March 21, 1961 H. O. McMAHON 2,975,604

METHOD OF DISTRIBUTION OF CONDENSABLE GASES

Filed May 7, 1956 3 Sheets-Sheet 1

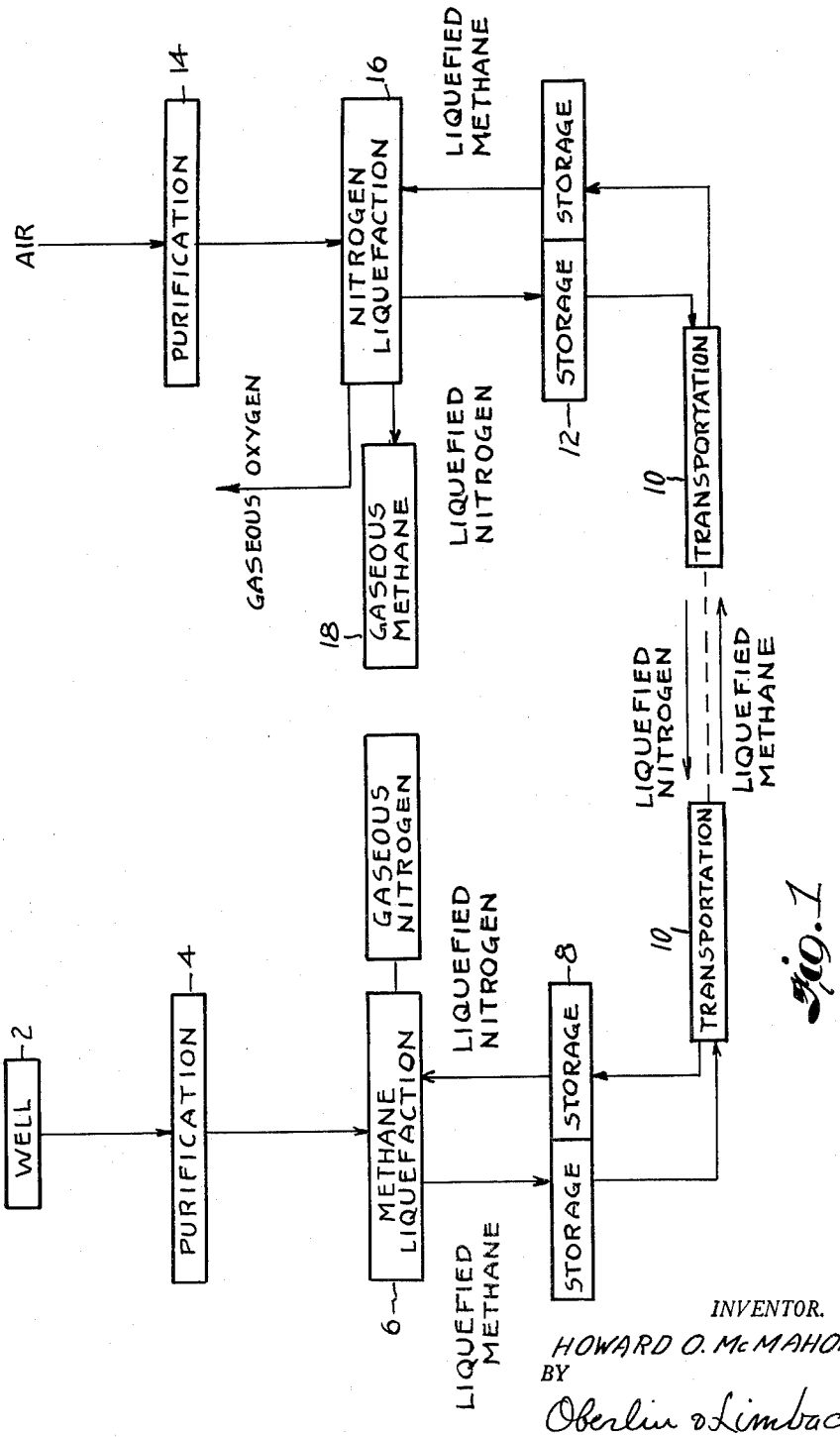


Fig. 1

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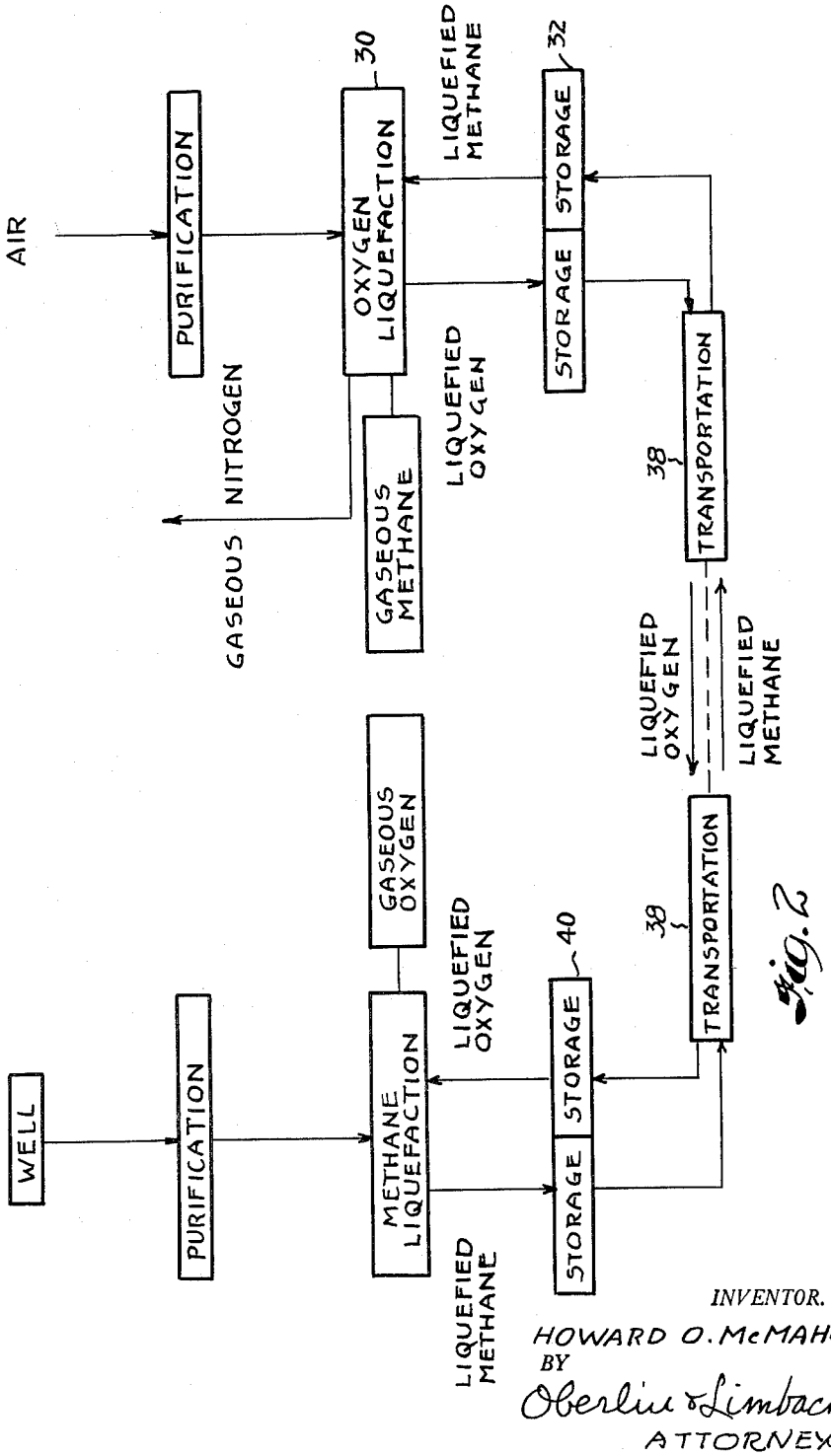


