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Characterizing Koch-Glitsch FLEXIPAC® CP™ Structured Packings with ION Clean Energy CO₂ Capture Solvent Technologies

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Abstract

Solvent-based post-combustion carbon capture involves close contact of a reactive solvent with flue gas to selectively absorb the CO₂ from the flue gas. This step is both energy and capital intensive as this close contact typically requires sizeable columns filled with packing material as well as large blowers to move the gas through the column. Innovation and optimization in these critical areas can lead to cost, material, and dimension reductions for commercial-scale facilities.

ION Clean Energy (ION) has strategically partnered with Koch-Glitsch (KG) to provide expertise of mass transfer equipment design during commercial opportunities, as well as the column internals for ION's pilot at Los Medanos Energy Center in Pittsburg, California, USA. As part of a larger strategic offering, ION and KG have developed a pilot program at KG's facilities in Wichita, Kansas, USA to further continuous learning and product growth of KG's mass transfer offerings. Mass transfer equipment from KG, working in tandem with ION's CO₂ capture solvent, forms the bedrock of the team's commercial offerings, leading to the project name "Bedrock". The objectives of the Bedrock pilot project were to verify the Optimized Gas Treating (OGT) ProTreat® modeling capabilities, test the mass transfer properties of various packing types with ION's solvents, determine the sensitivity between specific area and solvent performance metrics, and continuously evaluate solvent stability and mass balance closure throughout the campaign.

ION has collaborated with KG to test ION solvents with a suite of KG structured packings with a goal of optimizing design to lower both the capital and operating costs of the absorber. Preliminary testing included both FLEXIPAC® 1X Structured Packing and FLEXIPAC® 2X Structured Packing as standard, commercial KG offerings. These pilot results for both hydraulic and specific surface area parameters matched exceptionally well with default simulation parameters in the ProTreat® software across a wide range of inlet flue gas compositions (4 - 15 vol% CO₂), inlet flue gas flow rates (30 - 75% flood), and overall column L/G values (1 - 4 kg/kg). The fit to the simulation is due to the high-quality data from the KG pilot facility as well as the rigorous, rate-based approach to ProTreat® modeling. Further, the close match between modeled and piloted results provides additional confidence for determining commercial performance guarantee offerings with similar equipment and operating parameters.

As part of Koch-Glitsch's drive towards optimizing their product offerings for use in the CO₂ capture market, KG has developed a suite of technologies named FLEXIPAC[®] CP[™] structured packing. These packings are tailored for the post combustion carbon capture application, where low column pressure drops and high column efficiency are principal optimizations for atmospheric-pressure flue gases. The new suite of FLEXIPAC[®] CP[™] structured packing was also characterized with ION's solvents.

ION utilized the results from the Koch-Glitsch Bedrock Pilot in a large-scale FEED study with FLEXIPAC[®] CP[™] structured packing compared to traditional commercial packings to assess the commercial scale benefits. While maintaining the same column performance, ION modeled a total drop in packing volume of 26%. This included a packing height drop of 10-20% and a diameter decrease of 5-10%. ION and KG continue to develop learnings from the Bedrock Pilot and intend to apply them to a wide range of commercial applications and future partnership projects. This paper presents results from the pilot plant testing and application usage for these comparisons.

Keywords: Water-lean solvent; Post-combustion capture of CO₂; Mass Transfer Equipment; Absorber Optimization; Pilot Plant Operations

1. Introduction

ION Clean Energy (ION) has strategically partnered with Koch-Glitsch (KG) to provide mass transfer equipment design expertise in support of FEED studies, commercial opportunities, as well as the column internals for ION's pilot at Los Medanos Energy Center in Pittsburg, California, USA. As part of a larger strategic offering, ION and KG have developed a pilot at KG's facilities in Wichita, Kansas, USA to further continuous learning and product growth of KG's mass transfer offerings. Mass transfer equipment from KG, working in tandem with ION's CO₂ capture solvent, forms the bedrock of the team's commercial offerings, leading to the project name "Bedrock". The objectives of the Bedrock pilot project were to verify the Optimized Gas Treating (OGT) ProTreat[®] modelling capabilities, test the mass transfer properties of various packing types with ION's solvents, determine the sensitivity between specific area and solvent performance metrics, and continuously evaluate solvent stability and mass balance closure throughout the campaign.

