

NATURAL GAS TREATING SYSTEM

This invention relates to a natural gas treating system. More specifically, this invention relates to a method and system for removing sulphur compounds and water present in natural gas.

Raw natural gas must be treated prior to its liquefaction for several reasons. These include removing compounds which interfere with the liquefaction process; with the separation and recovery of hydrocarbon liquids; and with meeting the specifications set for the recovered products. For example, the gas must be dried to prevent ice formation during cryogenic operations. Hydrogen sulphide ordinarily must be removed because of its toxic nature. A large number of commercial processes are in use for treating and separating of raw wellhead gas. The steps used in these different processes are each well known to those skilled in the art.

In addition, some natural gas contains mercury at levels as high as 200 to 300 micrograms per cubic meter. For example, the mercury level of natural gas produced from one field is reported in the literature to range from 200 to 330 micrograms per cubic meter. In another field the concentration was reported to range between 15 and 450 micrograms per cubic meter.

The processing of natural gas in LNG plants requires, at some location in the system, contact with equipment made primarily of aluminum. This is particularly true in the stage of processing where the gas has been treated by caustic or carbonate washing to remove CO_2 and H_2S and then to treatment with liquid amine to complete H_2S removal. One of the next steps is to chill or cool the gas in aluminum-constructed heat exchangers. Because large volumes of gas must flow

through the aluminum heat exchangers, they are of a massive size and can represent a capital investment of several million dollars. Damage to these exchangers should be avoided, if at all possible. One threat of damage comes from the mercury present in the gas flowing through the heat exchangers. Although the concentration of mercury appears low, its effect is cumulative as it amalgamates with the aluminum. The result is damage to the system, such as corrosion and stress cracking, which can lead to equipment failure, fires, and similar catastrophe. Repair of the aluminum heat exchangers damaged by mercury is almost impossible. Replacement of the heat exchangers represents a large expenditure. The down-time results in loss of product production. The problem of mercury in natural gas is discussed further in US-A-4094777 and FR-A-2310795.

One method for removing mercury utilizes the addition of sulphurous materials, e.g., H_2S , to precipitate sulphides of mercury from the gas stream. US-A-4044098 discloses such a method which further utilizes treatment with organic base (amine) to absorb excess hydrogen sulphide to produce a gas stream of minimal sulphur content with a reduced mercury content. The product of such amine treatment can be passed through a dehydrator which comprises a zeolitic bed. One of the next steps is to chill or cool the gas in heat exchangers and to other additional equipment needed for further processing of the gas.

The zeolitic bed employed in the dehydrator can be damaged by carry-over of the organic base used in H_2S removal. Organic bases, e.g., alkanolamines, can deposit carbon and destroy the structure and crystallinity of the molecular sieve and render it useless for drying. The resulting shortened life of the

zeolitic bed requires unacceptably frequent replacement of the zeolitic bed as well as increased down time for the natural gas processing unit. Accordingly, it would be desirable to extend the service life of the zeolitic bed employed in the dehydrator by reducing carry-over of the organic base to the zeolitic bed.

According to the present invention there is provided a method for separating mercury and water from natural gas comprising addition of a sulphur-containing agent to react with said mercury to form precipitated sulphides of mercury, addition of an organic base to absorb unreacted sulphur-containing agent, and subsequent contacting of said natural gas with a molecular sieve desiccant thereby removing water therefrom, further comprising contacting said organic base-containing natural gas with an organic base absorbing guard bed to substantially remove said organic base prior to removing said water, and wherein the guard bed comprises material selected from the group consisting of activated charcoal, amorphous aluminium phosphate, crystalline aluminium phosphate, clay, silica, silica-alumina, ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, mordenite, clinoptilolite, erionite, and Zeolite Y.

In general, the material of the guard bed would be chosen for the following properties: 1) high adsorption capacity, i.e., porous and high surface area; 2) high selectivity for organic base, e.g., amines, over moisture; 3) structures stable to organic base attack; and 4) regenerability at typical drier regeneration conditions, e.g., 650°F (343°C).

