Choosing the ideal CO_2 drying solution for CCS applications

Aluminosilicate adsorbents provide a reliable, low-energy solution for CO_2 dehydration prior to transport, storage or usage

Kirstie Thompson, Margaret (Peg) Greene and Manish Mehta
BASF

Carbon capture and storage (CCS) is a rapidly growing market and will continue to grow as stakeholders emphasise the implementation of sustainable practices. In the CCS realm, much focus has been on the CO_2 capture itself, but dehydration of CO_2 for transportation and storage is also a key step. Many CO_2 capture technologies utilise aqueous amine solutions, saturating the CO_2 during the capture process. This wet CO_2 is extremely corrosive, causing concern for pipelines and other surfaces it may contact. Thus, before the captured CO_2 can be transported, stored, or utilised, a dehydration step is necessary.

A robust and efficient method for the dehydration of CO_2 will be necessary for the emerging CCS market. BASF has been providing materials for the dehydration of CO_2 in the beverage industry and enhanced oil recovery (EOR) applications for decades. Based on this experience and an extensive study comparing available technologies, BASF has concluded Sorbead, a specialty aluminosilicate, is best suited for the dehydration of CO_2.

This article will discuss the CO_2 dehydration technologies currently available and the criteria that should be considered when making technology selection decisions. It will also detail the benefits of choosing aluminosilicates such as Sorbead for CO_2 dehydration, including longer material lifetimes, lower energy duties, smaller bed sizes, and lower Capex/Opex costs compared to glycol and other adsorbent solutions.

Glycol – the old guard of dehydration

The archetypical dehydration solution for natural gas, and most industrial plant-based operations, is a triethylene glycol (TEG) solvent-based system. In these operations, ensuring efficiency and employee/environmental safety is of utmost concern. The solvent-based nature of TEG systems necessitates the use of circulating equipment, frequent chemical quality checks, and chemical make-up adjustments. In these complex plants, additional maintenance and chemical storage requirements can be very burdensome and limiting in some cases, i.e. off-shore operations. Also, the addition of any liquid-based chemical increases safety concerns by introducing the possibility of chemical spills and emissions.

Along with water, TEG will co-adsorb heavy hydrocarbon components such as benzene, toluene, and xylenes. After adsorption, these components would then be released into the atmosphere along with desorbed water in the regenerator off-gas stream. Additionally, recoveries greatly depend on the system used, and without enhancements such as a vapour recovery system, additional contaminants such as CO_2 and H_2S can also be present in the off-gas vapour stream. These emissions cause serious concern for the plant and the surrounding environment.

Standard TEG systems can achieve outlet H_2O contents of <100 ppmv. Though these systems are considered standard practice, they struggle to keep up with ever-changing pipeline specifications (<<50 ppmv H_2O), often requiring additional modifications or add-ons such as enhanced stripping and vapour recovery systems. It is also increasingly common for pipelines to dictate very strict glycol specifications, often <15 ppbv. With TEG systems alone, this specification is unattainable and requires the addition of an adsorbent guard bed. This raises the question: can adsorption alone be applied for CO_2 dehydration, eliminating the many complexities of TEG systems?

Adsorption dehydration options

Solid adsorption-based systems are another proven dehydration technology. These materials include activated alumina, molecular sieves, and silica gels. This article will closely compare activated alumina to amorphous aluminosilicate gel, two products in the BASF portfolio sold as F200 and Sorbead, respectively. BASF has decades of experience designing temperature swing adsorption units with these materials, so it is well positioned to offer the optimum solution for each project. The adsorption options available share some common benefits, including no maintenance between turnaround, quick start-up times (0-5 hours), and easily achieved pipeline glycol specifications. Also, the solid nature of these adsorbents eliminates the safety and storage concerns associated with the liquid chemical nature of TEG systems. While adsorption in general has many benefits, each of these materials has unique properties, making some better suited for CO_2 dehydration than others.

Molecular sieves have traditionally been employed in the dehydration of natural gas for liquefied natural gas (LNG) production. BASF supplies molecular sieves into numerous natural gas dehydration applications annually, but as much as these materials are well suited for the dehydration of natural gas, they are unsuited for that of CO_2. Molecular sieves are very unstable in acidic environments, like wet CO_2. To account for molecular sieve degradation in acidic conditions, much larger bed sizes are required, along with more difficult and frequent bed changeouts. Additionally, when compared to the other adsorbent solutions available, they have some of the highest regeneration temperatures (≥250°C depending on the specific material chosen) and thus the highest energy requirement. For these reasons, molecular sieves are not recommended for CCS applications. Activated alumina maintains many of the same pitfalls as molecular sieves, although to a lesser degree. They are not acid resistant, leading to shorter bed lifetimes, larger bed sizes, and the corresponding higher Capex and Opex costs. They also require a higher heat of regeneration. While these pitfalls exist, in some instances activated alumina may still be a good option for CCS dehydration applications.