2. Pilot Facility Configuration

The facility has a capacity of 3 tpd, based on 4-15 vol% CO₂, with artificially produced flue gas and full recycle for both the liquid and gas. Since the flue gas is artificially produced via air and injected CO₂, it is a very clean flue gas with no NO_x or SO_x. The inlet flue gas concentrations range from 4 – 15 vol% CO₂ in order to mimic applications ranging from natural gas to coal-fired flue gases. The facility is extremely flexible so packing types can be changed out to assess multiple configurations and simulate different design basis or different plant site limitation for commercial opportunities. With the focus of the pilot facility being mass transfer evaluation, optimization of energy and heat usage is not evaluated, and Specific Reboiler Duty (SRD) was not analyzed. The system recycles the stripper product gas back into the gas tank and is then mixed with a makeup stream from gas cylinders to achieve the desired inlet absorber flue gas composition.

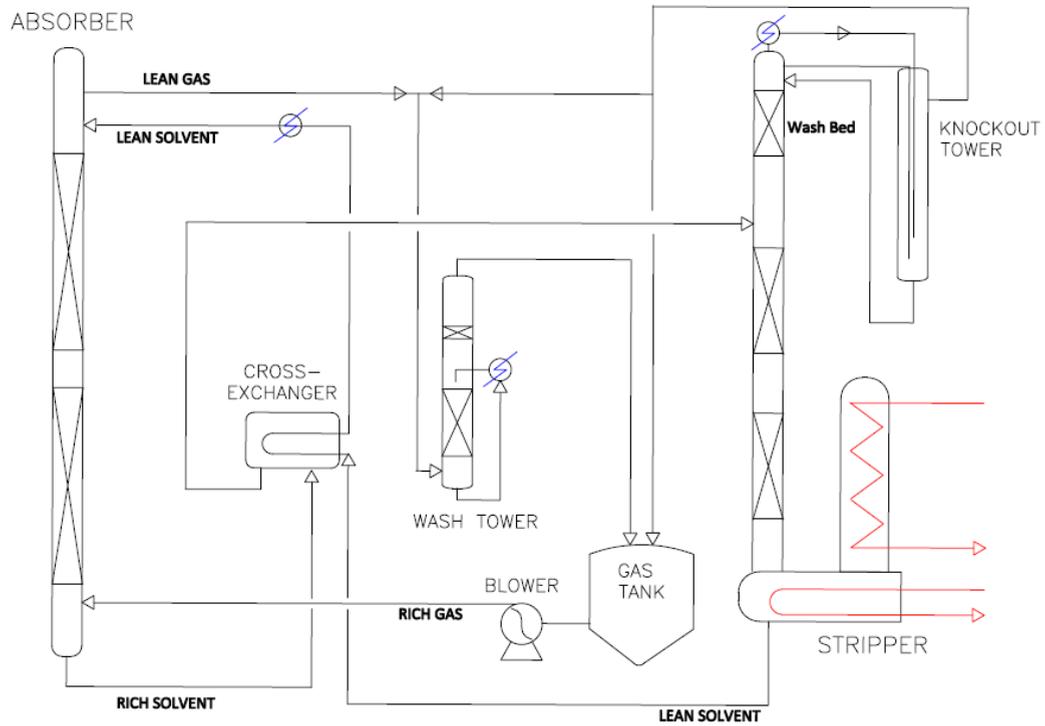


Figure 1: Koch-Glitsch Bedrock Pilot Process Flow Diagram

KG has developed multiple types of structured and random packings for mass transfer application in various industries. The packings evaluated during this pilot included FLEXIPAC[®] 1X structured packing, FLEXIPAC[®] 2X structured packing, FLEXIPAC[®] CP[™] Type H structured packing, and FLEXIPAC[®] CP[™] Type Q structured packing. While FLEXIPAC[®] 1X and 2X structured packings are mature packings with known physical characteristics, the physical characteristics of FLEXIPAC[®] CP[™] Type H and Q structured packings are proprietary and not known by available modeling software. FLEXIPAC[®] 1X and 2X structured packings were analyzed to evaluate the ability to align empirical and simulation results using ION's proprietary process module within Optimized Gas Treating's modeling software ProTreat[®]. For FLEXIPAC[®] CP[™] packings, ION developed correction factors through regression analysis, determined the sensitivity between packing area, reboiler sump temperature, lean solvent loading, and capture efficiency to evaluate the alignment between empirical and simulated results with the regressed interfacial area factor. With the packing correction factor applied to the model, the overall agreement of the empirical to simulated results indicated minimal error.

