer rate-based simulation. Rate-based simulation takes all the important factors into account in a way that adheres to rigorous scientific and engineering principles.

In the context of this case study, the best way to keep dew points low is not to cool the gas, an expensive proposition at best, but to increase the stripping gas flow to the reboiler at the regenerator, provided the stripping gas can be properly handled once it leaves the system, possibly as a fuel gas or by flaring. Raising reboiler temperature will also work although approaching the degradation temperature of the TEG (206°C) must be avoided

REFERENCE

1. GPSA Engineering Data Book, 12th Edition, Electronic, Figure 20–68, Page 20–34, Gas Processors Association, Tulsa, Oklahoma, 2004.

Endnote: The used in this study used the ProTreat® simulator.