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Declarations under Rule 4.17:

- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
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(54) Title: APPARATUS AND PROCESS FOR LIQUEFYING GASES

(57) Abstract: A liquefier device to be utilized with an air separation plant running in a maxim oxygen state, in a stable mode. The three gas flows to the liquefier from the plant are low pressure oxygen, low pressure nitrogen, and higher pressure nitrogen gas flows. All of the flows are found on the side of the main heat exchanger with a temperature of about 37 degrees Fahrenheit. All of the gases exit the liquefier as a subcooled liquid, for storage or return to the plant. The liquefier does not include a front end electrical compressor, and will take a self-produced liquid nitrogen, pump it up to a runnable 420 psig pressure, and with the use of turbines, condensers, flash pots, and multi pass heat exchangers. The liquefier will make liquid from a planned amount of any pure gas oxygen or nitrogen an air separation plant can produce.



APPARATUS AND PROCESS FOR LIQUEFYING GASES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/506,932, filed May 16, 2017, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to liquefying gases, and more particularly to an apparatus and process for liquefying gases such as nitrogen and oxygen using an air separation plant for the source of the nitrogen and oxygen, and having a top running pressure of about 420 psig without requiring electrical compressors to build this pressure. This is made to reduce the power bill.

BACKGROUND OF THE INVENTION

[0003] Systems and methods for liquefying gases such as nitrogen and oxygen are well-known. The main process of producing large amounts of liquid nitrogen, oxygen, and argon is with an air separation plant. An air separation plant takes in atmospheric air and through a process of fractional distillation at cryogenic temperatures the component gases, or fractions, can be separated by their boiling points. There are other processes to separate air into its different gases, such as pressure swing absorption, vacuum pressure swing absorption, and others, but these are not making a transportable liquid. Today the production of a transportable liquid gas in large quantities requires a large number of compressors and expanders with all of the associated equipment such as cooling towers that require large amounts of electrical power to run at a high cost.

[0004] The process of making liquid gas today is to take gaseous pure nitrogen from two exiting streams of the main heat exchanger's warm side, one stream being the larger flow which is the low pressure nitrogen stream, and the other nitrogen stream having about half the flow but being higher in pressure. The larger flow, lower pressure 2 psig +/-1.5 psig nitrogen gas, along with the flash pot return flow from the liquefier section, this multi low pressure flow comes from the exit of two heat exchanger's warm sides. This low pressure flow is not all used and some is vented back to the atmosphere, while the remaining flow is sent to a low pressure nitrogen compressor, where the exit of the compressor is equal in pressure to the higher pressure multi feeds. The higher pressure flow is made of the exit of the main heat

exchanger along with the exit of the low pressure nitrogen compressor and the gas off of the liquefier heat exchanger turbine return's warm side. All of the gas is sent to the recycle compressor, and then all of the gas is split to two turbine boosters. After each stage of compression the heat of compression is removed. This flow will be cooled down in four steps. The first step is the split off of gas to the warm turbine expander, and the second step is the split off of gas to the cold turbine. The remaining flow exits the liquefier heat exchanger where the gas is called a Soto liquid. The third step is to reduce the flow in pressure through a needle valve causing a Joule Thompson effect. The exit of the needle valve provides a two-phase liquid. The fourth step is to cool the liquid and gas down to all liquid, which is done in the flash pot. That is all the refrigeration needed.

[0005] Existing air separation plants designed to make liquids for sale in the industrial gas market normally use a liquefier. Current liquefiers make only a small amount of liquid per recycle pass (about 15.2% of the recycle compressor flow). Once the liquid is made, it is flash potted to become subcooled, and a small amount of liquid is returned to the air separation plant for refrigeration, while, the larger part of this liquid is sent to a storage tank. No liquid nitrogen is returned to the liquefier. There remains a need for an improved liquefier device.

BRIEF SUMMARY OF THE INVENTION

[0006] The present invention is directed to a system, apparatus and process for liquefying gases such as nitrogen and oxygen. The presented system is an open loop refrigeration system which uses far less electrical power than existing liquefaction systems, and can be gradually implemented to replace existing systems, as existing power contracts which typically have a term such as five years expire.

