CAPEX and OPEX Considerations for Gas Dehydration Technologies

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ABSTRACT

With the growth of gas demand over the next decades, there is an increasing need for gas production and thus for gas treatment technologies. Moreover the industry has become more diverse with deep water applications, shale gas and LNG production. This requires a different approach and different technology for gas dehydration.

Several technologies can be considered for gas dehydration. Typically glycol dehydration is applied, but other technologies such as low temperature separation and dehydration by adsorption are becoming more common. The application, process conditions and downstream equipment determine which technology suits best its purpose. A well-considered selection at an early engineering phase, prevents significant investment costs. Changing technology at a later stage can have substantial impact. For instance replacing glycol dehydration by molsieve dehydration results in a larger pressure drop over the dehydration unit; the up- and downstream equipment often needs to be adapted and re-engineered to accommodate this. The selection process for the best technology for the application will be presented with the corresponding CAPEX and OPEX considerations.

Also within each technology itself, the design can have a big impact on CAPEX and OPEX. For instance a smaller glycol contactor seems the most logical choice. However in many cases a lower glycol flow rate with a larger glycol contactor results in lower overall CAPEX. Another example could be adding equipment for heat recovery for a silica gel dew pointing system. CAPEX will increases, however OPEX decreases significantly since the average power consumption during regeneration will be substantially lower up to 50%.

Several potential CAPEX and OPEX savings within dehydration systems will be presented, using illustrative cases, supporting you in making the right choice at the right time during your next project.

KEY WORDS

Gas Dehydration, Process Optimization, CAPEX, OPEX

INTRODUCTION

Resulting from a worldwide trend towards using gas instead of oil, mainly because gas is in many ways less harmful for the environment, developing gas fields will remain on the agenda for the coming years. Major proven reserves shows that abundant gas is available. Downside and in some cases even a potential threat could be the relatively low gas price in combination with rapidly declining well pressures for typical gas fields in known areas. Since distances between producer and consumer are often huge due to geographical aspects, pipelines are not the perfect solution for transportation of gas. With a rapidly growing interest for LNG, the infrastructure should be prepared accordingly, as well as the conditioning processes.

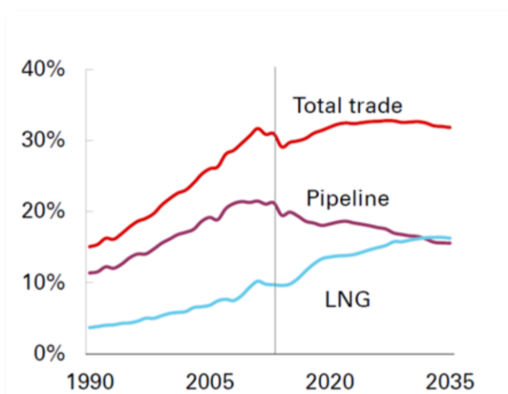

Figure 1: Shares of global gas consumption
Source: BP Energy Outlook 2035

In general the market calls for standardization. However, for larger process installations this doesn't seem to be the solution. A commercial advantage can be obtained by using project specific operating conditions and fluid compositions for equipment size reductions.

The applicable process conditions and specifications need to be considered by the technology provider, and their requirements need to be respected. From an operator point of view flexibility, reliability and maintainability are probably most important. Towards society the obligation is continuously growing to build and operate in a sustainable way, taking all environmental aspects into account.

As such, the title 'CAPEX and OPEX considerations for gas dehydration technologies' can be interpreted in several ways. Using some recently executed projects, the major considerations and/or optimizations will be explained.

WHY GAS DEHYDRATION

Gas dehydration is an important process in on- and offshore gas processing. It involves the removal of water vapor from the gas stream, such to mitigate the risk for water condensation leading to flow capacity issues, hydrate formation and/or corrosion problems. This ensures smooth operation in the downstream systems, which can be a subsequent liquefaction or other processing package, or the gas pipeline.

DEHYDRATION TECHNOLOGIES IN BRIEF

There are several technologies for the purpose of gas dehydration available on today's market. Three of them are widely recognized and applied since many years, each of them relying on a different principle. They are briefly described in the following subsections.

Low temperature separation

Low temperature separation (LTS) utilizes either Joule-Thomson (JT) choke and expansion technology, or a refrigeration mechanism. The aim is to cool the wet gas stream below its water dewpoint, such to condense the water vapor. Subsequently it is separated in a vessel containing gas/liquid separation internals to produce a dry gas stream. Due to the nature of the process, injection of hydrate inhibitor is required prior to cooling and condensing the water, which can be recovered from the liquid stream for reuse.

