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METHOD OF PURGING HEAT EXCHANGERS OF SOLIDIFIED IMPURITIES IN THE LIQUEFACTION OF NATURAL GAS

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Fig. 1

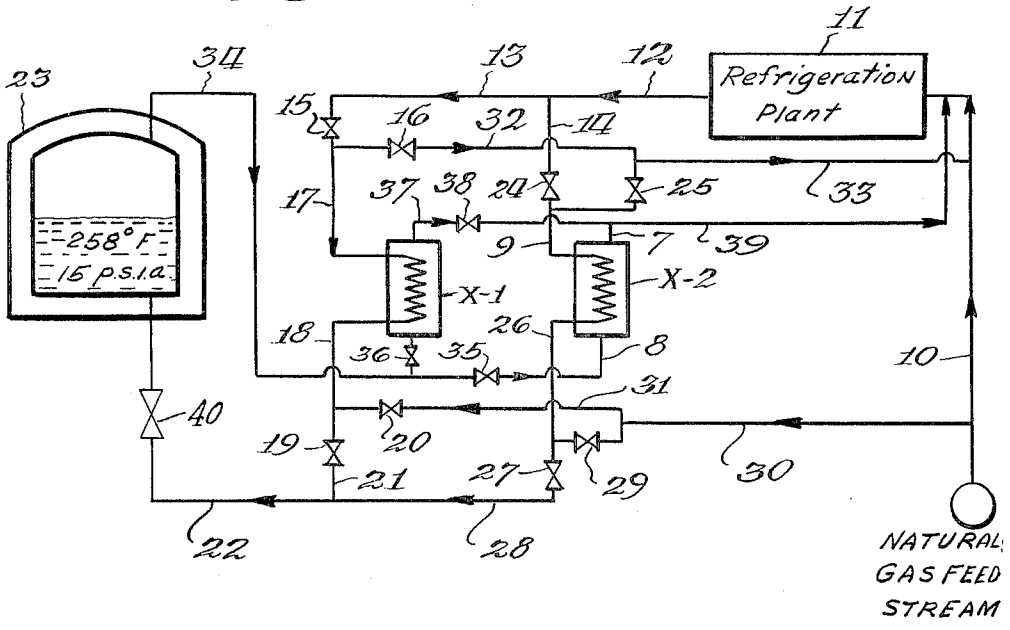
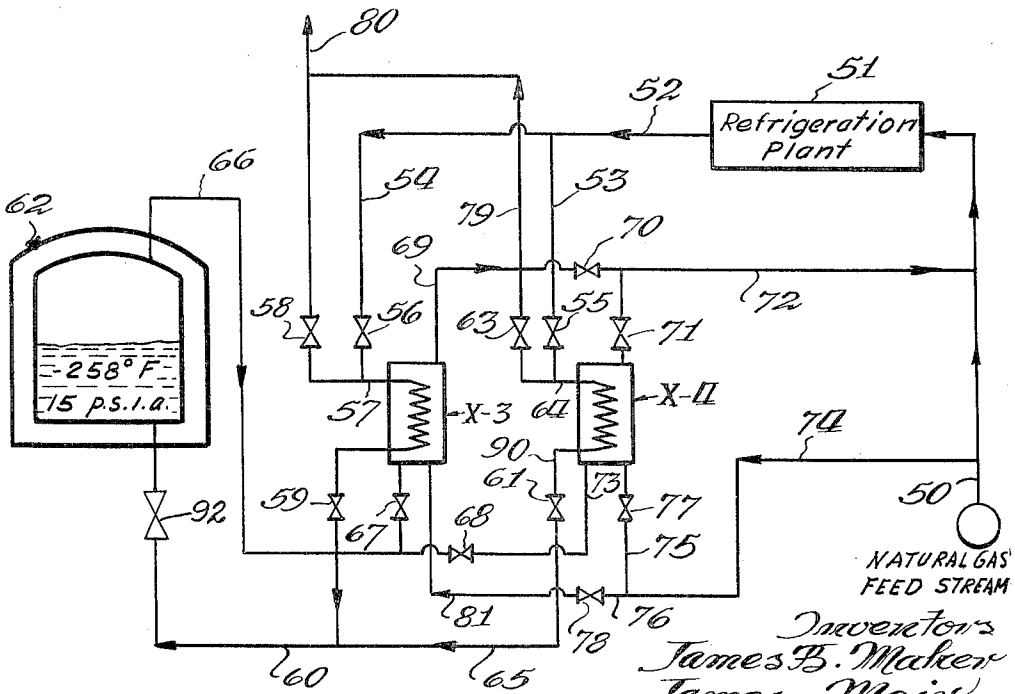