In one embodiment the guard bed comprises activated charcoal.

In another embodiment the guard bed material is selected from the group consisting of clay, silica,

silica-alumina, ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, mordenite, clinoptilonite, erionite, and Zeolite Y. More specifically, the guard bed material is selected from the group consisting of ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, mordenite, clinoptilonite, erionite, and Zeolite Y.

When the guard bed is a siliceous material, such as clay, silica, silica alumina or a zeolite, the is is preferred that said siliceous material has an alpha value of 0.001 to 10, more preferably 0.01 to 2. This approach entails the use of a guard be with slight acidity, a strong acidity being undesirable owing to the difficult regeneration of strongly sorbed organic bases. The zeolites can be partially ion-exchanged and in the hydrogen form to adjust their acidity.

Alpha Value is an approximate indication of the catalytic cracking activity of the catalyst compared to a standard catalyst and it gives the relative rate constant (rate of normal hexane conversion per volume of catalyst per unit time). It is based on the activity of silica-alumina cracking catalyst taken as an Alpha of 1 (Rate Constant = 0.016 sec^{-1}). The Alpha Test is described in US-A-3354078; in the Journal of Catalysis, Vol. 4, p. 527 (1965); Vol. 6, p. 278 (1966); and Vol. 61, p. 395 (1980). The experimental conditions of the test used herein include a constant temperature of 538°C and a variable flow rate as described in detail in the Journal of Catalysis, Vol. 61, p. 395.

In one preferred embodiment the guard bed comprises aluminum phosphate. Depending on the availability of proton in the compounds, i.e., $\text{Al}_2\text{O}_3/\text{P}_2\text{O}_5$ ratio, the acidities of the aluminum decrease in the following order: $\text{Al}(\text{H}_2\text{PO}_4)_3$, $\text{Al}_2(\text{HPO}_4)_3$, ALPO_4 , $\text{AL}(\text{PO}_3)_3$. Thus, the composition of the aluminum phosphate mixture can be varied to meet

the required acidity. The preferred mixture will have the Al/P atomic ratio of 0.6 to 1.

The structure of the aluminum phosphates and its mixtures can be either crystalline or amorphous. As a result, the aluminum phosphates can be synthesized hydrothermally or by mixing the desired amount of H_3PO_4 with alumina powder and steaming it at 100 to 400°C, preferably 200 to 300°C, for 1 to 2 hours.

The guard bed may have a surface area of 1 to 1000 m^2 per gram, preferably a surface area of 10 to 500 m^2 per gram.

When the guard bed is a siliceous material, such as clay, silica, silica alumina or a zeolite, the is is preferred that said siliceous material has an alpha value of 0.001 to 10, more preferably 0.01 to 2.

The guard bed is placed upstream of the molecular sieve desiccant. In a preferred embodiment, the guard bed is simply placed on top of the molecular sieve desiccant and selectively intercepts the organic base, e.g., amine, present in the feedstream prior to its reaching the desiccant. To save valuable reactor volume, at least part of the guard bed adsorbent can be in bead or ball form and placed on the very top of the molecular sieve desiccant bed in lieu of conventional ceramic balls for stabilizing the bed. The guard bed preferably comprises particles having at least 1/8 inch (0.32cm) diameter, preferably 1/4 to 2 cubic inches (4.1 to 33 cm^3). Cubic granules of 8 mesh to 2 inch (0.32cm) can be used in lieu of beads or balls.

The amount of guard material required depends on the concentration of organic base impurities in the gas and the competitive adsorption capacity of the guard material. It has been found that the volume ratio of the guard bed material to molecular sieve desiccant depends on the nature of the guard bed materials and

the concentration of the amines entrained in the feed gas. The volumetric ratio of said guard bed to said molecular sieve desiccant preferably ranges from 0.001 to 0.1.

