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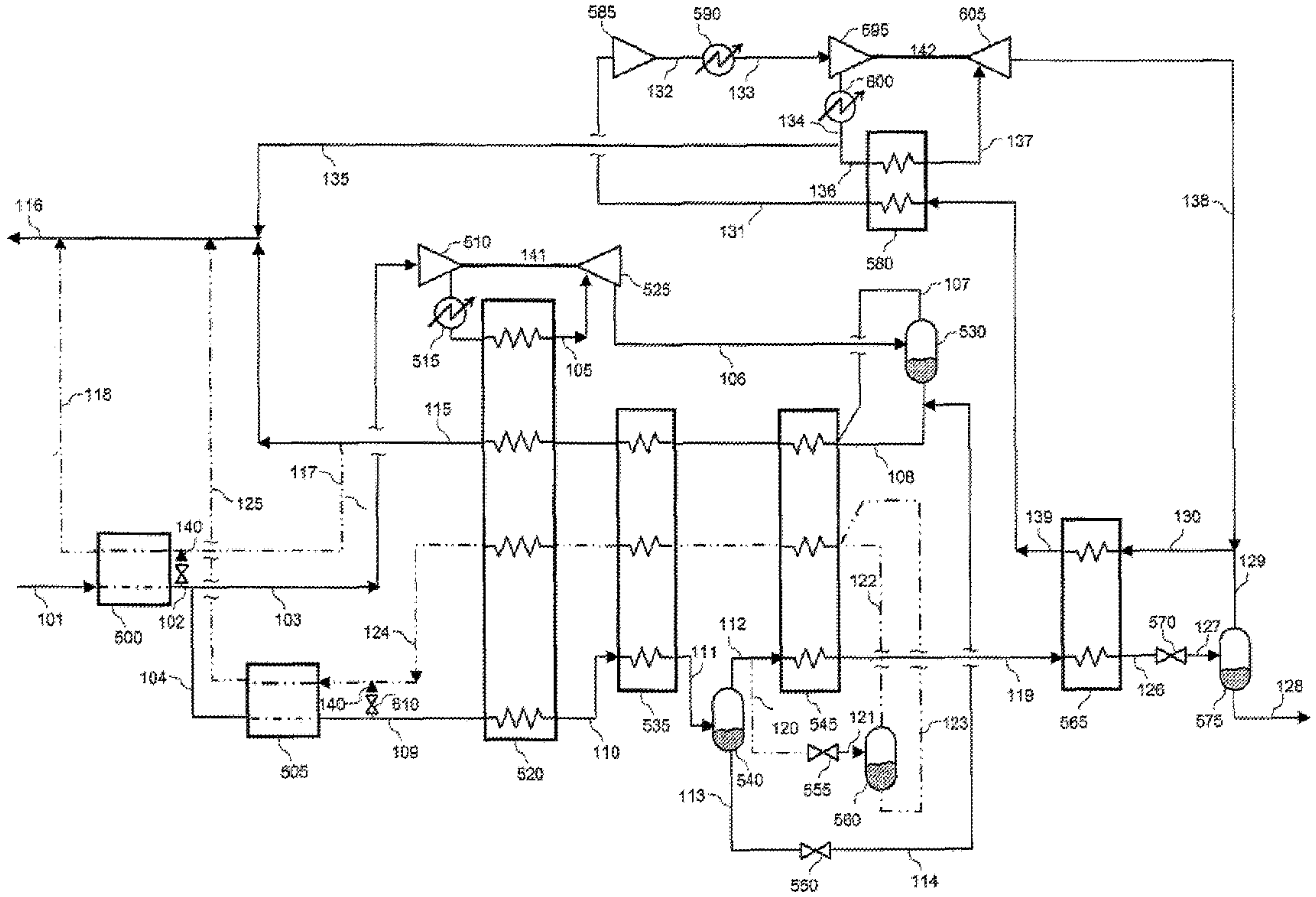

(57) **Abrégé/Abstract**:

A method for liquefying natural gas using the pressure energy of the natural gas, wherein flash vapor from natural gas depressurization is employed in a refrigeration cycle for subcooling high pressure natural gas prior to flashing.