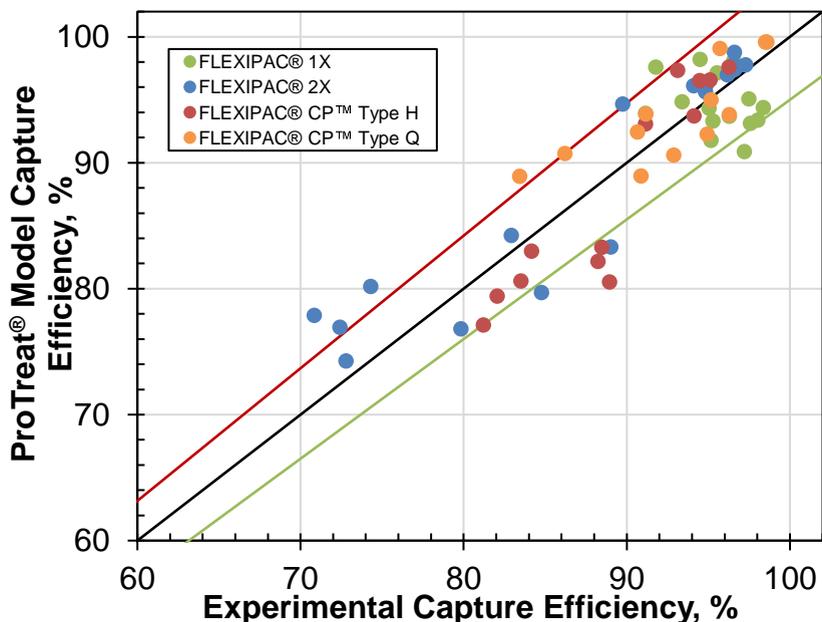


Figure 2: Capture Efficiency Parity Plot with ProTreat® Simulation

3. Pilot Execution

The Koch-Glitsch team developed the test plan in collaboration with the ION team to develop a comprehensive evaluation of all types of packing for the Bedrock pilot. For post combustion, point-source amine carbon capture, there is an optimal tradeoff configuration between capacity and efficiency. Capacity refers to the amount of flue gas that can be passed through the column in terms of pressure drop. Efficiency refers to the surface area available for mass transfer of the CO₂ to react with the solvent, which directly impacts the solvent loading capacity and the capture efficiency. Too high of a pressure drop is the result of a non-optimal quantity of flue gas moving through the system, which is seen as inefficient energy usage.

Too low of an efficiency will result in lower rich loadings and excess CO₂ in the flue gas due to insufficient time and area for absorption. Based on the Koch-Glitsch available packings, there is an optimization to be evaluated to decrease pressure drop (increasing capacity) while also increasing efficiency.

3.1. FLEXIPAC® CP™ Packing Evaluation

After the standard baseline packings were evaluated for their simulation alignment, FLEXIPAC® CP™ packings were modeled in ProTreat® to create a regression to model the mass transfer properties of these new packings. While the raw mass transfer properties of these packings is proprietary, Koch-Glitsch has developed correlations between pressure drop and capture efficiency with the associated vapor rate. Below in Figure 3, the pressure drop for both sizes of FLEXIPAC® CP™ packing tested is correlated to the associated vapor fraction. FLEXIPAC® CP™ Type Q (orange) and Type H (red) packings have been compared to the traditional FLEXIPAC® 2X (blue) packing. This data was collected while operating with 8% vol inlet CO₂ concentration and a constant L/G ratio of 1.8. As the vapor rate, or F_s , increases the liquid rate also increases. FLEXIPAC® CP™ Type Q packing indicated a similar pressure drop per height of packing curve to FLEXIPAC® 2X Structured Packing, while the FLEXIPAC® CP™ Type H packing indicated an 18 – 20% lower pressure drop overall. FLEXIPAC® CP™ Type H packing has an advantage over FLEXIPAC® 2X packing with the lower pressure drop resulting in the design of smaller column diameters for

commercial scale amine post-combustion carbon capture facilities. In terms of existing columns, smaller blowers and a reduction in operating costs would be realized by switching to FLEXIPAC[®] CP[™] Type H packing.

