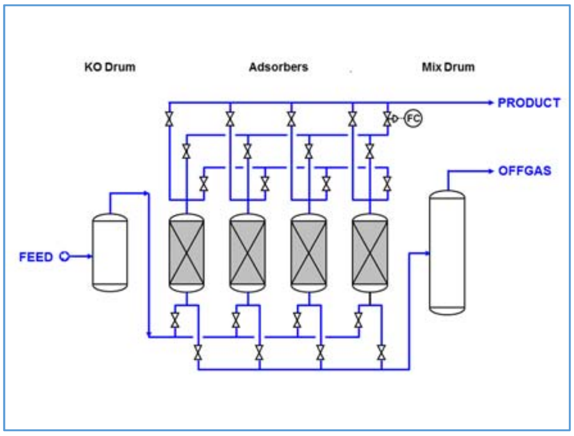
Refining Process Overview
Hydrogen Purification - Pressure Swing Adsorption



Process Description

The Pressure Swing Adsorption (PSA) Unit is a semi-batch, cyclic adsorption process which removes impurities from feed gas to produce a hydrogen product purity in excess of 99 vol% at pressures very close to the feed gas pressure over a wide range of feed gas compositions. The offgas stream from the PSA unit, containing the removed impurities and some residual hydrogen, is typically returned to the Reforming Furnace as fuel gas.

The PSA unit essentially comprises a knockout drum, a series of 4 – 14 killed carbon steel adsorber vessels filled with adsorbents such as activated carbon or zeolite molecular sieve, multiple automated sequential isolation valves, a PLC-based control system and an offgas mix drum. The adsorbents are carefully selected for specific feed gas contaminants and are loaded in layers with the weakest adsorbents at the inlet to remove heavy, easily-adsorbed contaminants. A larger number of adsorbers is used when high hydrogen recovery rates are required. A large PSA system may typically have 85 – 90% recovery whereas a small PSA system may have only 70 – 75% recovery. A larger number of adsorbers also helps deliver smooth flow with minimal disturbance while switching adsorbers and essentially constant offgas composition (minimal disturbance to operation of the Reforming Furnace or refinery fuel gas main).

Feed gas passes through the adsorber in an upflow direction and impurities are adsorbed. When the capacity of the adsorbent bed has been exhausted, feed is automatically switched to a fresh adsorber. Depressurisation takes place in two steps. The first step is co-current depressurisation in which residual product is recovered by using the depressuring gas stream to repressurise and purge other adsorbers. The second step is counter-current depressurisation in which the impurities are desorbed from the adsorbent bed and rejected to offgas (fuel). The adsorbent is then purged at constant pressure with high purity product from another adsorber in the co-current depressurisation step. The adsorber is then pressurised with a combination of co-current depressurisation gas from another adsorber and a slipstream of product.

Key Variables

The key independent variables affecting PSA performance are adsorption pressure, adsorption temperature and offgas pressure. There is a tradeoff between purity and recovery but the goal is usually to maximise hydrogen recovery at a specified hydrogen purity. To achieve this, adsorption pressure should be maximised while offgas pressure and adsorption temperature should be minimised. The feed gas:offgas pressure ratio should be at least 4:1 (absolute).

Safety Issues

Hydrogen self-heats as it expands so auto-ignition can occur at process temperatures below the theoretical autoignition temperature. It is highly flammable and burns with a blue flame which can be difficult to see in daylight. It is also capable of forming an explosive mixture in air over a wide range of concentrations. Hence loss of primary containment (LOPC) is the single biggest safety risk. This may be through moderate probability, low consequence events such as gland leaks on valves or low probability, high consequence events such as fatigue failure of the adsorber vessel (hydrogen accelerates fatigue crack growth in steels).

Availability Issues

The main availability issues are contamination of the feed gas or mechanical failure of the sequential control valves. The life expectancy of the adsorbent in a unit operating within its design limits is the same as the life of the adsorber vessels and associated equipment (20+ years). However, adsorbents can be irreversibly damaged if the feed gas is contaminated by hydrogen chloride (HCl) or entrained liquids such as water, heavy hydrocarbons (C4+) or compressor lube oil carryover. Frequent movement of valves can cause valve failure through wear and tear but modern microprocessor-based valve sequencing control systems can often detect these and automatically bypass faulty adsorber modules. Valve limit switch or actuator failure may cause the PLC to pause the sequential logic resulting in a decline in product purity. Valve seat leakage can cause attrition ("dusting") of the adsorbent leading to high pressure drop and flow maldistribution. Flow upsets during adsorber switchover can cause channeling in the adsorbent bed.

Peter Marsh
Director – XBP Refining Consultants Ltd