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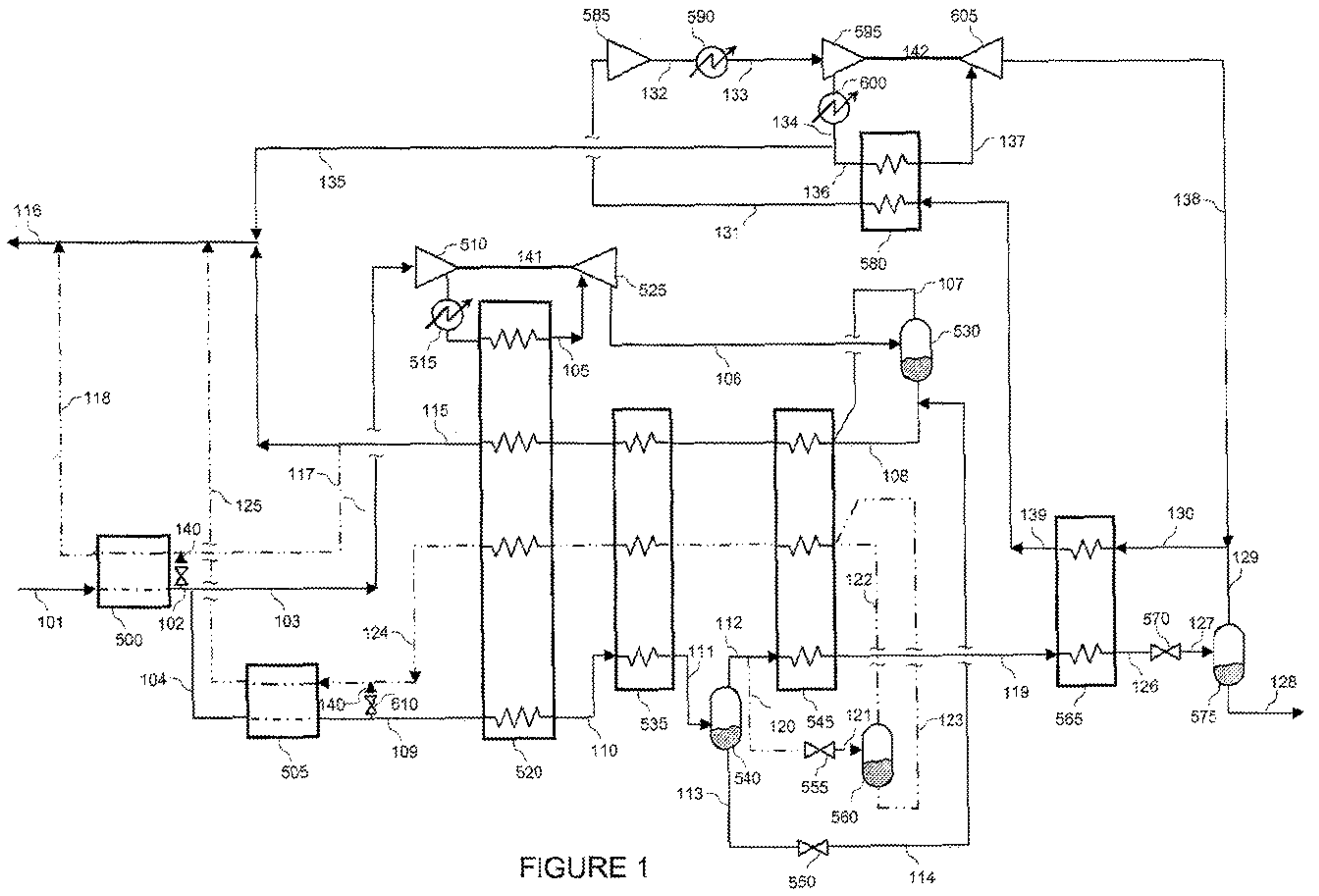

FIGURE 1

(57) **Abstract:** A method for liquefying natural gas using the pressure energy of the natural gas, wherein flash vapor from natural gas depressurization is employed in a refrigeration cycle for subcooling high pressure natural gas prior to flashing.

METHOD FOR PRODUCING LIQUEFIED NATURAL GAS

Technical Field

[0001] This invention relates generally to the production of liquefied natural gas and, more particularly, to the production of liquefied natural gas (LNG) using cryogenic expansion and the pretreatment of the natural gas for use in such a process.

Background Art

[0002] Typically, natural gas transmission pipelines operate at pressures ranging between 400 and 1500 psia. Natural gas (NG) pressure reduction points are often referred to as let-down stations. Such stations enable the regional distribution of natural gas (typically at pressures of 100 to 600 psia). In general, let-down stations are not designed for the useful recovery of the pressure energy. Processes which serve to let-down natural gas while producing a fraction of the inlet gas as liquefied natural gas are often referred to as expander cycles or expander plants.

[0003] Typically in an expander plant, only 5-10% of the feed flow can be liquefied by pressure letdown alone. Also, to obtain refrigeration at the very low temperatures required for NG liquefaction, a significant part of the cold NG will be lost at depressurization as flash gas. This flash gas can be used as regeneration for the pre-treatment system, but usually there will still be a portion remaining, which will be returned to the low pressure pipe-line, after re-compression. This increases the power requirement of the plant, and lowers the efficiency of the LNG letdown station.

[0004] In order to minimize the unit cost of LNG without affecting the heat transfer efficiency, two main directions can be taken: one is to minimize the pre-treatment required, and the second is to increase the production such as the plant will become more profitable.

[0005] U.S. Patent No. 7,134,296 describes a method for cooling a product gas wherein a working gas undergoes a staged expansion to a first temperature and a subsequent turbo-expansion to a second higher temperature and both expanded gas and the turbo-expanded gas provide cooling to the product gas. The turbo-expansion uses at least a portion of the warmed gas expanded in the first stage, the remaining portion being pressure boosted, preferably using the shaft work of turbo-expansion.

[0006] U.S. Patent No. 3,503,220 describes a process for natural gas liquefaction using solely letdown pressure energy, without additional refrigeration/work input. Even though the pressure ratio is relatively high (7/8), the LNG product is only 12% of feed due to very low feed pressure level (189 psia). The feed is split into working gas and liquefaction gas and warm end refrigeration is provided by turbo-expansion of working gas with the work produced being used to boost the pressure of the liquefaction gas. A portion of the refrigeration available at the warm end can be shifted to the cold end.

[0007] U.S. Patent No. 6,131,407 describes a process for liquefying nitrogen, oxygen or argon from an air separation unit using natural gas letdown as a source of refrigeration. The feed is split into two portions, one providing refrigeration for the warm end and the other providing refrigeration for the cold end. All feed is dehydrated and the second portion is further treated for carbon dioxide removal. Warm end refrigeration is provided by turbo-expansion of the working gas. The preferred embodiments show an electric generator brake on the expander. However, the energy from the expander can be used for compression of either nitrogen or natural gas at either higher or lower pressure levels to increase the pressure ratio of the expander and increase the liquefaction capacity of the letdown liquefaction unit. Cold end refrigeration is provided by two step cascaded Joule-Thomson expansion.

[0008] U.S. Patent No. 6,694,774 describes a process for liquefying natural gas using natural gas letdown to provide the warm end refrigeration and mixed gas refrigeration (MGR) for cold end refrigeration. The feed is split into working gas and liquefaction gas and warm end refrigeration is provided by turbo-expansion of the working gas. The energy produced by the expander is used in the MGR compressor.

[0009] U.S. Patent No. 7,228,714 describes a method for producing LNG wherein high pressure LNG is subcooled and then flashed to form flash vapor and LNG product, and the flash vapor is employed in a refrigeration cycle to generate refrigeration for subcooling the LNG. However, this process does not recover pressure energy from the regeneration gas before sending the regeneration gas for carbon dioxide removal.

