Aug. 19, 1941. H. J. STOEVER 2,252,738

PROCESS AND APPARATUS FOR REMOVING CONDENSATES FROM GAS

Filed Oct. 18, 1938

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[Diagram of apparatus for removing condensates from gas]
This invention pertains generally to the liquefaction and removal of readily condensable materials from a gaseous mixture, and particularly to the recovery by liquefaction of valuable substances from manufactured gas.

Manufactured gas such as carburetted water gas, oil gas, coal gas, etc., contains considerable quantities of valuable hydrocarbons which may be recovered upon a reduction in temperature of the gas. In the recovery of such materials on a large scale, however, considerable difficulty is experienced with the solidification of certain components of the gas such as water, benzene, etc., in the heat exchange equipment. Such solidification results in inefficient heat exchange and/or stoppages due to the building up of ice layers on the surfaces of heat exchange equipment.

A feature of this invention is the avoidance of heat exchange difficulties due to solidification of gas components.

Another feature of the invention is the employment as a cooling liquid of an absorbing oil which comprises condensate produced in the process.

Another feature of the invention is the provision of a process and means for the continuous removal of a gas of readily condensable materials without the necessity of shutting down to throw out solidified materials, or of duplicating the equipment.

A further feature of the invention resides in the utilization of the cold gas after leaving the last stage of its cooling to condense a part of the refrigerant and thereby reduce the load on the refrigeration plant.

A further feature of the invention resides in the utilization of the refrigeration available in the cold gas in a manner to avoid stoppages which would be occasioned if this gas were used to cool the incoming warm gas in a gas to gas heat exchanger.

Further features of the invention reside in the construction, arrangement and combinations of parts, and in the steps, sequences of steps and combinations of steps of the process, all of which together with other features will become more apparent to persons skilled in the art as the specification proceeds and upon reference to the drawings in which:

Figure 1 diagrammatically illustrates one embodiment of the invention;

Figure 2 is a sectional elevation (shown broken) illustrating the lower portion of a spray tower of Figure 1; and

Figure 3 is a diagrammatic illustration of another form of the invention.

Referring now more particularly to Figure 1 at 10, 11 and 12 are shown vertically arranged spray towers which are preferably free from any type of phase contacting material such as packing, bubble plates, etc.

Each of the towers 10, 11 and 12 is provided at its top with a spray head 13, 14, and 15 respectively, and at its bottom with a liquid-solid separator 16, 17, and 18 respectively.

Spray heads 13, 14, and 15 are identical in every respect. The same applies to liquid-solid separators 16, 17, and 18, the liquid-solid separator 18 being illustrated in detail in Figure 2.

Liquid-solid separator 16 has a liquid off-take 19 leading to a pump 20, the outlet of which is connected to the inlet 21 of a fluid space illustrated diagrammatically at 22 of heat exchanger 23. Outlet 24 of fluid space 22 is connected to spray head 12.

Likewise, liquid-solid separator 17 has a liquid off-take 25 leading to pump 27 the outlet of which is connected to the inlet 28 of a fluid space illustrated diagrammatically at 29 of heat exchanger 30. Outlet 31 of fluid space 29 is connected to spray head 14.

Also liquid-solid separator 18 has a liquid off-take 33 leading to a pump 34 the outlet of which is connected to the inlet 35 of a fluid space illustrated diagrammatically at 36 of heat exchanger 37. Outlet 38 of fluid space 36 is connected to spray head 16.

Liquid off-takes 22, 28, and 33 also lead to drain valves 40, 41, and 42 respectively.

The other fluid space 44, 45 and 46 of heat exchangers 23, 30 and 37 respectively is essentially an evaporating space for a liquefied refrigerant such as ammonia.

Fluid space 44 of heat exchanger 23 is connected adjacent its top through line 43 to the inlet of third stage compressor 49. The outlet of compressor 43 is connected through line 50 to fluid space 51 of condenser 52, the other fluid space 53 of which being provided with a suitable cooling liquid such as water.

