Comparing the Volume and Energy Consumption of Sour-Gas Cleaning by Condensed Rotational Separation and Amine Treatments

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Natural gas is expected to be an important energy source for decades to come. About 40% of the known natural gas reserves is known to be sour with the acid gases H₂S and CO₂. 16% is highly sour with more than 20% acid gas.[1,2] As the energy costs of conventional amine sweetening increase almost linearly with the contamination level, processes are developed that use cooling and selective condensation of the acid components; that is, SPREX by TOTAL and CFZ by EXXON.[3] The energy use in these processes is greatly reduced compared to conventional amine treatment but the equipment—large distillation towers under pressure—is still voluminous. The newly developed process of condensed rotational separation (CRS) is a compact alternative to the distillation tower.[3] In this communication we compare the amine treatment and CRS processes, considering energy and volume use for a binary mixture of CH₄ and CO₂. Details of the assumptions and models can be found in the supplementary report to this communication.[4]

Condensed rotational separation is based on two innovative ideas. The first innovation is the fast cooling of the gas mixture in the two-phase region by cooling and expansion (EXP1 in Scheme 1), whereby one component becomes a mist of fine droplets and the other remains in the gaseous phase. The second innovation is the rotational particle separator (RPS, and RPS1 in Scheme 1). It is an efficient and compact demister that is able to remove the fine droplets from the gas.[5] A representation of such a component is shown in Figure 1.

The pressure and temperature at point A in Figure 2 are chosen such that the methane recovery is maximized. The separated liquid CO₂ still contains a considerable amount of methane, however. The liquid produced in the first condensation step is flashed in a second expansion (EXP2 in Scheme 1) to point B in Figure 2 where the liquid CO₂ recovery is maximized.

The contaminated gas produced is compressed (COM in Scheme 1) and re-fed prior to the first step. In this way optimal gas and liquid purity is achieved. For a binary mixture of CH₄–CO₂ the methane can be purified to a contamination level of 14%, and the CO₂ leaves the process as a liquid of 98% purity.

The compressor is the main energy consumer in CRS. The compressor work scales with the mass flow, which in turn scales with the amount of CO₂ present in the feed stream. Rescaled to the primary energy with a conversion factor of 0.4, this amounts to to 1 MW per %CO₂ for an incoming gas flow of 125 MMscf per day (40 Nm³/s[1]). The size of the compressor is negligible compared to the total installed volume. As the volume of the RPS scales with the volumetric flow,
The incoming gas is reduced in pressure and temperature to the point where methane recovery is maximized (point A). The liquid is flashed to a point where CO₂ recovery is maximized (point B).

A simplified diagram for the amine gas-sweetening process is given in Scheme 2. The sour gas is contacted gas in counter flow with an amine solution in an absorption tower. The CO₂ flows out the top of the stripper and the CO₂-lean amine solution is pumped to the absorption tower. Choosing the operating pressure of the amine absorber is chosen to be 40 bar, regardless of the pressure of the incoming gas.

In Figure 3 a plot is shown of the absolute value of the available energy and the energy cost of the processes together with the higher heating value of the incoming gas. Amine behaves as expected; its energy cost rises linearly with the CO₂ content of the gas field, even consuming more than 100% of the available energy in the case of CO₂ concentrations over 65%. As the energy penalty of CRS is a factor of 8 lower than for the amine process, using CRS as a bulk separator above concentration levels of 15% lowers the total energy consumption, as the flow to the amine plant is reduced. The reduction in volume due to this effect is even larger, see Figure 4.
The absolute values of the energy and volume consumption of both processes are dependent on the assumptions made for process conditions, heat integration, required recovery, etc. Nevertheless we draw the conclusion that CRS and amine absorption complement each other very well. Amine absorption has the capability to bring the gas purity up to pipeline specification, whereas CRS has a resounding advantage over amine in terms of energy cost and equipment size. The combination of both technologies allows the exploitation of previously uneconomical gas fields.

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