Figure 1 Sorbead is the ideal adsorbent for CO_2 dehydration

BASF is a leading supplier of aluminosilicate gels, having served natural gas and CO_2 treatment applications with the Sorbead portfolio for over 60 years. While other standard silica gel options with cheaper initial material costs are available on the market, these materials do not exhibit all the same benefits, robustness, and lifetime cost savings. Sorbead aluminosilicate gel is made using a specialised production process that imparts increased durability and adsorbent surface area, resulting in an overall higher-performing material. There is a clear benefit to using an advanced aluminosilicate for CO_2 dehydration (see **Table 1**), as these provide the best combination of material properties for CO_2 dehydration.

Sorbead aluminosilicate – the best adsorbent for CO_2 dehydration

The acidic chemistry of an aluminosilicate makes it the only adsorbent stable to the acidic conditions in CO_2 dehydration. This stability ensures long lifetimes of 5-10 years and bed sizes up to 75% smaller than activated alumina. This further results in lower Capex costs (smaller bed sizes) and lower Opex costs (fewer bed changeouts, lower heat duty, less regeneration gas). While the acidic nature of an aluminosilicate provides stability in CO_2 streams, it makes it susceptible to instability in

	Activated alumina	Sorbead
Heat of regeneration	220-250°C	160-170°C
Acid resistant	No	Yes
Lifetime	~3 yrs	5-10 yrs
Bed size	Up to 4x larger bed sizes to match lifetime	Smallest bed sizes (high capacity material)
Cost	High Capex and Opex	Lowest Capex and Opex

Table 1 Comparison of activated alumina and Sorbead aluminosilicate properties

the presence of basic contaminants, such as ammonia, amines, and olefins. However, if these impurities are present in low concentrations, they can be easily accounted for in the design of the CO_2 dehydration unit. If such contaminants are present in higher quantities, many upstream treatment methods are available. There are also many references of Sorbead units successfully operating downstream of acid gas removal units (AGRUs), where amine carryover could be a concern. Overall, the benefits of Sorbead stability in the presence of the primary, acidic CO_2 streams outweigh any instability in the presence of minor, basic impurities.

Another significant benefit of Sorbead, particularly in CCS application, is its low heat of regeneration at 170°C. This lowers the overall energy duty of the dehydration unit and often allows for further cost reduction through the elimination of a regeneration heater. The regeneration temperature for the aluminosilicate can often be attained through the utilisation of compressor waste heat or waste heat with the addition of a trim heater, further reducing the carbon footprint of the process.

A standard Sorbead CO_2 dehydration unit utilising a trim heater to supplement compressor waste heat is shown in **Figure 2**. BASF designs that employ counter-current heating and co-current cooling with wet gas and can easily reach CO_2 specifications of 30 ppmv H_2O. The design of these systems is also very flexible, allowing for both lower and higher specification ranges to be met with only small changes in design and cost (higher and lower, respectively). For example, even lower specifications of 10 ppmv H_2O can be reached by simply applying treated gas for regeneration. With this design, a regeneration compressor will be necessary. This demonstrates the reliability and flexibility of Sorbead for CO_2 dehydration.

In an example study of a plant producing ~2.5 MTPA of CO_2, Sorbead was found to be significantly cheaper than an activated alumina-