Fig. 2



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METHOD OF PURGING HEAT EXCHANGERS OF SOLIDIFIED IMPURITIES IN THE LIQUEFACTION OF NATURAL GAS

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3 Claims. (Cl. 62—12)

This invention relates to apparatus and methods for storing materials which are normally gases at ambient temperatures and pressures, in the form of liquids. More particularly, this invention is concerned with novel processes and apparatus for liquefying methane, such as in the form of natural gas, and subsequently storing the gas in liquefied form.

Natural gas, which is primarily methane, is often stored in liquid form at about atmospheric pressure and usually 15 p.s.i.a., and at a temperature of about —258° F. Although there are several methods of liquefying natural gas, they broadly employ a refrigeration system for substantially increasing the pressure of incoming natural gas such as to about 600 to 2000 p.s.i., and to a low temperature, such as about from —100° F. to about —210° F. The refrigeration means is usually of the cascade type. After the natural gas has been so pressurized and cooled, it is then usually passed through a final heat exchanger where it is further cooled such as down below —210° F. while maintaining or increasing the pressure to which the gas has already been subjected. Upon leaving the final heat exchanger the natural gas is then passed through an expansion valve to about atmospheric pressure and as a result of this flashing operation the temperature of the gas is lowered to about —258° F. The flashing operation usually results in liquefaction of the major portion of the gas stream with the lesser portion remaining as a vapor. This vapor is usually recycled through the system, and particularly through the shell side of the final heat exchanger in order to lower the temperature of incoming natural gas. After leaving the shell side of the final heat exchanger the cooled natural gas can be recycled further through the system for additional cooling purposes.

The liquefaction of natural gas leads to the solidification of various impurities present in the gas, including hydrocarbons having four carbons or more, such as butane, pentane, hexane and other higher hydrocarbons, as well as impurities such as carbon dioxide and water vapor. Although such impurities are sometimes removed before the natural gas is liquefied, even the residual amounts often cause difficulties during the liquefaction operation. Such impurities often solidify in the final heat exchanger and adhere to the tube side surfaces thereof. The continual build-up of these solids lowers the efficiency of the heat exchanger and requires that the solids be removed in order for it to be employed satisfactorily. Of course, the solidified material which contaminates the heat exchange surface is only a part of that which forms since many of the solid particles pass through the heat exchanger. However, since enough of the particles do adhere to interfere with suitable operation of the system, they must be removed from the heat exchanger at appropriate intervals. Since this operation must be performed even when suitable gas treating apparatus is provided for removing most of the impurities prior to liquefaction of the natural gas, it would be desirable to eliminate such contaminant-removal equipment if this could be done since such equipment is expensive.

There is accordingly provided by the subject invention novel apparatus and methods for removing solidified impurities which form on the tube side of heat exchangers used in systems for liquefaction of natural gas.

The invention broadly comprises the provision of two similar final heat exchangers placed in parallel arrangement in a natural gas liquefaction system. Each of the final heat exchangers is provided with means for cooling liquefied natural gas which is passed alternately through one and then the other of said final heat exchangers. As the gas is passed through the heat exchanger, impurities present in the natural gas are solidified and some adhere as frozen solids to the tube side surfaces of the heat exchanger. Means are provided on the shell side of the heat exchanger for lowering the temperature thereof below the temperature of the natural gas fed into the heat exchanger.

