

- [54] **FLASHING LIQUID REFRIGERANT AND ACCUMULATING UNVAPORIZED PORTIONS AT DIFFERENT LEVELS OF A SINGLE VESSEL**
- [75] Inventor: **Ronald S. Rogers**, Bartlesville, Okla.
- [73] Assignee: **Phillips Petroleum Company**, Bartlesville, Okla.
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- [58] Field of Search **62/9, 11, 40, 23, 24, 27, 62/28, 510, 512, 199, 200, 117**

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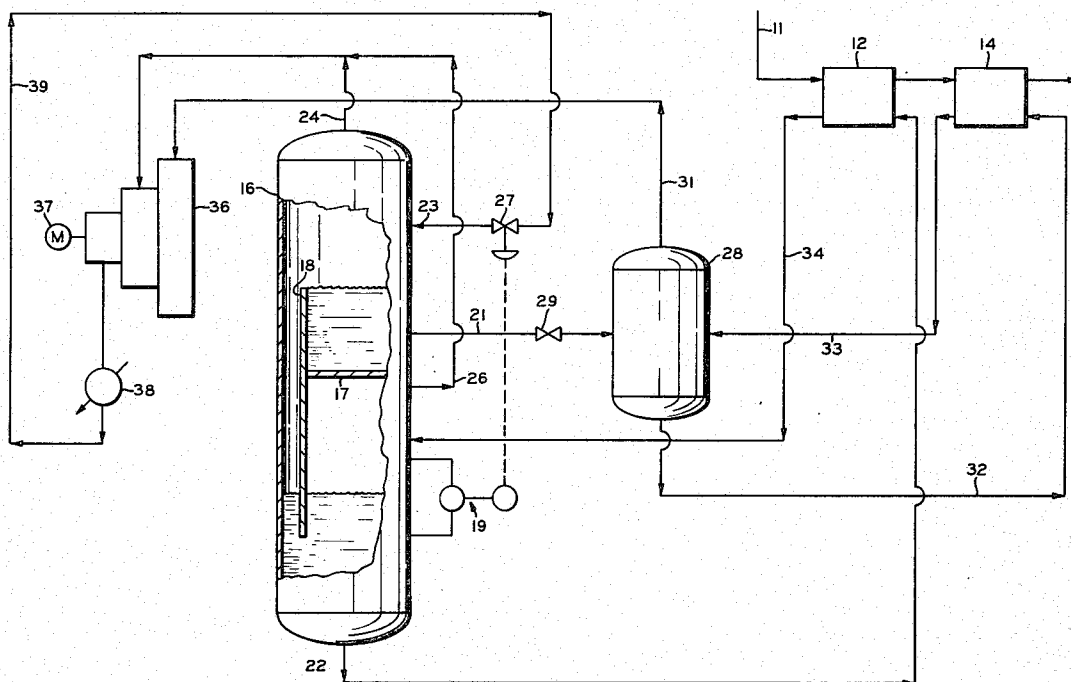
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Assistant Examiner—Frank Sever

[57] **ABSTRACT**

A liquid refrigerant is flashed into a chamber and the liquid accumulated in separate upper and lower pools from which liquid refrigerant is supplied to two separate refrigeration stages at different pressures. A flash vessel is provided comprising upper and lower liquid holding spaces.

