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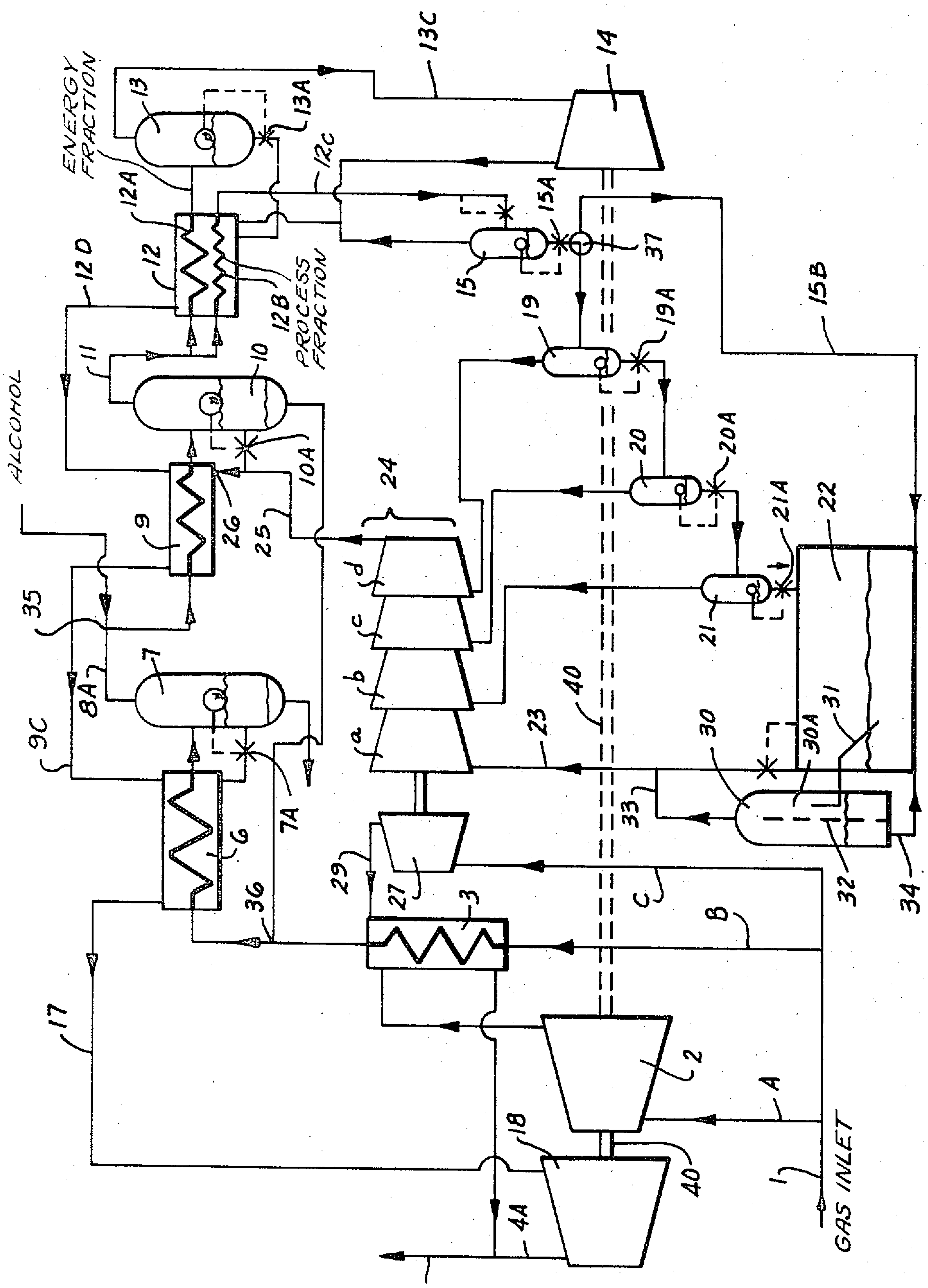

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LIQUEFACTION OF A GASEOUS MIXTURE EMPLOYING WORK EXPANDED GASEOUS MIXTURE AS REFRIGERANT

