

CLAIMS:

~~1. A temperature swing adsorbent contactor comprised of an inlet end and an outlet end, further comprising:~~

~~i) a plurality of open flow channels whose length is fluidly connecting the inlet end to the outlet end of the contactor, wherein at least one wall of said at least one open flow channel is comprised of an adsorbent material;~~

~~ii) at least one support layer, in contact with, and supporting the adsorbent material; and~~

~~iii) a plurality of microtubes in contact with, and supported by, the at least one support layer.~~

2.1. A swing adsorption process for separating contaminant gas components from a feed gas mixture (*e.g.*, comprising methane and/or comprised of a natural gas stream) containing at least one target gas component (*e.g.*, CO₂ and/or H₂S), which process comprises:

a) conducting the feed gas mixture to a temperature swing adsorbent contactor having at least an inlet end and an outlet end, wherein the adsorbent contactor further comprises

(i) a plurality of open channels whose length is fluidly connecting the inlet end to the outlet end of the contactor, wherein at least one wall of said at least one open flow channel is comprised of an adsorbent material;

(ii) at least one support layer, in contact with, and supporting the adsorbent material; and

(iii) a plurality of microtubes in contact with, and supported by, the at least one support layer;

b) flowing at least a portion of the feed gas mixture through the open flow channels;

c) during an adsorption cycle, adsorbing at least a portion of the target gas in the adsorbent material;

d) retrieving a first product stream from the outlet end, wherein the first product stream has a lower mol% of the target gas component than the feed gas mixture; and

e) during a desorption cycle, passing heating fluid through at least a portion of the microtubes, thereby desorbing at least a portion of the target gas in the adsorbent material to form a second product stream.

~~3.2. The contactor or process of claim 1 or claim 2, comprising, wherein the~~
adsorbent contactor comprises at least two support layers, and the support layers, when viewed in a plane perpendicular to the length of the open flow channels, are each substantially flat and are substantially parallel relative to each other.

~~4.3. The contactor or process of claim 1 or claim 2, wherein the at least one~~
support layer of the adsorbent contactor is wound into a spiral when viewed in a plane perpendicular to the length of the open flow channels.

~~5.4. The contactor or process of any one of the previous claims claim 1, wherein~~
each microtube has an inside diameter from 0.20 mm to 2 mm.

~~5. The process of claim 4, wherein the heating fluid is selected from water and~~
steam.

~~6. The contactor or process of any one of the previous claims, wherein the~~
~~contactor is comprised of multiple support layers, wherein at least two support layers are~~
~~each comprised of a first surface and a second surface wherein said first surface is in~~
~~contact with at least a portion of the microtubes, and wherein said second surface is in~~
~~contact with a coating of the adsorbent material, and wherein the contactor is constructed~~
~~by assembling the subunits such that each microtube is in contact with at least a portion of~~
~~the adsorbent material.~~

~~7. The contactor or process of any one of claims 1-5, wherein the contactor is~~
~~comprised of multiple support layers, wherein at least two support layers are each~~
~~corrugated and each of the at least two support layers are in contact with at least a portion~~
~~of the microtubes, and further wherein both surfaces of the support layers are in contact~~
~~with at least a portion of the adsorbent material.~~

8. ~~The contactor or process of any one of claims 1-5, which is characterized as being comprised of multiple support layers, wherein at least two support layers have each a first surface and a second surface, wherein said first surface is in contact with at least a portion of the microtubes, and wherein the adsorbent material is contained on at least a fraction of said first surface thereby covering at least a fraction of said first surface and covering at least a fraction of said microtubes.~~

9. ~~The contactor or process of any one of the previous claims, wherein the contactor is comprised of multiple open flow channels, optionally not fluidly connected to one another, and is contained within a vessel that is capable of directing the flow of a feed gas mixture through the multiple open flow channels, and comprises separate fluid connections for the feed gas mixture and for a heating/cooling fluid (e.g., selected from water and steam).~~

10. ~~The contactor or process of any one of the previous claims, wherein one or more of the following are satisfied: the microtubes are comprised of a material selected from stainless steel, aluminum, nickel, polymeric materials, carbon, glass, ceramics, and combinations and composites thereof; the adsorbent material is comprised of a material selected from cationic zeolites, amine functionalized mesoporous materials, stannosilicates, carbon, and combinations and composites thereof; the adsorbent material is comprised of a microporous material selected from zeolites, AlPOs, SAPOs, MOFs, ZIFs, carbon, and combinations and composites thereof; the adsorbent material is comprised of an 8-ring zeolite; the adsorbent material is comprised of a zeolite having an Si/Al ratio from about 1 to about 25; the adsorbent material is comprised of a zeolite having a diffusion coefficient for CO₂ over methane (D_{CO_2}/D_{CH_4}) greater than 10; the adsorbent material is comprised of a zeolite having a diffusion coefficient for N₂ over methane (D_{N_2}/D_{CH_4}) greater than 10; the adsorbent material is comprised of a zeolite having a diffusion coefficient for H₂S over methane (D_{H_2S}/D_{CH_4}) greater than 10; the adsorbent material is comprised of a zeolite selected from DDR, Sigma-1, ZSM-58, and combinations thereof.~~

11.6. ~~The process of claim 8 or claim 9, wherein the heating fluid is passed through at least a portion of the microtubes during at least a portion of the desorption~~

cycle of the temperature swing process and a cooling fluid (~~e.g., comprised of water~~) is passed through at least a portion of the microtubes during at least a portion of the adsorption cycle of the temperature swing process.