10 Claims, 1 Drawing Figure



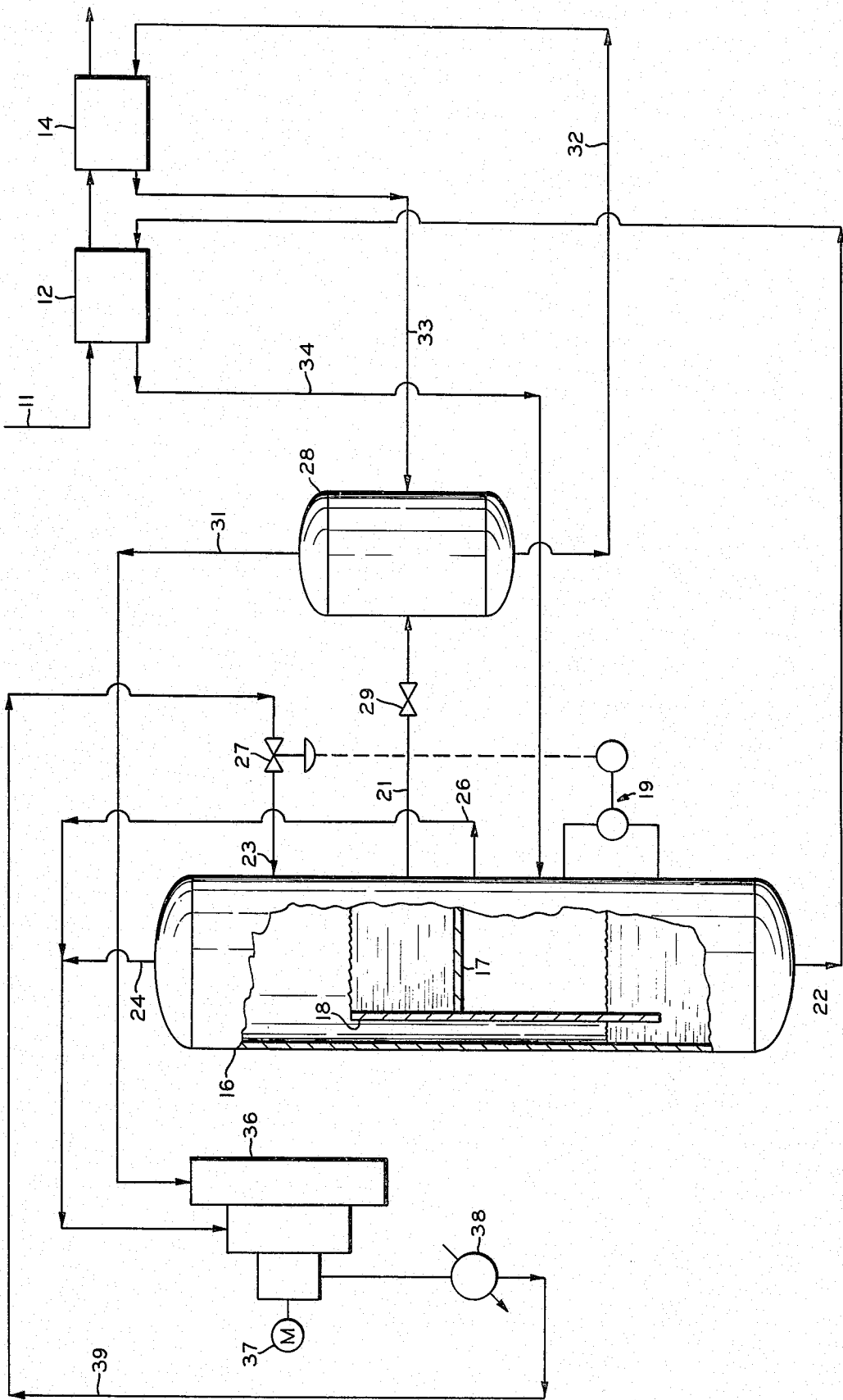


FIG. 1

FLASHING LIQUID REFRIGERANT AND ACCUMULATING UNVAPORIZED PORTIONS AT DIFFERENT LEVELS OF A SINGLE VESSEL

BACKGROUND OF THE INVENTION

This invention relates to a method and apparatus for plural stage refrigeration.

Systems involving plural refrigeration stages are known in the art, as for example in U.S. Pat. Nos. 3,581,510, Hughes, 1971, and 3,020,723 De Lury et al., 1962. In such a system it is desirable to reduce the size and cost of equipment as much as possible without reducing efficiency of operation.

SUMMARY OF THE INVENTION

According to my invention an improved refrigeration method is provided comprising flashing a liquid refrigerant in the upper portion of an enclosed chamber, accumulating unvaporized liquid at two levels in the chamber and utilizing the two separate pools of liquid in separate refrigeration stages at different pressures. Apparatus is provided comprising a closed vessel having a horizontally disposed liquid holding tray spaced from the bottom and a weir associated with the tray to permit accumulation of liquid on the tray at a given height while permitting overflow of excess liquid to a lower level.

In the normal operation of my invention it is preferred that the upper pool of liquid be used for the lower pressure stage of refrigeration, by subsequent flashing, while the lower pool of liquid is used at a higher stage of refrigeration, normally without further flashing. By so doing, it is possible to utilize a very simple level control, i.e., a level control on the lower pool controlling the inlet of refrigerant into the upper portion of the chamber and a weir on the upper level of liquid. Since the fluid returned to the lower portion of the chamber in this type of operation is only that removed from the lower portion of the chamber, the level control system permits efficient operation regardless of the balance between the two refrigeration stages. Since there is always some demand for additional liquid in the lower portion of the chamber, caused by evaporation of the liquid in performing the refrigeration function, the system automatically will keep the upper pool of liquid continually at weir height.