Any additional cost due to the second heat exchanger will be partially offset by the saving in eliminating other equipment that would be required for the removal of impurities in the gas.

After one of the two final heat exchangers placed in parallel has become coated or caked by the adherence of the solid impurities, natural gas from the feed stream is circulated through the heat exchanger to vaporize the solidified impurities. The circulating natural gas can be fed through the tube side or the shell side of the heat exchanger. As the circulating natural gas is fed through the tube side, the solidified impurities are redispersed in the natural gas and it can then be refed to the feed stream for subsequent passage through the refrigeration system for liquefaction. If desired, the circulating natural gas fed through the tube side of the heat exchanger can be flared off together with the impurities which are vaporized by it.

Another alternative is to pass the circulating natural gas from the feed stream through the shell side of the coated heat exchanger to simultaneously vaporize the solidified impurities on the tube side while lowering the temperature of the circulating natural gas. The so-vaporized impurities on the tube side can then be flared off while the circulating natural gas cooled in this manner can be fed into the refrigeration system for liquefaction. In this flow pattern, almost all of the vapor going to the flare is composed of vaporized impurities. As one of the two final heat exchangers placed in parallel arrangement is being defrosted or decontaminated in this manner to remove solidified impurities, the other final heat exchanger can be simultaneously employed in the liquefaction system to convert natural gas into liquid form.

The invention will now be discussed further in connection with the attached drawings in which:

FIGURE 1 shows a system for liquefying natural gas having two final heat exchangers in parallel with means provided for removing solidified impurities which adhere on the tube side of the heat exchangers and for circulating the impurities, after being vaporized, into the natural gas feed; and

FIGURE 2 shows a system for liquefying natural gas having two final heat exchangers in parallel with means for removing impurities which solidify in the heat exchangers and for vaporization of the impurities so that they can be flared off and thereby removed from the system and the natural gas.

As shown in FIGURE 1, incoming natural gas at about 300 p.s.i. is conveyed by pipe 10 to the refrigeration plant 11 where the gas is cooled and pressurized such as to about 600 to 2000 p.s.i. and to a temperature of about —100° F. to about —200° F. The so-cooled and pressurized natural gas is then conveyed by line 12 to either pipeline 13 or 14. When it is conveyed through pipe 13, valve 15 is open and valve 16 is closed. The gas passes through line 17 into heat exchanger X–1 on the tube side thereof. The gas leaves the heat exchanger by line 18 and then passes through valve 19 which is open and valve 20 is closed. The gas then goes through pipe 21

into pipe 22 through which it is conveyed to an expansion valve 40, where the gas pressure is lowered and the gas liquefied and then conveyed into the main storage tank 23 for storage at about atmospheric pressure or slightly thereabove and at a temperature of about −258° F.

The gas from line 12, instead of being conveyed through line 13, can be conveyed through line 14. Valve 15 in this instance is closed, valve 24 is open and valve 25 is closed. The gas goes through valve 24 into line 9 and then through the tube side of heat exchanger X–2. The heat exchangers X–1 and X–2 are similar and are seen to be placed in the liquefaction system in parallel arrangement. In such heat exchangers the temperature of the gas is dropped considerably, and usually down at least to about −200° F. The extent to which the temperature of the gas is lowered in such heat exchangers will depend upon the means used to cool the same. After being cooled in heat exchanger X–2, the gas is conveyed by pipeline 26 through valve 27 into line 28 and then into line 22 for flashing into the storage tank 23. When the gas passes through line 28, valves 19 and 29 are closed.