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ABSTRACT OF THE DISCLOSURE

A process of liquefying natural gas and the like wherein only the expansion energy of the gas is employed for liquefaction. A throughput portion of the gas is expanded and cooled by a turboexpander and then used to cool a liquid producing portion of the gas. Heavy hydrocarbons in the liquid producing portion are separated from this portion by countercurrent heat exchange with previously separated condensibles. The cooled and lighter liquid producing portion is divided into an energy fraction and a process fraction. The energy fraction is cooled and expanded by a second turboexpander and by countercurrent heat exchange cools the process portion to form and separate a liquid product. The liquid product is then flashed to atmospheric pressure and collected. Before expansion the throughput portion and the energy fraction are at pressure of the gas at the input of the process. The expansion of the throughput portion and the energy fraction generates mechanical work which drives a compressor. The compressor has its outlet at the pressure of the expanded throughput portion and its inlet at the pressure of the expanded energy fraction so that this latter pressure is maintained, and the expansion of the energy fraction is through a wide pressure differential.

This invention relates to the liquefaction of gas and in one of its aspects relates to a process for the liquefaction of natural gas which may consist of methane and relatively heavier hydrocarbons such as ethane, propane, butane, and the like, and in which only the expansion energy of the gas stream is used for refrigeration.

When natural gas is liquefied a very great reduction in volume is obtained which allows for storage in economical containers, or for transportation by vehicle in such containers to locations not served by a gas pipeline. In conventional liquefaction processes heretofore employed substantial refrigeration energy is generally required if the gas is to be completely condensed to a liquid having the same composition as the original gas. In such a process external liquefaction energy is generally required for a large part of the cooling and condensation processes because the pressure energies required to provide the large quantities of refrigeration necessary are usually greater than pressures available in the gas stream. It would be desirable, however, in many instances such as in remote locations, in order to conserve energy and resultant expense, to use only the expansion energy of the pipeline gas for the liquefaction energy. For example, it would be especially advantageous to liquefy at or near a natural gas well site a portion of the gas produced from the well, which liquid portion may then be stored or transported as a liquid while the main stream of gas is readied for pipeline transportation. This invention provides a process by which the desired liquid product portion can be provided in many such situations simply and economically by utilizing for refrigeration only the expansion energy of the natural gas as it is expanded from well pressure to a lesser pressure for pipeline transportation. In such a situation, if conventional methods are used the amount of refrigeration energy required is so

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great that, unless the expansion energy available is extremely large, only a small fraction of the gas stream could be condensed by the gas stream expansion energy, and this fraction would comprise only the more easily condensible components. In contrast, the process of this invention allows for complete condensation of a portion of a gas stream by the use of only the pipeline expansion energy, by using this energy to develop a larger expansion ratio across a small portion of the gas stream. In this manner the process may also utilize smaller and less expensive equipment.

If the gas stream includes some of the heavier hydrocarbons and it is not required that the liquid product be more enriched in these heavier components (for example in natural gas, the heavy hydrocarbons such as ethane, propane, butane and the like) than the original gas, the portion of the gas to be liquified can be stripped of some of these heavier components and the resulting lighter component, for example, methane will for all practical purposes be the energy equivalent of the original gas. This resulting constituent can then be liquefied by using the available energies in the heavy constituents separated and the original gas stream to form the liquid product. By use of this principle this invention provides, for example, for complete liquefaction of a portion of a main stream of gas by use of only the expansion energy of the main gas stream and without resultant loss of the gases employed, even though the expansion energy in the main stream of gas is relatively small.

It is thus an object of this invention to provide a process for the liquefaction of a small stream of gas from a main stream of gas, in which only the expansion energy of the main gas stream is used to accomplish the liquefaction.

It is a further object of this expansion to provide such a process in which the gas expanded for liquefaction is conserved.

Another object of this invention is to provide such a process and apparatus which will operate from a small expansion energy from the main stream of gas.

It is a further object of this invention to provide such a process which will permit the utilization of smaller and less expensive equipment than utilized in other processes for the same purpose.

The process of this invention may be used at almost any place along a pipeline. Generally, the available expansion energy in a pipeline is widely variable and it is desirable for the liquefying process to be operable at various pressures in order to take advantage of whatever energy is available in a stream of gas. Thus, it is another object of this invention to provide a process for liquefying gas which will operate on a variable expansion ratio in a main stream of gas.