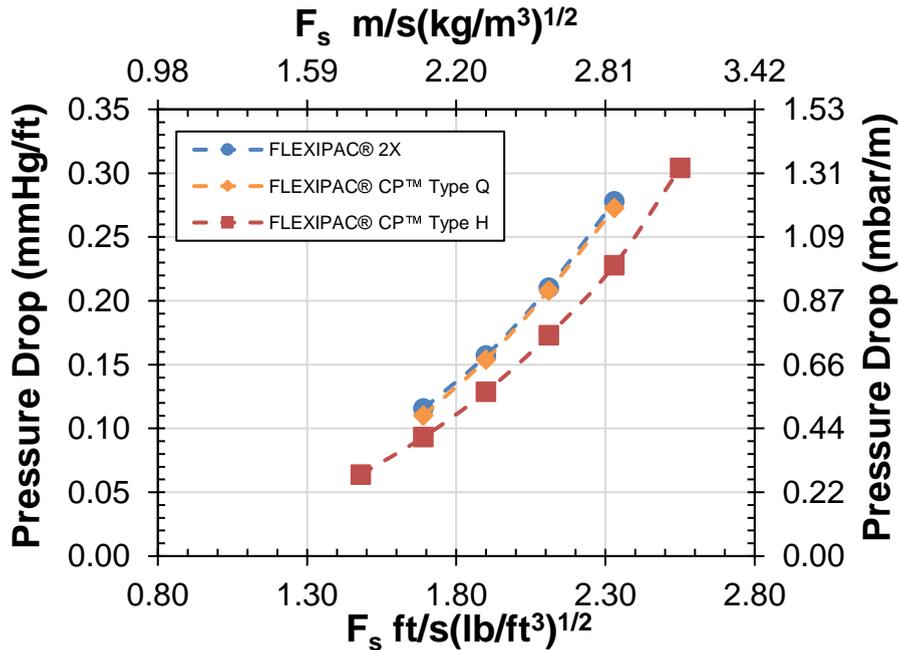


Figure 3: ION Solvent Pressure Drop 8 vol% CO₂, comparing FLEXIPAC[®] CP[™] and FLEXIPAC[®] 2X packings

The following graph was derived from the same 8 vol% CO₂ and L/G ratio of 1.8 results, but instead analysing the comparison between capture efficiency and vapor rate. The results indicate that FLEXIPAC[®] CP[™] Type Q packing has a 20% higher capture efficiency over the FLEXIPAC[®] 2X packing, while maintaining a similar pressure drop per height of packing throughout the absorber column. The additional capacity of FLEXIPAC[®] CP[™] Type Q packing compared to FLEXIPAC[®] 2X packing allows for a shorter height of packing to accomplish the same CO₂ capture efficiency, resulting in a lower total pressure drop to accomplish the desired absorption. Additionally, FLEXIPAC[®] CP[™] Type H packing has a 10% increase in capture efficiency compared to FLEXIPAC[®] 2X packing, while maintaining a 20% lower pressure drop throughout the absorber column. These results indicate that the implementation of either type of FLEXIPAC[®] CP[™] packing will realize additional cost savings with the opportunity to save on overall packing height and for existing towers with the same bed height, FLEXIPAC[®] CP[™] packings will remove additional CO₂ compared to FLEXIPAC[®] 2X packing.