[0010] Accordingly, it is an object of this invention to provide an improved method for producing liquefied natural gas using subambient expansion.

Summary of the Invention

[0011] The above and other objects, which will become apparent to those skilled in the art upon a reading of this disclosure, are attained by the present invention which is:

[0012] A method for producing liquefied natural gas comprising:

[0013] compressing a first portion of a high pressure natural gas, bringing it to a temperature above its dew point and turbo-expanding such first portion to produce at least a part of the refrigeration required to liquefy the remaining second portion of the natural gas;

[0014] liquefying the remaining second portion of the natural gas and subcooling said liquefied second portion and flashing the subcooled natural gas to produce flash vapor and liquefied natural gas at low pressure;

[0015] compressing a refrigeration gas and turbo-expanding the compressed refrigeration gas to produce cooled refrigeration gas; and

[0016] warming the flash vapor and the cooled refrigeration gas by indirect heat exchange with the high pressure natural gas to produce subcooled liquified natural gas.

[0017] The present invention relates to an optimized cycle for LNG production at letdown stations where the process is divided into two regions: a warm end where a portion of the NG is cooled by using only the pressure letdown energy from the remaining portion, and a cold end where an externally powered turbo-expander cycle is used to sub-cool the NG, in order to minimize the flash gas lost at depressurization and maximize LNG production. The ratio between the two portions of the feed is optimized for minimum pre-treatment and minimum unit power requirement (kW/gal LNG produced). In order to achieve the best performance, the optimal arrangement of the warm end cycle varies depending on process conditions.

[0018] One embodiment of the invention is a method for producing liquefied natural gas comprising:

[0019] an optional step of purifying a high pressure natural gas in a first purification system;

[0020] compressing a first portion of a high pressure natural gas, cooling it to a temperature above its dew point and turbo-expanding such first portion to produce at least a part of the refrigeration required to liquefy the remaining second portion of the natural gas;

[0021] an optional step of using a part of the first portion as regeneration gas for the first purification system;

[0022] purifying the second portion of natural gas in a second purification system and cooling said purified second portion;

[0023] flashing a first part of the second portion of natural gas to a pressure marginally above letdown pressure and using it as regeneration gas for the second purification system;

[0024] recovering contained refrigeration of such first part of the second portion by indirect heat exchange with the remaining second portion;

[0025] compressing a refrigeration gas and turbo-expanding the compressed refrigeration gas to produce cooled refrigeration gas; and

[0026] warming the flash vapor and the cooled refrigeration gas by indirect heat exchange with the liquefied natural gas to effect the sub-cooling of the liquefied natural gas.

[0027] Another embodiment of the invention is a method for producing liquefied natural gas comprising:

[0028] an optional step of purifying a high pressure natural gas in a first purification system;

[0029] compressing and cooling a first portion of a natural gas and expanding such first portion in a first expansion to produce at least a part of the refrigeration required to liquefy the remaining second portion of the natural gas;

[0030] heating such first portion to bring it to a temperature above its dew point and turbo-expanding such heated first portion;

[0031] an optional step of using a part of the first portion as regeneration gas for the first purification system;

[0032] purifying the second portion of natural gas in a second purification system and cooling said purified second portion;

[0033] flashing a first part of the second portion of natural gas to a pressure marginally above letdown pressure and using it as regeneration gas for the second purification system;

[0034] recovering contained refrigeration of such first part of the second portion by indirect heat exchange with the remaining second portion;

[0035] compressing a refrigeration gas and turbo-expanding the compressed refrigeration gas to produce cooled refrigeration gas; and

[0036] warming the flash vapor and the cooled refrigeration gas by indirect heat exchange with the cooled second portion of natural gas to produce sub-cooled liquefied natural gas.

Brief Description Of The Drawings

[0037] For a more complete understanding of the present invention and the advantages thereof, reference should be made to the following Detailed Description taken in conjunction with the accompanying drawings in which:

[0038] Figure 1 is a schematic representation of one preferred embodiment of the liquefied natural gas production method of this invention.

[0039] Figure 2 is a schematic representation of another preferred embodiment of the liquefied natural gas production method of this invention.

Detailed Description

[0040] The present invention relates to an optimized cycle for LNG production at letdown stations where the process is divided into two regions: a warm end where a portion of the NG is cooled by using only the pressure letdown energy from the remaining portion, and a cold end where an externally powered turbo-expander cycle is used to sub-cool the NG, in order to minimize the flash gas lost at depressurization and maximize LNG production. The ratio between the two portions of the feed is optimized for minimum pre-treatment and minimum unit power requirement (kW/gal LNG produced). In order to achieve the best performance, the optimal arrangement of the warm end cycle varies depending on process conditions.

[0041] As used herein, the term "adsorption unit" means a system incorporating at least one vessel, preferably two or more, containing a solid adsorbent such as silicon dioxide or molecular sieves, which preferentially adsorbs at least one constituent from a feed gas. The adsorption unit also comprises necessary valving to direct both feed and regeneration gases through the bed(s) at varying time intervals.

[0042] As used herein, the term "regeneration gas" means a fluid that contains substantially less adsorbing contaminant than the feed stream to an adsorption unit.

[0043] As used herein, the term "Joule-Thomson valve expansion" means expansion employing an isenthalpic pressure reduction device which typically may be a throttle valve, orifice or capillary tube.

[0044] As used herein, the term "turboexpansion" means an expansion employing an expansion device which produces shaft work. Such shaft work is produced by the rotation of a shaft induced by the depressurization of a fluid through one or more fluid conduits connected to the shaft, such as a turbine wheel.

[0045] As used herein, the term "subambient expansion" means a Joule-Thomson valve expansion or a turboexpansion which produces a lower pressure stream having a temperature lower than ambient.

[0046] As used herein, the term “flashing” means depressurizing a liquid through an expansion device with the conversion of a portion of the liquid to the vapor phase.

[0047] As used herein, the term “indirect heat exchange” means the bringing of two fluids into heat exchange relation without any mixing of the fluids with each other.