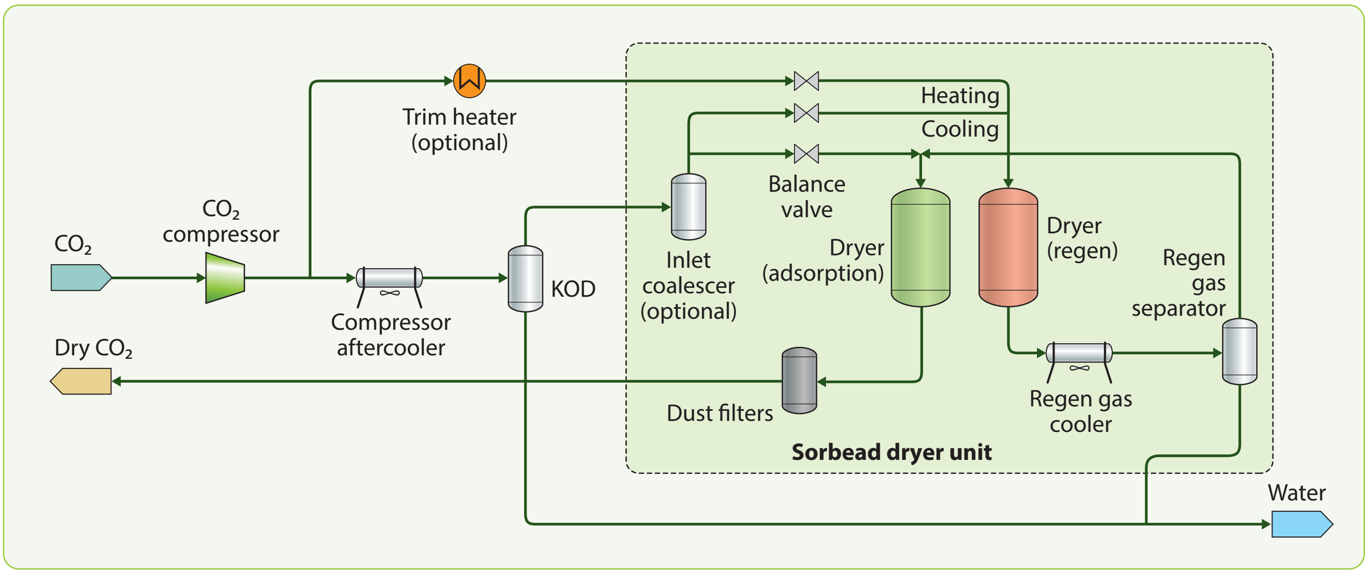

Figure 2 Example CO_2 dehydration unit design that allows for CO_2 specifications as low as 30 ppmv H_2O

based system over a 30-year lifetime (see **Table 2**). This study considered estimated turnaround (TAR), Capex and Opex costs, each of which was lower for the aluminosilicate. The stability and longer material lifetime of Sorbead results in fewer TAR days and lower associated costs. Additionally, smaller bed sizes drastically reduce the Capex and Opex costs. Overall, for CO_2 dehydration, smaller bed sizes and increased stability when using an aluminosilicate for CO_2 dehydration result in a 50% reduction in cost when compared to activated alumina.

	Activated alumina	Sorbead	
Number of days down for TAR	67	25	Days over 30 years
Capex cost	14.9	7.2	$ MM
Opex energy	94.2	45.9	$ MM
Opex maintenance	6.3	4.5	$ MM
Total cost over lifetime	115.4	57.6	$ MM

Table 2 Cost comparison of activated alumina and Sorbead over a 30-year lifetime for a plant producing 2.5 MTPA CO_2. Opex costs estimated using average energy cost in the US (0.14 $/KWH)

BASF offerings – CO_2 capture, purification, and dehydration

In addition to its CO_2 dehydration technology, BASF offers a range of CO_2 capture, purification, and utilisation solutions (see **Figure 3**). One such product, OASE blue, is used in the capture of CO_2 from industrial flue gas streams. This product not only provides a highly stable, low-maintenance solvent solution but also provides a customised technology package. Additionally, BASF has a wide array of purification technologies for the removal of many different impurities, including oxygen, sulphur, halogens, carbon monoxide, and more. Together these technologies cover every stage of CCS projects.

Conclusion

Sorbead, a specialised aluminosilicate adsorbent, is stable to the acidic conditions found in CCS. This stability allows for the longest adsorbent bed lifetimes, smallest bed sizes, and the lowest Capex and Opex costs when compared to other adsorbent materials. Over a 30-year lifetime, costs are typically 50% lower than activated alumina for the same application.

Sorbead is a cost-effective solution that also delivers a low carbon footprint. A lower heat of regeneration, 170°C, allows for elimination of the regeneration heater requirement and utilisation of waste heat for regeneration. This, along with smaller bed sizes, drastically decreases the energy duty of the process. Further, longer bed lifetimes and the adsorbent nature of an advanced aluminosilicate reduces the amount of waste generated. For the CCS market, whose goal is to reduce carbon emissions, the solution with the lowest carbon footprint is the best fit.

With many years of experience, BASF is well positioned to design effective dehydration solutions and has demonstrated the proficiency of these designs firsthand. This experience extends into all phases of CCS. This experience, together with the process benefits of a specialty aluminosilicate, make Sorbead a compelling choice for CO_2 dehydration.

LINKS

More articles from the following categories:

Carbon Capture, Utilisation and Storage

Catalysts, Chemicals & Adsorbents

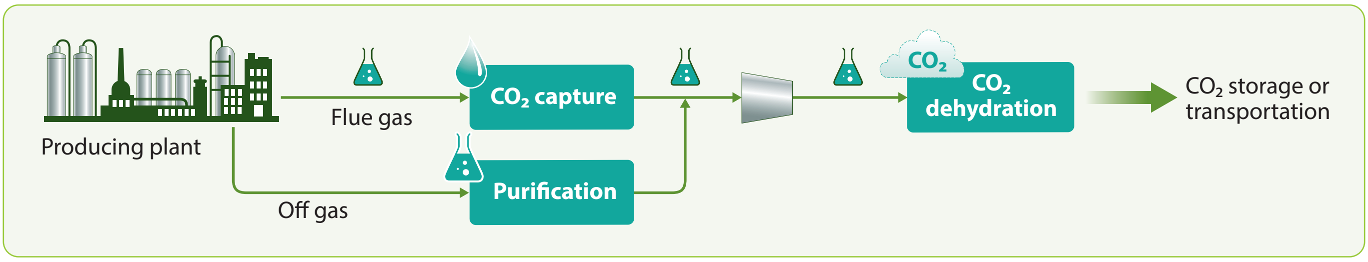

Figure 3 BASF knowledge and technologies are available at every phase of CCS including CO_2 capture, purification, and dehydration. Purification can be implemented in various stages of the process depending on the specific project needs