Publication No. 2003/064014 (Kumar et al.) and U.S. Patent No. 8,940,263 (Golden, et al.) The Kumar et al. reference shows that it has been well known for over 20 years that a hopcalite catalyst removes hydrogen and carbon monoxide from air and is particularly useful for removing both carbon monoxide and hydrogen from a feed air stream during pre-purification in cryogenic air separation units. Golden, et al. also discloses the use of a single layer of hopcalite for removal of substantially all of the hydrogen and carbon monoxide. The examples in Golden et al. confirm what is taught in Kumar et al. that hydrogen is chemisorbed in the single layer of hopcalite material such that the use of a longer bed of hopcalite catalyst which translates to longer residence times of the dry gas in the hopcalite layer generally improves the hydrogen chemisorption process in the hopcalite material

(00013) While the above-identified prior art pre-purification systems and methods target removal of impurities such as hydrogen, carbon monoxide, water, and carbon dioxide from feed air streams, the relative costs associated with pre-purification systems and methods remain high. Accordingly, there is a continuing need to improve such pre-purification systems and processes, particularly to reduce the costs of such pre-purification without sacrificing performance. In other words, there is a need for improved systems and methods for pre-purification of an incoming feed air stream to a cryogenic air separation unit, including substantial removal of hydrogen, carbon monoxide, water and carbon dioxide in the production of high purity or ultra-high purity nitrogen that has cost advantages and performance advantages over prior art pre-purification systems and methods.

Summary

(00013a) According to an aspect of the present invention, there is provided 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 a first purification section of a pre-purifier 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; (b) passing the dry feed stream through a second purification section of the pre-purifier unit disposed downstream of the first purification section and comprising 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, a second layer disposed downstream of the first layer, the second layer configured to remove at least water and carbon dioxide from the intermediate effluent and produce a second intermediate effluent, and a third layer disposed downstream of the second layer, the third layer configured to remove at least hydrogen from the second intermediate effluent to yield an intermediate purified stream substantially free of hydrogen and carbon monoxide; and (c) passing the intermediate purified stream through a third purification section of the pre-purifier unit disposed downstream of the second purification section and comprising at least one other layer of adsorbent configured to remove water and carbon dioxide from the intermediate purified stream and yield a purified stream substantially free of at least water, carbon dioxide, carbon monoxide and hydrogen, wherein the third layer is a catalyst layer comprising a mixture of manganese oxide and copper oxide and is configured to remove at least hydrogen and carbon monoxide from the second intermediate effluent.

(00014) The present invention may broadly be characterized as a method of purifying a dry gas stream, such as air, to reduce the hydrogen and carbon monoxide impurities present in the gas stream, the method comprising: (a) passing the dry gas stream that is substantially free of carbon dioxide and water through a first catalyst layer comprising a mixture manganese and copper oxides configured to remove at least some

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 a first purification section of a pre-purifier 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;

(b) passing the dry feed stream through a second purification section of the pre-purifier unit disposed downstream of the first purification section and comprising 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, a second layer disposed downstream of the first layer, the second layer configured to remove at least water and carbon dioxide from the intermediate effluent and produce a second intermediate effluent, and a third layer disposed downstream of the second layer, the third layer configured to remove at least hydrogen from the second intermediate effluent to yield an intermediate purified stream substantially free of hydrogen and carbon monoxide; and

(c) passing the intermediate purified stream through a third purification section of the pre-purifier unit disposed downstream of the second purification section and comprising at least one other layer of adsorbent configured to remove water and carbon dioxide from the intermediate purified stream and yield a purified stream substantially free of at least water, carbon dioxide, carbon monoxide and hydrogen;

wherein the third layer is a catalyst layer comprising a mixture of manganese oxide and copper oxide and is configured to remove at least hydrogen and carbon monoxide from the second intermediate effluent.

2. The method of claim 1, wherein the residence time within the third layer is less than 1.5 seconds.

3. The method of claim 1, wherein the second purification section further comprises a fourth layer disposed downstream of the third layer, wherein the fourth layer is a noble metal containing catalyst layer.

4. The method of claim 3, wherein the fourth layer of the second purification section is a palladium containing polishing layer.

5. The method of claim 1, wherein the second purification section further comprises one or more additional catalyst layers comprising a mixture of manganese oxide and copper oxide configured to remove carbon monoxide and hydrogen and one or more additional adsorbent layers configured to remove water and carbon dioxide.

6. The method of claim 1, wherein the second layer of the second purification section comprises 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 in the first purification section 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 the at least one other adsorbent layer in the third purification section is a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.

9. The method of claim 1, wherein the feed stream is compressed air and contains less than 20 ppm hydrogen and less than 50 ppm carbon monoxide.

10. The method of claim 1, wherein the second intermediate effluent contains no more than about 10 ppm carbon dioxide at the end of the prepurification cycle.

11. The method of claim 1, wherein the purified stream comprises between 10 ppb hydrogen and 500 ppb hydrogen no more than about 10 ppb carbon monoxide at the end of the prepurification cycle.

12. The method of claim 1, wherein the purified stream comprises no more than about 10 ppb hydrogen no more than about 10 ppb carbon monoxide at the end of the prepurification cycle.