On the other hand, particularly in instances in which the balance of refrigeration permits, it is possible to utilize the upper pool for the higher pressure refrigeration stage and the lower level pool for the lower level refrigeration stage by further flashing. In the latter instance, however, to permit full utilization of the liquid surface available for separation of vapor and liquid is necessary to return fluid from the higher pressure stage (upper level liquid) to the lower portion of the vessel. Unless the balance between the two stages is such that overloading of the lower portion of the vessel is avoided, a more complex control system will be needed and a substantial amount of the advantages of the invention lost.

The drawing is a schematic representation of the invention utilized in a two-stage refrigeration system. The invention also is applicable for more than two stages with a single refrigerant system and of course can be utilized in a larger system in which more than one refrigerant is utilized.

Referring to the drawing, a fluid to be cooled enters through pipe 11 and flows through a first heat ex-

changer 12 and then through pipe 13 and second heat exchanger 14.

A closed vessel 16 is provided with a generally horizontally disposed liquid holding tray 17 spaced from the bottom of vessel 16, and a generally vertical baffle 18 extending downwardly from tray 17 to a location intermediate tray 17 and the bottom of vessel 16.

Tray 17, together with the vertical wall of vessel 16 and baffle 18 forms a first liquid holding space, the height of which is determined by the upper edge of baffle 18 which forms a weir. In the embodiment illustrated, the lower portion of vessel 16 forms a second liquid holding space. Liquid level controller 19 determines the upper level of liquid of the second liquid holding space and baffle 18 extends into the lower liquid holding space intermediate the top and bottom thereof.

A first fluid conduit 21 communicates with the first liquid holding space and with the exterior of vessel 16 to remove liquid from the first liquid holding space. A second fluid conduit 22 communicates with a second liquid holding space and with the exterior of vessel 16 to remove liquid from the second liquid holding space. A third fluid conduit 23 communicates with vessel 16 at a point above the level of liquid in the first liquid holding space but below the point of removal of vapor from the upper portion of vessel 16 to supply feed to vessel 16. A fourth fluid conduit 24 communicates with the upper portion of vessel 16 above the point of inlet of feed through conduit 23 (and also therefore above the first liquid holding space) to remove vapor from the upper portion of vessel 16. A fifth fluid conduit 26 communicates with the lower portion of vessel 16 above the second liquid holding space to remove vapor from the lower portion of vessel 16 below tray 17.

A control valve 27 is provided, under the control of liquid level controller 19, to regulate the inlet of liquid refrigerant into vessel 16 to maintain the desired level in the lower portion of vessel 16.

A second closed vessel 28 communicates with first fluid conduit 21 through a flash valve 29. A vapor removal conduit 31 communicates with the upper portion of vessel 28 for the removal of vapor therefrom.

First heat exchanger 12 has first and second heat exchanger passageways for refrigerant and process stream respectively. The inlet of the first passageway communicates with conduit 22.

Second heat exchanger 14 has third and fourth heat exchange passageways for flow of refrigerant and process fluid respectively and a sixth fluid conduit 32 is provided communicating with the inlet of the third passageway and with the lower portion of vessel 28. A seventh fluid conduit 33 communicates with the outlets of the third passageway and with vessel 28 at a point above the point of communication of the sixth fluid conduit, preferably at about the same level as the refrigerant inlet into vessel 28.

An eighth fluid conduit 34 communicates with the outlet of the first passageway of first heat exchanger 12 and with vessel 16 in the lower portion thereof for return of refrigerant to vessel 16.

In the refrigerant system a compressor 36 driven by motor 37 compresses vapor from vapor removal conduit 31, in a low pressure stage, and vapor from fourth conduit 24 and fifth conduit 26, in a higher pressure stage, the combined higher and lower pressure refrigerant being compressed to a desired condensation pres-

sure and passed through condenser 38 and returned through conduit 39 through third conduit 23 (controlled by valve 27) to the upper portion of vessel 16. Details of construction, controls, etc. known to those skilled in the art have been deleted from the description of the invention to avoid unnecessary complication. In particular it is noted that the pressure in vessel 16 is under the control of pressure control devices in the vapor removal system. Other items of equipment which may be necessary or desirable but which also are known in the art have also been deleted, such as for example refrigerant accumulation means, pressure control means, etc.

