The experimental study on the performance of a small-scale oxygen concentrator by psa

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A small-scale adjustable rich oxygen concentrator by pressure swing Adsorption (PSA) was designed and manufactured to study influences of nozzle size, purge quantity on characteristics of the production oxygen, such as its pressure, purity and volume flux. The purity of oxygen produced by this device could reach above 90% and up to 96% in volume. The flux of rich oxygen product could be adjusted intelligently in the range of 0.5l/min~3.5l/min. The device is quite usable in hospital, domestic application, oxygen bar and other places in shortage of oxygen. It would have great economic benefit in the future.

INTRODUCTION

The basic principle of producing oxygen from air by PSA is based on the fact that the adsorbed nitrogen quantity of Qn by adsorbents at higher pressure is larger than it at lower pressure [1,2,3]. The operation can be performed as the following processes [4,5]. Firstly, the pressurized, dry and filtered feeding air flows into the adsorption column which is filled with 5A zeolite molecular sieves (ZMS). Then most of nitrogen will be adsorbed by 5A ZMS and most of oxygen flows through the column. In this paper, a small-scale oxygen concentrator is constructed to investigate the effects of the operating parameters on the performance of the device so as to optimize them [4,5].

Nomenclature

Q_O The flow of production oxygen, L/min
Q_P The flow of purge quantity, L/min
Q_e The flow of oxygen- enriched air exiting out of adsorption column, L/min
Q_a The flow of air feeding into adsorption column, L/min
Q_n The flow of adsorbed nitrogen in adsorption column, L/min
P The high plateau adsorption pressure (HPAP) , MPa.

EXPERIMENTAL ARRANGEMENTS

The experiments are performed to investigate how to get either large flow of production oxygen or high purity of it by adjusting HPAP and purge quantity of Qp. The schematic drawing of the experimental system is shown in Figure 1.Firstly the feed air is passed through the air filter 1 to remove dust and other solid substances, then enters the compressor 2 to be pressed to the required HPAP. Finally, it flows into the adsorption columns 5 to produce oxygen-richened air. Under the controlled by the control system 7, Two columns of A and B, operate alternately to be controlled by the controlling system 7. While A is adsorbing, B is desorbing at the same time, then the valve V1 will be opened and valve V2 be closed with V3 closed and V4 opened .The high- pressure air flows into column A via V1 and the component of nitrogen in the air is adsorbed in column A. Then one part of the oxygen-richened air is supplied to the consumer as product oxygen of Qo. Another part of the oxygen-richened air will act as the purge gas of Qp to enter the column B. At last the purge gas is discharged into atmosphere via valve V4 and via muffler 6.

In next step, the column B will be in adsorbing and the column A will be in desorbing with the similar process .The flow and purity of the production oxygen are measured by 8 and 9 respectively.

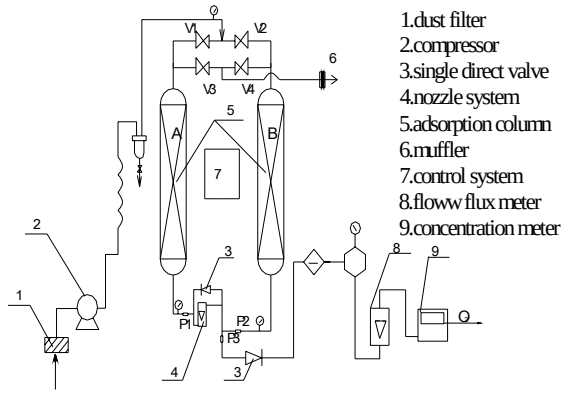

Figure 1 Experimental system

<u>The testing condition are as follows:</u>

The dimension of the adsorption column (two): 82 mm (diameter); 650 mm (height);
Adsorption period: 10 ~ 30 seconds (adjustably);
Void fraction: 0.32 ~ 0.47;
Temperature: ambient temperature;
Adsorbent: 5A Molecular sieve (d=1.6~2.5mm);
Experimental pressure: 0.11Mpa ~ 0.28 MPa.

<u>New packing arrangement for molecular sieves.</u>

An important improvement has been made in packing arrangement for molecular sieve in the two adsorption columns.

The traditional packing arrangements are uniform packing by using only one kind of molecular sieve. Namely, the same size of diameter of one kind of molecular sieve is uniformly distributed in the adsorption column. The disadvantage of this uniform packing is insufficient usage of molecular sieve for whole column. It is caused by the mal-distribution of flow velocity in the column. The maximum velocity lies in the central core of the column. While the velocity outside the central core, it is much smaller. Therefore the molecular sieve in central core is firstly saturated by adsorbing enough nitrogen and thus firstly penetrated by feed-air. However the molecular sieve outside the central core is still not saturated, and is not sufficiently used. In order to use the molecular sieve sufficiently, the flow velocity in the central core must be reduced in comparison with the traditional packing.