When the liquid product of this process is in storage, a certain amount of evaporation will occur and it is a further object of this invention to provide as a part of a process for liquefying gas a method by which evaporation vapor from the liquid collected is conserved.

Also, the pressures through which the stream to be processed are expanded will be lower than the original pipeline pressure, and some points in the system can be near atmospheric. These points can provide injection points for flash gas and the like without the use of excessive equipment.

Other objects and advantages of this invention will become apparent during the course of the following descriptino and with reference to the accompanying drawing illustrating a preferred embodiment of this invention.

In the single figure of the drawing is shown a flow diagram through a liquefaction plant in which the process of this invention is utilized.

In accordance with this invention a main stream enters the process from a pipeline at a relatively higher input first pressure and discharges from the process into a pipeline at a relatively lower output second pressure. This main stream is first divided into a throughput portion and a liquid producing portion and energy is extracted from the throughput portion by expanding it to the output second pressure. The liquid producing portion is divided into an energy portion and a process fraction and energy and refrigeration is extracted from the energy fraction by expanding it to a third pressure lower than the output second pressure. The refrigeration from this expansion is used to cool and partially liquefy the process portion to provide the liquid product, and any gaseous residue is separated from the liquid. In order to insure that the third pressure is low, so that expansion of the energy fraction is through a wide pressure differential and the energy extracted from this stream is high, the extracted energies from the throughput portion and the energy fraction are utilized to withdraw the expanded energy fraction to maintain the third pressure. This withdrawal may be accomplished by discharging the expanded energy fraction into the output pipeline, after raising its pressure to output second pressure, along with the throughput portion.

The liquid product may be flashed to atmospheric pressure for storage and transportation, for example, by being introduced into successive flash stages at lower temperature and pressure.

If the main stream of gas contains more easily condensed heavy hydrocarbons these are separated from the liquid producing portion and utilized, after separation, for refrigeration energy to cool the liquid producing portion before it is divided into its energy and process fractions. After such refrigeration, these condensibles are withdrawn from the process with the expanded energy fraction.

The exhaust gases from the flashing step are also withdrawn from the process with the expanded energy fraction. First, however, expansion energy extracted from the main stream of gas is used to raise the pressure of these gases to the third pressure (the pressure of the expanded energy fraction) and these gases are injected into the expanded energy fraction for withdrawal therewith.

Referring to the drawing which shows a flow diagram of a preferred process of this invention and a preferred arrangement of a liquefaction plant utilizing this invention, a main stream of gas having, for example, a high content of a lighter component such as methane and a lower content of relatively heavier components such as the hydrocarbons, butane, ethane, and propane enter the liquefaction plant at the pipeline inlet **1** at high input first pressure and discharges from the plant at an outlet **4** at a relatively lower output second pressure. The difference between the mass of this stream at the inlet **1** and the outlet **4** represents substantially the mass of the liquid product from the process.

As the main stream of gas enters the liquefaction plant it is divided into three portions indicated in the drawing as the streams A, B and C.

The stream B represents a liquid producing portion of the main stream of gas which will be treated by the process of this invention and from which the liquid product is to be obtained. The stream of gas as it enters the inlet less the stream B, comprises a throughput portion of the main stream of gas which is divided into the streams A and C. Streams A and C are utilized in supplying part of the necessary liquefaction energies for this process from this main stream of gas.

The stream B contains the same relatively heavier components which may be included in the main incoming stream and the initial step of this process is to separate some of these components from this stream B. As shown in the preferred embodiment, this separation is accomplished by passing the stream B through cascaded heat exchange zones and extracting pressure energy from the stream A and thermal energy from the separated components of stream B. Of course, if the main stream of gas does not contain any of these heavier components, this step would be unnecessary.

A turboexpander **2**, heat exchangers **3**, **6**, **9** and **12** and separator vessels **7**, **10** and **13** are utilized in the preferred embodiment in performing the separation step. The stream A passes through the turboexpander **2** and is expanded through the turboexpander **2** to the outlet **4** pressure and is thus cooled, while doing mechanical work. The cooled stream discharges from the expander into the cold end of the heat exchanger **3**. The stream B is also passed through the heat exchanger **3** entering at the warm end, and is cooled by countercurrent heat exchange with the stream A. The stream A is warmed and discharged to the outlet **4** from the warm end of the heat exchanger **3**.