To achieve the desired temperature drop in the JT process, the wet gas is forced through a throttling valve which allows the gas to pass into a predefined lower-pressure state. This expansion of the wet gas causes its temperature to fall to the required dewpoint at the prevailing pressure. Chilling to obtain water condensation can also be achieved by incorporating a heat exchanger as part of a closed loop refrigeration circuit. To optimize the energy consumption, in both options the cold dry gas stream leaving the knock-out vessel can be used to pre-cool the wet gas upstream the JT valve or chiller heat exchanger.

Absorption

Adsorption involves the use of a solid desiccant contained in a column to capture the water vapor from the wet gas stream on its surface. Physical adsorbents having the ability to be regenerated in the process such as molecular sieve and silicagel are most common. As such, the dehydration process consists of cyclic batch operation, being adsorption until the bed is loaded with water and subsequent regeneration. In order to guarantee continuous operation the batch stages need to be alternated between multiple columns, each operating at a different stage. This means regeneration of a column needs to be finalized before another column becomes fully loaded during adsorption.

Regeneration includes heating of the bed such to release the captured components, followed by a cooling stage to prepare the column for adsorption again. Both are usually performed by diverting a portion of the dry gas stream, and circulating it through the regeneration loop. Typically a compressor is used as driving force, in order to reinsert the gas used for regeneration back into the wet gas production stream. For the heating stage the regeneration gas is heated to high temperature. When the full column reaches the desired end temperature, the heating stage is terminated by switching off the heater. The column is then cooled by the cold regeneration gas, such to make it ready for the next adsorption cycle.

DEHYDRATION PERFORMANCE

Temperature, pressure and gas composition affect the amount of water to which can be dissolved in the gas phase. The combination of these parameters defines the amount to be removed from the gas stream, while having a certain dry gas water content specification. As such, the solution for an attractive dehydration unit not always lays in the unit itself. Nevertheless, when selecting a technology for dehydrating the gas, the level of required dehydration is the primary parameter in defining the technology.

Solid desiccant technology can go down to the ppm level, and is therefore the technology for e.g. LNG facilities. Molecular sieve material is superior to activated alumina and silicagel; respectively dry gas water contents of around 0.1, 5 and 10 ppm can be realized. Also the dehydration performance is relatively unaffected by process conditions.

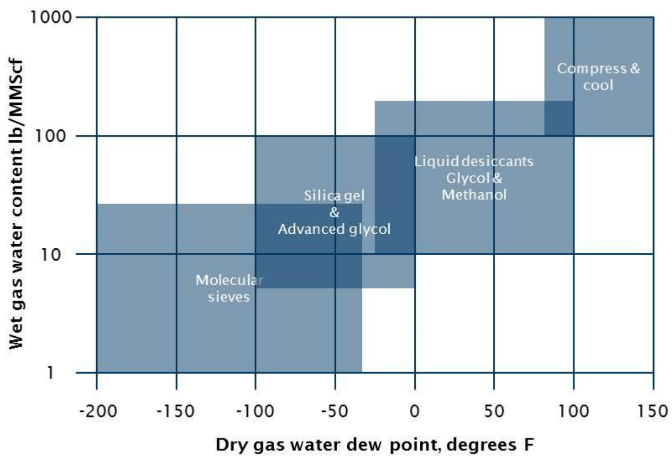

Figure 2: Dehydration Technology Selection Chart

On the contrary, TEG dehydration is limited by the involved process conditions, and therefore tailor fitted accordingly. With a conventional TEG unit dry gas water contents down to 150 ppm can be achieved, although often limited by a dewpoint depression of roughly 90°F. The latter is due to the fact that the absorption efficiency of TEG depends on the temperature and pressure. Water cannot be removed beyond the gas-water-TEG equilibrium related to the set of conditions. As such, both the wet and dry gas water dewpoint need to be carefully evaluated. With enhanced TEG units where glycol is regenerated to a higher purity than in a conventional set-up, dry gas water contents as low as 30 ppm or an additional dewpoint depression of approx. 13 °F are possible. Anyhow, conventional TEG dehydration is mostly suitable for dehydration of wet gas to pipeline specifications.

Low temperature separation is also tailor fitted to the involved process conditions, although here the limitation lies in the vapour-liquid equilibrium for the gas-water system. The deeper the gas is cooled, the more water will condense and thus the lower the resulting dry gas water content will be. As such, the available pressure loss to generate the JT effect and/or the type of refrigerant for chilling, define achievable dry gas water content. An additional effect one should be aware of is the carry-over rate of condensed water. Some water droplets will not be knocked out due to inefficiency of the gas/liquid separation internals in the vessel. These entrained droplets will dissolve again in the gas later on in the gas train. Also note that lower LTS temperature requires more inhibitor for hydrate prevention, and as these also contain water it contributes again the carry-over rate.