The outlet of fluid space 51 is connected by line 55 to the inlet of fluid space 56 of heat exchanger 57. The other fluid space 58 of heat exchanger 57 will be referred to hereinafter.

The outlet of fluid space 56 is connected by line 60 to fluid space 44 through expansion valve 51.
Fluid space 45 of heat exchanger 30 is connected by line 63 to the inlet of second stage compressor 64, the outlet of which is connected by line 65 to fluid space 68 of condenser 67. 

A liquid outlet from fluid space 66 is connected by line 70 to line 71, the latter connecting fluid space 44 with fluid space 45 through expansion valve 72.

A vapor outlet from fluid space 66 is connected by line 69 to line 48.

Fluid space 46 of heat exchanger 37 is connected by line 74 to the inlet of first stage compressor 75, the outlet of which is connected by line 76 to the inlet of fluid space 77 of condenser 78.

The other fluid space 76 of condenser 78 will be referred to hereinafter.

Fluid space 77 has a vapor outlet 80 leading to line 63, and a liquid outlet 81 leading to line 82, the latter connecting fluid space 45 with fluid space 46 through expansion valve 73.

Tower 10 is provided with a gas inlet adjacent to its bottom to which is connected line 85 leading from a gas source not shown.

Tower 16 adjacent to its top is provided with a gas outlet which is connected to a gas inlet adjacent to its bottom by line 11 through line 87.

Tower 11 adjacent to its top is provided with a gas outlet which is connected to a gas inlet adjacent to its bottom by line 12 through line 88.

Tower 13 adjacent to its top is provided with a gas outlet which is connected to the inlet of fluid space 79 of condenser 78 through line 89.

The outlet of fluid space 79 is connected to the inlet of fluid space 68 of condenser 67 through line 90.

The outlet of fluid space 68 is connected to the inlet of fluid space 58 of heat exchanger 57 through line 91.

The outlet of fluid space 58 is connected to line 92 which leads to a suitable point such as a gas holder not shown.

A broken sectional elevation of the lower portion of tower 10 is shown in Figure 2 and comprises a casing 94 having an inlet 95 leading from the main portion of tower 10, intermediate arcuate portions 96 and 97 conforming to the periphery of a rotating strainer 98, and wells 99 and 100 for the accumulation of liquid and solid respectively.

Off-take 99 is connected to well 98 and off-take 101 controlled by valve 102 is connected to well 100.

Well 100 is provided with a heating coil 103.

In the operation of the apparatus shown in Figures 1 and 2, gas to be treated enters the system through line 86 and passes up through tower 10 where it is met by a downward spray of cooled absorbent liquid comprising material previously condensed from the gas in this tower.

The up flowing gas is cooled by the down flowing liquid causing the more readily condensible materials to condense therefrom, and drop to the bottom of tower 10 along with the spray.

In addition, considerable quantities of the more soluble portions of the gas are carried down in solution in the down flowing liquid. This liquid collects in the bottom of tower 10, and flows down through inlet 95 of liquid-solid separator 16, impinging upon the rotating strainer 98 thereof. The liquid passes down through the strainer and collects in well 99, and any solid material such as water ice, or benzol ice is removed by the radial screens 104 of strainer 98 and is deposited in well 100.

The solid material collected in well 100 is melted by heat supplied by any convenient means such as through heating coil 103, and the liquid thus produced is withdrawn through off-take 101 by opening valve 102.

The liquid collecting in well 99 is withdrawn continuously through off-take 19, a part being recirculated through pump 20, fluid space 22 and spray head 13, and the rest flowing through valve 40 to a suitable storage tank not shown.

Gas leaving the top of tower 10 enters the bottom of tower 11 through line 87.

The treatment of the gas in tower 11 is in all respects similar to the treatment in tower 10 with the exception that the temperature is considerably lower. The operation of tower 11 and its accessories is in all respects similar to that of tower 10 and its accessories.

The gas leaving the top of tower 11 enters the bottom of tower 12 through line 88.