The stream B passes successively through the heat exchanger **6** and into the separator **7**, through line **8A** into and through the heat exchanger **9** into the separator **10**, and through line **11** into the heat exchanger **12**. As this stream is cooled, the condensed heavier hydrocarbons are collected in the bottom of the separator vessels **7** and **10** to be used as refrigerants in the prior heat exchange stages **6** and **9**. When adequate levels of stored liquid refrigerants are reached in these separators **7** and **10**, level control valves **7A** in separator **7** and **10A** in separator **10** allow part of the stored liquid to pass into the return passes in the heat exchangers **6** and **9**. In this manner the liquid hydrocarbons re-evaporate in the heat exchangers **6** and **7** and take up latent heat of evaporation to cool the stream passing through these heat exchangers. The exhaust gas formed by this re-evaporation may be discharged as a discharge stream into the discharge outlet **4** in the manner set out below.

The residue of the liquid producing portion from the separating step described above is divided into two streams, one constituting an energy fraction and the other constituting a process fraction, and these fractions enter the heat exchanger **12** from the line **11** in two parts. The energy fraction, which constitutes a major part of the stream B, continues through the heat exchanger **12** through the pass **12A** and into the separator vessel **13**. The process fraction which constitutes a minor part of the stream B passes through the pass **12B**. Condensed products are separated from the energy fraction in separator **13** and discharged back to the heat exchanger **12** as a refrigerant for cooling through a level control valve **13A**. The residue gas from this separation in the separator **13**, has, in all the stages of cooling and separation, been well stripped by partial condensation of the heavier hydrocarbons and consist substantially of methane gas at substantially inlet **1** pressure, but at a considerably lower temperature. Pressure energy is extracted from the residue of the major part by expansion as it is passed via line **13C** to a low temperature turboexpander **14** where, while doing mechanical work to generate power it undergoes a substantial pressure reduction to a third pressure lower than the output second pressure and is further cooled. The turboexpander **14** is coupled by the drive shaft **40** to the turboexpander **2** so that they are operated in unison. This expansion provides the main refrigeration requirements for the process. In order to best utilize the expansion energy available and permit the use of small equipment for liquefaction, it is preferred that the energy fraction be small relative to the main stream and that it be expanded through a wide pressure difference.

The outlet of turboexpander **14** is connected to the return pass of exchanger **12**, and a shaft **40** of turboexpander **2** and **14** is connected to drive a compressor **18**. The compressor **18** inlet **17** is connected to the return passes of the heat exchangers **6**, **9**, and **12** into which turboexpander **14** discharges at said third presure. Thus, the compressor **18** constantly withdraws gases accumulated in these return passes so that the third pressure, which is substantially lower than the second pressure is maintained, and the energy fraction is expanded through a wider pressure ratio than the stream A. The outlet **4***a* of compressor **18** is at outlet second pressure, and discharges the gases in the return passes into outlet **4** at this pressure.

Thermal energy is thus extracted from the expanded energy portion and utilized to assist in liquefying the process portion. The expanded and cooled energy portion is injected into the cold end of the heat exchanger **12** and from there flows back through the return passes of the heat exchangers **6** and **9**, and any liquid extracted therefrom re-evaporates to absorb heat and thus also generates refrigeration. These sources of refrigeration cool and partly liquefy the process portion in the incoming pass **12B** of the heat exchanger **12**. The liquid produced from this process portion which also consists mostly of liquid methane due to the earlier condensation and separation of the heavier hydrocarbons, is still at nearly the inlet **1** pressure, and must be reduced to atmospheric pressure for storage. The temperature of the liquid must also be reduced to the boiling point of methane at atmospheric pressure which is −258° F.

In order to accomplish this reduction in pressure and temperature the liquid methane is flashed to atmospheric pressure by, for example, being subjected to successive stages of flashing at successively lower pressures until atmospheric pressure is reached. In the preferred embodiment shown the liquid is passed by the line **12C** through a series of stage separators **15**, **19**, **20** and **21** containing flash gases at successively lower pressure and into a storage vessel **22** at atmospheric pressure.