TECHNOLOGY SELECTION

It is of utmost importance to consider the gas dehydration unit as part of the facility, instead of merely a stand-alone black box. A holistic approach will prove to be beneficial when realizing several gas processing technologies, all serving their purpose, should work with each other in order to produce quality gas at the intended capacity. Mutual interfaces between the units need to be clear, and the effect of changing interface parameters in a later stage should be well understood in the early days of the project. Nothing new here, but certainly noteworthy to mention as this seems to be overlooked and/or underestimated easily. Some key considerations in addition of the desired dehydration performance will be highlighted along the course of some illustrative cases.

Case 1

This case concerns a UGS facility. Gas is taken from the pipeline network and injected into a depleted field by means of compressors. When gas demand is high, the gas is extracted again. Initially the gas flows freely upon well pressure, but after a certain point the injection compressors are used to boost the pressure to pipeline conditions. During the period in which the gas was stored, residual contaminants in the field (water, heavy hydrocarbons and BTEX) will have been absorbed in the gas. Hence, prior to pipeline entry the gas is required to be treated to specification.

The objective of the project was to have a zero emission plant, with a focus on minimizing utility consumption. Absorption by mean of TEG serves the sole purpose of gas dehydration. Low temperature separation and adsorption on silicagel on the other hand, can also be applied for simultaneous hydrocarbon dewpointing. Even though more elaboration on this matter is outside the scope of this paper, one should be aware of these capabilities when selecting a gas dehydration technology as part of a plant. For this application it posed the opportunity for combining multiple gas purification steps into a single solution. Due to the required operational flexibility and investment cost for the LTS related chiller equipment, a selection was made for Silica Gel based technology. In the end, adsorption of contaminants on silicagel was considered to be the best fit. Having selected a technology while knowing its application and the surrounding processes, there is more to gain.

As already mentioned it is common to use a portion of the dry gas stream for regeneration, and to apply a compressor to overcome loss in the regeneration loop. For typical pipeline gas specifications, using wet gas for regeneration should however be considered. A slipstream of the wet production gas is diverted by means of a control valve, which cuts off a slight pressure of the wet production gas stream. After a passage through the regeneration loop, the used gas is injected again downstream the control valve. When diverting wet regeneration gas upstream the silicagel columns, the design does not have to accommodate circulation of dry regeneration gas on top of the wet production stream. This allows the columns to be smaller, directly reducing CAPEX, but also OPEX since less material needs to be heated during regeneration. Moreover, since no expensive compressor is needed to circulate the regeneration gas, a further reduction of CAPEX and OPEX is achieved. Off course some additional pressure drop over the unit is the result, but thanks to early involvement this could be accommodated by the upstream situated main gas compressors.

As already mentioned, the staggered batch process of adsorption and regeneration between all columns needs to align in order to guarantee continuous production. Typically this is done on the basis of a predefined fixed switching time, related to the design flow and conditions. Having a certain column size, the time for reaching full saturation is depending on the gas composition, gas flow, gas temperature, gas pressure and silicagel bed state. Knowing the application concerns an UGS, fluctuating operating conditions can be expected as well as differing gas composition. (i.e. storage time influences the amount of absorbed contaminants.) Understanding the effect of deviations from the parameters which have set the design, allows significant optimization. With a control system measuring field data, online optimization of the adsorption cycle time can be achieved on a continuous basis. Basically the predefined switching time is prolonged, whenever the operating parameters allow to do so. As such, the amount of regenerations per unit time is minimized, directly reducing the OPEX. In addition, the life time of the expensive silicagel bed can be generously extended beyond the typical 3-4 years, minimizing the bed replacement frequency and related long term CAPEX.

Optimizing the number of regenerations is one thing, but enhancing the efficiency of regeneration is another. Due to heating temperatures as high as 550 ^{o}F, a lot of energy is present in the beds after the heating step. Cooling, on its turn, basically comes down to disposal of that inputted heat. By introducing an additional column and a heat exchanger, this heat can be recovered. Although this might appear less favorable in terms of CAPEX, the OPEX advantage is significant. Ensuring the cooling step of one column coincides with the heating step of another, allows the heat exchanger to re-use the energy. It acts as a pre-heater and pre-cooler for respectively the regeneration gas heater and cooler. Also, by splitting the heating and cooling cycle between 2 columns, shorter adsorption cycles and/or smaller bed sizes are possible. Instead of heating plus cooling, only heating time needs to be accommodated in the adsorption cycle.

Altogether the total energy input from external sources is reduced with roughly 50%. On top of that, it also allows the installed duty of the regeneration gas heater and cooler to be reduced with roughly 50%, which optimizes the equipment size and also pushes CAPEX down.