Preferably, the sulphur-containing agent may be added in the form of hydrogen sulphide; or by contacting the natural gas with a sulphur containing substrate, e.g., activated carbon, impregnated with sulphur or sulphur compounds.

Preferably, the organic base comprises amine, more preferably alkanol amine. Most preferably the amine is selected from the group consisting of diethanolamine, monoethanolamine, triethanolamine, and methyldiethanolamine; alkanoldiamines, alkenylpolyamines or solutions of salts of weak organic acids, such as amino carboxylic acids and aminosulfonic acids, or other alkaline liquids may also be used. The organic base is preferably introduced in solution such as alkanolamines, like monoethanolamine, diethanolamine, triethanolamine, methyldiethanolamine, alkanoldiamines, alkenylpolyamines, Alkanolamines are especially preferred.

The molecular sieve desiccant used to dry the natural gas before passing to the heat exchanger can have an effective pore size ranging from 3 to 10 angstroms, preferably from 3 to 5 angstroms. Desirably the molecular sieve desiccant is selected from the group consisting of Zeolite 3A, Zeolite 4A, and Zeolite 5A; mordenite or clinoptilolite may also be used. The molecular sieve desiccant most preferably comprises Zeolite 4A.

In a particularly preferred embodiment the organic base is diethanolamine, the molecular sieve desiccant is Zeolite 4A, the guard bed comprises a siliceous material having an alpha value of 0.01 to 2 and

comprising particles having at least 1/8 inch (0.32cm) diameter, and the volumetric ratio of the guard bed to the molecular sieve desiccant ranges from 0.005 to 0.1.

The amines adsorbed on the guard bed material is stripped off simultaneously during the regeneration of the wet molecular sieve desiccant using hot gases. Thus, the guard bed material is regenerated along with the molecular sieve in one operation and is ready for the next cycle operation.

The present invention provides a process to remove the mercury present in natural gas to a concentration sufficiently low to avoid mercury damage to liquefaction equipment, such as aluminum heat exchangers, in a liquefied natural gas plant, while extending the life of molecular sieve desiccant used to remove water from the treated gas stream.

The present invention also provides a process for preventing or reducing organic base carry-over into molecular sieve desiccants which are employed to subsequently dry the treated gas stream wherein organic base is used to remove unreacted sulphur compounds which are added to remove mercury by precipitation to mercury sulphides.

Reference is now made to the accompanying drawing which show a system for treating natural gas in accordance with the invention.

In the drawing, the natural gas 2 to be treated is first contacted in a treating bed 4 with an agent designed to remove the bulk of the mercury contamination. This treating zone can be a bed filled with a sorbent material such as silica, alumina, silica-alumina, or activated carbon having deposited on the surfaces thereof an active form of elemental sulphur or sulphur-containing material.

The gas in this section of the treating zone loses much of its mercury content by virtue of the reaction between the mercury and the sulphur to form mercuric sulphide. The effluent gas therefrom flows via line 30 to a conventional Benfield caustic sweetner unit 8, while separated mercury exits via line 32. The unit 8 removes carbon dioxide and sulphides (particularly hydrogen sulphide) via line 34. The effluent from the unit 8 flows via line 36 to a conventional amine treater unit 12, which removes sulphides (particularly hydrogen sulphide) via line 38). The effluent gas from the unit 12, which contains amine, generally in a form of entrainment, flows to a guard bed 15 via line 40. In the guard bed 15 the amine is absorbed.

The effluent from guard bed 15 flows via line 42 to a dehydrator unit 16 where the moisture content of the gas is reduced to a desired level: water exit unit 16 via line 44; while natural gas effluent exits unit 16 via line 46, which communicates with a heat exchanger 24.

To save equipment and operation costs, the guard 15 bed can be combined with the dehydrator unit 16 by placing the guard bed material on the top of the drier bed.

The mercury-depleted dry gas is chilled in heat exchanger 24. The effluent from the heat exchanger 24 is passed to further processing via line 48.