Referring to the cold liquid separated in separator **15**, it has a part of its pressure released by a level control valve **15A** and is discharged into the stage separator **19** at the pressure in separator **19**. The liquid from separator **19** is discharged at lower pressure, the stage pressure of separator **20**, into separator **20** via level control valve **19A**; the liquid from separator **20** discharges at a still lower pressure via level control valve **20A** into separator **21** which discharges its liquid at a still lower pressure, namely atmospheric pressure, via level control valve **21A** into storage tank **22**. During this process the liquid is cooled by expansion to approximately −258° F., the boiling point of methane at atmospheric pressure.

The process of this invention in its preferred embodiment also includes the step of returning the flash exhaust gases from the flash stages and the storage tank **22**, plus any evaporation gas from this storage tank, to the return passes of the heat exchangers and thence re-injecting them into the main stream of gas along with the re-evaporated condensate in these return passes. In order to accomplish this step the exhaust gases must be compressed and incidentally warmed to a pressure at which they can be injected into the return passes of the heat exchangers, and injected preferably at points near where the temperatures match. This step may utilize, for example, a multi-stage compressor **24** driven by a turboexpander **27** for this purpose. The turboexpander **27** is driven by the expansion of the stream C while such stream does mechanical work.

The flash and evaporation gases from the flashing step pass into the suction of the compressor **24**, which has four stages, *a*, *b*, *c* and *d*. The flash stage pressures match the suction pressures of the successive compressor stage. For example, the first stage *a* of compressor **24** takes suction at approximately atmospheric pressure which is the pressure of the last flashing stage maintained in tank **22**. Stage *a* of compressor **24** discharges into stage *b* of the compressor. This stream into stage *b* is joined by the flash gas from separator **21** to be compressed in stage *b* and discharged from stage *b* into stage *c*. In entering stage *c* it combines with flash gas from separator **20** to be compressed in stage *c* and discharged into stage *d*, joined as it enters stage *d* by flash gas from separator **19**. The discharge from stage *d*, which is the compressor discharge, passes through line **25** to a point in the return passes of the heat exchanger system where the temperatures match, illustrated by point **26**. The streams of gas passing from the flashing stages to the compressor **24** are all cold and the compressor therefore requires less energy than if this gas had been warm before compression. The gas injected at point **26** from the compressor **24** will still be cold despite its compression accompanied by some warming.

The stream C of incoming pipeline gas cooled by its expansion is exhausted from the expander **27** through line **29** into the cold end of heat exchanger **3** where it aids in cooling.

During the process of heat exchanging in exchangers **6**, **9** and **12** referred to above, residual exhaust gases in the return passes of the heat exchangers are formed as the condensates from separators **7**, **10** and **13** re-evaporate. The return passes of heat exchangers **6**, **9** and **12** are connected in series. The outlet of the return pass of exchanger **12** is connected to the inlet of the return pass of exchanger **9** by a line **12***d*, the outlet of the return pass in exchanger **9** is connected to the inlet of the return pass in exchanger **6** by a line **9***c*, and the outlet of the return pass in exchanger **6** in connected to the intake of compressor **18** by a line **17**. The pressure in the return passes of these heat exchangers is maintained at the third pressure which is lower than the output second pressure of the withdrawal of gases therefrom by the suction of the compressor **18**. In order to conserve these exhaust gases they are reinjected into the main stream of gas at the discharge outlet **4** after being compressed by compressor **18** to the output pressure at **4**. Also discharged at **4** is the exhaust from heat exchanger **3** which includes partially expanded streams A and C. Thus, the mass of gas at this point is substantially that which originated at the inlet **1** less the mass of the liquid collected and stored.

The compressor **18** is driven by the turboexpanders **2** and **14** and absorbs all the power from these expanders. These turboexpanders are driven entirely from the gas stream as is the turboexpander **27**, by the pressure difference or expansion ratio between the inlet **1** and the discharge **4** of the main stream of gas and the expansion ratio of the liquid producing portion. Another important feature of this invention is that even though this expansion ratio is small, it is possible, by proper proportioning of streams A, B and C and limitation of the amount to be ultimately liquefied, for the energy available from these streams to be sufficient to drive the turboexpanders **2** and **14** which in turn drive compressor **18** for increasing the expansion ratio available on the liquid producing portion which is subjected to low temperature processing. That is, the compressor **18** maintains the low pressure in the return passes of the heat exchangers into which the outlet of turboexpander **14** discharges.