Case 2

This case involves a production facility where gas is dehydrated to a level for which TEG dehydration is fit for purpose. Saying that, the equipment is generally small in comparison to adsorption processes, minimizing CAPEX and the required footprint. The process is continuous and the regeneration temperature is relatively low at max 400^{o}F. As a result, OPEX wise TEG dehydration is one of the cheaper solutions when looking at energy consumption per unit water removed. Altogether, TEG dehydration is the cheapest solution.

Due to a high wet gas temperature, an enhanced TEG regeneration was needed to acquire a TEG purity sufficient to fulfill the dry gas specification. Heated TEG is brought in contact with stripping gas by means of packing contained in a column installed in the reboiler. This reduces the partial pressure of water in the vapor phase in the reboiler. As such, residual water is stripped from the TEG resulting in purities as high as 99.95 wt%, depending on the stripping gas rate. Fuel gas is often used for this purpose. Instead, off gas from the flash vessel was used to eliminate or minimize fuel gas consumption and thus OPEX. These off gases are otherwise disposed anyway.

To heat the TEG in the reboiler and vaporize the absorbed water, thermal energy is required. For this purpose a dedicated hot oil package was available. The overhead vapors were routed to an dedicated incinerator package for safe disposal, since the overhead vapors contained BTEX. The used stripping gas also comes along with the overhead vapors, and as such, the overhead vapor stream holds combustibles which are unused. Hence, instead of using hot oil as an indirect heating medium overall efficiency can be increased when utilizing the overhead vapor stream in the so called Overhead Vapor Combustor (OVC™). The OVC treats the overhead vapors through a condition controlled combustion process. The emission of BTEX and hydrocarbons will be completely eliminated. The heat generated by the combustion of the waste stream results in hot flue gasses, of which a portion is used to heat up the TEG in the reboiler. Since the reboiler and OVC are separated, the duty to the reboiler can be controlled without interfering with the combustion process. By reusing heat, the OVC significantly decreases the overall energy consumption. Additionally, a complete hot oil package could be omitted while the incinerator package is basically replaced. As such, both CAPEX and OPEX are optimized.

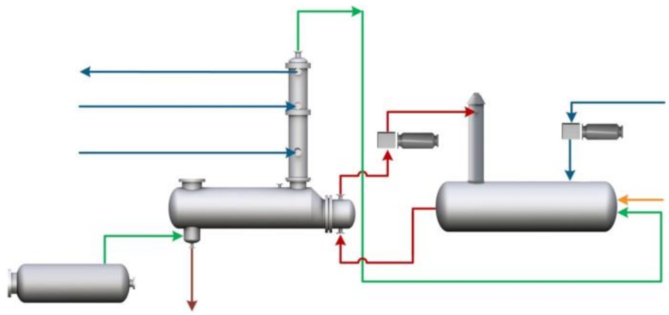

Figure 3: Schematic flow diagram with OVC™

Case 3

The final case concerns a production facility where means of transport lead to strict process requirements in terms of dew point. With a maximum allowable water content of 10 ppm in order to prevent compressor damage, the dew point is below what can be achieved by using TEG based gas dehydration technology.

For dew points below 20 ppm typically a molecular sieve is the best available and suitable technology. Compared to dehydration based on TEG both CAPEX and OPEX are significantly higher however. Due to the relatively large flows handled in this facility and the ambient and process conditions at hand, a study was conducted to split the dehydration process into bulk removal with TEG and polishing with a molecular sieve.

OPEX benefits are clear since the average energy consumption per kg water removed is very much in favor of the TEG based technology, however at first thought adding a second technology and all related equipment doesn't have a positive effect on CAPEX. By limiting the complexity, for instance refrain from using stripping gas, the reliability and cost were kept relatively low. By using a straight forward TEG package with a purity of 98.5 wt% TEG for bulk removal of water the number of beds became half in the downstream located molecular sieve system. Based on the physical restrictions like pressure drop and velocities further reduction in size was not recommend.

As a result of the reduced water loading stand times for the beds of the molecular sieve increased and regeneration flows decreased, which over time leads to OPEX reductions.

The anticipated reduction of OPEX related to energy consumption adds up to approximately 60% of the original value. Consequently power supply demands could be significantly decreased leading to indirect savings which are not addressed in detail, but at least worth mentioning.

CONCLUSION

Crucial factor for all the cases presented is early involvement during the concept selection phase of a project. Once a project reaches the state of realization, boundaries are set and can hardly be moved.

Strongly related to OPEX, but often overlooked, is the environmental impact. Lowering the power consumption will lead to less consumption of precious fossil fuels and emissions will be reduced. Optimizing designs for absorption based systems, leading to extended life time of the molecular sieve or silica gel materials, will have a significant impact on the amount of waste to be disposed of.

By presenting the example cases it becomes clear that applying existing technologies, but using a different approach, will enable both CAPEX and OPEX savings. Taking into account the developments in technology, for instance membranes, the potential for further improvement is very much present.