A Two-Bed Simulated Moving-Bed Adsorber for the Fractionation of Gas Mixtures

S.V. Sivakumar, K.K. Gupta and D.P. Rao
Department of Chemical Engineering, Indian Institute of Technology Kanpur,
Kanpur – 208 016, INDIA
sivaku@iitk.ac.in , kkgupta@iitk.ac.in , dprao@iitk.ac.in

The hypersorber is a moving-bed adsorber similar to a distillation column. Its stripping and enriching zones are identical to their counterparts in distillation. Its regeneration and presaturation sections are functionally the same as the condenser and the reboiler. Here, it is possible to obtain clean separation as in distillation. However, due to the problems associated with solid handling, the moving beds have not been commercialized. To overcome the problem, simulated moving-bed (SMB) technology has been developed. In a simulated moving-bed the countercurrent contact is achieved by the switching of the inlet and outlet ports of streams located along the length of the bed. Recently, Rao et al. (2005) described simulated moving beds embedded with 'moving-port systems'. These moving-port systems facilitate continuous movement of a port used for the withdrawal and injection of a fluid into the bed (A patent pending). These simulated moving-beds can be used for the sharp separation of binary gas mixtures. It has been shown that an ideal simulated moving-bed adsorber can fractionate a mixture of propane and propylene into two product streams with 99 % purity (Rao et al. 2005).