[0048] As used herein, the term “subcooling” means cooling a liquid to be at a temperature lower than the saturation temperature of that liquid for the existing pressure.

[0049] In the practice of this invention, a high-pressure natural gas stream is extracted from a high-pressure pipeline. A portion of this stream is directed to a first adsorption unit for the removal of water. Warming the exhaust/outlet of a sub-ambient expansion generates at least a portion of the gas required for regeneration of this first adsorption unit. Optionally, additional regeneration gas can be taken from the dehydrated gas exiting this first adsorption unit. The stream is then split into a first portion, referred to as working gas, and a second portion referred to as liquefaction gas. The liquefaction gas is directed to a second adsorption unit, which serves to remove at least carbon dioxide (and potentially hydrogen sulfide and water). At least a portion of the regeneration gas for the second adsorption unit is obtained from subsequent down stream sub-ambient temperature processing. Optionally, the remaining portion of the gas needed for regeneration can be provided by taking a portion of the purified liquefaction gas exiting this second adsorption unit. After prepurification, the working gas is used to generate refrigeration for the cooling and condensation of the product from the second unit. The working gas is first pressure boosted, cooled to ambient temperature and then further cooled to a temperature lower than ambient. The cooled working gas is then turbo-expanded; the work generated can be used to power the booster compressor. The resulting stream is then warmed to ambient by indirect heat exchange with the liquefaction gas. The liquefaction gas exits the heat exchanger in a high pressure cooled state, and is further cooled and expanded to produce low pressure LNG product.

[0050] The invention will be described in greater detail with reference to the Drawings. In both Figure 1 and Figure 2, the solid lines represent the primary process stream and the dotted/dashed lines represent pre-treatment regeneration streams.

[0051] Referring now to Figure 1, high pressure natural gas stream 101, which is at a pressure generally within the range of from 400 to 1500 pounds per square inch absolute (psia), is first dried by passage through treatment system 500, which may be a thermal swing adsorption system.

[0052] The resulting natural gas stream 102 is divided into two portions 103 and 104. A first portion 103, referred to as working gas, is first compressed in booster compressor 510 and cooled to ambient temperature in compressor after-cooler 515. The working gas is further cooled in heat exchanger 520, emerging therefrom as cooled stream 105.

[0053] Cooled natural gas stream 105 is turbo-expanded in turbo-expander 525 to provide cold gas stream 106, having a temperature above its dew point, generally within the range of -30 to -160°F. The shaft work produced by turbo-expander 525 is preferably employed to provide at least a portion of the power 141 required to operate booster compressor 510.

[0054] In the embodiment of the invention illustrated in Figure 1, turbo-expanded stream 106 is passed to phase separator 530 and the vapor and liquid fractions are passed in respective streams 107 and 108 to a common pass of heat exchanger 545, and further to heat exchangers 535 and 520. Within heat exchangers 545, 535 and 520, the turbo-expanded gas stream is warmed by indirect heat exchange to provide cooling to the process natural gas streams 112, 110 and 109, respectively.

[0055] Resulting warmed turbo-expanded gas stream 115 is withdrawn from heat exchanger 520 and may be recovered in stream 116. A small portion from stream 115 is taken in stream 117 as regeneration gas for the water removal system 500. The water laden regeneration gas exits pre-purification system 500 as stream 118 and may be recovered in stream 116.

[0056] A second portion 104, referred to as liquefaction gas, is passed to additional purification system 505 for the removal of carbon dioxide to a level generally less than 50 ppm. Hydrogen sulfide is also almost entirely removed in this adsorption unit because it is more strongly adsorbed than carbon dioxide. Resulting further cleaned natural gas stream 109 is cooled by passage through heat exchanger 520, emerging therefrom as cooled gas 110. A small part of the natural gas stream 109 may be passed through valve 610 as stream 140 and combined with natural gas stream 124 as regeneration gas for the additional purification system 505.

[0057] Cooled gas 110 is further cooled in heat exchanger 535 to a temperature such that all heavy hydrocarbons, if present in the stream, are removed from the gas to levels which will prevent their potential freezing in the cold box. Natural gas emerges from heat exchanger 535 as stream 111, which is then passed to the phase separator 540. The liquid containing the heavy hydrocarbons is then withdrawn from phase separator 540 in stream 113, passed through valve 550 and, in the embodiment illustrated in Figure 1, passed in stream 114 for combination with stream 108 and further processing as described above. Vapor is withdrawn from phase separator 540 in stream 112 and further cooled by passage through heat exchanger 545 against warming Joule-Thomson expanded gas to form at least partially liquefied natural gas in stream 119. Depending on process conditions, stream 119 may have only a small portion liquefied or be completely liquefied. The natural gas in stream 119 has a pressure generally within the range of 400 to 1500 psia and a temperature generally within the range of -70 to -160°F.

[0058] Before sending to heat exchanger 545, a portion of the stream 112 is taken as regeneration gas in stream 120. Stream 120 is then flashed by passage through valve 555 to form two-phase stream 121, having a pressure within the range of 100-600 psia. Two-phase stream 121 is passed to the phase separator 560 and the vapor and liquid fractions are passed in respective streams 122 and 123 to a common pass of heat exchanger 545, and further for indirect heat exchange in heat exchangers 535 and 520, exiting heat exchanger 520 as stream

124 at ambient temperature. The gas is then sent to the carbon dioxide removal system 505, where it is used as regeneration gas.

[0059] The carbon dioxide laden regeneration gas exits the carbon dioxide removal system 505 as stream 125 and can be recovered in stream 116. High pressure cooled natural gas in stream 119 is further cooled to a temperature within the range of -200 to -260°F by passage through heat exchanger 565 to form subcooled liquid natural gas stream 126. Stream 126 is flashed by passage through valve 570 to form two-phase stream 127, having pressure generally within the range of from 14.7 to 40 psia. Two-phase stream 127, which comprises flash vapor and liquefied natural gas, is passed into phase separator 575 from which product liquefied natural gas is withdrawn and recovered in stream 128. Flash vapor is withdrawn from phase separator 575 in stream 129 and combined in stream 130 with refrigeration gas 138 and with flash gas from storage tanks (not shown).

