

CLAIMS:

1. A process for the separation of C₂₊ hydrocarbons from a natural gas stream, which process comprises:

a) subjecting said natural gas stream to an adsorption step by introducing it into the feed input end of an adsorbent bed selective for adsorbing said C₂₊ hydrocarbons, which adsorbent bed comprises at least one adsorbent material and a feed input end and a product output end, and which adsorbent bed is operated at a first pressure and a first temperature wherein C₂₊ hydrocarbons are selectively adsorbed by the adsorbent bed and wherein a first C₁ product stream having a higher mol% of C₁ hydrocarbons than said natural gas stream is retrieved from the product output end of said adsorbent bed;

b) stopping the introduction of said natural gas stream;

c) depressurizing said adsorption bed to a second pressure lower than said first pressure;

d) externally heating said depressurized adsorbent bed to a second temperature greater than said first temperature, thereby causing at least a fraction of the adsorbed C₂₊ hydrocarbons to desorb from the adsorbent bed;

e) counter-currently flowing through said heated adsorbent bed a first purge gas stream at a third pressure; and

f) recovering a C₂₊ product stream comprising C₂₊ hydrocarbon components and methane; ~~optionally~~

~~g) externally cooling said adsorbent bed to a third temperature lower than said second temperature; and optionally~~

~~h) repressurizing the adsorbent bed to within 90% of said first pressure~~

wherein a second purge gas stream is passed co-currently through the adsorption bed following depressurization step (c) and prior to heating step (d).

2. The process of claim 1, further comprising:

g) externally cooling said adsorbent bed to a third temperature lower than said second temperature; and

h) repressurizing the adsorbent bed to within 90% of said first pressure.

2.3. The process of claim 1, wherein one or more of the following are satisfied:

the first C₁ product stream is greater than 95 mol% methane, ~~e.g., greater than 98 mol% methane; the first purge gas stream is selected from the group consisting of nitrogen and methane; the first purge gas stream is greater than 95 mol% methane; the first temperature is from -195°C to 300°C, e.g., from 20°C to 150°C; the first pressure is from 1 bara to 600 bara, e.g., from 2 to 200 bara; the second temperature is from 10°C to 300°C, e.g., from 20°C to 200°C; the third temperature is from -195°C to 300°C; and the first pressure is at least 500 psig.~~

4. The process of claim 3, wherein the first C₁ product stream is greater than 98 mol% methane.

5. The process of claim 1, wherein the first purge gas stream is greater than 95 mol% methane.

6. The process of claim 1, wherein the first temperature is from -195°C to 300°C and the first pressure is from 1 bara to 600 bara.

7. The process of claim 6, wherein the first temperature is from 20°C to 150°C and the first pressure is from 2 to 200 bara.

8. The process of claim 1, wherein the second temperature is from 10°C to 300°C.

9. The process of claim 8, wherein the second temperature is from 20°C to 200°C.

10. The process of claim 1, wherein the third temperature is from -195°C to 300°C.

11. The process of claim 1, wherein the first purge gas stream is selected from the group consisting of nitrogen and methane.

3.12. The process of claim 1 or claim 2, wherein a the second purge gas stream (e.g., comprising comprises propane, such as greater than 95 mol% or greater than 98 mol%) is passed co-currently through the adsorption bed following depressurization step

(e) and prior to heating step (d).

13. The process of claim 12, wherein the second purge gas stream comprises greater than 95 mol% propane.

14. The process of claim 13, wherein the second purge gas stream comprises greater than 98 mol% propane.

4.15. The process of claim 3, further comprising retrieving from the product output end of said adsorbent bed ~~(e.g., concurrently with passing the second purge gas stream through the adsorption bed)~~ a first C₂₊ product stream having a higher mol% of C₂₊ hydrocarbons than said natural gas stream, ~~e.g., comprising greater than 95 mol% ethane or greater than 98 mol% ethane.~~

16. The process of claim 15, wherein the retrieving of the first C₂₊ product stream is performed concurrently with passing the second purge gas stream through the adsorption bed.