Either heat exchanger X–1 or heat exchanger X–2 can be used in the liquefaction cycle but both ordinarily are not so used simultaneously. As the natural gas passes through the tube side of either heat exchanger X–1 or X–2 on the liquefaction cycle, impurities present in the natural gas are converted from vapors and liquids to solids and at least a part of the contaminants are thereby caused to adhere to the colder tube side surfaces of the heat exchangers. As a result, there is a continuous build-up of such solid deposits. In order to continue to use such heat exchangers and maintain their efficiency, these solids must be removed periodically.

The solids are removed from such heat exchangers alternately while one or the other is used in the liquefaction cycle. Thus, while heat exchanger X–2 is on the liquefaction cycle the solids can be removed from heat exchanger X–1 by conveying natural gas feed, which is at a much higher temperature than the solids in the heat exchanger X–1, through pipe 30 and into pipe 31. When this is done, valves 19 and 29 are closed. Valve 20 is open and the natural gas is conveyed through line 18 into the tube side of heat exchanger X–1 where it warms the solidified contaminants to vapors which are dispersed in the natural gas feedstock. The natural gas feedstock containing the vaporized contaminants is then fed into pipe 17. Valve 15 is closed and valve 16 is open so that the natural gas can be conveyed by pipe 32 into line 33. As this is done valve 25 is closed. The gas as it passes through pipe 33 is then fed therefrom into the refrigeration plant since it has been cooled by going through heat exchanger X–1.

While heat exchanger X–1 is on the liquefaction cycle, heat exchanger X–2 can be defrosted by passing natural gas through line 30, through valve 29 and into line 26 and thereby through the tube side of heat exchanger X–2. When this is done valves 27 and 20 are closed. In passing through the tube side of heat exchanger X–2 the natural gas vaporizes the solidified contaminants and the resulting mixture is passed through pipe 9, through valve 25 and into line 33. While this is done valve 24 is closed, as is valve 16.

Cooling of the heat exchangers X–1 and X–2 is achieved by removing gas vapor from the main storage tank 23 by means of line 34 by which it is conveyed through the shell side of either heat exchanger X–1 or X–2. In order to convey the vapor through the shell side of heat exchanger X–1, valve 35 is closed and valve 36 is open. The vapor leaves heat exchanger X–1 by pipe 37 and passes through valve 38 and into line 39 by which means it is recirculated back to the refrigeration system.

In order to cool heat exchanger X–2 valve 36 is closed and valve 35 is open so that the cold vapors are conveyed by pipes 34 and 8 into the shell side of heat exchanger X–2 from which they leave by line 7 to pipeline 39, with valve 38 closed, back to the system for recycle into the refrigeration plant.

Referring now to FIGURE 2, incoming natural gas at about 300 p.s.i. is conveyed by line 50 to refrigeration plant 51 where it is further pressurized and cooled such as to −100° F. or down as low as −200° F. The so cooled and pressurized natural gas is then fed by line 52 either through line 53 or line 54. When it is fed to line 54, valve 55 is closed and valve 56 is open. After passing through valve 56 the gas is fed into pipe 57, with valve 58 closed, through the tube side of heat exchanger X–3 where it is further cooled such as down to about −200° F. or below. After leaving heat exchanger X–3 the natural gas is fed through valve 59, which is open, and into line 60. At this time, valve 61 is closed. By means of pipe 60 the gas is fed through an expansion valve 92 from which it is flashed into the main storage tank 62. During the flashing operation the pressure of the gas is dropped down to about 15 p.s.i.a. and the temperature lowered to about −258° F. In the flashing operation a major part of the gas is liquefied while the remaining part remains at a vapor although at a very reduced temperature.

Alternative to passing the gas through pipe 54, valve 56 may be closed and the gas fed through pipe 53 through valve 55, which is open, while valve 63 is closed. In this manner, the gas is conveyed through pipe 64 and through the tube side of heat exchanger X–4 from which it emerges to line 90 through valve 61, which is open, into pipe 65 and then into pipe 60, with valve 59 closed. The gas is then flashed into the storage tank 62 and liquefied. It is thus seen that either heat exchanger X–3 or heat exchanger X–4 can be employed in the liquefaction cycle of the system.