In order to return the exhaust gases from the process back into the discharge stream, the pressure on the incoming stream before processing could be increased, or the pressure on the exhausting stream from the process could be decreased. In a preferred embodiment shown, the latter is done so that the special multi-stage compressor **24** for the flash gas has a pressure as low as possible into which it may discharge.

In operation, the pressures in the pipeline and the pressures at the inlet **1** and the outlet **4** may vary. As the pressures at these points come closer together the main turboexpander **2** will generate less power for a given proportion between streams A, B and C, and therefore compressor **18** will reduce the discharge pressure on turbo-expander **14** a lesser amount. This will mean a lesser amount of liquid forming in separator **15**. However, with suitable construction of compressor **18**, it can operate so as to pass a smaller flow of gas while maintaining a somewhat improved compression ratio, thereby alleviating this situation somewhat. As the pressure at the suction **17** of compressor **18** rises, it is necessary for compressor **24** to discharge at a higher pressure into line **25** in order to put its discharge into the system at point **26**. This must be accomplished while the pressure ratio across the inlet and discharge of the process is reduced. By using widely variable nozzles in turbine **27** so as to vary the quantity of gas and thereby compensate somewhat for a smaller pressure differential it can operate to maintain the same or higher power thereby making the necessary power available to accomplish the compression job required of compressor **24**.

When the liquid separated in separator **15** is small, the flash gas from it as it passes through stage separators **19**, **20** and **21** may be insufficient to prevent the stages in compressor **24** from surging (a characteristic of centrifugal compressors). One method which may be used to avoid surging is to establish a minimum closure on the level control valves in the various stage separators so that if there is insufficient liquid to form enough gas to supply the compressor requirements, the valve closure is not sufficient to maintain a level in the separator and some gas goes along with the liquid. This gas makes up the necessary requirements in each of the stages of compressor **24**.

When the pressure difference across the inlet **1** and the discharge outlet **4** is insufficient to power the turbine **27** for the maintenance of the necessary pressures therein, the turbo-expander **27** and compressor **24** may be shut down and a liquid product from a stage separator **15** may be by-passed directly into the storage tank **22** through a three-way valve **37** and line **15B**.

Also, when the expansion energy is low, less refrigeration will be produced in the turbo-expander **14** and, thus, less liquid will be produced from the pass **12B** of heat exchanger **12**. That which is produced, however, must be flashed to atmospheric pressure for storage.

As a preferred way to accomplish this, the lower layers of liquid in the storage tank **22** may be sub-cooled below the boiling point of liquid methane to be cold enough to absorb all of the flash gas from this stream.

This sub-cooling is accomplished because when the pressure coming into inlet **1** is high with respect to the discharge pressure at the outlet **4**, turbo-expander **27** has ample power to generate more than the normal compressor ratio in compressor **24**. At such times a vacuum is pulled on vessel **30** connected to liquid storage tank **22** for communication therewith through the line **33**. Liquid from near the surface in storage tank **22** enters through a line **31** into a chamber **30A** on one side of a perforated baffle **32** disposed vertically in the storage vessel **30**. Liquid so entering from the storage tank **22** flashes into vapor and liquid in the vessel **30**, and the vapor leaves through line **33** and is exhausted with vapors from the storage tank through compressor **24** as previously stated. The sub-cooled liquid returns on the other side of perforated baffle **32** to the bottom of vessel **30** and returns to the lower zone of liquid storage through line **34** thus cooling the lower portions of the liquid in storage tank **22**, below the boiling point of the stored liquid so that when the liquid comes in from line **15B**, as above described, it may be absorbed and cooled. The upper layer of liquid in the storage tank **22** remains warm (at the boiling point of the liquid) because it is undisturbed and stays there because of its lower density. This prevents a vacuum from being developed in storage tank **22**. To further guard against such a vacuum an atmospheric gas inlet line (not shown) may be provided to protect the storage tank **22**.