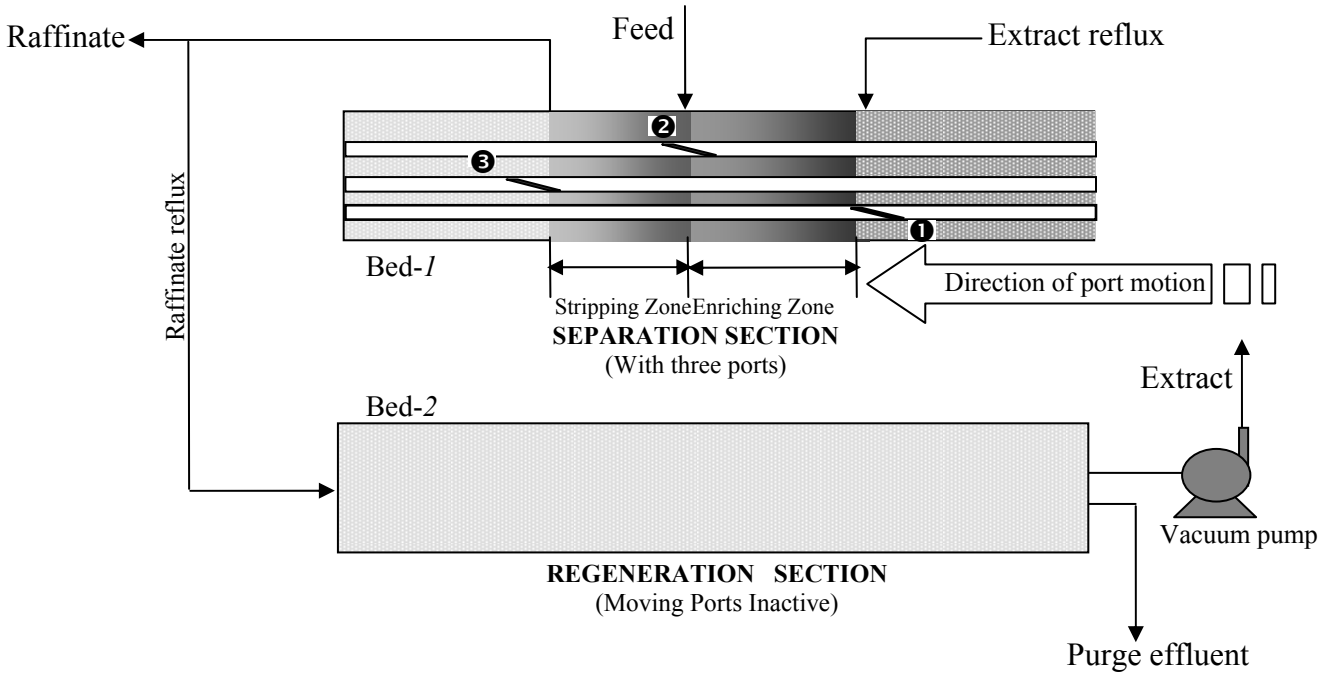
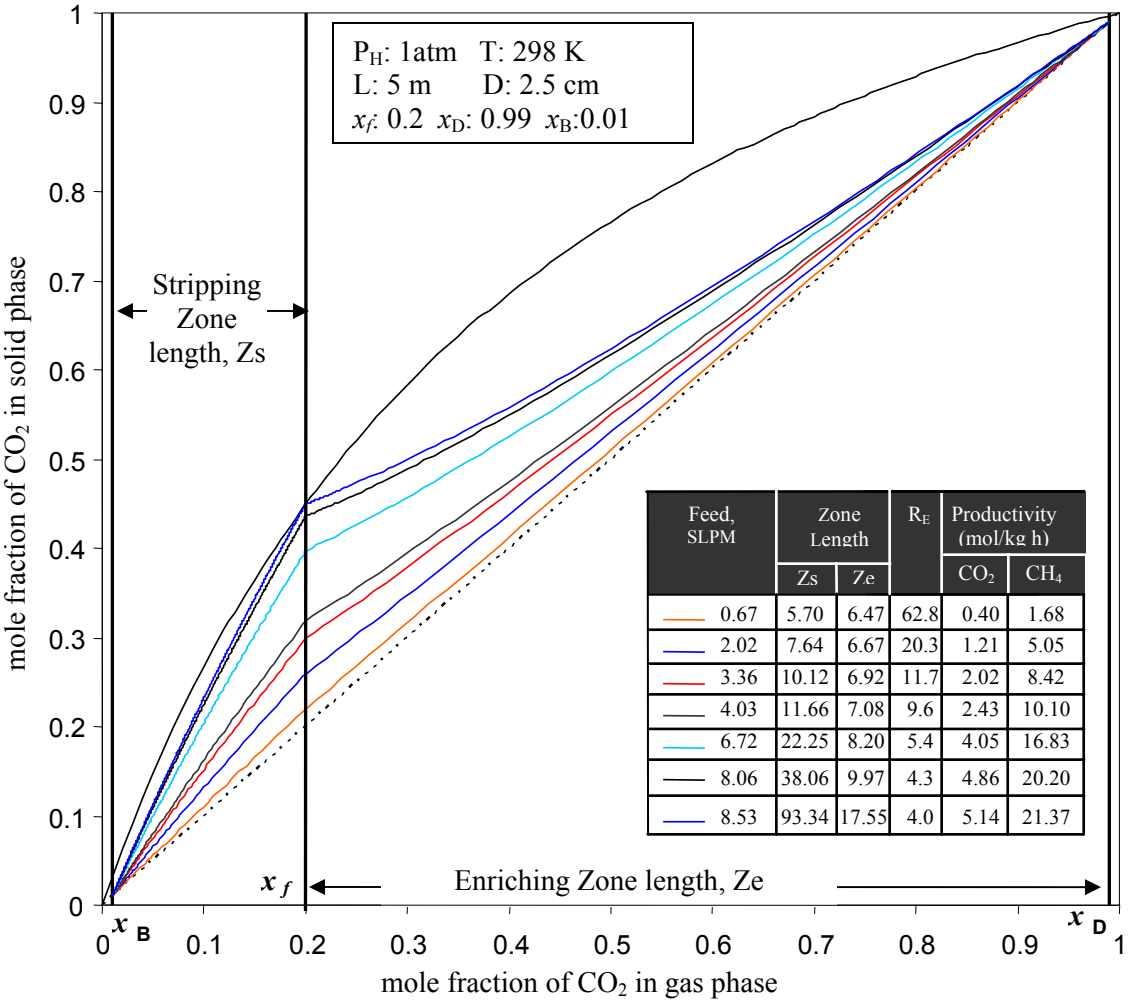


Figure 1: Two bed SMB adsorber configuration for gas fractionation with pressure swing

In this paper, to realize the SMB operation in practice, we propose a two-bed SMB adsorber for the fractionation of gas mixtures. A similar one has been used to exchange heat between two gas streams (Murthy et al. 2004). Figure 1 shows the proposed SMB. Each bed is embedded with three moving-port systems. The proposed adsorber is operated in such a

way that while one bed is effecting separation; the other bed is under regeneration. In the former bed the stripping and enriching zones are formed at either sides of the moving-port that is used for feed injection. The raffinate is withdrawn as a product from the moving-port in front of the stripping zone. A part of the extract product withdrawn from the bed under regeneration is refluxed using the moving-port behind the enriching zone. The stripping and enriching zones are carried along the bed from one end to the other by the moving-ports. The zone lengths can be adjusted by adjusting the position of the ports at the beginning of the operation. When the enriching zone breaks through the bed, the bed is fully saturated with the heavy component and is ready for regeneration. After regeneration by pressure swing, the bed is saturated with the raffinate component at the adsorption pressure. After saturation, the bed is ready to perform separation. The separation and regeneration steps are synchronized between the two beds using solenoid valves.



