Control Valve Sourcebook — Chemical Unit Operations

Adsorption

Topic **Page**

EMERSON™
Process Management

Adsorption

I. How It Operates

Adsorption is a typical mass transfer operation used in process plants to remove or separate specific components of a liquid or gaseous mixture. The specific definition of adsorption is the adhesion of atoms, ions, or molecules to a solid surface.

This process is different from absorption because absorption consumes the particles, while adsorption is the binding of molecules or particles to a surface. This binding takes place primarily on the walls of the porous material. The pores within these materials trap the unwanted impurities so they can then be purged from the bed. This allows for the particles to be separated from the mixture.

The design of the beds within the adsorption process can differ depending on the speed of regeneration needed. For example, a shorter bed length means a smaller inventory of the material performing the adsorption, also called sorbent, and a lower pressure drop within the bed. More frequent regeneration is required and consequently the cost is higher.

The design also involves highly porous materials to ensure that certain particles can be separated from a material. Typically a flow-down orientation is preferred, especially in the pressure swing adsorption process, because a flow-up orientation at high pressure rates might fluidize the particles, causing attrition and loss of fines. In other words, a flow up orientation at high pressure can lift the adsorbent material off the bed and cause it to float for a period of time. When the pressure is cut off or lowered, the adsorbent material/beads will fall back to the bed, damaging the adsorbent beads. This can be a very expensive mistake for customers.

There are three common types of the adsorption regeneration processes: pressure swing adsorption (PSA), temperature swing adsorption (TSA), and vacuum pressure swing adsorption (VPSA).

A simple PSA scheme for air separation uses at least two beds of molecular sieves, with one adsorbing and the other regenerating (Figure 1).

