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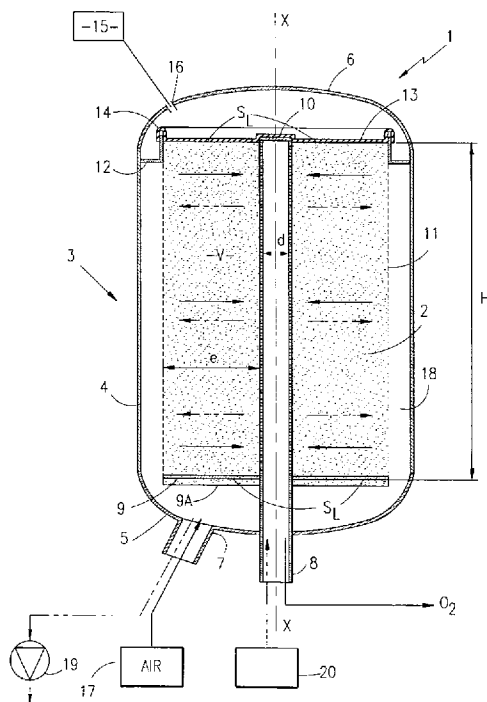
(71) L'AIR LIQUIDE, SOCIÉTÉ ANONYME POUR L'ÉTUDE ET
L'EXPLOITATION DES PROCÉDÉS GEORGES CLAUDE, FR

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(54) **PROCEDE ET INSTALLATION DE SEPARATION DE L'AIR
PAR ADSORPTION**

(54) **PROCESS AND PLANT FOR THE SEPARATION OF AIR BY
ADSORPTION**



(57) D'après le présent procédé, les débits de gaz dans l'adsorbeur (1) sont déterminés en faisant passer le gaz, de manière essentiellement radiale par un lit annulaire (2) qui contient un volume (V) d'adsorbant au moins égal à un mètre cube et dont la hauteur (H), mesurée en mètres, est au moins égale à $0,8 \times V^{0,35}$. Le procédé est utilisé pour la production d'oxygène à partir de l'air atmosphérique.

(57) According to this process, the gas flows in the adsorber (1) are established by passing the gas streams substantially radially through an annular bed (2) which contains a volume (V) of adsorbent at least equal to 1 m^3 and whose height (H), measured in metres, is at least equal to $0.8 \times V^{0.35}$. Application to the production of oxygen from atmospheric air.



PROCESS AND PLANT FOR THE SEPARATION OF AIR BY
ADSORPTION

ABSTRACT

According to this process, the gas flows in the adsorber (1) are established by passing the gas streams substantially radially through an annular bed (2) which contains a volume (V) of adsorbent at least equal to 1 m^3 and whose height (H), measured in metres, is at least equal to $0.8 \times V^{0.35}$.

Application to the production of oxygen from atmospheric air.

The present invention relates to a process for the separation of air by pressure swing adsorption in a plant which has at least one adsorber.

The term "pressure swing adsorption" (PSA) is used to mean the various cycles which have been proposed for producing oxygen from atmospheric air by substantially isothermal selective adsorption, with the pressure of the adsorber or each adsorber varying between a high pressure and a low pressure. The high pressure of the cycle may be greater than or equal to atmospheric pressure, while the low pressure of the cycle may be equal to or less than atmospheric pressure. These processes have various combinations of steps of adsorption, decompression/regeneration and recompression of the adsorber or adsorbers.

Complex thermal phenomena take place within the adsorbent in PSA processes. They are due, on the one hand, to the heats of adsorption or desorption of the adsorbed constituents, and on the other hand to the heat exchanges between the fluids which are flowing and the adsorbent. It has been observed (see, for example US-A-5,529,610) that, as a result of these phenomena, thermal gradients tend to form within the bed of adsorbent.

However, a given adsorbent has an efficiency which varies with temperature. In consequence, the thermal gradients have an effect on the performance of the adsorbers. Various measures have been proposed, either to reduce this effect when it is detrimental, or to take advantage of it, for example by increasing the thermal transfer within the adsorbent by means of metal bars (US-A-4,026,680), or by using multiple beds to adapt several types of adsorbents to the temperature zones.

