A New Reactor Concept for Conversion of CO_2 to Methanol

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Abstract

The reduction of carbon footprint as well as the valorization of CO_2 rich gases are of increasing interest for many industries and methanol is a perfect fit for energy storage, for producing clean fuels and will be a building block for producing high value chemicals. Therefore Air Liquide Engineering and Construction (AL E&C) is already proposing a first generation of CO_2 to Methanol plant based on the well-referenced Lurgi Methanol technology with some specific optimizations regarding the CO_2 conversion [1]. It follows the classic synthesis loop design utilizing high recycle ratios to achieve overall high conversion rates. Typically a recycle ratio of around 4 is foreseen. This technology is commercially offered with commercial guarantees on catalyst lifetime and methanol production. Commercially available electrolyzers or other low carbon hydrogen sources will result in first methanol plants based on CO_2 with a capacity up to 1000 mtpd. The most efficient synthesis solution for large scale plants is a Lurgi Megamethanol™ loop with two reaction steps in series to reach single train capacities up to 10000 mtpd. Air Liquide developed and is further optimizing a second generation "CO_2 to Methanol" plant setup (Figure 1). This integrated synthesis loop consists of an "12 in 1" reactor with multiple stages of reaction, gas to gas heat exchange, condensation and interstage product removal (Figure 2). The new multi-stage solution allows very effective conversion rates at reduced recycle rates (down to ~1), reduced costs (CAPEX & OPEX) for low reactive gases like CO_2. Therefore the key features of the "12 in 1" Air Liquide CO_2 to methanol can be summarized in the following points:

- reactor design based on plates
- higher per pass conversion and lower recycle ratio (1 instead 4)
- longer catalyst lifetime
- small footprint & low equipment count
- approx 20% lower CAPEX of the synthesis section
- scalability for a wide range of capacities and feedstock

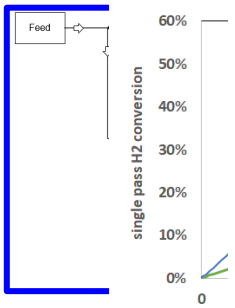

Figure 1: Principle of the CO_2 to methanol multi-stage concept "12 in1"

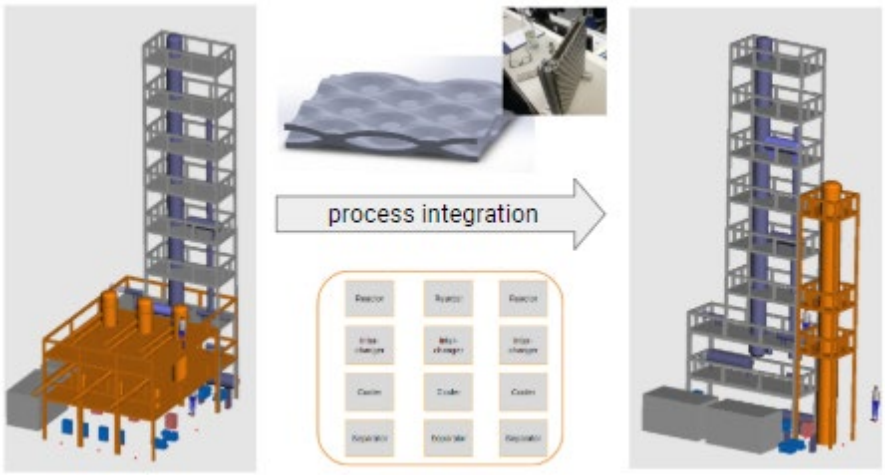

Figure 2: Non integrated 3 stage concept (left) vs fully integrated solution (right)

The multistage reactor concept offers a high potential in the conversion of gases with high inert content. To develop a tailor made solution for these carbon sources a new pilot plant is constructed at Air Liquide Innovation Campus Frankfurt (Figure 3).

Figure 3a: Mega Methanol pilot plant

Figure 3b: New multi-stage pilot plant

Reference: [1] S. Haag, F. Castillo-Welter, T. Schuhmann, B.A. Williams, T. Oelmann, A. Günther, M. Gorny: *How to Convert CO_2 to Green Methanol* in Challenges for Petrochemistry and Fuels: Integration of Value Chains and Energy Transition DGMK Conference October 10 – 12, 2018 in Berlin, Germany