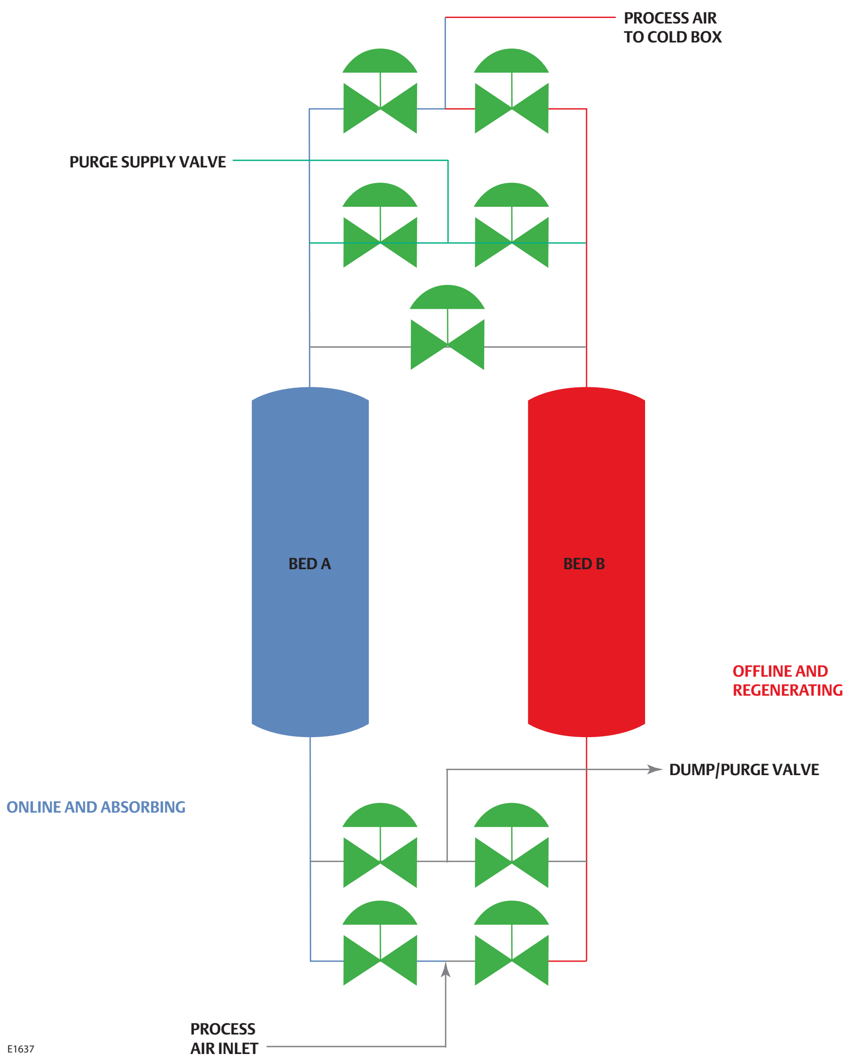

Figure 1. Adsorption beds—bed A is adsorbing while bed B is regenerating.

The following example will be for an air separation process where oxygen or nitrogen are the primary components being separated.

During the production step, air is pumped into a cylinder containing beads of adsorbent material at pressure. Adsorbent material is selected based on what component of the air is needed. As the air passes through the bed, the adsorbent material separates the unwanted air components and only allows the desired product to pass through. During the regeneration step, a small amount of product nitrogen or oxygen is used to flush the waste gas through an exhaust port, preparing the vessel for another production cycle.

The VPSA process is very similar to the PSA process, but the process is done in a vacuum. This vacuum pressure allows the pressure swings to be much lower and the regeneration step to occur at atmospheric pressure. The valve selection is the same as the PSA process, with one exception being that the packing in the VPSA must be upgraded for vacuum service and this may include the Fisher™ ENVIRO-SEAL™ packing system.

In the TSA production process, wet gas is pumped into a cylinder at pressure. The moisture in the feedstock gas is then adsorbed onto the internal surfaces of the beads, which leaves dry gas in the vessel. During the regeneration step, heated purge gas raises the temperature of the loaded bed. The loaded bed is the bed that was originally adsorbing and is filled with the impurities from the feed gas that it had passing through it. The high temperature then drives off the adsorbed moisture. Before returning online, the desorbed bed must cool down so that it can adsorb again in the next cycle. TSA uses different pressures to allow for dry feed gas to pass through the beds and the desired product to pass through while the impurities that remain behind.

II. Where Adsorption is Used

Adsorption removes unwanted particles from mixtures, so it is used in a variety of process industries. For example, some places you may see adsorption are:

- Removal of sulfur compounds from natural gas
- Removal of water content in cracked gas for ethylene production
- Air separation units
- Dehydration of ethanol
- Clarification of sugar
- Softening of hard water
- Carbon dioxide (CO_2) removal

III. Adsorption Application Review

Typical critical valves found in PSA processes are described next.

Switching Valve

The switching valve is used in the adsorption process to switch the beds between online and offline. This valve is very important because if it is incorrectly controlled, it could fluidize or fluff the adsorption beds, which causes damage to the adsorbent materials and the bed itself. This fluffing can be a very expensive problem and should be prevented.

Cycles are time dependent on the regeneration method that is used. For example, in the TSA process the cycle time is around eight hours and much longer than the PSA and VPSA process. The PSA and VPSA switching process take between one to three minutes. One bed is online adsorbing while the other is offline regenerating in the adsorption process. The difference in time between these processes comes from the fact that pressure can be changed much quickly than temperature. To avoid fluffing the beds, Fisher and Bettis™ actuators can be used for fast switching and accurate control. Also, Fisher FIELDVUE™ DVC6200 digital valve controllers are used to ensure accuracy when opening the switching valves so they are not opened too quickly.

Feed Gas Valve

This valve introduces feed gas into the clean, adsorbent bed. Feed gas can be air, hydrogen, biogas, or another gas. This valve opens simultaneously with the product valve to ensure that the feed gas passes through the bed, allowing the bed to remove impurities from the feed gas to make the desired finished product. The product valve is described in more detail below.