The treatment of the gas in tower 12 is in all respects similar to the treatment in towers 10 and 11 with the exception that the temperature in tower 12 is considerably lower. The operation of tower 12 and its accessories is in all respects similar to that of tower 10 and 11 and their respective accessories.

The cold gas leaving the top of tower 12 passes serially through heat exchangers 76, 67, and 57, and finally passes through line 82 to storage.

The absorbing liquid supplied to tower 10 is cooled in fluid space 22 of heat exchanger 23, the fluid space 22 being submerged in a liquefied refrigerant contained in fluid space 44, the cold being produced by the evaporation of the refrigerant in fluid space 44.

Refrigerant vapor from fluid space 44 through line 48 to the inlet of compressor 49, the compressed vapor flowing through line 50 into fluid space 51 of heat exchanger 52 wherein the vapor is condensed upon being cooled by a cooling medium such as water flowing through fluid space 53.

Liquefied refrigerant flows from fluid space 51 through line 55 into fluid space 56 of heat exchanger 57 wherein it is further cooled by cold gas flowing through fluid space 58.

Liquefied refrigerant flows from fluid space 56 by line 60 into fluid space 44 through expansion valve 61, the evaporation in fluid space 44 being, of course, produced by the reduction in pressure on the liquid refrigerant.

Liquid refrigerant from fluid space 44 flows by line 71 through expansion valve 72 into fluid space 45.

Because of the reduction in pressure on the liquid refrigerant as it passes into fluid space 45 which is accompanied by further evaporation, the temperature in fluid space 45 is considerably lower than the temperature in fluid space 44. As a result the temperature of the absorbing liquid leaving fluid space 45 is considerably lower than the temperature of the absorbing liquid leaving fluid space 22, and the temperature of the spray at 14 is considerably lower than the temperature of the spray at 13.

Vapor produced in fluid space 45 flows through line 63 to the inlet of compressor 64 and the compressed vapor flows through line 65 into fluid space 66 of condenser 67, wherein it is at least partially liquefied due to cooling as a result of the flow of cold gas through fluid space 68.

Liquefied refrigerant produced in fluid space
66 flows through line 18 into line 17 and is returned through expansion valve 12 to fluid space 45 along with liquid refrigerant flowing from fluid space 44.

Cooled vapor from fluid space 46 flows through line 69 to line 48 and joins the vapor flowing from fluid space 44 to the inlet of compressor 49.

Liquid refrigerant from fluid space 45 flows by line 82 through expansion valve 83 into fluid space 46 of heat exchanger 31, the temperature in fluid space 46 being considerably lower than the temperature in fluid space 45 because of the reduction in pressure on and consequent evaporation of the liquid refrigerant as it passes through expansion valve 83.

As a result the absorbent liquid passing through fluid space 36 and entering tower 12 through spray 15 is considerably lower than the temperature of the absorbing liquid flowing through fluid space 29 and entering tower 14 through spray 14.

Vaporized refrigerant from fluid space 45 flows through line 74 to the inlet of compressor 75 and the compressed vapor flows through line 76 into fluid space 77 of condenser 78, wherein it is at least partially condensed as a result of being cooled by cold gas flowing through fluid space 78.

Liquefied refrigerant produced in fluid space 77 flows through line 81 to line 82 where it joins the liquid refrigerant flowing through line 82 to fluid space 45.

Cooled refrigerant vapor flows from fluid space 77 through line 80 to line 63 where it joins refrigerant vapor flowing from fluid space 45 to compressor 64.

It will be seen that by a variation of temperatures and pressures in the refrigeration system, the temperatures of the sprays in towers 10, 11, and 12 may be varied over a wide range.

As an example of the temperatures which may obtain throughout the composite system, the gas to be treated may enter tower 10 at 90°F., and be met by a spray at 35°F., the temperature in fluid space 45 being 40°F.

The gas leaves tower 10 and enters tower 11 at 37°F. The spray of absorbing liquid enters tower 11 at -37°F, the temperature in fluid space 45 being -40°F.