Referring to turbine **14**, the gas that it received through the line **13C** must have a water dew point at least as low as −75° F. Furthermore, heat exchangers and the like would be fouled by a gas that has a higher dew point. To meet this requirement, regenerated concentrated alcohol may be injected at point **35** so that it passes concurrently with the gas in heat exchanger **9** as it is cooled down to −75° F. This removes all the water down to that temperature and reduces the water vapor pressure of the gas leaving separator **10** by many degrees more by virtue of its contact with alcohol. The alcohol is separated in the lower section of separator **10** and recovered for introduction (by any suitable, well known means, not shown) at point **36** into the inlet of heat exchanger **6**. This partially diluted but still effective alcohol passes along with the gas as it is chilled in the heat exchanger **6** and separated in separator **7** where it is by this time well diluted by the rather large quantity of water available at this high temperature. The alcohol is removed from the bottom zone of separator **7** and discharged for recovery or other disposition.

In the preferred arrangement of the liquefaction plant, the heat exchangers **3** and **6**, separator **7**, heat exchanger **9**, separator **10**, heat exchanger **12** and separator **13** are cascaded so that the portion to be processed to produce the liquefied product passes successively into and through each of them and the heavier hydrocarbons are successively condensed therefrom and returned countercurrently in the return passes of the heat exchangers for recovery of refrigeration energy. The storage separators **15**, **19**, **20**, **21** and the storage tank **22** are also cascaded and connected to receive via the pass **12B** of heat exchanger **12** the portion to be finally processed to produce the liquefied product.

As one specific example only of the above process the following values of temperature, pressure, quantities, etc., to be found at different points in the flow diagram of the process, are given. A quantity of gas 400 million standard cubic feet per day (hereafter referred to as MM at an inlet first pressure of 535 p.s.i.a. and 38° F., enters at the inlet **1** and is divided into streams of 275 MM, 114 MM and 11 MM, representing the streams A, B and C, respectively. The streams A and C are expanded and cooled to an outlet second pressure of 380 p.s.i.a. and 8° F. through the expanders **2** and **27** and are warmed to 40° F. as they leave the warm end of the heat exchanger **3**. The discharge stream at the outlet **4** is 393.15 MM, 380 p.s.i.a. and 40° F.

The stream B less components separated from it is successively cooled from 38° F. to 15° F. at the point **36**, −30° F. at the point **35**, and −75° F. in the line **11** and the quantity of this stream is 114 MM, 107 MM and 100 MM, respectively, at these points. The reduced quantity is a result of the separation of condensed heavier components.

The residue from the major part of the stream B as it enters the turboexpander **14** is 93.5 MM, at 535 p.s.i.a. (ideally) and −120° F., and is expanded and cooled to a third pressure lower than said second pressure of 150 p.s.i.a. and −186° F. as it discharges from the expander **14**.

The minor part of the stream B in the pass **12B** is at 10.7 MM, 535 p.s.i.a. and −130° F. It is successively flashed in the separators **15**, **19**, **20**, **21** and the storage tank **22** to 9.7 MM at 85 p.s.i.a. and −211° F., 8.6 MM at 50 p.s.i.a. and −228° F., 7.9 MM at 30 p.s.i.a. and −242° F., and 6.9 MM (the liquid product) and .42 MM vapor at 14.7 p.s.i.a. (atmospheric) and −258° F. The declining volume represents the vapors flashed in each stage separator, which are conserved through the compressor **24**.

In the above example the turbo-expander **2** develops 3064 horsepower and the turboexpander **14**, 2166 horsepower. The compressor **18** absorbs all this power and its inlet pressure is 150 p.s.i.a., the pressure in the return passes of the heat exchanger and it discharges at 380 p.s.i.a. into the outlet **4**.

The turboexpander **27** develops 114 horsepower and this is utilized by the compressor **24** which discharges at the point **26**, 2.8 MM of the exhaust flash vapors at 150 p.s.i.a. and −114° F. The vapor from the separator **15**, 1 MM at 150 p.s.i.a. and −186° F. is injected into the return pass of heat exchanger **12** along with the discharge of the turboexpander **14**.

In the above example, as a result of the conservation of the gases employed for energy by injecting them in the outlet **4**, the volume of gas at the outlet **4** (393, 15 MM) represents approximately the volume at the incoming stream of gas at the inlet **1** (400 MM) less the liquid product collected (6.9 MM).