7. The process of claim 6, wherein the cooling fluid is comprised of water.

8. The process of claim 1, wherein the target gas component is selected from CO₂ and/or H₂S.

9. The process of claim 1, wherein the target gas component is CO₂.

10. The process of claim 1, wherein the feed gas mixture is comprised of methane.

11. The process of claim 1, wherein the adsorbent material is comprised of an 8-ring zeolite.

12. The process of claim 11, wherein the zeolite has a Si/Al ratio from about 1 to about 25.

13. The process of claim 1, wherein feed gas mixture is comprised of methane and CO₂ wherein CO₂ is the target gas component, and the zeolite has a diffusion coefficient for CO₂ over methane (D_{CO_2}/D_{CH_4}) greater than 10.

14. The process of claim 1, wherein feed gas mixture is comprised of methane and N₂ wherein N₂ is the target gas component, and the zeolite has a diffusion coefficient for N₂ over methane (D_{N_2}/D_{CH_4}) greater than 10.

15. The process of claim 1, wherein feed gas mixture is comprised of methane and H₂S wherein H₂S is the target gas component, and the zeolite has a diffusion coefficient for H₂S over methane (D_{H_2S}/D_{CH_4}) greater than 10.

16. The process of claim 15, wherein the first adsorbent bed and the second

adsorbent bed are comprised of a zeolite selected from DDR, Sigma-1, ZSM-58, and combinations thereof.

17. The process of claim 1, wherein the adsorbent material is comprised of a microporous material selected from zeolites, AlPOs, SAPOs, MOFs, ZIFs, carbon, and combinations and composites thereof.

18. The process of claim 1, wherein the adsorbent material is comprised of a material selected from cationic zeolites, amine-functionalized mesoporous materials, stannosilicates, carbon, and combinations and composites thereof.

~~12.19.~~ The process of ~~any of claims 2-10~~ claim 1, wherein the process is a rapid cycle temperature swing adsorption process in which wherein the total cycle time greater than 10 seconds and less than 10 minutes, ~~and/or wherein the feed gas mixture is conducted to the open flow channels at a pressure greater than 1000 psig.~~

~~13.20.~~ The process of ~~any of claims 2-11~~ claim 1, wherein during the desorption cycle: the temperature of the adsorbent material is increased and the partial pressure of the target gas is reduced.

21. The process of claim 20, wherein during the desorption cycle; ~~and/or~~ a purge gas is passed through at least a portion of the open flow channels.

22. The process of claim 1, wherein the feed gas mixture is comprised of natural gas.

23. The process of claim 22, wherein the feed gas mixture is conducted to the open flow channels at a pressure greater than 1000 psig.

~~13.24.~~ A heat exchange process comprising:

a) conducting a gaseous feed stream to a temperature swing adsorbent contactor having at least an inlet end and an outlet end and having a length, wherein the adsorbent contactor further comprises

(i) a plurality of open channels whose length is fluidly connecting the inlet end to the outlet end of the contactor, wherein at least one wall of said at least one open flow channel is comprised of an adsorbent material;

(ii) at least one support layer, in contact with, and supporting the adsorbent material; and

(iii) a plurality of microtubes in contact with, and supported by, the at least one support layer;

b) flowing at least a portion of the gaseous feed stream at a first temperature and a first pressure through the open flow channels;

c) contacting the adsorbent contactor containing the gaseous feed stream with a heat exchange fluid under conditions sufficient for the contactor to exhibit a sharp thermal wave and to form a product stream at a second temperature lower than the first temperature and a second pressure, wherein the conditions include a feed stream pressure from about 250 psig to about 2000 psig and/or a heat exchange fluid pressure sufficient to attain a differential pressure between the gaseous feed stream pressure and the heat exchange fluid pressure from about 250 psig to about 2000 psig.

14.25. The process of claim ~~13~~ 24, wherein the heat exchange fluid is initially at a heat exchange temperature allowing a T_{90} and a T_{10} can be defined with respect to the first temperature and the heat exchange temperature such that a temperature differential of $(T_{90}-T_{10})$ occurs over at most 50% of the length of the contactor.

15.26. The process of claim ~~13~~ or claim 14 24, wherein a maximum Peclet number, Pe , is less than 10, where $Pe = (U \cdot L) / \alpha$, 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.