Cooling of the heat exchangers X–3 and X–4 is provided for by removing vapor from the storage tank 62 by means of pipe 66 and conveying it through valve 67, which is open, while valve 68 is closed. The cold vapor then passes through the shell side of heat exchanger X–3, out through pipe 69 through valve 70, which is open, while valve 71 is closed, and then into pipe 72 for recycling into the refrigeration plant.

Alternatively, the vapor can be conveyed through line 66 to open valve 68, with valve 67 closed, through line 73 and thus through the shell side of heat exchanger X–4 from which it goes through open valve 71 with valve 70 closed and thus into pipe 72 for recycling into the refrigeration plant. In this way, either heat exchanger X–3 or X–4 can be cooled.

Contaminants in the natural gas which solidify in heat exchangers X–3 and X–4 when on the liquefaction cycle can be removed by conveying natural gas from the feed stream through line 74 and into line 75 or line 76. When it is fed through line 75, valve 77 is open while valve 78 is closed. The gas is passed through the shell side of heat exchanger X–4 and out valve 71, which is open, valve 70 being closed, and then into pipe 72 for recycling to the refrigeration plant.

In order to remove the vaporized solids from heat exchanger X–4, valves 55 and 61 are closed and the vaporized contaminants are passed through open valve 63 into pipe 79 and out pipe 80 to a flare.

To remove solids from heat exchanger X–3, valve 77 is closed and the natural gas feed from pipe 74 is passed through pipe 76 and open valve 78 to pipe 81 and thus into the shell side of heat exchanger X–3 from which it exits into pipe 69 and is then passed through open valve 70, with valve 71 closed, into pipe 72 for cycling to the refrigeration plant. The natural gas which passes through the shell side of heat exchanger X–3 is much warmer than the solidified contaminants in the tube side of heat

exchanger X–3. The contaminants are thereby vaporized. By closing valve 59 they are conveyed through pipe 57, with valve 56 closed, through open valve 58 and out pipe 80 to a flare. During the vaporization of solids in heat exchanger X–3 as described, valve 67 is closed as is valve 68 when solids are similarly vaporized in heat exchanger X–4.

It is important to observe that, as a portion of the warm, natural gas stream is used to vaporize solidified contaminants, this portion is thereby cooled to a lower temperature, thus reducing the duty of the refrigeration system.

Various changes and modifications of the invention can be made and, to the extent that such variations incorporate the spirit of this invention, they are intended to be included within the scope of the appended claims.

What is claimed is:

1. The method of liquefying natural gas which comprises subjecting an incoming stream of natural gas to refrigeration means to substantially cool the gas and place it under high pressure, passing the gas through the tube side alternately through one and then the other of two similar final heat exchangers placed in parallel arrangement just prior to liquefying the gas and cooled on the shell side to a temperature substantially below the temperature of incoming gas, flashing the gas after it leaves said final heat exchanger to liquefy the gas, conveying the liquid gas to a storage tank, conveying cooled natural gas alternately through one and then the other of said final heat exchangers cooled on the shell side to a temperature substantially below the temperature of incoming gas on the tube side so that impurities normally present in the natural gas are solidified and adhere to the tube side surfaces of the heat exchanger, circulating natural gas from the feed source alternately through one and then the other of said final heat exchangers when not in use in the liquefaction system to vaporize solids therein, thereby removing the vaporized solids from the heat exchanger, and conveying the circulating natural gas containing the vaporized solids back to said incoming stream preceding said refrigeration means at a lower temperature for subsequent liquefaction.

2. A method according to claim 1 wherein the natural gas from the feed source is circulated through the tube side alternately through one and then the other of said final heat exchangers when not in use in the liquefaction system to vaporize solidified impurities therein.

3. A method according to claim 1 wherein the natural gas from the feed source is circulated through the shell side alternately through one and then the other of said final heat exchangers when not in use in the liquefaction system to vaporize solidified impuries therein.

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