All of the equipment employed in the above-described process and as components of the liquefaction plant shown as an example for practicing this invention, as distinguished from the system and the arrangement and connections of components, are conventional and readily available to those skilled in the art.

From the foregoing, it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus and process.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. A process for obtaining a liquefied fraction from a main stream of gas available at a relatively higher input first pressure and disposable at a relatively lower output second pressure, comprising the steps of: (a) dividing said main stream of gas into a throughput portion and a liquid producing portion, (b) dividing said liquid producing portion into an energy fraction and a process fraction, (c) expanding said energy fraction to a third pressure lower than said second pressure to extract energy therefrom and produce refrigeration, (d) cooling and partially liquefying said process fraction with said refrigeration from said expanded energy fraction, (e) separating the gaseous and liquid parts of said process fraction to produce the desired liquid product, (f) expanding said throughput portion to said second pressure while extracting energy therefrom, and utilizing a part of said extracted energy from said throughput portion to withdraw said expanded energy fraction to thereby maintain said third pressure.

2. The process of claim **1** wherein the main stream of gas contains more easily condensed heavy hydrocarbons and further including the steps of: utilizing the extraction of energy from said throughput portion to cool said liquid producing portion; further cooling the liquid producing portion and separating condensate therefrom, and reevaporizing said condensate by expanding it to said third pressure and further cooling the liquid producing portion by use of the refrigeration produced in such revaporization.

3. The process of claim **2** further including the step of utilizing a part of said extracted energy from said throughput portion to raise said revaporized condensate to said output second pressure for discharge with said throughput portion.

4. The process of claim **1** wherein the liquid producing portion is cooled before division into said energy and process fractions by refrigeration generated by the extraction of energy from said throughput portion.

5. The process of claim **1** wherein the process portion is flashed, after said cooling and liquefaction, to said third pressure, and the gaseous residue therefrom is withdrawn with said expanded energy fraction.

6. The process of claim **5** wherein said gaseous residue and expanded energy fraction withdrawal step includes utilizing said extracted energy from said throughput portion to raise said withdrawn expanded energy fraction and gaseous residue to said output pressure for discharging them with said throughput portion.

7. The process of claim **5** wherein the liquefied process portion is flashed to atmospheric pressure and the vapors therefrom are collected and withdrawn with said gaseous residue and expanded energy fraction.

8. The process of claim **7** wherein said withdrawal step includes utilizing another part of the extracted energy from expansion of said throughput portion to compress the vapors from the flashing to said third pressure, and bypassing to said compression step unliquefied gas from previous treatment of said process fraction when gas from said flashing falls below a predetermined minimum to prevent surging in said compression step.

9. The process of claim **7** wherein the flashing is accomplished in successive stages of lowering pressure each lower than said third pressure and said withdrawal step includes utilizing another part of the extracted energy from expansion of said throughput portion to raise the vapors from each stage of flashing to said third pressure, and utilizing said extracted energy from expansion of said throughput portion and energy fraction to raise said vapors, said residue gas, and said expanded energy fraction from said third pressure to said output second pressure for discharging with said throughput portion.

10. The process of claim **5** wherein the liquid from the flashed process portion is collected in a stored body at said third pressure and during a period of higher available expansion energy in said main stream of gas a part of the energy from expansion of said throughput portion is utilized to subcool the liquid at a lower level in a further stored body at atmospheric pressure.

11. The process of claim **10** wherein, during a later period of lower available expansion energy in said main stream, the unflashed process portion is passed directly into a lower level of said stored body at atmospheric pressure and simultaneously cooled and flashed therein whereby excessive gas loss from such flashing is avoided.

12. The process of claim **5** wherein the liquid from the flashed process portion is collected in a stored body and during a period of higher available expansion energy in said main stream another part of the energy from expansion of said throughput portion is utilized to withdraw a portion of said liquid and flash it to a pressure below said third pressure, withdraw the gaseous residue therefrom and reinject the liquid therefrom into a lower level of said stored body to subcool the same at said lower level, and during a later period of lower available expansion energy in said main stream, the unflashed process portion is passed directly into a lower level of said body and simultaneously cooled and flashed therein whereby excessive gas loss from such flashing is avoided.

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