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Applications of Pressure Swing Adsorption Technology

CHRISTIAN VOSS
Linde AG, Linde Engineering Division, Adsorption Technology, Dr.-Carl-von-Linde-Str. 6-14, 82049 Hoellriegelskreuth, Germany
Christian.Voss@Linde-Le.com

Abstract. Pressure Swing Adsorption (PSA) technology represents an important separation process for gases. In addition to typical integration of PSA units in the plant structures (e.g. combination of steam reformer and H_2-PSA) more complex combinations are possible to optimise the overall process performance. The PSA process itself is strongly influenced by certain process parameters like tail gas pressure, number of pressure equalisation steps etc. PSA units can handle growing throughputs meanwhile they are getting specifically smaller. Sophisticated control systems enhance the performance, flexibility and automation.

Keywords: adsorption, PSA, TSA, hydrogen

1. Introduction

PSA technology is widely applied in gas purification and gas recovery. Main fields of applications are the recovery and purification of hydrogen, carbon dioxide removal and purification, methane purification as well as nitrogen and oxygen generation. The essentials of PSA processes are

- the improved, established technology, even if the process is comparably young (industrial application started in the 1970's),
- the reliability with availabilities higher than 99%,
- the flexibility (typical operation range is 25–100%),
- the fully automated operation even at pressure, temperature and flow fluctuations.

Highest product purities are achievable with high recovery rates up to 90% and more.

2. Combination and Integration of PSA Units

Hydrogen recovery PSA units are usually integrated in larger grids, for example hydrogen recovery units processing a shifted raw hydrogen gas from a steam reformer. The tail gas is recycled to the reformer burners, the hydrogen product is fed into the plant's hydrogen grid.

More complex integration can occur in combining a refinery off gas (ROG) PSA with a steam reformer and the respective steam reformer off gas (SMR) PSA (Fig. 1). The tail gas from the ROG PSA with high hydrocarbon content is recompressed and used as reformer feed.

The SMR PSA tail gas with high CO_2 content can be processed in a CO_2 recovery PSA (Fig. 2). This process is running at moderate pressures to minimize the energy consumption for recompression. After a final purification step and liquefaction the CO_2 product is of food grade quality.

The CO_2 removal in a PSA process is applied in steel mill processes (Fig. 3). The CO_2 is removed from the recycled reduction gas, the tail gas is routed to the recycle gas heater and therefore the enthalpy of the gas is exploited completely. An oncoming application of CO_2 removal PSA is the CO_2 sequestration induced by environmental needs.

In CO/H_2 plants the hydrogen from the cold box is purified in the PSA unit (Fig. 4). For regeneration of the Temperature Swing Adsorption (TSA) unit a part of the raw hydrogen stream is routed to the TSA unit and mixed with the main hydrogen stream upwards

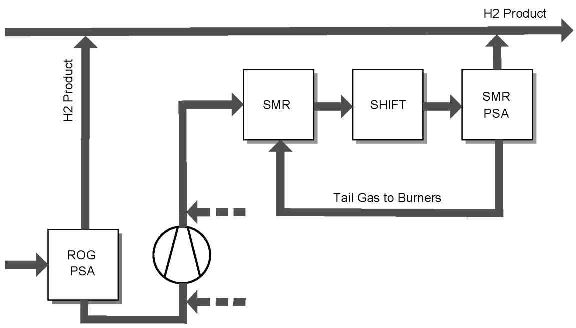

Figure 1. Combination of ROG and SMR PSA.

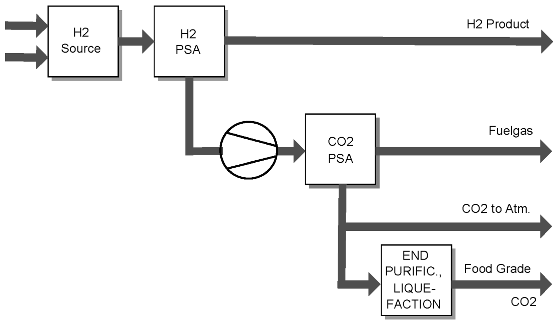

Figure 2. Combination of H_2- and CO_2-PSA.

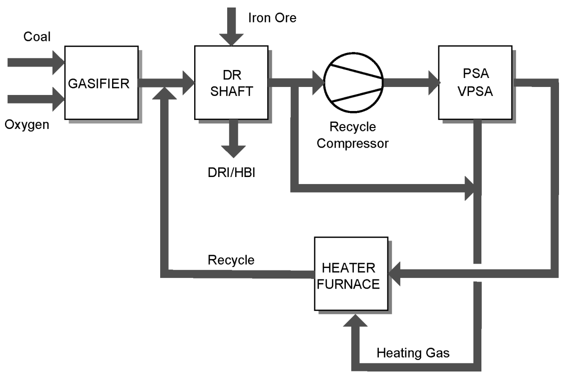

Figure 3. CO_2 removal from direct reduction gas.

the PSA. Because the gas quality changes during the TSA regeneration the PSA must be able to react on the fluctuating composition of the regeneration stream. The PSA tail gas can be used as fuel gas or be recycled.

