

INNOVATION IN DEHYDRATION



Margaret Greene (USA) and Tobias Eckardt (Germany), BASF, and Patrick Peters and Javed Adam (Trinidad and Tobago), EG LNG, discuss how new materials and bed designs can solve molecular sieve degradation issues and increase LNG production.

To achieve efficient production of LNG, natural gas must be dehydrated to cryogenic dew points. For decades, molecular sieves have been used to accomplish this critical task. However, standard molecular sieve dehydration can cause significant challenges to operations, including increased pressure drop and short lifetimes; both of which have a negative impact on the profitability of the plant by reducing throughput and increasing plant downtime.

BASF has taken an innovative approach to natural gas dehydration for LNG production by challenging the conventional wisdom of relying on molecular sieve.

The temperature swing adsorption (TSA) process creates a harsh environment that causes regeneration reflux and retrograde condensation in some services. These conditions cause standard molecular sieve to degrade and decrease in performance over their typical service life. To reduce the rate of degradation of performance, BASF applies a more robust aluminosilicate gel material. This material is resistant to the physical effects experienced in the dehydration vessel and can remove bulk water, adding to the overall capacity of the bed.

This article will describe the first retrofit installation of Durasorb Dehy in dehydration service in LNG

pre-treatment at Equatorial Guinea LNG (EG LNG). EG LNG was experiencing some of the common challenges associated with standard dehydration beds, including liquid carry-over and regeneration reflux. This environment caused molecular sieve degradation, pressure drop increase, and premature failure of the molecular sieve bed. To address these issues, BASF employed an innovative bed design using specially developed molecular sieves to solve these problems and double the bed life. This article will describe the innovative dehydrator bed design employed at the EG LNG plant to

achieve this extended lifetime, which resulted in one less change-out of material over a four-year period and improved operation of the dehydration unit. Implementing the Durasorb Dehy solution establishes EG LNG as an early adopter of new technologies, willing to explore opportunities to optimise plant performance.

Operational performance

Operational availability is a key metric used by EG LNG to track its performance over time. It is a function of both planned and unplanned downtime. EG LNG's average reliability between 2010 - 2017 had been greater than 99%, or less than 1% unplanned downtime, demonstrating performance in excess of the industry benchmark of 98%. For the same period, the average operational availability was 97.1% once planned downtime was incorporated.

As equipment reliability was already high, EG LNG sought further improvements in operational availability through the reduction of planned downtime. One area of opportunity identified was to address the accelerated degradation of the dehydrator beds in the front-end of the plant that had been experienced historically. Free liquid carryover from upstream separation equipment and regeneration reflux within the vessels led to bed replacements after two years, compared to typical adsorbent life expectancy of four years.

With bed replacement requiring operation at half-rate, approximately 1.2% additional planned downtime and a cost of approximately US\$975 000 (materials and labour) was incurred every two years. As such, EG LNG commenced an investigation into solutions to extend the life of the beds without major capital investment or having to completely shut down the plant. Extended bed life would result in less planned downtime, increased operational availability by 1.2%, more LNG production over a specified timeframe, and reduced operating expenses through less frequent replacement.

Problem identification

EG LNG is supplied with lean natural gas from an upstream NGL extraction facility. The flow rate is nominally 620 million ft³/d at 71 bar, and the target H₂O content exiting the dehydrator is <0.3 ppmv.

To identify the optimal solution for EG LNG, BASF performed time-based, multi-dimensional modelling of the molecular sieve bed under normal regeneration conditions to give a detailed look at the conditions inside the dehydrator during regeneration. An example of the output from such analysis is shown in Figure 1. This plot shows the theoretical capacity of the adsorbent for water under the transient conditions of a regeneration gas thermal wave passing through the bed. A capacity of 1.0 represents saturation of the adsorbent. Capacity >1.0 therefore reflects super-saturation leading to localised condensation. The results show that as the regeneration gas moves through the bed and contacts colder environments (e.g., adsorbent, vessel walls) in the middle to upper part of the bed, the ability of the upper bed to adsorb moisture from the regeneration gas becomes exceeded. At this point, condensation occurs, and liquid water is formed in the bed. The regeneration gas continues to be pushed through the bed, entraining liquid

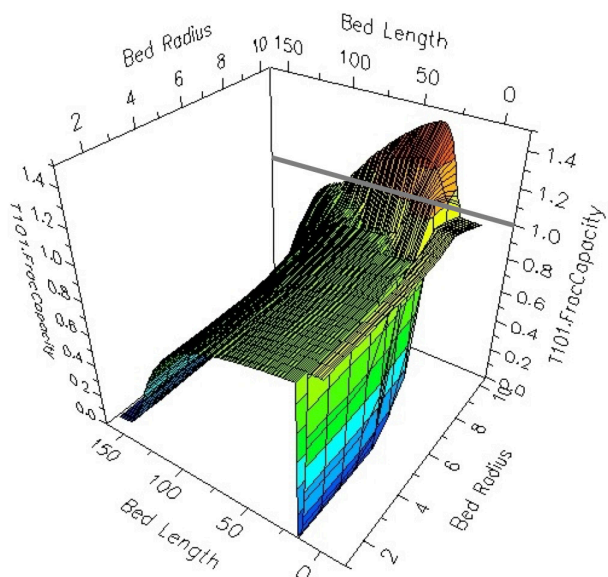


Figure 1. Time-based, multi-dimensional model. Capacity of 1.0 represents saturation.