[0060] Stream 130 is sent to heat exchanger 565 for indirect heat exchange with incoming high pressure liquid natural gas stream 119. Refrigeration gas 131, which has been warmed to about ambient temperature by passage through heat exchanger 580, is compressed first by passage through compressor 585. Resulting compressed refrigeration gas 132 is cooled of the heat of compression by passage through heat exchanger 590 to form stream 133. Stream 133 is then further compressed in booster compressor 595, and cooled in the compressor after-cooler 600 to form stream 134, having a pressure within the range of 100-600 psia.

[0061] A portion 135 of stream 134 is removed from the refrigeration gas cycle and preferably recovered as natural gas, most preferably as illustrated in Figure 1, by combination with stream 115 to form stream 116. The remaining portion 136 of the compressed refrigeration gas is cooled by passage through heat exchanger 580 to a temperature within the range of -70 to -170°F.

[0062] Cooled refrigeration gas is passed in stream 137 from heat exchanger 580 to turbo-expander 605, wherein it is turbo-expanded to a pressure within the range of from 14.7 to 40 psia to generate refrigeration. The shaft work produced by turbo-expander 605 is preferably employed to provide at least some of the power 142 to operate compressor 595. Resulting refrigeration bearing gas from turbo-expander 605 is passed to stream 138 and warmed in heat exchanger 565 to effect the subcooling of the natural gas in stream 119.

[0063] Preferably, as illustrated in Figure 1, the cooled refrigeration gas in stream 138 is combined with the flash vapor in stream 129 to form combined stream 130 which is passed to heat exchanger 565 and warmed by indirect heat exchange to effect the subcooling of the liquid natural gas in stream 127. The resulting warmed refrigeration gas is passed in stream 139 to heat exchanger 580, emerging therefrom in stream 131 for processing as previously described.

[0064] Referring now to Figure 2, high pressure natural gas stream 201, which is at a pressure generally within the range of from 400 to 1500 pounds per square inch absolute (psia), is first dried by passage through treatment system 700, which may be a thermal swing adsorption system.

[0065] The resulting dried natural gas stream 202 is divided into two portions 203 and 204. A first portion 204, referred to as working gas, is compressed in booster compressor 710 and cooled to ambient temperature in cooler 715. A second portion 203, referred to as liquefaction gas, is sent for further purification to system 705. The working gas is further cooled in heat exchangers 720, 725 and 730, emerging there from as cooled stream 205.

[0066] Cooled natural gas stream 205 is expanded in a first expansion, such as by passing through Joule-Thomson valve 735, to produce an expanded gas stream 206 at a first temperature, which is typically in the range of -70 to -150°F. The first expansion may be with or without the production of the shaft work. In the embodiment of the invention illustrated in Figure 2, the first expansion is a Joule-Thomson expansion which results in two-phase stream 206.

[0067] Stream 206 is passed to separator 740, wherein it is separated into vapor stream 207 and liquid stream 208. Streams 207 and 208 are then fed to the same pass of heat exchanger 730, exiting as two-phase stream 209, which contains less than 5% liquid.

[0068] Stream 209 is then passed to separator 745, where it is separated into vapor stream 210 and liquid stream 211. The vapor stream 210 is further warmed in heat exchanger 725, exiting the heat exchanger as superheated natural gas stream 212.

[0069] Stream 212 is then passed to the turbo-expander 750 wherein it is turbo-expanded to a pressure marginally above letdown pressure. The shaft work 248 produced by turbo-expander 750 may be employed to provide at least some of the power to operate compressor 710. Temperature of stream 212 is chosen such that the temperature of turbo-expanded stream 213 is close to the temperature of stream 206. Stream 213 is fed to phase separator 755 together with liquid stream 211 and with the heavy hydrocarbon condensate 233. The resulting liquid 243 and vapor 244 phases from phase separator 755 are fed to the same passage of heat exchanger 730 wherein it is warmed by indirect heat exchange with liquefaction gas 222, exiting heat exchanger 730 as stream 214. Stream 214 is then further warmed in heat exchangers 725 and 720 by indirect heat exchange with the liquefaction gas 219.

[0070] Working gas exits the cold box at ambient temperature as stream 215 and may be recovered in stream 216. A small portion from stream 215 is taken in stream 217 as regeneration gas for the water removal system 700. The water laden regeneration gas exits the pre-purification system 700 as stream 218 and may be recovered in stream 216.

[0071] After drying in system 700, liquefaction gas 203 is sent for additional purification to system 705, which may be a thermal swing adsorption system. In system 705, carbon dioxide is removed to a level generally less than 50 ppm. Hydrogen sulfide is also almost entirely removed in this adsorption unit because it is more strongly adsorbed than carbon dioxide. The clean liquefaction gas 219 is then cooled by passage through heat exchangers 720 and 725, emerging therefrom as two phase stream 220. A small part of the clean liquefaction gas 219 may be passed through valve 825 as stream 245 and combined with natural gas stream 227 as regeneration gas for the additional purification system 705.

[0072] Stream 220 is separated in phase separator 760 in a liquid phase 221 containing most heavy hydrocarbons, and vapor stream 222. Liquid stream 221 is passed through valve 765 and, in the embodiment illustrated in Figure 2, passed in stream 223 for combination with stream 211 and 213 and further processing as described above. Vapor stream 222 is further cooled by passage through heat exchanger 730 against warming expanded natural gas streams (combined 243 and 244 and combined 207 and 208) and exits the heat exchanger as cooled high pressure natural gas stream 224. The natural gas in stream 224 has a pressure generally within the range of 400 to 1500 psia and a temperature generally within the range of -70 to -160°F.