Feed, SLPM	Zone Length		R_E	Productivity (mol/kg h)	
	Zs	Ze		CO_2	CH_4
0.67	5.70	6.47	62.8	0.40	1.68
2.02	7.64	6.67	20.3	1.21	5.05
3.36	10.12	6.92	11.7	2.02	8.42
4.03	11.66	7.08	9.6	2.43	10.10
6.72	22.25	8.20	5.4	4.05	16.83
8.06	38.06	9.97	4.3	4.86	20.20
8.53	93.34	17.55	4.0	5.14	21.37

Figure 3: Performance of the adsorber in the McCabe-Thiele Diagram – CO_2-CH_4-activated Carbon system with complete regeneration

To evaluate the performance of the two-bed adsorber, two mathematical models have been developed: one for the stripping and enriching zones, and the other one for blowdown, purge and saturation. The stripping and the enriching sections have been modeled as steady-

state countercurrent contactors whereas the regeneration is modeled as a transient process. We have studied the fractionation of air using 13X zeolite and of the CO_2-CH_4 mixture using activated carbon with complete and partial regeneration.

At any given instant of time, the zone composition profiles can be represented on the McCabe-Thiele diagram. Figure 3 shows typical concentration profiles, the zone lengths and productivities for the fractionation of CO_2-CH_4 system with complete regeneration.