It will be understood that the thermal gradients are particularly pronounced in the case of producing oxygen from air, when most of the incoming flow is adsorbed then desorbed, with the result that

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very large amounts of heat of adsorption/desorption are involved in each cycle.

The Applicant Company has observed that, surprisingly, the efficiency of the PSA-air separation process can be increased substantially by giving the bed of adsorbent a particular geometry.

The process according to the invention is thus characterized in that the gas flows in the adsorber are established by passing the gas streams substantially radially through an annular fixed bed which contains a volume V of adsorbent at least equal to 1 m^3 and whose height H , measured in metres, is at least equal to $0.8 \times V^{0.35}$, typically between $1 \times V^{0.35}$ and $3 \times V^{0.35}$.

The invention also relates to an air separation plant intended for implementing a process of this type.

This plant, of the type comprising a pressurized air source and at least one adsorber which can be connected selectively to this source, is characterized in that:

- the volume V of adsorbent is at least equal to 1 m^3 ;
 - the adsorber contains an annular fixed bed of adsorbent; and
 - the height H of the annular bed, measured in metres, is at least equal to $0.8 \times V^{0.35}$.
- Typically, $H \geq 1 \times V^{0.35}$ and does not exceed $3 \times V^{0.35}$.

In one embodiment, the annular bed is supported by a base provided with thermal insulation.

An illustrative embodiment of the invention will now be described with reference to the appended drawing, in which the single figure schematically represents a plant according to the invention.

The drawing schematically shows an adsorber 1 which contains an annular bed 2 of an adsorbent suitable for the separation of nitrogen from oxygen by a PSA process for the treatment of atmospheric air. The adsorbent 2 may be any type of particulate material known in the art, for example a molecular sieve 5A.

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The adsorber 1 has an outer casing 3 of vertical axis X-X, consisting of a cylindrical shell 4, a lower convex dome 5 and an upper convex dome 6. The dome 5 is equipped with an outer lateral pipe 7, and has a central tube 8 of diameter d passing through it in leaktight fashion.

A rigid lower base 9, in the form of an annular disc, is welded around the tube 8 at a small distance above the dome 5. The part of the tube 8 lying below the base 9 is not perforated, whereas that part of it which lies above this base is perforated. An upper plate 10 closes off the upper end of the tube 8. An annular grill 11 coaxially surrounds the perforated part of the tube 8 and is welded by its foot to the periphery of the base 9. The top of the grill is welded to an annular cornerpiece 12, itself welded to the upper end of the shell 4.

The adsorbent 2 fills the entire space delimited between the tube 8 and the grill 11. A flexible diaphragm 13, the unrolling edge 14 of which is adhesively bonded in leaktight fashion to the cornerpiece 12, bears elastically via its central region on the plate 10, and via its intermediate annular region on substantially the entire upper surface of the adsorber. In order to ensure that the diaphragm is properly applied permanently on the adsorbent, a pressure in excess of the maximum pressure of the adsorption cycle is maintained in the dome 6, using a gas source 15 which is connected to an orifice 16 in the dome.

The adsorber thus contains an annular bed of adsorbent whose volume V is at least equal to 1 m^3 , whose height H is equal to the distance separating the base 9 from the diaphragm 13, and whose radial thickness e is equal to the distance between the tube 8 and the grill 11.

In service, the adsorber undergoes a cycle which comprises: an adsorption phase, in which the pipe 7 is connected to a source 17 of air under the high

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pressure of the cycle, which is at least equal to atmospheric pressure; a phase of regenerating the adsorbent, including at least one step of decompression to the low pressure of the cycle; and a phase of recompression to the high pressure. This cycle may be any one of the many cycles which have been proposed.

During the adsorption phase, the air to be treated enters the annular space 18 which separates the grill 11 from the shell 4 of the casing 3, and passes substantially radially inwards through the bed 2 (solid arrows) while the nitration is adsorbed. The oxygen which is produced collects in the tube 8 and leaves the adsorber through its lower end.