The new packing arrangement is called multi-layer and multi-section packing method. The small diameter ofmolecular sieves is packed in the central core while the larger diameter of sieve lies in the outer layers outside of the central core. According to previous experimental results the arrangement of layers will be adjusted so as to obtain

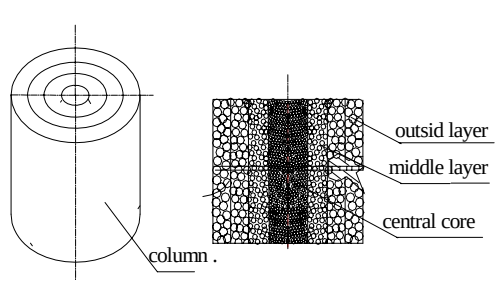

Figure 2 New packing arrangements in radial and axial

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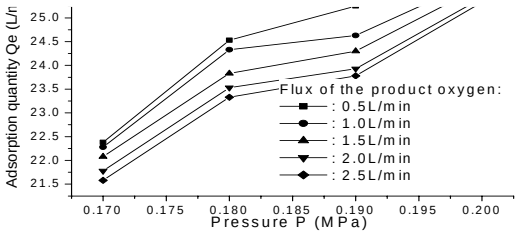

a p pr o pr ia te flow resistance and flow velocity distribution at last. In our experiment, there are three layers in radial direction and two sections in axial direction of the column, which is shown in Figure 2. The size of molecular sieve in the central core, in outside layer and in middle layer are of 1.6 mm, 2.5mm, and 2mm , respectively. By this new packing arrangement the flow velocity distribution has been improved greatly.

EXPERIMENTAL RESULTS AND DISCUSSIONS

<u>The influence of HPAP on Q_e</u>

The discharge flux out of adsorption column of Q_e, that is total flux of high purity oxygen, is equal to the flux of production oxygen of Q_O plus the flux of purge quantity of Q_P. The Q_e is related to the HPAP as shown in Figure3.The relationship between the discharge flux of Qe and HPAP shows the same tendency as the typical

Langmuir curve. The results also indicate that the higher the volume flux of the production oxygen of Qo, the lower the Q_e in the condition that the HPAP was kept constant, and the flow of feed air of Qa was also kept constant. When the flux of the production oxygen is higher the purge quantity of Qp will drop. The quantity of the purge gas of Qp has decisive effect on the process of regeneration of adsorbent. Thus the regeneration of the adsorbent in the adsorption column is not sufficient due to the insufficient quantity of the purge gas of Qp. The adsorption ability will be decreased. It will directly lead to the decrease of the effective adsorption, that is, the decrease of Qe. Therefore, the Q_e decreases with the increase of the volume flow of the product oxygen when the purity of production oxygen and the HPAP were kept constant.

The effect of HPAP on the flux of production oxygen Qo

Figure 4 also shows the relationship between the flow of the production oxygen and the purity of the production oxygen with different adsorption pressure. Only in case the pressures were kept in medium range both the purity of production oxygen and the flux of production oxygen can obtain optimum performance. Neither the higher nor the lower HPAP would make the performance of the device better according to the Figure 4.The main reason is as follows. When the HPAP is below a minimum value, the adsorbent will have a little adsorption ability. It will directly lead to the drastic drop of the purity of the production oxygen according to basic theory of PSA. Inversely, when the HPAP is too high, the purge quantity will decrease based on above analysis. When the purge quantity is so small to be less than the quantity required by the regeneration of the adsorbent, the adsorption ability will be decreased. It will cause the decrease of the effective adsorption so as to decrease the purity of the production oxygen. Therefore the HPAP should be in an appropriate range to ensure both the high flow flux and purity of the product oxygen at the same time. The appropriate HPAP is found to be 0.17Pa to 0.23Pa according to the Figure 4. The corresponding nozzle diameter is from 0.7mm to 1.2mm.