[0073] Before sending to heat exchanger 730, a portion of the stream 222 is taken as regeneration gas in stream 225. Stream 225 is then flashed by passage through valve 770 to form two phase stream 226, having a pressure within the range of 100 to 600 psia. Two-phase stream 226 is passed to the phase separator 775 and the vapor 246 and liquid 247 fractions are fed to a common passage of heat exchanger 725, and further sent for indirect heat exchange in heat exchanger 720, exiting heat exchanger 720 as stream 227 at ambient temperature. The gas is then sent to the CO_2 removal system 705 where it is used as regeneration gas. The CO_2 laden regeneration gas exits the CO_2 removal system 705 as stream 228 and can be recovered in stream 216.

[0074] High pressure natural gas in stream 224 is further sub-cooled to a temperature within the range of −200 to −260°F by passage through heat exchanger 780 to form subcooled liquid natural gas stream 229. Stream 229 is flashed by passage through valve 785 to form two-phase stream 230 having a pressure generally within the range of 14.7 to 40 psia, but possibly having a pressure greater than 40 psia. Two-phase stream 230, which comprises flash vapor and liquefied natural gas, is passed into phase separator 790 from which product liquefied natural gas is withdrawn and recovered in stream 231. Flash vapor is withdrawn from phase separator 790 in stream 232 and combined with refrigeration gas in stream 233 to sub-cool the natural gas 224 as will be more fully described below. Flash gas from storage tank (not shown) may also be combined in stream 233.

[0075] Refrigeration gas 234, which has been warmed to about ambient temperature by passage through heat exchanger 795, is compressed first by passage through compressor 800 and resulting compressed refrigeration gas 235 is cooled of the heat of compression by passage through heat exchanger 805 to form stream 236. Stream 236 is then further compressed in booster compressor 810, and cooled in the compressor after-cooler 815 to form stream 237 having a pressure within the range of 150 to 500 psia.

[0076] A portion 238 of stream 237 is removed from the refrigeration gas cycle and preferably recovered as natural gas, most preferably as illustrated in Figure 2, by combination with stream 215 to form stream 216. The remaining portion 239 of the compressed refrigeration gas is cooled by passage through heat exchanger 795 to a temperature within the range of −70 to −170°F.

[0077] Cooled refrigeration gas is passed in stream 240 from heat exchanger 795 to turbo-expander 820 wherein it is turbo-expanded to a pressure within the range of from 14.7 to 40 psia to generate refrigeration. The shaft work 249 produced by turbo-expander 820 is preferably employed to provide at least some of the power to operate compressor 810. Resulting refrigeration bearing gas from turbo-expander 820 is passed to stream 241 and warmed in heat exchanger 780 to effect the subcooling of the liquid natural gas in stream 224. Preferably, as illustrated in the Figure 2, the cooled refrigeration gas in stream 241 is combined with the flash vapor in stream 232 and with the flash vapor from storage tanks (not shown) to form combined stream 233 which is passed to heat exchanger 780 and warmed by indirect heat exchange to effect the sub-cooling of the liquid natural gas. The resulting warmed refrigeration gas is passed in stream 242 to heat exchanger 795, emerging therefrom in stream 234 for processing as previously described.

[0078] Although the invention has been described in detail with reference to a certain preferred embodiment, those skilled in the art will recognize that there are other embodiments of the invention within the spirit and the scope of the claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for producing liquefied natural gas comprising:

(A) purifying a high pressure natural gas in a first purification system;

(B) compressing a first portion of a high pressure natural gas, cooling it to a temperature above its dew point and turbo-expanding such first portion to produce at least a part of the refrigeration required to liquefy the remaining second portion of the natural gas;

(C) using a part of the first portion as regeneration gas for the first purification system;

(D) purifying the second portion of natural gas in a second purification system and cooling said purified second portion;

(E) flashing a first part of the second portion of natural gas to a pressure marginally above letdown pressure and using it as regeneration gas for the second purification system;

(F) recovering contained refrigeration of such first part of the second portion by indirect heat exchange with the remaining second portion;

(G) compressing a refrigeration gas and turbo-expanding the compressed refrigeration gas to produce cooled refrigeration gas; and

(H) warming the flash vapor and the cooled refrigeration gas by indirect heat exchange with the liquefied natural gas to effect the sub-cooling of the liquefied natural gas.

2. The method of claim 1 wherein the flash vapor and the cooled refrigeration gas are combined prior to warming by indirect heat exchange with the subcooled liquefied natural gas.

3. The method of claim 1 wherein a portion of the refrigeration gas is withdrawn prior to turbo-expansion.

4. The method of claim 1 wherein the flash vapor and the cooled refrigeration gas, after the said warming, are compressed to form the said compressed refrigeration gas.

5. The method of claim 1 wherein the subcooled liquefied natural gas has a pressure within the range of from 400 to 1500 psia, and the flash vapor and liquefied natural gas resulting from the flashing of the subcooled natural gas have a pressure within the range of from 14.7 to 40 psia.

6. A method for producing liquefied natural gas comprising:

(A) purifying a high pressure natural gas in a first purification system;

(B) compressing and cooling a first portion of a natural gas and expanding such first portion in a first expansion to produce at least a part of the refrigeration required to liquefy the remaining second portion of the natural gas;

(C) heating such first portion to bring it to a temperature above its dew point and turbo-expanding such heated first portion;

(D) using a part of the first portion as regeneration gas for the first purification system;

(E) purifying the second portion of natural gas in a second purification system and cooling said purified second portion;

(F) flashing a first part of the second portion of natural gas to a pressure marginally above letdown pressure and using it as regeneration gas for the second purification system;

(G) recovering contained refrigeration of such first part of the second portion by indirect heat exchange with the remaining second portion;

(H) compressing a refrigeration gas and turbo-expanding the compressed refrigeration gas to produce cooled refrigeration gas; and

(I) warming the flash vapor and the cooled refrigeration gas by indirect heat exchange with the cooled second portion of natural gas to produce sub-cooled liquefied natural gas.

7. The method of claim 6 wherein the flash vapor and the cooled refrigeration gas are combined prior to warming by indirect heat exchange with the subcooled liquefied natural gas.

8. The method of claim 6 wherein a portion of the refrigeration gas is withdrawn prior to turbo-expansion.

9. The method of claim 6 wherein the flash vapor and the cooled refrigeration gas, after the said warming, are compressed to form the said compressed refrigeration gas.