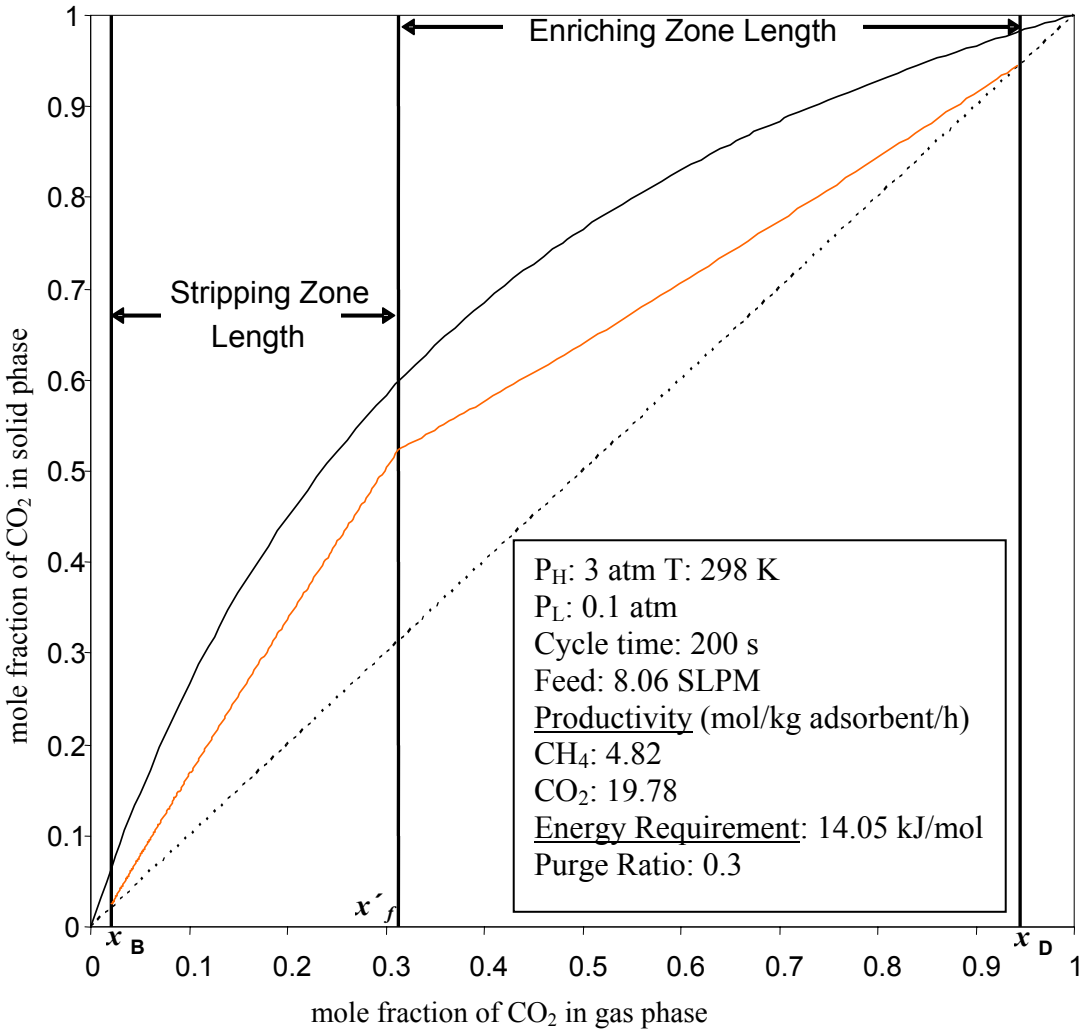


Figure 4: Performance of the adsorber in the McCabe-Thiele Diagram – CO_2-CH_4-activated Carbon system partial regeneration with purge

Figure 4 shows typical concentration profiles along with the operating conditions and the zone lengths for the case of partial regeneration with purge for the CO_2-CH_4 system. Figure 5 shows the adsorbate amount in the bed at the end of blowdown, purge and saturation steps. The performance of the SMB appears to be superior to the conventional PSA.

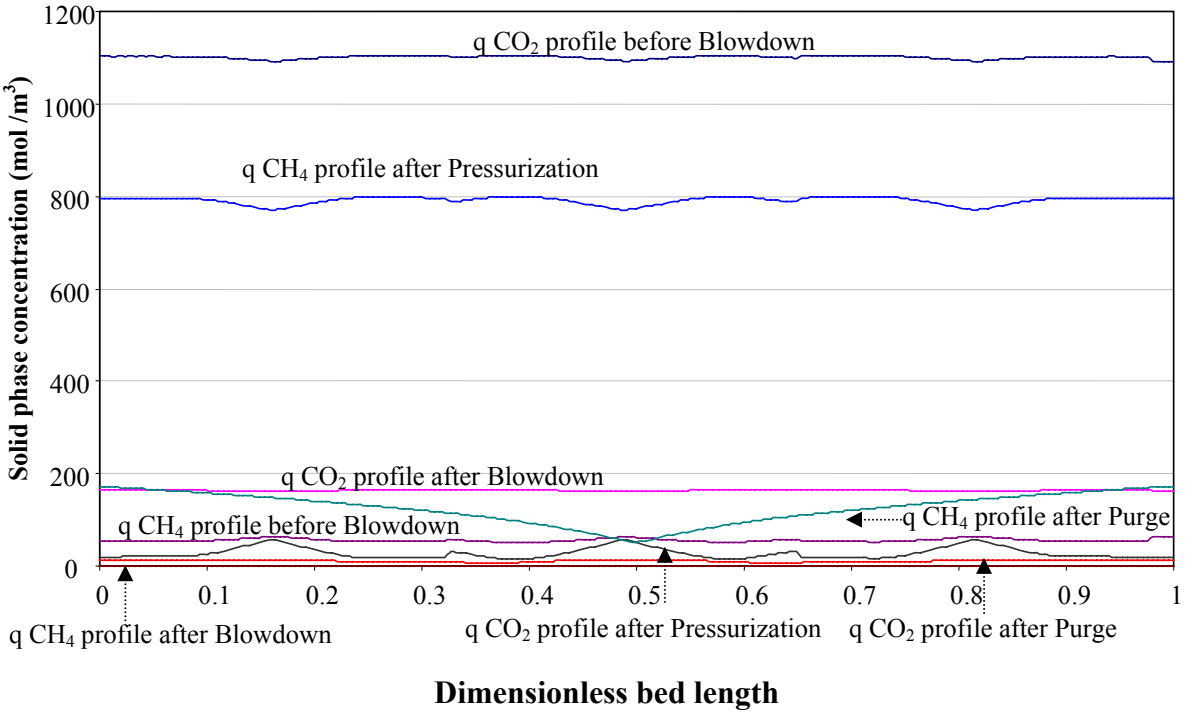


Figure 5: Solid-phase concentration profiles of methane and carbon dioxide during end of a step at cyclic steady-state

The studies indicate that it is possible to obtain both the raffinate and extract purities in excess of 99 mole percent as in distillation. The productivity is about 20 times higher than that obtained in conventional PSA.

Reference:

1. D.P. Rao, S.V. Sivakumar, S. Mandal, S. Kota and B.S.G. Ramaprasad, Journal of Chromatography A, Volume 1069 (2005), 141.
2. D.S. Murthy, S.V. Sivakumar, K. Kant and D.P. Rao, ASME Heat Transfer / Fluids Engineering Summer Conference, North Carolina, USA, 2004.