3. Optimisation Parameters

A number of optimisation parameters for PSA processes have to be considered. For H_2-PSA that is—

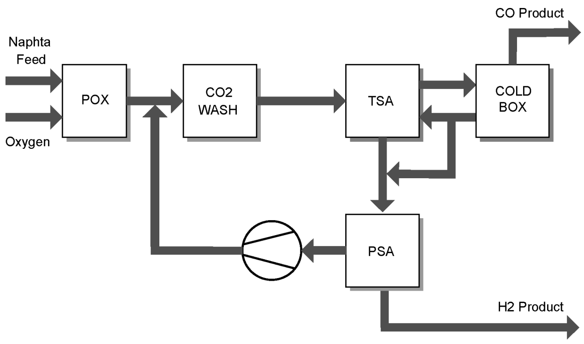

Figure 4. Combination of TSA and PSA in a H_2/CO Plant.

among others—the design of the filling, the tail gas pressure, the number of possible pressure equalisation steps followed by a minimum number of required adsorber vessels and the product purity of non key components (the product purity of key components is usually determined by the application).

Exemplarily the influence of the tail gas pressure shall be discussed: The adsorption takes place at elevated pressures, typically in the range of 15 to 35 bara (lower and higher adsorption pressures are also applied, but this is not typical). Typical tail gas pressures are 1.3 to 1.5 bara if the tail gas is fed into e.g. steam reformer burners or if a tail gas compressor is installed. Even small changes of the tail gas pressure in the range of 100 mbar have a measurable effect on the capacity of the adsorbent filling.

Because of this the design of the tail gas line and—if installed—a well tuned tail gas control

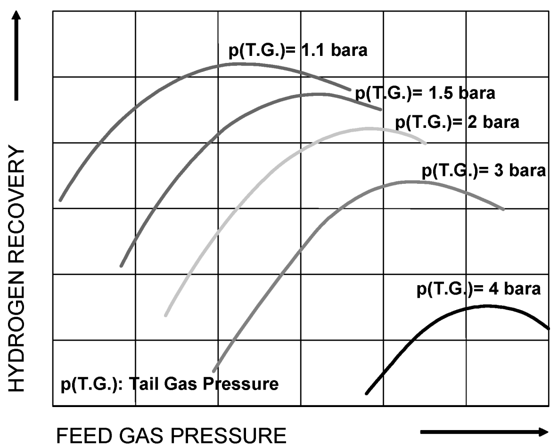

Figure 5. Influence of tail gas pressure on the hydrogen recovery rate in dependence on the feed gas pressure.

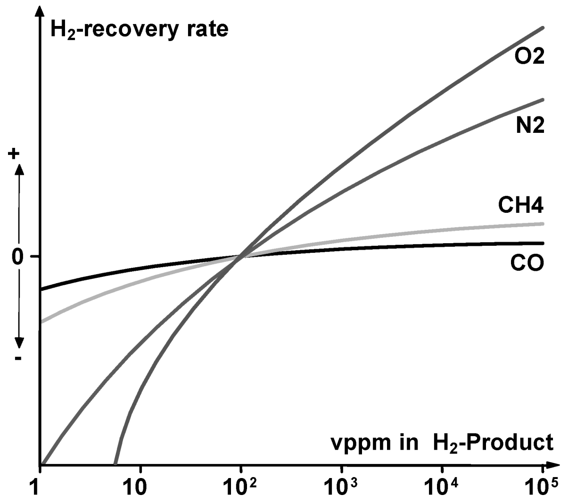

Figure 6. Hydrogen recovery vs. hydrogen purity.

system are essential for an improved process. The influence of the tail gas pressure on the hydrogen recovery rate depending on the feed gas pressure is visualised in Fig. 5.

The required product purity also has an important influence on the PSA performance. The dependence of the hydrogen recovery rate on the product concentration of relatively strong adsorbed components like CO is lower than the dependence on highly volatile components like N_2 or O_2. This means that a relaxation of the purity criteria for e.g. nitrogen has a strong effect on the achievable recovery rate (Fig. 6).

4. Conclusions

PSA units have a very high importance in industrial processes and they cope with the set expectations. In addition to stand alone solutions the combination and integration of these units improve gas separation and recovery processes. A strong influence on the performance of PSA units is exerted by the tail gas pressure, the process reacts very sensitive on it. It has to be considered that the required product purity of non key components like N_2 also determines the performance of the process.

Trends can be seen in plants growing larger with 1-train philosophy even for feed gas flows exceeding 300.000 Nm^3/h. The plants are getting specifically smaller caused by improved cycles and new adsorbents. The control systems are getting more and more sophisticated for further improvement of flexibility and automation.