Fig. 2

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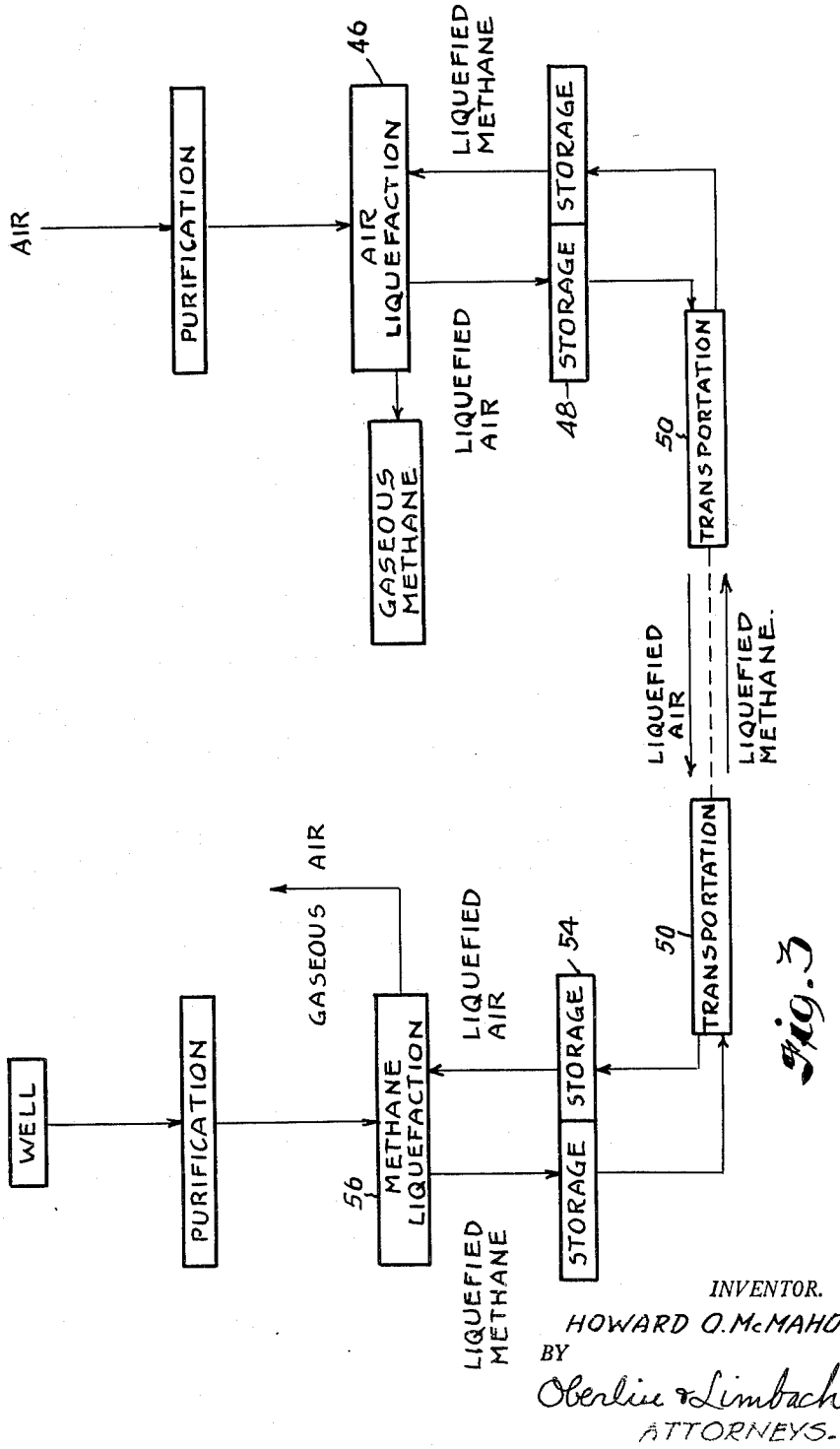


Fig. 3

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METHOD OF DISTRIBUTION OF CONDENSABLE GASES

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2 Claims. (Cl. 62—9)

This invention relates to a method of making condensable gases available at points other than the source of the condensable gases.

An important object of this invention is to provide an efficient method of distributing condensable gases to remote locations.

Another object of this invention is to retain liquefied-natural-gas-distributing containers at the desired temperature during their return to the source of the liquefied natural gas.

A further object of this invention is to provide a method of distributing methane to remote locations in a liquefied form wherein the inherent cooling properties of the liquefied methane are utilized at the point of consumption of the methane.