10. The method of claim 6 wherein the subcooled liquefied natural gas has a pressure within the range of from 400 to 1500 psia, and the flash vapor and liquefied natural gas resulting from the flashing of the subcooled natural gas have a pressure within the range of from 14.7 to 40 psia.

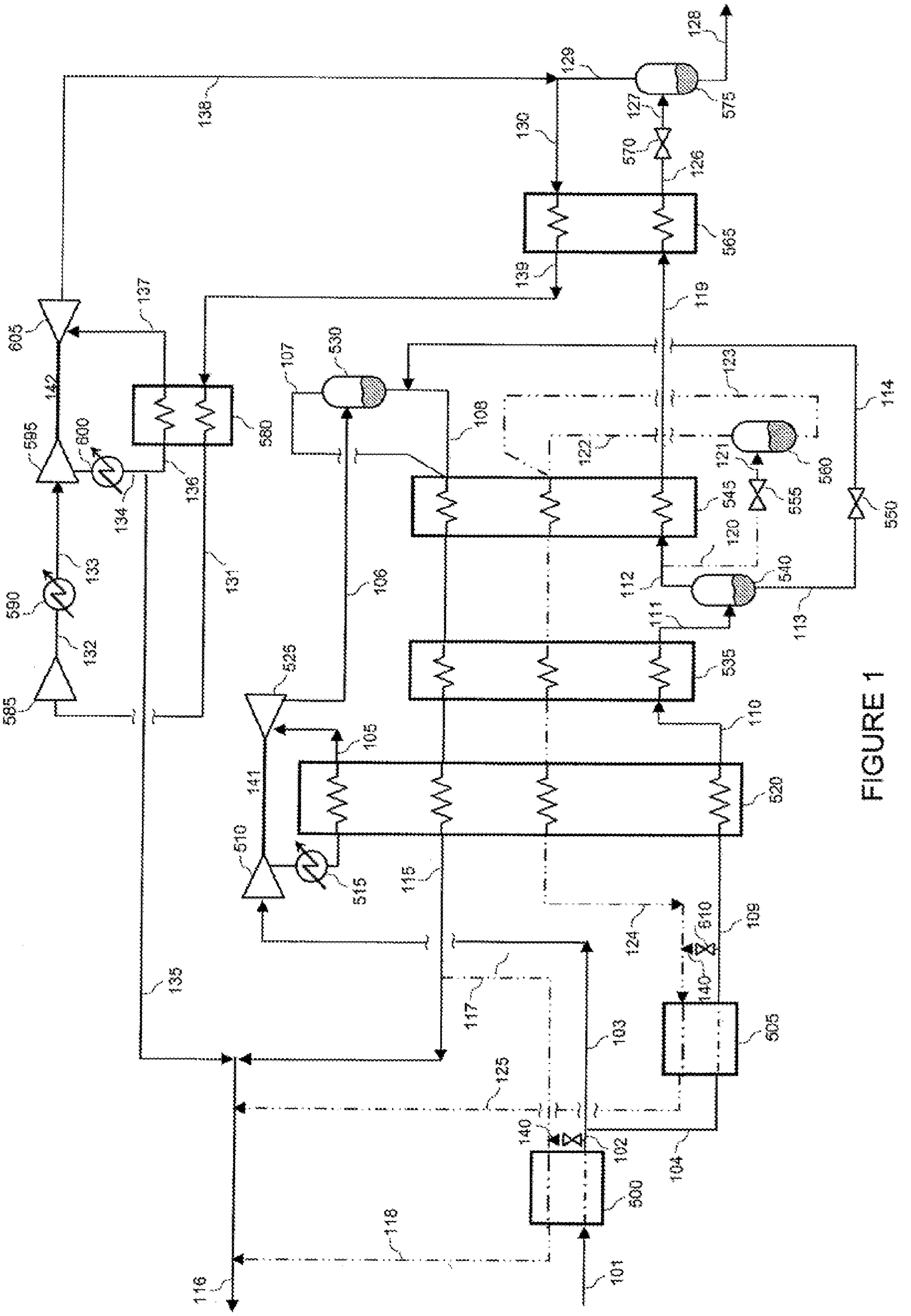
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FIGURE 1