In a calculated example according to the present invention as illustrated in the FIGURE, a natural gas stream enters through pipe 11 with the following composition and conditions:

Component	Moles/Day
Helium	1,936
Nitrogen	55,412
Methane	769,593
Ethane	64,263
Propane	19,915
Isobutane	3,043
n-Butane	4,794
Isopentane	830
n-Pentane	1,014
Heavies	1,199
Total, moles/day	921,999
Temperature	= -65°F.
Pressure	= 550 psia

After heat exchange with cold ethylene in first heat exchanger 12, the natural gas stream flowing to second heat exchanger 14 at a temperature of -104°F. and a pressure of 545 psia. After additional cooling with still colder ethylene in second heat exchanger 14, the natural gas stream leaving the system from heat exchanger 14 has a temperature of -127°F. and a pressure of 540 psia, the composition in the stream leaving exchanger 14 being the same as that entering through pipe 11.

In the refrigerant system, the cooled liquid ethylene enters the system through pipe 39 at the rate of 731,571 moles/day, a pressure of 120.9 psia, and a temperature of -87.2°F. Upon passage through expansion valve 27, a substantial portion of the liquid ethylene flashes into vapor upon reduction in pressure to 51.3 psia with a resulting reduction in temperature to -112°F. The liquid in conduit 23 amounts to 670,000 moles per day or about 91.5 percent of the liquid ethylene entering through pipe 39 before flashing. Flashed vapor in conduit 23 amounts to 61,569 moles/day or about 8.5 percent of the stream in 39. Thus about 8.5 percent of the liquid in pipe 39 flashes upon reduction in pressure from 120.9 psia to 51.3 psia.

The flashed mixture of liquid and vapor flows into vessel 16 wherein the vapor portion exits via conduit 24. The liquid portion is partially retained in the upper compartment of vessel 16, as formed by tray 17 and baffle 18, with the remainder overflowing the weir of baffle 18 into the lower portion of vessel 16. Liquid ethylene at -112°F. at the rate of 203,051 moles/day is withdrawn from the second body of liquid refrigerant from the lower portion of vessel 16 through conduit 22 and passed through first heat exchanger 12 wherein it cools the natural gas stream as previously described.

The ethylene refrigerant is essentially completely vaporized in heat exchanger 12 and the resulting gaseous ethylene at -112°F. returned through conduit 34 to the lower portion of vessel 16. The gaseous ethylene, now free of entrained liquid ethylene, is removed from vessel 16 through conduit 26 and thence to compression, condensation and recycle. The amount of gaseous ethylene returned to vessel 16 is equal to the amount removed, i.e., 203,051 moles per day. The diameter of vessel 16 is sized to handle this volume of vapor, bearing in mind that the upper compartment handles 61,569 moles of vapor per day. By thus using a single vessel divided into upper and lower compartments, with each compartment handling part of the vapor, a tank with a smaller diameter can be employed with appreciable economies. Vessel 16, handling the above-mentioned quantities of refrigerant, requires a diameter of 10.7 feet. Without division into two compartments, that is if tank 16 were an open vessel handling the entire amount of the refrigerant, a diameter of 12.5 feet would be required.

Returning now to the liquid ethylene refrigerant in the first body of liquid refrigerant in the upper portion of vessel 16, refrigerant is withdrawn through conduit 21 at the rate of 466,950 moles per day and at a temperature of -112°F. Preferably the stream is heat exchanged with gaseous ethylene in conduit 31 by means of heat exchanger (not shown), the temperature thereby being reduced to -118.1°F. The stream is then flashed by passage through expansion valve 29 with a reduction in pressure from 51.25 psia to 27.69 psia with a corresponding reduction in temperature from -118.1°F. to -135°F.

Liquid ethylene is withdrawn from the lower portion of vessel 28 at the rate of 442,004 moles/day and passed via conduit 32 to second heat exchanger 14 where it boils at -118.1°F. and thereby cools the natural gas to a temperature of -127°F. as previously described. The now gaseous ethylene is returned to vessel 28 through conduit 34 and exits vessel 28 through conduit 31 to heat exchange with the stream in pipe 21 (not shown) and then returned to compression, condensation and recycle.

As explained above, a more economical refrigeration system has been devised wherein a flash tank is made smaller by dividing it into two compartments and thus dividing the flash vapors into two portions, as compared with flashing both portions in a single compartmented tank. Advantages also are obtained over the use of two completely separate flash vessels for the reason that the single (longer) vessel is cheaper to build than two separate flash vessels and also because the control system is simplified. That is a single liquid level controller suffices utilizing the flash vessel of the present invention whereas, with two separate flash vessels for the same function, separate control equipment would be required.

The invention is particularly suited for utilization in a system in which the refrigerant flash step is performed outside the heat exchangers. For example, heat exchangers 12 and 14 advantageously can be of the plate type as opposed to the shell and tube type, thus providing higher heat transfer rates. Reasonable variation and modification are of course possible within the scope of the invention as for example by extending tray 17 to cover the entire cross section of vessel 16 and replacing baffle 18 with a vertical pipe extending through

tray 17, by combining the invention into larger systems involving other stages of refrigeration, changing the shape and size of the vessels, adding additional control equipment, etc.