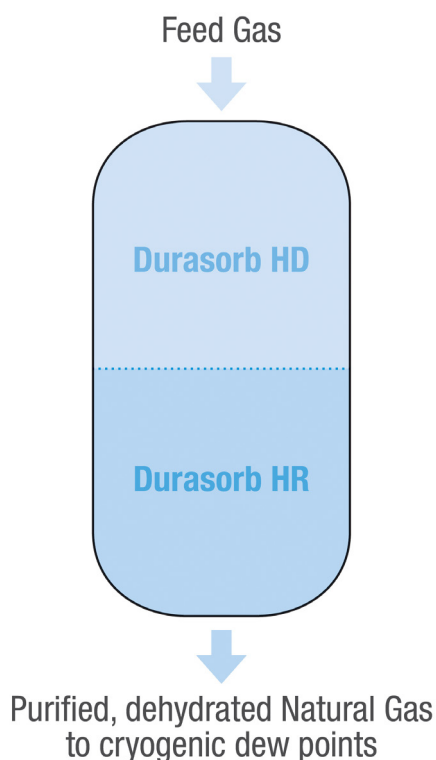


Figure 2. Durasorb Dehy layered bed design.

water and leading to a boiling effect, commonly known as refluxing.

If the adsorbent would be stable under such conditions, there would be no problem, as ultimately the saturated regeneration gas will exit the adsorber, and the saturated gas is cooled to condense the water in the regeneration gas separator. However, molecular sieve adsorbents are not completely stable under these conditions. Molecular sieves, whether beaded or extruded, are typically formed with a clay binder. It is this clay binder that is attacked by the condensing water, leaching the binder from the adsorbent material and causing two main effects:

- Deterioration of the adsorbent strength.
- A caking effect as the leached binder is precipitated back onto the exterior of the bead.

A two-pronged approach

The Durasorb Dehy technology addresses the issues caused by degradation of molecular sieve in reflux environments with a two-pronged approach: bed designs and specialty materials. A Durasorb Dehy bed is a combination of two BASF adsorbents: Durasorb HD, loaded at the top of the bed, and Durasorb HR, loaded at the bottom of the bed (Figure 2). Durasorb HD is a water-resistant aluminosilicate gel adsorbent, which protects the more sensitive molecular sieve section from incidental liquid carryover. Durasorb HR is a reflux resistant molecular sieve adsorbent which has been developed to withstand harsh conditions that exist with cycling in temperature swing adsorption systems.

The bed design leverages the adsorption properties of each Durasorb product. Durasorb HD has high water uptake capacity at high inlet moisture conditions and Durasorb HR has high water uptake capacity at low moisture conditions (Figure 3). This bed design results in better overall adsorption capacity for the dehydration bed. Durasorb HD works as both a protective layer for the molecular sieve and as an active adsorbent layer removing bulk water.

Durasorb HD aluminosilicate gel by itself is an extremely robust adsorbent with a very high equilibrium uptake capacity. However, it is not typically employed in applications in which a very low water dewpoint is required, i.e. by a cryogenic LNG unit. Therefore, the combination of the two types of materials in series has been utilised for the optimum combination of dewpoint and durability required in this service.

The advantages of adding a high-capacity adsorbent on top of a molecular sieve bed can be seen after a further model run (Figure 4). The calculated super-saturation of the regeneration gas is shown to be significantly reduced. This is not a result of lower moisture content in the regeneration gas, but rather it reflects the higher capacity of the aluminosilicate gel adsorbent. Of course, a standard silica gel would also show the same benefits of high capacity, but it is the superior physical characteristics (i.e. robustness and water stability) reducing the rate of degradation of Durasorb HD which allows such a design to be considered.

Based on computer modelling of regeneration reflux and simulation of bed performance, BASF technologists proposed a solution to the short dehydration bed lifetimes experienced by EG LNG, which was a dehydration bed consisting of 30% Durasorb HD in the upper section of the bed and Durasorb HR in the lower section of the bed. To minimise COS formation, Durasorb HR3 was chosen as the molecular sieve. In addition to reducing the degradation mechanisms associated with regeneration reflux, this bed configuration would provide resistance to liquid carry-over events, increasing the lifetime of the material.

The solution proposed by BASF was evaluated and accepted by EG LNG, and, after working together on an implementation plan, the new Durasorb material and bed design was implemented in January 2018. Installation was a simple exchange of adsorbents with no modifications to the internal structure of the vessel necessary.