During the regeneration phase, the pipe 7 may be connected to the atmosphere or to a vacuum pump 14, and the tube 8 may be closed off or connected to an eluent gas source 20, for example production oxygen or impure oxygen obtained during a phase of depressurizing the adsorber. In all cases, a substantially radial flow of gas is produced in the opposite direction to the one above, that is to say passing through the bed 2 in the centrifugal direction (dot and dash arrows), leaving the adsorber via the tube 8.

The geometry of the bed 2 is such that $H \geq 0.8 \times V^{0.35}$, with advantageously $H \geq V^{0.35}$ and $H \leq 3 \times V^{0.35}$, and preferably H between $1.0 \times V^{0.35}$ and $2.5 \times V^{0.35}$.

It has surprisingly been observed that, for a bed of radial thickness e , the performance improves when upscaling from a short pilot unit to a tall industrially sized unit, whereas there is nothing in the theory to predict this result and, on the contrary, the distribution of the gas streams is less advantageous in the case of the industrial unit.

This result is attributed to the fact that the lateral inputs of heat through the surfaces S_L parallel to the gas flows, which modify the temperature of the adjacent region of adsorbent, are then proportionately much smaller.

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The lesser relative importance of the thermal gradients orthogonally to the gas flows would thus lead to the adsorbent working more homogeneously over the entire cross-section perpendicular to the gas streams, and therefore to better overall performance.

It has furthermore been observed that, surprisingly, the specific energy for the separation of oxygen is substantially less with an adsorber according to the invention than what it would be if the same volume V of the same adsorbent was arranged in the form of a conventional cylindrical bed of height e with the gas streams flowing vertically through this bed.

It is thought, once more, that this advantageous result is due to the fact that the slender shape of the adsorber corresponds to upper and lower surface areas S_L , parallel to the gas flows, which are particularly small and less than what they are in the case of the adsorber with conventional cylindrical bed, which reduces the thermal gradients in the direction perpendicular to the gas flows, that is to say parallel to the axis X-X.

Thermal insulation may optionally be provided for the base 9, as schematically represented at 9A, so as to reduce further the vertical thermal gradients within the adsorbent.

As a variant, the bed 2 may consist of at least two concentric elementary annular beds, each of which is formed by a different adsorbent.

CLAIMS

1. Process for the separation of air by pressure
5 swing adsorption in a plant which has at least one
adsorber, characterized in that the gas flows in the
adsorber (1) are established by passing the gas streams
substantially radially through an annular fixed bed (2)
10 which contains a volume V of adsorbent at least equal
to 1 m^3 and whose height H , measured in metres, is at
least equal to $0.8 \times V^{0.35}$.
2. Process according to Claim 1, characterized in
that the said height (H) is at least equal to $V^{0.35}$.
3. Process according to Claim 2, characterized in
15 that the said height (H) does not exceed $3 \times V^{0.35}$.
4. Plant for the separation of air by pressure
swing adsorption, of the type comprising a pressurized
air source (12) and at least one adsorber (1) which can
be connected selectively to this source, characterized
20 in that:
- the volume V of adsorbent is at least equal
to 1 m^3 ;
 - the adsorber (3) contains an annular fixed
bed of adsorbent (2); and
 - 25 - the height H of the annular bed, measured in
metres, is at least equal to $0.8 \times V^{0.35}$.
5. Plant according to Claim 4, characterized in
that the said height (H) is at least equal to $V^{0.35}$.
6. Plant according to Claim 5, characterized in
30 that the said height (H) does not exceed $3 \times V^{0.35}$.
7. Plant according to any one of Claims 4 to 7,
characterized in that the annular bed (2) is supported
by a base (9) provided with thermal insulation.
8. Plant according to any one of Claims 4 to 7,
35 characterized in that the said annular bed (2)
comprises at least two concentric elementary annular
beds of adsorbent.

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9. Plant according to Claim 8, characterized in that the said annular beds consist of different adsorbents.

