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

(00014) An aspect of the present invention may broadly be characterized as a pre-purification system or a pre-purifier unit for an air-separation unit comprising: (i) a vessel having an inlet configured for receiving a stream of compressed feed air and an outlet configured to direct a purified stream substantially free of water, carbon dioxide, carbon monoxide and hydrogen to another part of the air separation unit; (ii) a first purification section disposed

within the vessel comprising at least one layer of adsorbent configured to remove water and carbon dioxide from the compressed feed air stream and yield a dry feed stream substantially free of water and carbon dioxide; (iii) a second purification section disposed within the vessel downstream of the first purification section, the second purification section 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 configured to remove water and carbon dioxide from the intermediate effluent and produce a second intermediate effluent, and a third layer disposed downstream of the second layer configured to remove hydrogen from the second intermediate effluent to yield an intermediate purified stream substantially free of hydrogen and carbon monoxide; and (iv) a third purification section disposed within the vessel 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 water, carbon dioxide, carbon monoxide and hydrogen, wherein the third layer is a catalyst layer comprising manganese oxide and copper oxide containing catalyst..

(00015) The above-described pre-purification systems may also include one or more additional layers of manganese oxide and copper oxide containing catalysts as well as one or more additional adsorbent layers disposed between the catalyst layers to remove any water and carbon dioxide exiting the catalyst layers.

Brief Description of the Drawings

(00016) While the specification concludes with one or more claims specifically pointing out the subject matter that Applicants regard as the invention, it is believed that the present systems and methods for pre-purification of a feed gas stream will be better understood when taken in connection with the accompanying drawing in which:

(00017) Fig. 1 depicts a partial, cross-section view of a section of a pre-purification unit or pre-purification vessel suitable for use in pre-purification of a feed air stream in a cryogenic air separation unit;

(00018) Fig. 2 depicts a partial, cross-section view of a section of an alternate embodiment of a pre-purification unit or pre-purification vessel also suitable for use in pre-purification of a feed air stream in a cryogenic air separation unit;

(00019) Fig. 3 depicts a partial, cross-section view of a section of yet another embodiment of a pre-purification unit or pre-purification vessel also suitable for use in pre-purification of a feed air stream in a cryogenic air separation unit;

Claims

1. A pre-purifier unit for an air-separation unit comprising:

a vessel having an inlet configured for receiving a stream of compressed feed air and an outlet configured to direct a purified stream substantially free of water, carbon dioxide, carbon monoxide and hydrogen to another part of the air separation unit;

a first purification section disposed within the vessel comprising at least one layer of adsorbent configured to remove water and carbon dioxide from the compressed feed air stream and yield a dry feed stream substantially free of water and carbon dioxide;

a second purification section disposed within the vessel downstream of the first purification section, the second purification section comprising (i) 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, (ii) a second layer disposed downstream of the first layer configured to remove water and carbon dioxide from the intermediate effluent and produce a second intermediate effluent, and (iii) a third layer disposed downstream of the second layer configured to remove hydrogen from the second intermediate effluent to yield an intermediate purified stream substantially free of hydrogen and carbon monoxide; and

a third purification section disposed within the vessel 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 the purified stream substantially free of water, carbon dioxide, carbon monoxide and hydrogen;

wherein the third layer is a catalyst layer comprising manganese oxide and copper oxide containing catalyst.

2. The pre-purifier unit 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.

3. The pre-purifier unit of claim 1, wherein the fourth layer is a palladium containing polishing layer.

4. The pre-purifier unit of claim 1, wherein the second purification section further comprises one or more additional layers of manganese oxide and copper oxide containing catalyst configured to remove carbon monoxide and hydrogen and one or more additional adsorbent layers configured to remove water and carbon dioxide.

5. The pre-purifier unit of claim 1, wherein the dry feed stream is substantially free of hydrocarbons and nitrous oxide.

6. The pre-purifier unit of claim 1, wherein the second layer comprises a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.

7. The pre-purifier unit 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 pre-purifier unit of claim 1, wherein the at least one other adsorbent layer in the third purification section comprises a molecular sieve layer or a layer of alumina or both a molecular sieve layer and a layer of alumina.

9. The pre-purifier unit of claim 1, wherein the pre-purifier unit is configured to purify the compressed feed air stream that contains less than 20 ppm hydrogen.

10. The pre-purifier unit of claim 1, wherein the pre-purifier unit is configured to purify the compressed feed air stream that contains less than less than 50 ppm carbon monoxide.

11. The pre-purifier unit of claim 1, wherein the purified stream comprises between 10 ppb hydrogen and 500 ppb hydrogen and no more than 10 ppb carbon monoxide.

12. The pre-purifier unit of claim 1, wherein the purified stream comprises no more than 10 ppb hydrogen and no more than 10 ppb carbon monoxide.