Another and more specific object of this invention is effectively to utilize the refrigeration inherent in liquefied methane near the point of consumption for liquefying another gas, and in turn utilizing the liquefied gas for cooling the methane containers during return of the containers to the methane source, as well as utilizing the liquefied gas in the liquefaction of additional methane.

A still further object of this invention is to provide a method of distributing methane or other condensable gases wherein low-pressure, economically feasible containers may be used for transporting the methane or other condensable gases.

Other objects of the invention will be evident from the following detailed description, when read in conjunction with the accompanying drawings, which illustrate the invention.

Broadly stated, the present invention may be defined as the method of making methane and other condensable gases available at a point other than its source, which comprises:

(*a*) liquefying the methane or other condensable gas by a process wherein the methane or other gas, preferably available at high pressure, is liquefied in part by a reduction in pressure thereof accompanied by cooling thereof and in part by supplemental refrigeration thereof from an outside source;

(*b*) conveying the thus liquefied methane or other liquefied gas to another location in thermally insulated containers;

(*c*) in the vicinity of said other location, liquefying a different medium by a refrigeration process utilizing the refrigerating effect of the liquefied methane or other gas received at said other location, in such thermally insulated containers;

(*d*) transporting such different liquefied medium to the vicinity of said source of methane or other gas in said thermally insulated containers on their return trip thereto; and

(*e*) utilizing said different liquefied medium to supply said supplemental refrigeration required for liquefaction of the succeeding cargo of methane or other gas.

For a better understanding of my invention, attention is directed to the following detailed specification taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a flow diagram illustrating the distribution of methane or other liquefied gas in accordance with my invention, wherein the different medium conveyed to the vicinity of the source of methane or other gas is nitrogen;

Fig. 2 is a flow diagram illustrating the distribution of methane or other liquefied gas in accordance with my invention, wherein the different medium conveyed to the vicinity of the source of methane or other gas is oxygen; and

Fig. 3 is a flow diagram illustrating the distribution of methane or other liquefied gas in accordance with my invention, wherein the different medium conveyed to the vicinity of the source of methane or other gas is air.

It will be understood that the method of my invention may be practical in order to achieve the distribution of methane or any one of a number of other condensable gases, and that, similarly, any one of a number of different condensable media may be employed for conveying the refrigeration from the point of utilization of the methane or other gas back to the source of such methane or other gas. However, the principles of my invention may well be illustrated by assuming that methane is the gas which is to be transported, in liquefied form, from its source to its point of utilization. Such methane may appear either in substantially pure form or as a principal constituent of natural gas, which is to be distributed from its source to a point of utilization.

Referring to Fig. 1 of the drawings, reference character 2 designates a gas well which produces methane in commercial quantities. Generally speaking, the methane produced by the well 2 will contain various impurities, such as carbon dioxide, hydrogen sulfide, water, etc. Therefore, the gas stream from the well 2 is first directed through a purification apparatus 4 for removing the various impurities. The apparatus 4 may be any desired arrangement and combination of equipment which will effectively eliminate the impurities from the gas produced by the well 2 and provide a resulting product which is substantially pure methane.

The purified methane is then directed to a suitable liquefaction plant 6, where the methane is liquefied at a low temperature, such as —258° F., and at substantially atmospheric pressure. In accordance with the present invention, the liquefaction plant 6 utilizes at least a partial-refrigeration-type liquefaction process, wherein liquefied nitrogen is converted to a gas to produce the desired refrigeration. It is preferred that the liquefied nitrogen provide the major portion of the refrigeration required to liquefy the methane, whereby approximately one pound of liquid nitrogen will be used in producing one pound of liquid methane. However, the precise ratio of nitrogen-to-methane amounts will vary with the specific type of liquefaction plant available. The liquefied methane is then directed into a suitable storage 8 before transportation to the desired remote location. It is preferred that the storage facilities 8 be positioned adjacent the liquefaction plant 6, inasmuch as the liquefied methane will exist at a very low temperature, and the unnecessary transportation thereof into storage will entail a complicated heat-transfer problem.

When and as desired, the liquefied methane may be transferred from the storage facilities 8 into thermally insulated containers (not shown) disposed on any suitable transportation facilities 10, such as barges or ships for water transportation, or railroad cars for overland transportation. It is to be particularly noted that the liquefied methane is transported at substantially atmospheric pressure; therefore, the containers for the methane

may be lightly and economically constructed. However, the containers should be well insulated and should be maintained at substantially constant and uniform temperature to prevent a warming and evaporation of the methane as the methane is loaded therein, as well as to facilitate the economical construction of the containers.