The gas leaves tower 11 and enters tower 12 at -35°F. The spray of absorbent liquid enters tower 12 at -37°F., the temperature in fluid space 45 being -60°F.

The gas leaves tower 12 and enters fluid space 78 at -55°F, and leaves fluid space 78 at -42°F.

The gas enters fluid space 68 at -42°F and leaves at 28°F.

The gas enters fluid space 68 at 28°F, and leaves at 70°F, or in other words at substantially atmospheric temperature depending, of course, upon the season of the year.

It will be noted that substantially all of the refrigerant available in the gas under treatment is recovered before the gas leaves the system, and that while a certain amount of refrigeration is lost through the condensate leaving towers 10, 11, and 12, the latter might be readily recovered and utilized by means of efficient heat exchangers.

Since the towers 10, 11, and 12 contain no packing or other contacting medium, no stoppage occurs as a result of the solidification of gas components, that is, as a result of what is commonly known as "frost." Consequently, it is unnecessary to have a duplication of equipment to permit on and off stream operation for thawing purposes.

The process is a continuous one which permits considerably closer regulation and control over the composition of the condensates produced.

Should the solid material tend to adhere to the radial screens of the rotating strainers of liquid-solid separators 16, 17, and 18, it is merely necessary to by-pass a portion of the incoming gas in a manner to cause it to flow into the respective tower through the radial screens.

Suitable by-passes are illustrated at 106, 107, and 108; these by-passes being controlled by valves 109, 110, and 111 respectively.

The point of entry of by-pass 106 is illustrated in Figure 2.

It will be noted that gas entering the casing 94 through by-pass 106 enters between the radial screens 104. Such gas will pass upwardly through the radial screens 104, thereby raising the temperature thereof. The quantity of gas thus by-passed is, of course, sufficient to remove any solid matter adhering to the radial screens.

The by-passed gas, of course, passes up into the tower and continues on through the system along with the gas admitted to the tower in the regular way.

Another form of the invention is illustrated in Figure 3 wherein tower 115 is provided with a spray 116 supplied with absorbing liquid taken from the bottom of the tower through off-take 117. This absorbing liquid passes through pump 118, is cooled in refrigerating plant 119, and passes through a liquid-solid separator 120 before its delivery to the spray head 116.

The construction of tower 115 may be in all respects similar to the construction of towers 16, 17, and 18, including the liquid-solid separators at the bottoms thereof.

The incoming gas enters through line 122, heat exchanger 123, and line 124 into the bottom of tower 115.

The incoming gas while flowing through fluid space 125 of heat exchanger 123, is brought into heat exchange relationship with the treated or outflowing gas. The treated gas leaves tower 115 at the top thereof and flows through line 126 to and through fluid space 127 of heat exchanger 123 and then through line 128 to storage.

It will be seen that the temperatures at various points may be varied as desired over a considerably wide range. Therefore, the following is merely illustrative.

The incoming gas enters through line 122 at 20°C, and is brought into heat exchanger relationship with the cold gas in heat exchanger 123, whereby its temperature is reduced to 0°C. The gas enters tower 115 through line 124 at this temperature and ascends thereafter through being brought into contact with a downwardly moving spray of absorbing liquid which enters the tower 115 through spray head 116 at -70°C.

As a result, the temperature of the gas is reduced to -60°C, before it flows out through line 125 into heat exchanger 123. The temperature of the gas is brought back to 15°C in heat exchanger 123 and it then flows through line 128 to storage.

The condensate at the bottom of tower 115 is at -60°C. A portion thereof is withdrawn through line 117 and pump 118 and is treated in refrigerating plant 119 to reduce its temperature to -70°C. Since this is likely to cause some deposition of solids, the cooled absorbing liquid...
is passed through liquid-solid separator 120 before its delivery to spray head 118. It should be noted that if desired, a liquid-solid separator similar to 120, might be inserted to Figure 1 between fluid space 22 and spray head 14, between fluid space 29 and spray head 14, and/or between fluid space 58 and spray head 15. Many other variations are possible.