Typical process conditions:

- — Fluid = hydrogen (H_2), methane (CH_4), air, biogas, ethane (C_2H_8), propane (C_3H_8)
- — Inlet pressure = 11 bar (160 psi)
- — Pressure drop = 0 to 0.050 bar (0 to 1 psi)
- — Temperature = -7 to 45°C (-19 to 113°F)
- — Q = dependent on process design

Typical valve selection:

- — Fisher HPBV, GX valve
- — Materials of construction: 316SST disk with chrome, WCC body, Fisher ENVIRO-SEAL packing system, 316L/PTFE seat ring
- — Stroking speed requirement = typically two seconds
- — Class VI bi-directional shutoff

Dump/Purge Valve

The dump/purge valve removes and dumps impurities from the process. This process can also be called the offgas process because the impurities are removed as offgas.

Typical process conditions:

- Fluid = H2, CH4, C2H8, C3H8
- Inlet pressure = 0.5 to 2 bar (7 to 30 psi)
- Pressure drop = 0 to 1.5 bar (0 to 22 psi)
- Temperature = -28 to 45°C (-19 to 113°F)
- Q = dependent on process design

Typical valve selection:

- Fisher 8580 valve
- Materials of construction: 316SST disc with chrome, WCC body, Fisher ENVIRO-SEAL packing system, 316L/PTFE seat ring
- Stroking speed requirement = typically two seconds
- Class V or VI bi-directional shutoff

Purge Supply Valve

This valve allows purge gas to enter the beds by connecting bed A to bed B. Gas then flows from the higher pressurized bed into the lower pressurized bed. Pressure in the lower pressurized bed is maintained as low as possible to minimize the impurity partial pressure and maximize the adsorbent regeneration. This valve also can perform equalization between the beds. Refer to the equalization process for more detail.

Typical process conditions:

- Fluid = H2, air impurities, biogas
- Inlet pressure = 2 to 7 bar (30 - 96 psi)
- Pressure drop = 0.5 to 5.5 bar (10 to 80 psi)
- Temperature = -7°C to 45°C (-19°F–113°F)
- Q = dependent on process design

Typical valve selection:

- Fisher GX valve
- Materials of construction: WCC body, PTFE seal, live-loaded PTFE V-ring,
- Stroking speed requirement: typically two seconds

Product/Repressurization Valve

This valve allows the final product to pass through the top of the adsorption beds then into the product storage tanks. It works in conjunction with the feed gas valve so that the feed gas goes through the bed, has impurities removed, and passes through as the final product. This valve also can perform equalization between the beds. Refer to the equalization process for more detail.

Typical process conditions:

- Process fluid = hydrogen (H2), oxygen (O2), nitrogen (N2)
- Inlet pressure = 10.6 to 10.8 bar (154 to 157 psi)
- Pressure drop = 0.1 to 5 bar (2 to 76 psi)
- Temperature = -28°C to 45°C (-19°F to 113°F)
- Q = dependent on process design

Typical valve selection:

- Fisher 8580 valve
- Materials of construction: 316SST disc with chrome, WCC Body, Fisher ENVIRO-SEAL packing system, 316L/PTFE seat ring.
- Stroking speed requirement: typically two second
- Class VI bi-directional shutoff

Equalization Process

Equalization is achieved through the product/repressurization valve or the purge supply valve. These valves connect adjacent or opposite beds together and allow for the bed with higher pressure to balance its pressure with the bed at the lower pressure. This valve is used to ensure that the pressures between the beds in the adsorption process are equalized after having varying pressures.

Typical process condition:

- Process fluid = H2, air, biogas
- Inlet pressure= 10.6 to10.8 bar (154 to157 psi)
- Pressure drop= 0.1 to 5 bar (2 to 76 psi)
- Temperature= -28°C to 45°C (-19°F to 113°F)
- Q = dependent on process design

Typical valve selection:

- Fisher GX valve, Fisher 8580 valve
- Materials of construction: 316SST disc with chrome, WCC, Fisher ENVIRO-SEAL packing system, 316L/PTFE seat ring.
- Stroking speed requirement: typically two seconds
- Class VI bi-directional shutoff

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