The transportation facilities 10 are then moved in any desired fashion to deliver the liquefied methane to a storage 12, perhaps remote from the source and preferably located in the vicinity of the place where the methane will be consumed. Upon arrival of the transportation 10 at the remote location, the liquefied methane is transferred into the intermediate storage 12 in any desired manner. However, the methane should be retained in liquefied form in the storage 12 to preserve the inherent cooling ability of the methane.

When the liquefied methane is evaporated, substantial refrigeration is available to aid in refrigerating the gas to be liquefied at the location remote from the methane source. This refrigeration is utilized in a liquefaction apparatus 16 in the liquefaction of nitrogen from the air. Thus, for example, in the production of the liquefied nitrogen, the air may be first directed through a suitable purification apparatus 14, where the impurities are removed. The purified air may then be directed into liquefaction plane 16, where it is compressed, expanded and oxygen distilled off as a gas to leave liquefied nitrogen. The liquefied nitrogen at about —320° F., and substantially atmospheric pressure, may then be introduced into the storage containers 12 and then into the transportation facility 10 or the storage containers may be bypassed. Any suitable liquefaction equipment may be used. However, as indicated above, it is preferred that the liquefaction of the nitrogen involve a refrigeration process which can utilize the inherent cooling ability of the liquefied methane.

The low-temperature liquefied nitrogen is stored in the vicinity of the liquefaction plant 16, and may be suitably stored in a portion of storage facilities 12. When and as desired, the liquid nitrogen is transferred from storage 12 into the containers of the transportation facilities 10. As previously mentioned, the containers of the transportation facilities 10 are well insulated and are preferably maintained at substantially uniform and constant temperature. Therefore, the containers should be filled with liquefied nitrogen immediately after the transfer of the liquefied methane into the storage 12. Since the liquefied nitrogen will have at least as low a temperature as the liquefied methane, and the containers are not left empty for any appreciable time, the containers will not warm up to any appreciable extent. It will thus be seen that the cargo of the transportation facilities 10 is simply changed from liquefied methane to liquefied nitrogen for the return trip of the transportation facilities 10 to the vicinity of the methane source 2.

Upon arrival of the transportation facilities 10 at the end of the return trip, the liquefied nitrogen is transferred into a suitable storage, such as a portion of the storage facilities 8, and another load of liquefied methane is transferred to the transportation facilities 10. Thus, the containers of the transportation facilities 10 are almost constantly exposed to either liquefied methane or liquefied nitrogen, thereby maintaining the containers at a substantially uniform temperature. The liquefied nitrogen delivered to the storage facilities 8 is utilized in the liquefaction of the methane in the liquefaction plant 6 as previously described.

From the foregoing, it will be apparent that the present invention provides an efficient method of distributing methane or other condensable gas to locations either nearby or remote. The methane is liquefied at substantially atmospheric pressure for convenient transportation, and the liquefied methane is utilized in the liquefaction of nitrogen in the vicinity of the location where the methane is to be consumed. Also, the nitrogen, which is liquefied at least partially by means of the refrigeration inherent in liquefied methane, is transported to the source of the methane in the same facilities which were used for transporting the methane, thereby obtaining an economical transportation system, as well as retaining the methane containers in the desired temperature conditions during their return trip. The construction of the methane containers will thus be placed on an economically feasible basis. It will also be noted that the liquefied nitrogen is utilized in liquefying the methane in the vicinity of the methane source, thereby utilizing the inherent cooling ability of the liquefied nitrogen. The gaseous nitrogen which is a product of methane-liquefaction plant 6 might be employed in any desired way, such as causing it to combine with hydrogen, derived from natural gas, to synthesize ammonia.