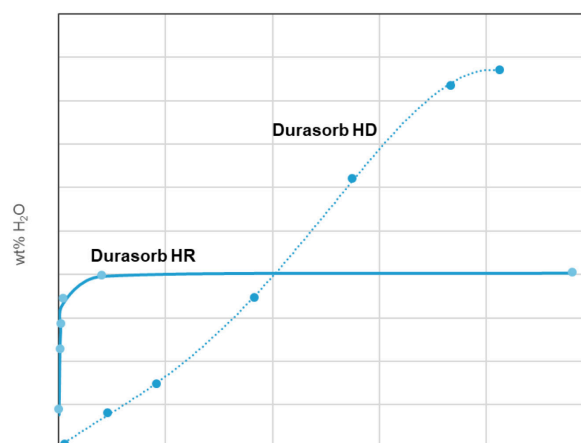


Figure 3. Adsorption capacity of Durasorb HD and Durasorb HR at increasing Wt% water.

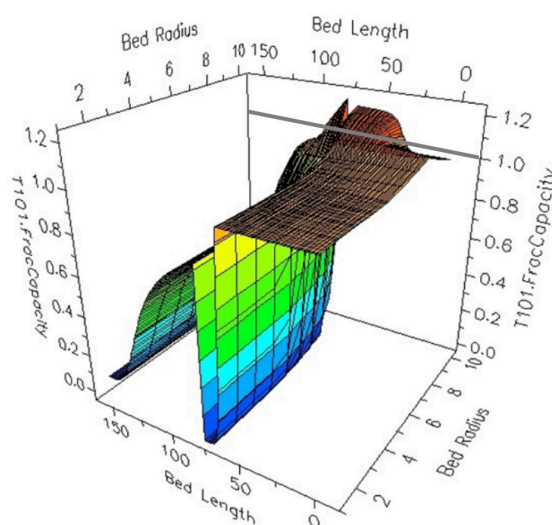


Figure 4. Time-based, multidimensional model showing reduced levels of saturation in the bed. Capacity of 1.0 represents saturation.

Operation before and after bed design solution

Prior to the installation of Durasorb, EG LNG operations were on a two-year turnaround cycle for the dehydration bed adsorbent material before water breakthrough.

The uniquely harsh conditions caused by free liquid carryover in combination with regeneration reflux led to a rapid decline in bed performance and degradation of the molecular sieve after only 500 cycles. In addition, an uneven decay of the molecular sieve in the three individual adsorber towers caused an uneven distribution of bed pressure drops and an unbalanced flow distribution, further adding to operational issues.

The current experience by EG LNG with the BASF Durasorb solution has mitigated the previous causes of accelerated bed failure. Durasorb HD provides a safe space in the bed for regeneration reflux to occur, protecting the molecular sieve. Utilising a water-stable adsorbent in the top 30% of the bed alleviates the uneven decay observed in the three beds, eliminating the uneven pressure drop and unbalanced flow distribution.

After installation, BASF technologists worked closely with EG LNG to further optimise the regeneration cycle and ramp time to ensure refluxing takes place in the water-stable Durasorb HD layer, where no damage to the adsorbent can occur. The dehydrator continues to operate on longer adsorption cycle times compared to the previous adsorbent used at EG LNG, illustrating additional bed capacity. Now at the four-year mark, the novel Durasorb bed configuration has been cycled 800 times and still has an overall bed capacity of 11 Wt% for water uptake. With this bed capacity and extended cycle times, EG LNG operations expects one more year of service and

expects to replace the beds in early 2023 in conjunction with other planned activities. When replaced in 2023, Durasorb will have undergone 1100 cycles and performed to meet LNG water specifications for five years.

Conclusion

BASF has developed an approach to the dehydration of natural gas for LNG production which employs superior materials and unique bed designs. This approach utilises a more robust, high capacity, water stable aluminosilicate gel adsorbent to protect the molecular sieve from the typical degradation pathways. Utilising the Durasorb Dehy approach has been shown to significantly increase bed life and decrease turnaround frequency, thereby increasing the overall throughput of the plant.

Although consistently exceeding industry reliability benchmarks, EG LNG continued to look for cost-effective ways to optimise production. Working closely with BASF allowed the two teams to develop a custom-tailored solution, optimised for the EG LNG plant, while utilising the equipment already in place and avoiding a complete plant shutdown.

Over a four-year period, EG LNG gained five full production days, improved on its operational availability metrics, and significantly reduced its operating expense by reducing the frequency of bed replacements. The bed life extension to-date has allowed EG LNG to reduce its planned downtime by five full production days, increase its 2020 operational availability from 97.3% to 98.5%, and avoid the operating expenses associated with bed replacement. Implementing the Durasorb Dehy solution further solidifies EG LNG's reputation as one of the most reliable operators in the world. [LNG](#)