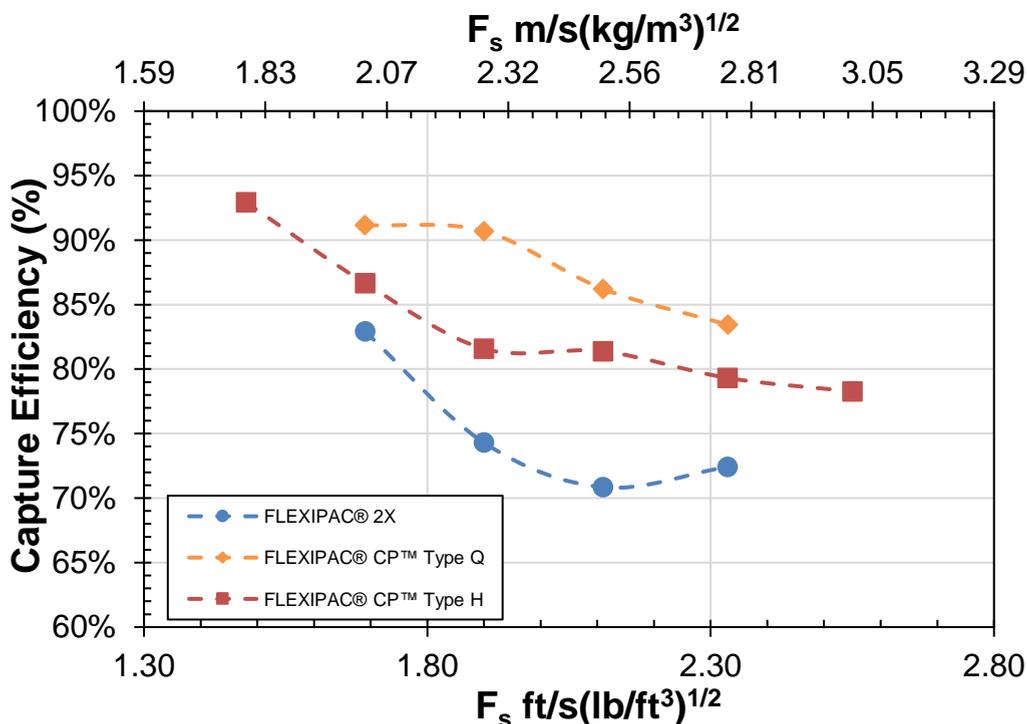


Figure 4: ION Solvent Capture Efficiency 8 vol% CO₂, comparing CP Packings and FLEXIPAC® 2X

The capture efficiencies presented were based on a reduced bed height compared to typically desired CO₂ capture efficiencies to avoid influences by operation close to a pinch point. This is intended to show relative performance of the packings. Higher capture efficiencies can and have been achieved utilizing ION's ICE-31 solvent and FLEXIPAC® CP™ structured packings using proper bed heights for the desired capture efficiencies.

4. Commercial Applicability

ION utilized the results from the Koch-Glitsch Bedrock Pilot in a commercial opportunity with FLEXIPAC® CP™ Type Q structured packing compared to traditional commercial packings to assess the commercial scale benefits. While maintaining the same column performance, ION modelled a total drop in packing volume of 26%. This included a packing height drop of 10 - 20% and a diameter decrease of 5-10%. ION and KG continue to develop learnings from the Bedrock Pilot and intend to apply them to a wide range of commercial applications and future partnership projects.

5. Conclusion

ION conducted a successful campaign testing Koch-Glitsch's traditionally available and new dedicated carbon capture packings for mass transfer and hydraulic performance evaluation. ProTreat® was leveraged to develop a process model validation for FLEXIPAC® 1X and 2X packings, as well as develop mass transfer packing parameters for FLEXIPAC® CP™ packings. Koch-Glitsch constructed comparison plots to evaluate the improved capacity and efficiency of FLEXIPAC® CP™ packings. The results indicate that FLEXIPAC® CP™ Type Q packing has a 20% higher capture efficiency over the FLEXIPAC® 2X packing, while maintaining a similar pressure drop per height of packing throughout the absorber column. Additionally, FLEXIPAC® CP™ Type H packing has a 10% increase in capture efficiency compared to FLEXIPAC® 2X packing, while maintaining a 20% lower pressure drop throughout the absorber column. These R&D results fed into a commercial opportunity which realized a column height

reduction potential of 10 – 20% and a diameter reduction of 5 – 10%, with FLEXIPAC[®] CP[™] Type Q packing. ION and Koch-Glitsch continue to develop their partnership through pilots that evaluate post-combustion carbon capture mass transfer performance.