The explanation of my invention which has been presented in the paragraphs above has been based upon the embodiment of Fig. 1, in which nitrogen is the medium employed for conveying the refrigeration from the point of utilization of the methane or other gas back to the source of such methane or other gas. Now, if oxygen is employed in place of nitrogen as such medium, as shown in Fig. 2 of the drawings, oxygen is separated from the other constituents of air and is liquefied in apparatus 30, taking advantage of the refrigeration derived from the vaporization of the methane. The liquefied oxygen then may pass through suitable storage 32, and by transportation 33, to the vicinity of the source of the methane where, after passing through storage 40, the liquefied oxygen may supply its inherent refrigeration to assist in liquefaction of methane from the source. Thereupon, having given up its inherent refrigeration and assumed the gaseous state, the oxygen may be employed for any desired purpose, such as sale in commerce or for chemical processing. The gaseous nitrogen given off by apparatus 30 may likewise be put to any desired use such as synthesis of ammonia. It should be noted that, if liquefied oxygen is placed in transportation containers which have been occupied by a flammable material, an intermediate purging step should be employed in order to ensure that no explosion will take place.

Turning to the embodiment of Fig. 3, it will be noted that air, instead of nitrogen or oxygen alone, is employed as the medium for conveying the refrigeration from the point of utilization of the methane or other gas back to the source of such methane or other gas. In such a case, of course, no separation of gases need take place, and air is simply purified and liquefied in an apparatus 46, taking advantage of the refrigeration derived from the evaporation of the methane near its point of utilization. The liquefied air then may pass through suitable storage 48 and, by transportation 50, to the vicinity of the source of methane where, after passing through storage 54, the liquefied air may supply its inherent refrigeration to assist in the liquefaction of methane from the source. Such liquefaction takes place in any suitable heat-exchange apparatus 56, the outputs of which are liquefied methane, and air in the gaseous state.

While particular embodiments of the invention have been described, it will be understood, of course, that the invention is not limited thereto since many modifications may be made, and it is, therefore, contemplated to cover by the appended claims any such modifications as fall within the true spirit and scope of the invention. It is especially to be understood that the method of my invention may be applied to the distribution, not merely of methane, but of any condensable gas.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims, or the equivalent of such, be employed.

I therefore particularly point out and distinctly claim as my invention:

1. The method of making a condensable natural gas available at a location remote from a source, which comprises:

(*a*) liquefying the condensable gas;
(*a'*) introducing the liquefied natural gas into insulated storage tanks;
(*b*) transporting said liquefied gas in the insulated storage tanks to a remote location;
(*b'*) removing the liquefied gas from the insulated storage tanks at the remote location;
(*c*) vaporizing said gas to produce refrigeration at said remote location;
(*d*) utilizing said refrigeration in liquefying air in the vicinity of said remote location;
(*e*) permitting at least a portion of the oxygen in said air to become separated from said air, leaving the nitrogen substantially in liquefied form;
(*e'*) introducing the liquefied nitrogen into said storage tanks from which the liquefied gas was removed without purging the tanks and while the tanks are still cold from the liquefied gas;
(*f*) transporting said liquefied nitrogen to the source of said condensable gas in the facilities used for transporting said condensable gas;
(*g*) vaporizing said nitrogen at the source of said condensable gas to produce refrigeration; and
(*h*) utilizing said last-mentioned refrigeration in liquefying additional condensable gas at the source.

2. The method of making a condensable natural gas available at a location remote from a source, which comprises:

(*a*) liquefying the condensable gas;
(*a'*) introducing the liquefied natural gas into insulated storage tanks;

(*b*) transporting said liquefied gas in the insulated storage tanks to a remote location;
(*b'*) removing the liquefied gas from the insulated storage tanks at the remote location;
(*c*) vaporizing said gas to produce refrigeration at said remote location;
(*d*) utilizing said refrigeration in liquefying air in the vicinity of said remote location;
(*e*) permitting at least a portion of the oxygen in said air to evaporate, leaving the nitrogen substantially in liquefied form;
(*e'*) introducing the liquefied nitrogen into said storage tanks from which the liquefied gas was removed without purging the tanks and while the tanks are still cold from the liquefied gas;
(*f*) utilizing the refrigeration obtained from evaporation of said oxygen for liquefying more air;
(*g*) transporting said liquefied nitrogen to the source of said condensable gas in the facilities used for transporting said condensable gas;
(*h*) vaporizing said nitrogen at the source of said condensable gas to produce refrigeration; and
(*i*) utilizing said last-mentioned refrigeration in liquefying additional condensable gas at the source.

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