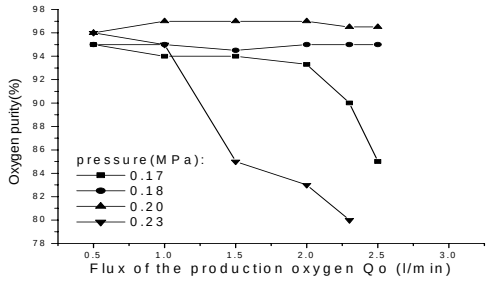

Figure 4 The purity of oxygen related to Qo

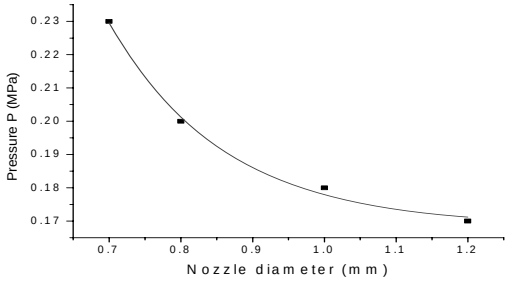

Figure 5 Pressure related to nozzle size

The effect of nozzle size on HPAP

A series of nozzles are designed and manufactured to ensure the stable and effective operation of the small device. The nozzle size is related to the adsorption pressure as shown in the Figure 5 .The smaller the nozzle diameter is, the higher the HPAP is. The higher HPAP can be attained in short adsorption time by the small diameter nozzle so that the energy consumption will be reduced. According to the experimental results in Figure 5 the right size of nozzle can be selected in accordance with the required HPAP.

The effect of the purge quantity Qp on the purity of oxygen

With the nozzle size unchanged the purity of the production oxygen is related to the purge quantity as shown in the Figure 6. When the purge quantity Qp is moderate, the high purity of the product oxygen Qo can be obtained. Too small purge quantity leads to the decrease of the regeneration of the adsorbent in the adsorption column and cause the remarkable drop of the purity of the production oxygen Qo. On the other hand, when the purge quantity Qp is too high to exceed the quantity required by the adsorbent, the excessive quantity of pressurized oxygen- richened air is filled into the adsorption column. It will cause a higher pressure in the adsorption column to reduce the adsorbing ability of the adsorbent. Therefore the purity of the production oxygen is also reduced.

The effect of the purge quantity Qp on the flux of production oxygen Qo

Figure 7 shows the relationship between the flow of the purge quantity Qp and the flow of the product oxygen Qo for different nozzle sizes when the purity of the production oxygen is kept above 93% in volume. The higher the flow of the production oxygen Q_O, the lower the purge quantity Q_P, when the nozzle size is kept constant. As is known, the flow of the product oxygen Q_O subtracted from Q_e gives the purge quantity Q_P. Therefore the purge quantity Q_P decreases with the increase of the flow of the production oxygen Q_O when the HPAP is kept constant. Only when the ratio of the purge quantity Qp to the flow of the product oxygen Qo is maintained above 2.5 shown in the curve of the nozzle 0.8mm in Figure 7, the device can be ensured to operate properly.

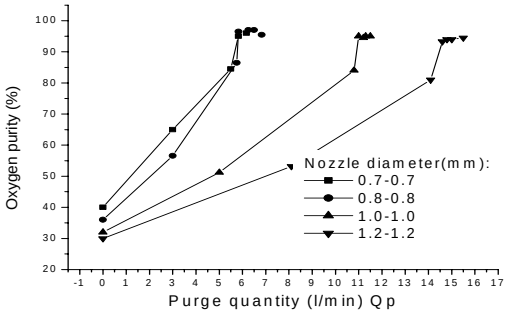

Figure 6 Oxygen purity related to Qp

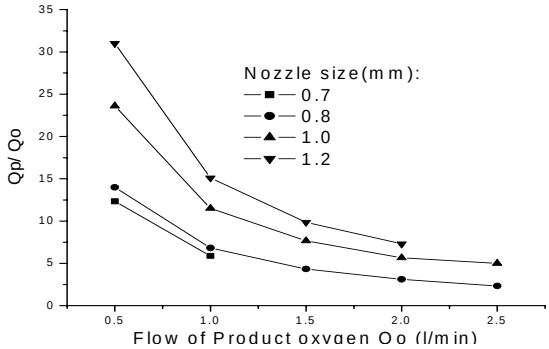

Figure 7 Qp/Qo related to Qo

CONCLUSIONS

(1) It is found that the small-scale concentrator could operate in optimum performance, with the purity of oxygen being above 90%. The relationship between the HPAP and the Q_e is a typical curve of Langmuir. (2) The optimal operating pressure of the experiment device is 0.18Mpa to 0.2MPa. (3) The ratio of the purge quantity Qp to the flow of the product oxygen Qo is maintained above 2.5. (4) The smaller the nozzle diameter, the higher the HPAP. The optimal nozzle diameter is from 0.8mm to 1.2mm while the adsorption time is 10 seconds (5) The highest purity of the production oxygen is about 96% in volume by using this small-scale concentrator while the flow of the production oxygen is of 2.0 l/min. The small-scale concentrator is quite suitable for hospital, domestic usage and oxygen bar.

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