For instance, any desired number of spray towers might be connected in series with corresponding refrigerating equipment. Also one or more towers might be eliminated. For instance, tower 12 might be cut out of the system by connecting line 80 directly to line 90 and shutting off flow through lines 86 and 82. Likewise, towers 11 and 12 might be eliminated by connecting line 87 directly to line 91 and shutting off flow in lines 89 and 91.

Furthermore, while the invention has been described in connection with the condensing of valuable hydrocarbons from manufactured gas, it is to be understood that, broadly speaking, it may be employed for the condensing of hydrocarbons from any other gas, such as natural gas, or in fact, for the treatment of gases generally.

Therefore, while I have particularly described my invention it is to be understood that this is by way of illustration and that changes, omissions, additions, substitutions and/or modifications might be made within the scope of the claims without departing from the spirit of the invention.

I claim:

1. A process for removing condensable materials from a gas comprising passing said gas serially through a plurality of unobstructed phase contacting paths countercurrently to absorbing liquid in spray form, the absorbing liquid entering each subsequent phase contacting path in the series being at a temperature lower than that of the absorbing liquid entering the preceding phase contacting path and sufficiently low to solidify a part of the condensate produced, the absorbing liquid introduced into each phase contacting path being a part of the condensate formed in said path after the separation of solid material therefrom, and utilizing the cold stored up in the finally treated gas in the reduction of the temperature of the absorbing liquid entering said phase contacting paths.

2. Apparatus of the kind described, comprising a plurality of towers, each tower having an unobstructed, phase contacting path, means for connecting said towers for the passage of gas serially therethrough and countercurrently in each path to a spray of absorbing liquid, means for obtaining the absorbing liquid for each path from the condensate formed in said path after separation of solidified material, means for reducing the temperature of the absorbing liquid for each path prior to its re-entry into said path, said last mentioned means maintaining the respective absorbing liquids entering said paths at successively lower temperatures in the series, and means for segregating and removing solidified material produced in each phase contacting path.

3. Apparatus of the kind described comprising a plurality of towers, each tower having an unobstructed, phase contacting path, means for connecting said towers for the passage of gas serially therethrough and countercurrently in each path to a spray of absorbing liquid, means for obtaining the absorbing liquid for each path from the condensate formed in said path after separation of solidified material, means for reducing the temperature of the absorbing liquid for each path prior to its re-entry into said path, said last mentioned means maintaining the respective absorbing liquids entering said paths at successively lower temperatures in the series, and means for segregating and removing solidified material produced in each phase contacting path.

4. Apparatus of the kind described comprising a plurality of towers, each tower having a phase contacting path adapted to permit the fall therethrough of solidified material, means for connecting said towers for the passage of gas serially therethrough and countercurrently in each path to a spray of absorbing liquid, means for obtaining the absorbing liquid for each path from the condensate formed in said path after separation of solidified material, means for reducing the temperature of the absorbing liquid for each path prior to its re-entry into said path, said last mentioned means maintaining the respective absorbing liquids entering said paths at successively lower temperatures in the series, means for segregating and removing solidified material produced in each phase contacting path, and means for utilizing the cold in the finally treated gas in reducing the temperature of said absorbing liquids in the order of increasingly higher temperatures thereof.

5. Apparatus of the kind described, comprising a plurality of towers, each tower having an unobstructed phase contacting path, means for connecting said towers for the passage of gas serially therethrough and countercurrently in each path to a spray of absorbing liquid, means for obtaining the absorbing liquid for each path from the condensate formed in said path after separation of solidified material, means for reducing the temperature of the absorbing liquid for each path prior to its re-entry into said path, said last mentioned means maintaining the respective absorbing liquids entering said paths at successively lower temperatures in the series and sufficiently low in at least one said path to solidify components of said gas, means for segregating and removing solidified material produced in each phase contacting path, and means for successively utilizing the cold in the finally treated gas in reducing the temperatures of said absorbing liquids in the order of increasingly higher temperatures thereof.