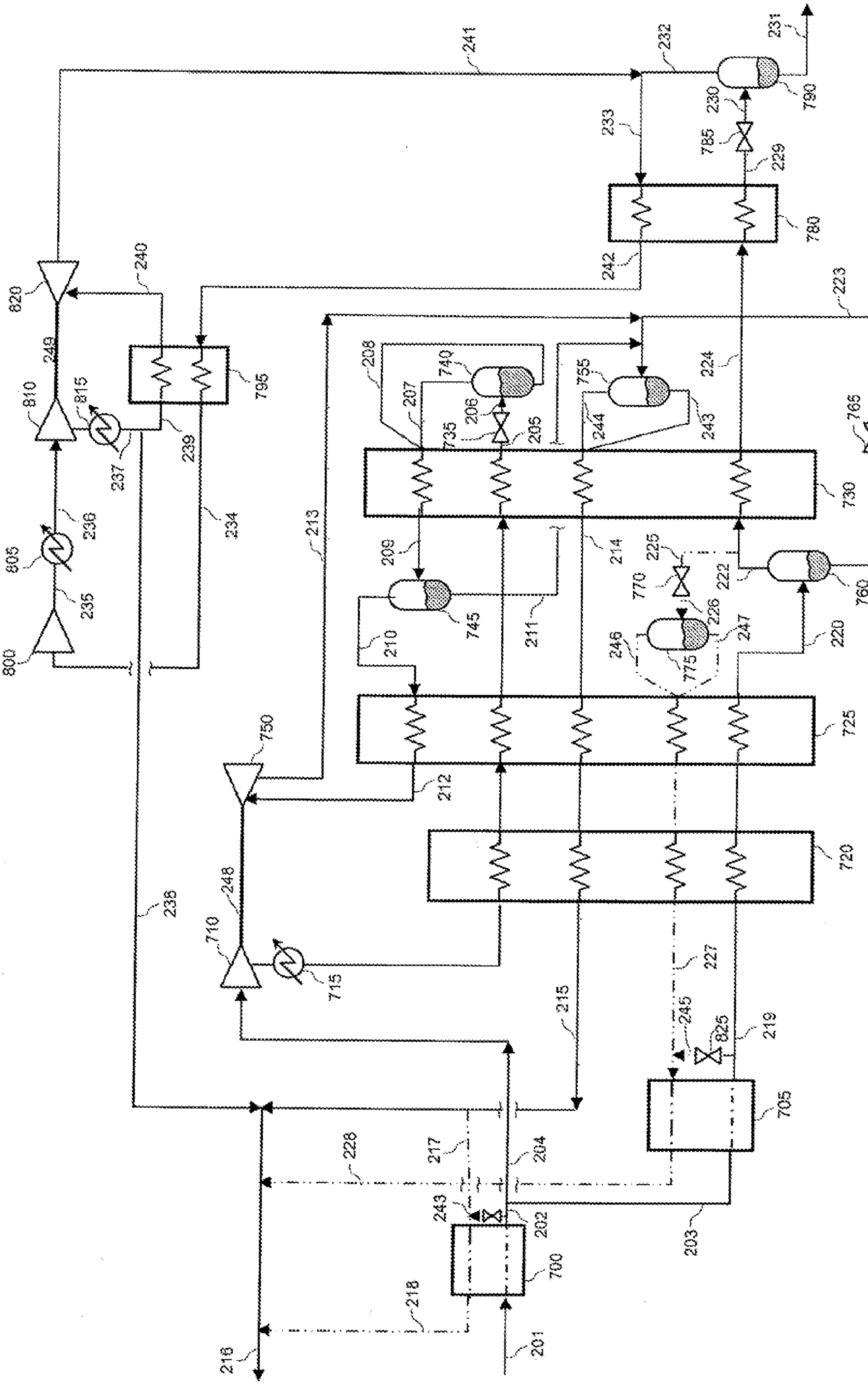
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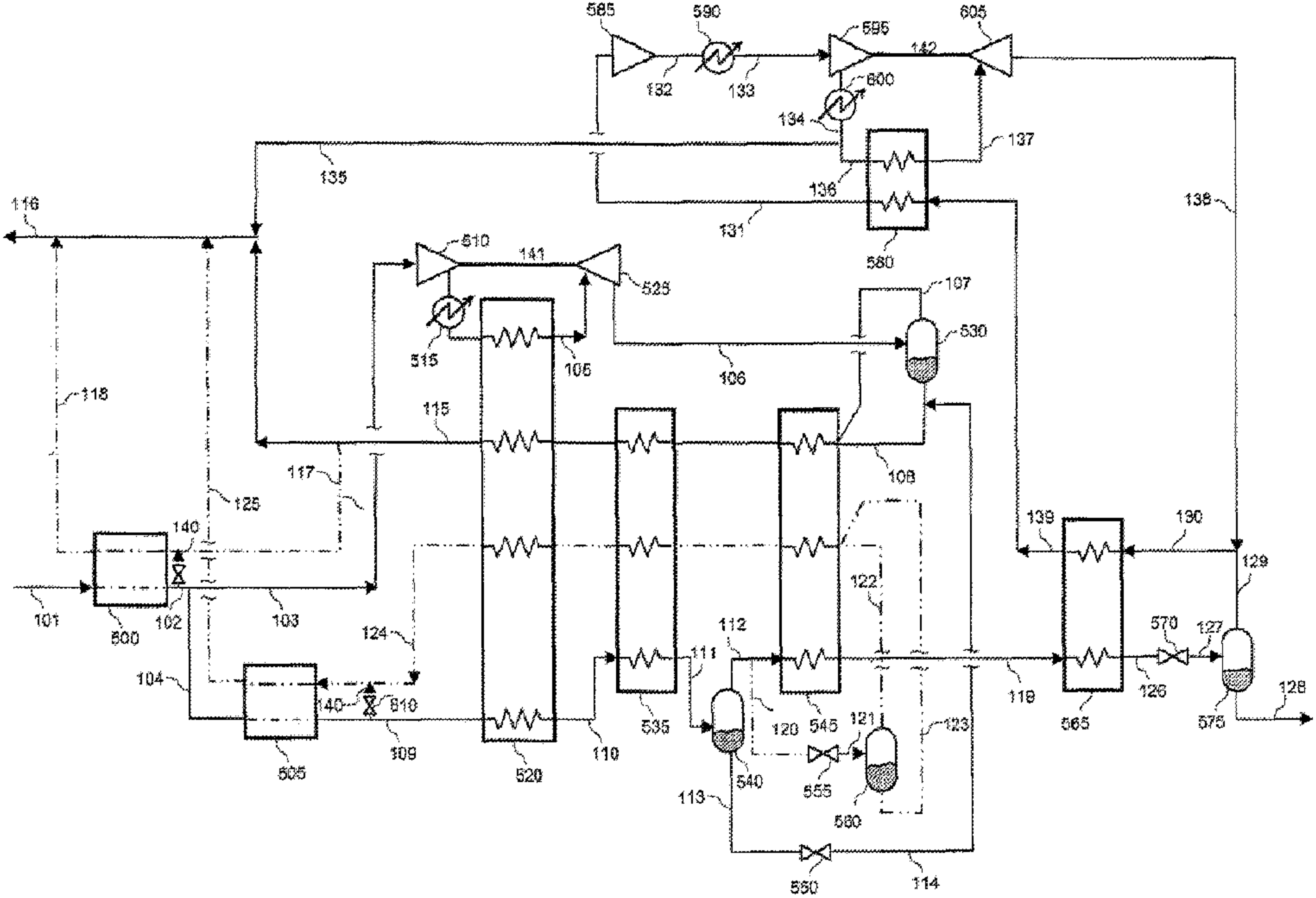
FIGURE 2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