The gas flowing to the liquefaction process is a gas substantially reduced in mercury content. The problems associated with mercury on aluminum, brass or copper surfaces present in the liquefaction portion of the system are accordingly alleviated.

Example 1

The amine adsorption capacity of the guard bed material is tested as follows:

Nitrogen gas is passed through a bath of aqueous solution containing 25% of DEA (diethanolamine) at 100°F (38°C). The effluent is then passed through beds of the guard bed materials for 24 hours to saturate the beds with the moisture and DEA. The DEA contents of the beds are:

<u>Material</u>	<u>DEA Adsorption, % of sorbent</u>
Aluminum phosphate, Al/P = 0.8	8
HZSM-5 Zeolite, Si/Al = 100	3
Active carbon	2

Example 2

The saturated guard bed materials are generated by passing N₂ gas at 650°F (343°C) for 3 hours to simulate the drier bed regeneration condition. The regenerated guard bed material is used for adsorption testing as in Example 1. The adsorption capacities are the same as the first adsorption shown in Example 1.

Claims

1. A method for separating mercury and water from natural gas comprising addition of a sulphur-containing agent to react with said mercury to form precipitated sulphides of mercury, addition of an organic base to absorb unreacted sulphur-containing agent, and subsequent contacting of said natural gas with a molecular sieve desiccant thereby removing water therefrom, further comprising contacting said organic base-containing natural gas with an organic base absorbing guard bed to substantially remove said organic base prior to removing said water, and wherein the guard bed comprises material selected from the group consisting of activated charcoal, amorphous aluminium phosphate, crystalline aluminium phosphate, clay, silica, silica-alumina, ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, mordenite, clinoptilolite, erionite, and Zeolite Y.
2. A method according to claim 1, wherein said guard bed comprises activated charcoal.
3. A method according to claim 1, wherein said guard bed material is selected from the group consisting of clay, silica, silica-alumina, ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, mordenite, clinoptilolite, erionite, and Zeolite Y.
4. A method according to claim 3, wherein said guard bed material is selected from the group consisting of ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, mordenite, clinoptilolite, erionite, and Zeolite Y.



5. A method according to any preceding claim, wherein said sulphur-containing agent comprises hydrogen sulphide.
6. A method according to any preceding claim, wherein said organic base comprises amine.
7. A method according to claim 6, wherein said amine is alkanol amine.
8. A method according to claim 7, wherein said amine is selected from the group consisting of diethanolamine, monoethanolamine, triethanolamine, and methyldiethanolamine.
9. A method according to any preceding claim, wherein said molecular sieve desiccant is selected from the group consisting of Zeolite 3A, Zeolite 4A, and Zeolite 5A.
10. A method according to claim 9, wherein said molecular sieve desiccant comprises Zeolite 4A.
11. A method according to any preceding claim, wherein said guard bed comprises aluminum phosphate having an Al/P atomic ratio of 0.6 to 1.
12. A method according to any preceding claim, wherein said guard bed has a surface area of 1 to 1000 m² per gram.
13. A method according to claim 12, wherein said guard bed has a surface area of 10 to 500 m² per gram.



14. A method according to any preceding claim, wherein said siliceous material has an alpha value of 0.001 to 10.

15. A method according to claim 14, wherein said guard bed comprises a siliceous material has an alpha value of 0.01 to 2.

16. A method according to any preceding claim, wherein said guard bed is disposed above said molecular sieve desiccant.

17. A method according to any preceding claim, wherein said guard bed comprises particles having at least 1/8 inch (0.32cm) diameter.

18. A method according to any preceding claim, wherein the volumetric ratio of said guard bed to said molecular sieve desiccant ranges from 0.001 to 0.1.

19. A method according to claim 1, wherein said organic base is diethanolamine, said molecular sieve desiccant is Zeolite 4A, said guard bed comprises a siliceous material having an alpha value of 0.01 to 2 and comprising particles having at least 1/8 inch (0.32cm) diameter, and the volumetric ratio of said guard bed to said molecular sieve desiccant ranges from 0.005 to 0.1.