6. A process for recovering valuable hydrocarbons by absorption from a manufactured gas containing a part which readily solidifies upon reduction in temperature, said part including benzene, which comprises counter-currently contacting said gas while flowing upwardly with a dispersed downwardly flowing absorbing liquid having a temperature sufficiently low to solidify a part of the material which separates from the gas due to said contact, said contact taking place in a phase contacting path in a manner to permit the downward fall through said phase contacting path of solidified material, separating said solidified material from the liquid mixture of absorbing liquid and absorbed material resulting from said contact of gas and absorbing liquid, and recycling a cooled part of said separated liquid mixture as absorbing liquid.

7. A process for recovering valuable hydrocarbons by absorption from a manufactured gas containing a part which readily solidifies upon
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reduction in temperature, said part including benzene, which comprises flowing said gas serially through a plurality of phase contacting paths in each of which said gas is countercurrently contacted while flowing upwardly with a downwardly flowing dispersed absorbing liquid of considerably lower temperature, said contact taking place in a manner to permit the downward fall through any phase contacting path of solidified material formed in that path, the absorbing liquid in each subsequent phase contacting path in the direction of gas flow being of a temperature lower than that of the absorbing liquid in the preceding phase contacting path, the temperature of the absorbing liquid in at least one of said phase contacting paths being sufficiently low to solidify a part of the material separated from the gas by absorbing liquid, separating any solidified material from the liquid mixture of absorbing liquid and absorbed material formed in each phase contacting path as a result of said contact, and recycling a cooled part of said separated liquid mixture of each phase contacting path as absorbing liquid in said particular phase contacting path.

8. A process for recovering valuable hydrocarbons by absorption from a manufactured gas containing a part which readily solidifies upon reduction in temperature, said part including benzene, which comprises flowing said gas serially through a plurality of phase contacting paths in each of which said gas is countercurrently contacted while flowing upwardly with a downwardly flowing dispersed absorbing liquid of considerably lower temperature, said contact taking place in a manner to permit the downward fall through any phase contacting path of solidified material formed in that path, the absorbing liquid in each subsequent phase contacting path in the direction of gas flow being of a temperature lower than that of the absorbing liquid in the preceding phase contacting path, the temperature of the absorbing liquid in at least one of said phase contacting paths being sufficiently low to solidify a part of the material separated from the gas by absorbing liquid, separating any solidified material from the liquid mixture of absorbing liquid and absorbed material formed in each phase contacting path as a result of said contact, recycling a cooled part of said separated liquid mixture of each phase contacting path as absorbing liquid in said particular phase contacting path.

9. Apparatus of the kind described, comprising a tower having a phase contacting path adapted to permit the fall therethrough of solidified material, means for flowing a gas upwardly and a dispersed absorbing liquid downwardly through said phase contacting path for countercurrent contact therein, means for reducing the temperature of said absorbing liquid sufficiently to solidify constituents of said gas, means for separating solidified material from the liquid mixture of absorbing liquid and absorbed material resulting from said contact of gas and absorbing liquid, means for passing relatively warm incoming gas through said separating means in heat exchange relationship with separated solidified material, and means for recycling a part of said separated liquid mixture obtained from said path as absorbing liquid in said path.

10. A process for recovering valuable hydrocarbons by absorption from a gas containing a plurality of hydrocarbons including benzene which readily solidifies upon reduction in temperature, comprising contacting said gas with an absorbing liquid with which benzene is miscible, said absorbing liquid having a temperature sufficiently low to solidify a part of the benzene which separates from the gas due to said contact, said contact taking place in a phase contacting path in a manner to permit the removal from said phase contacting path of benzene in solidified form, separating solidified benzene from the liquid mixture of absorbing liquid and absorbed material resulting from said contact of said gas and said absorbing liquid, and recycling cooled absorbing liquid after said separation from solidified benzene.

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