17. The process of claim 16, wherein the first C₂₊ product stream comprises greater than 95 mol% ethane.

18. The process of claim 17, wherein the first C₂₊ product stream comprises greater than 98 mol% ethane.

19. The process of claim 1, wherein the adsorbent bed is comprised of a zeolite adsorbent material comprising a framework structure selected from FER, MFI, BEA, DON, and combinations thereof.

20. The process of claim 19, wherein the zeolite exhibits an Si/Al ratio of at least about 500.

21. The process of claim 15, wherein the adsorbent bed is comprised of zeolite adsorbent material comprising a framework structure selected from FER, MFI, BEA,

DON, and combinations thereof.

22. The process of claim 21, wherein the zeolite exhibits an Si/Al ratio of at least about 500.

5.23. The process of ~~any one of the previous claims~~ claim 1, wherein the adsorbent bed has open flow channels throughout its entire length through which the natural gas stream flows, ~~e.g., is a parallel channel contactor.~~

24. The process of claim 23, wherein the adsorbent bed is a parallel channel contactor.

6.25. The process of ~~any one of the previous claims~~ claim 1, wherein the reduction in pressure of step c) takes place in two or more steps, and wherein each step reduces the pressure of the adsorbent bed to a lower pressure than the next previous step.

7.26. The process of ~~any one of the previous claims~~ claim 1, wherein the external heating of step d) takes place co-current to the direction of the flow through the adsorbent bed; ~~the external heating of step d) takes place counter-current to the direction of the flow through the adsorbent bed.~~

27. The process of claim 1, wherein the external heating of step d) takes place counter-current to the direction of the flow through the adsorbent bed.

8.28. The process of ~~any one of the previous claims~~ claim 1, wherein the heating of step d) is performed under conditions sufficient to cause a thermal wave to travel along the adsorbent bed, ~~e.g., co-current to the direction the gas mixture flow through the adsorbent bed.~~

29. The process of claim 28, wherein the thermal wave travels co-current to the direction the gas mixture flow through the adsorbent bed.

9.30. The process of claim 8 28, wherein a T_{90} and a T_{10} can be defined with

respect to the second temperature and the first temperature such that a temperature differential of $(T_{90}-T_{10})$ occurs over at most 50% of the length of the adsorbent bed.

~~10.31.~~ The process of claim ~~8~~ 28, wherein the thermal wave exhibits a maximum Peclet number, Pe , less than 10, wherein $Pe = (U \cdot L) / \alpha$, where U represents a heat exchange fluid velocity, L represents a characteristic distance over which heat is transported in a direction roughly perpendicular to fluid flow, and α represents an effective thermal diffusivity of the contactor over the distance L , and wherein U is from about 0.01 m/s to about 100 m/s, and L is less than 0.1 meter.

~~11.32.~~ The process of ~~any one of the previous claims~~ claim 1, wherein less than about 40% of the open pores of the adsorbent bed have diameters greater than about 20 angstroms and less than about 1 micron.

33. The process of claim 1, wherein the first pressure is at least 500 psig.

~~12.~~ The process of ~~any one of the previous claims~~, wherein the adsorbent bed is comprised of a zeolite adsorbent material comprising a framework structure selected from FER, MFI, BEA, DON, and combinations thereof, *e.g.*, exhibiting an Si/Al ratio of least about 500.

~~13.34.~~ The process of ~~any one of the previous claims~~ claim 1, wherein the adsorbent bed is comprised of a microporous adsorbent material selected from zeolites, AlPOs, SAPOs, MOFs, ZIFs, carbon, and combinations thereof.

~~14.35.~~ The process of ~~any one of the previous claims~~ claim 1, wherein the adsorbent bed is comprised of an adsorbent material selected from cationic zeolites, amine-functionalized mesoporous materials, stannosilicates, carbon, and combinations thereof.