What is claimed is:

1. A refrigeration method comprising the steps of:
 - a. flashing a liquid refrigerant into the upper portion of an enclosed chamber thereby vaporizing a portion of said refrigerant;
 - b. accumulating unvaporized liquid refrigerant at an intermediate level in said chamber thereby establishing a first body of liquid refrigerant in said chamber;
 - c. flowing accumulated unvaporized liquid from a level above said intermediate level to a lower level in said chamber, thereby limiting the maximum level of said first body of liquid refrigerant and establishing a second body of liquid refrigerant at said lower level;
 - d. utilizing liquid from said first body and said second body of liquid refrigerant in separate refrigeration stages at different pressures; wherein a first vapor stream is removed from said chamber through a conduit in the upper portion thereof above said first body of liquid refrigerant and a second vapor stream is removed from said chamber through a conduit in the lower portion thereof below said first body of liquid refrigerant and above said second body of liquid refrigerant.
2. The refrigeration method of claim 1 wherein step (d) comprises:
 - flowing liquid from said second body of liquid refrigerant into a high pressure exchange stage without further flashing; and
 - flashing liquid from said first body of liquid refrigerant for use in a low pressure heat exchange stage.
3. The refrigeration method of claim 2 wherein said first vapor stream and said second vapor stream are combined, the combined vapor is returned to a refrigerant compressor, and said combined vapor is compressed, condensed and returned to step (a) as said liquid refrigerant.
4. The refrigeration method of claim 2 also including the step of passing a process stream being refrigerated in heat exchange first with said liquid from said second body of liquid refrigerant in said higher pressure heat exchange step and then with said flashed liquid from said first body of liquid refrigerant in said lower pressure heat exchange step.
5. Refrigeration apparatus comprising:
 - a. a closed vessel;
 - b. a generally horizontally disposed liquid holding tray in said chamber spaced from the bottom thereof;
 - c. a weir connected with said tray, said vessel, said tray and said weir being associated one with another to form a first liquid holding space from which liquid is permitted to flow from said tray into a lower portion of said vessel comprising a second liquid holding space only when the height of liquid on said tray is greater than the liquid overflow height of said weir;
 - d. a first fluid conduit communicating with said first

liquid holding space and with the exterior of said vessel to remove liquid from said first liquid holding space;

- e. a second fluid conduit communicating with said second liquid holding space and with the exterior of said vessel to remove liquid from said second liquid holding space;
- f. a third fluid conduit communicating with said vessel above said tray to supply feed to said vessel;
- g. a fourth fluid conduit communicating with the upper portion of said vessel above said first liquid holding space and above said third fluid conduit to remove vapor from the upper portion of said vessel; and
- h. a fifth fluid conduit communicating with the lower portion of said vessel above said second liquid holding space and below said tray to remove vapor from the lower portion of said vessel.

6. The refrigeration apparatus of claim 5 also including a generally vertical baffle extending downwardly from said tray to a location intermediate the top and bottom of said second liquid holding space.

7. The refrigeration method of claim 2 wherein fluid flows from said second body of liquid refrigerant to said high pressure heat exchange stage, is partially vaporized and returned to said chamber at a level below said first body and above said second body of liquid refrigerant.

8. The refrigeration method of claim 7 wherein the liquid from said first body of liquid is flashed in a second chamber from which liquid flows to said low pressure heat exchange stage, is partially vaporized and returned to said second chamber, and vapor is removed from said second chamber and returned to a refrigerant compressor at a first pressure and vapor from said first chamber is returned to said refrigerant compressor at a second pressure higher than said first pressure.

9. The refrigeration apparatus of claim 6 also including:

- a second closed vessel communicating with said first fluid conduit;
- a first heat exchanger having first and second heat exchange passageways, the inlet of said first passageway communicating with said second fluid conduit;
- a second heat exchanger having third and fourth heat exchange passageways;
- a sixth fluid conduit communicating with the inlet of said third passageway and with the lower portion of said second closed vessel;
- a seventh fluid conduit communicating with the outlet of said third passageway and with said second closed vessel at a point above said sixth fluid conduit;
- an eighth fluid conduit communicating with the outlet of said first passageway and with said closed vessel in the lower portion thereof.

10. The refrigeration method of claim 1 wherein said liquid refrigerant is substantially a single component refrigerant whereby the composition of refrigerant accumulated at said intermediate level is substantially the same as that accumulated at said lower level.

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