

Claims

What is claimed is:

1. A method of purifying a feed stream to reduce the hydrogen and carbon monoxide impurities present in the feed stream, the method comprising the steps of:
 - (a) passing the feed stream through at least one layer of adsorbent configured to remove water and carbon dioxide from the feed stream and yield a dry feed stream substantially free of water and carbon dioxide;
 - (b) passing the dry feed stream through a first layer of manganese oxide and copper oxide containing catalyst configured to remove at least some of the carbon monoxide and hydrogen from the dry feed stream and produce a first intermediate effluent stream;
 - (c) passing the first intermediate effluent stream through a first intermediate layer disposed downstream of the first layer of manganese oxide and copper oxide containing catalyst, the first intermediate layer configured to remove at least carbon dioxide from the first intermediate effluent stream and produce a second intermediate effluent stream; and
 - (d) passing the second intermediate effluent stream through a second layer of manganese oxide and copper oxide containing catalyst disposed downstream of the first intermediate layer and configured to remove at least hydrogen from the second intermediate effluent stream to yield third intermediate effluent stream;wherein the first intermediate layer comprises a molecular sieve layer or a layer of alumina.
2. The method of claim 1, wherein the dry feed stream, the first intermediate effluent stream, the second intermediate effluent stream, and the third intermediate effluent stream are never in contact with a noble metal catalyst.
3. The method of claim 1, wherein the third intermediate effluent stream is substantially free of hydrogen and carbon monoxide throughout a cycle time of 6.5 hours.

4. The method of claim 3, further comprising the step of passing the third effluent stream through one or more further layers of adsorbent configured to remove water and carbon dioxide and yield a purified stream substantially free of at least water, carbon dioxide, carbon monoxide and hydrogen throughout the cycle time of 6.5 hours.
5. The method of claim 4, wherein the dry feed stream, the first intermediate effluent stream, the second intermediate effluent stream, and the third intermediate effluent stream, and the purified stream are never in contact with a noble metal catalyst.
6. The method of claim 4, wherein the one or more further layers of adsorbent further comprise a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.
7. The method of claim 1, wherein the at least one adsorbent layer comprises a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.
8. The method of claim 1, wherein a residence time of the dry feed stream within the first layer of manganese oxide and copper oxide containing catalyst is less than or equal to 1.5 seconds.
9. The method of claim 1, wherein a residence time of the second intermediate effluent within the second layer of manganese oxide and copper oxide containing catalyst is less than or equal to 1.5 seconds.
10. The method of claim 4, wherein the purified stream comprises between 5 ppb hydrogen and 500 ppb hydrogen.

11. The method of claim 4, wherein the purified stream comprises no more than about 10 ppb hydrogen.

12. The method of claim 4, wherein the purified stream comprises no more than about 10 ppb carbon monoxide.

13. The method of claim 1, further comprising the steps of:
passing the third intermediate effluent stream through a second intermediate layer disposed downstream of the second layer of manganese oxide and copper oxide containing catalyst, the second intermediate layer configured to remove at least carbon dioxide from the third intermediate effluent stream and produce a fourth intermediate effluent stream; and

passing the fourth intermediate effluent stream through a third layer of manganese oxide and copper oxide containing catalyst to produce a fifth intermediate effluent;

wherein the second intermediate layer comprises a molecular sieve layer or a layer of alumina.

14. The method of claim 13, wherein the fifth intermediate effluent stream is substantially free of hydrogen and carbon monoxide throughout a cycle time of 6.5 hours.

15. The method of claim 14, further comprising the step of passing the fifth intermediate effluent stream through one or more further layers of adsorbent configured to remove water and carbon dioxide and yield a purified stream substantially free of at least water, carbon dioxide, carbon monoxide and hydrogen throughout the cycle time of 6.5 hours.

16. The method of claim 15, wherein the one or more further layers of adsorbent comprises a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.

17. The method of claim 13, further comprising the steps of:

passing the fifth intermediate effluent stream through a third intermediate layer disposed downstream of the third layer of manganese oxide and copper oxide containing catalyst, the third intermediate layer configured to remove at least carbon dioxide from the fifth intermediate effluent stream and produce a sixth intermediate effluent stream; and

passing the sixth intermediate effluent stream through a fourth layer of manganese oxide and copper oxide containing catalyst to produce a seventh intermediate effluent

wherein the third intermediate layer comprises a molecular sieve layer or a layer of alumina.

18. The method of claim 17, wherein the seventh intermediate effluent stream is substantially free of hydrogen and carbon monoxide throughout a cycle time of 6.5 hours.

19. The method of claim 18, further comprising the step of passing the seventh intermediate effluent stream through one or more further layers of adsorbent configured to remove water and carbon dioxide from the stream substantially free of hydrogen and carbon monoxide and yield a purified stream substantially free of at least water, carbon dioxide, carbon monoxide and hydrogen throughout the cycle time of 6.5 hours.

20. The method of claim 19, wherein the one or more further layers of adsorbent comprises a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.

21. The method of claim 1, wherein the feed stream is compressed air.
22. The method of claim 1, wherein the dry feed stream is substantially free of hydrocarbons and nitrous oxide.
23. The method of claim 1, wherein the feed stream comprises less than 20 ppm hydrogen.
24. The method of claim 1, wherein the feed stream comprises less than 50 ppm carbon monoxide.
25. The method of claim 1, wherein the dry feed stream contains less than 10 ppm water.
26. The method of claim 1, wherein the dry feed stream contains less than 10 ppm carbon dioxide.
27. The method of claim 1, wherein the second intermediate effluent contains no more than about 10 ppm carbon dioxide.
28. The method of claim 1, wherein the feed stream is at a pressure between 3 bar(a) and 30 bar(a).
29. The method of claim 1, wherein the feed stream is at a temperature between 0°C and 70°C.
30. A pre-purification unit for purifying a feed stream to reduce the hydrogen and carbon monoxide impurities present in the feed stream, the pre-purification unit comprising:

at least one layer of adsorbent configured to remove water and carbon dioxide from the feed stream and yield a dry feed stream substantially free of water and carbon dioxide;

a first layer of manganese oxide and copper oxide containing catalyst configured to remove at least some of the carbon monoxide and hydrogen from the dry feed stream and produce a first intermediate effluent stream;

a first intermediate layer disposed downstream of the first layer of manganese oxide and copper oxide containing catalyst, the first intermediate layer configured to remove at least carbon dioxide from the first intermediate effluent stream and produce a second intermediate effluent stream;

a second layer of manganese oxide and copper oxide containing catalyst configured to remove at least hydrogen from the second intermediate effluent stream to yield a third intermediate effluent stream; and

one or more further layers of adsorbent configured to remove water and carbon dioxide from the third intermediate effluent stream yield a purified stream substantially free of at least water, carbon dioxide, carbon monoxide and hydrogen.

31. The pre-purification unit of claim 30, wherein the pre-purification unit contains no palladium catalyst material.

32. The pre-purification unit of claim 30, wherein the pre-purification unit contains no noble metal containing catalysts.

33. The pre-purification unit of claim 30, wherein the first intermediate layer comprises a molecular sieve layer or a layer of alumina.

34. The pre-purification unit of claim 30, wherein the one or more further layers of adsorbent comprise a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.