[0007] In an embodiment, the liquefier device is one part of an air separation plant, and in another embodiment is a retrofit to an existing plant. The same process can take almost any gas to a liquid. For purposes of illustration, there is shown diagrammatically in FIG. 1 an air separation plant having an air flow coming in of 780,000 scfh at the inlet meter point 111. The nitrogen, points 203 and 216 in FIG. 1, and oxygen, point 321 in FIG. 1, utilized by the liquefier device of the invention is produced by high pressure column 114 and low pressure column 116 (there are some plants that have three main columns) of the air separation plant. These nitrogen and oxygen flows will exit from a stable running air separation plant's main heat exchanger 113 warm side as pure oxygen gas at 321, and the two streams of nitrogen gas at 203 and 216 in FIG. 1 to be liquefied. In the illustrated embodiment, the liquefier device will be part of a retrofit to an existing air separation plant. All air separation plants can use this liquefier. In FIG. 1, the oxygen at point 321 exits the main heat exchanger 113 warm side with a temperature of 37 degrees Fahrenheit at a pressure of 19.928 psia and a flow of 161,521.037842 scfh. The nitrogen stream exits the main heat exchanger 113 to point 216 at 14.94 psia with a flow of 371,184.701923 scfh holding 37.29 degrees Fahrenheit, and the nitrogen stream exits heat exchanger 113 to point 203 at a pressure of 67 psig with a flow of 211,000 scfh holding 37 degrees Fahrenheit.

[0008] The oxygen stream 321 and the nitrogen streams 203 and 216 are fed to the liquefier device, which is an open loop refrigeration unit that takes in the separate streams as a pure gas and which streams will exit the liquefier device as a saleable liquid nitrogen at point 537 (see FIG. 6) and liquid oxygen at point 381 (see FIG. 8). The liquefier device of the present invention has significantly reduced power requirements as compared to conventional liquefiers and therefore can produce saleable liquids less expensively.

[0009] The present system takes advantage of many properties of liquid nitrogen. One of

these properties is that liquid nitrogen is mostly a non-compressible fluid that can be pumped up in pressure which occurs in the liquefier device at point 528 (FIG 6), which will take less force than compressing a compressible gas to achieve runnable pressures. The liquid nitrogen streams can be brought up in pressure by a pump (either liquid nitrogen pump 169 or 170 in FIG. 6), which pump in the embodiment shown is using less than 100 horsepower. Then, the liquid is brought to a heat exchanger (boiler 145 in FIG. 4) where the pumped liquid at point 528 in FIG. 4 is boiled to a vapor point. The pressure vapor point of the vapor is held back by the four variable guide vanes in turbines 154, 158, 162, and 166, all of which are shown in FIG. 5. The vapor produced can then be used to run the four turbine expanders 153, 157, 161, and 165, also shown FIG. 5. The exit of the turbine expanders at point 450 in FIG. 5 yields a lower pressure gas, with a temperature almost at its boiling point, which is directed into a phase separator 151 and then to add refrigeration to the condenser 146 in FIG. 4, which makes more liquid. The turbine expanders' exiting gas will remove the latent heat of vaporization from the higher pressure nitrogen stream at point 500 to the point 149, and the lower pressure oxygen stream at point 332 to the point 305 all in FIG. 4.

[0010] Some conventional air separation plants might have an oxygen and/or nitrogen pipe line which will take the gas described here to another compressor for the pipe line's use. The remaining gas can be used along with any gas the pipe line compressor would vent from time to time. Although not illustrated, it will be understood that these types of changes are able to be performed with a minimum number of modifications or changes to the air separation plant and the liquefier device of the present invention.

[0011] Additional areas of applicability for the present invention will become apparent from the detailed description provide hereinafter. It should be understood that the detailed description and specific examples of this preferred embodiment of the invention are intended for purposes of illustration only, that the temperatures, pressures, and purities shown here are close to actual readings but may not be exact, and are not intended to limit the scope of the invention. Other embodiments could be, for example, for the production of liquefied natural gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0014] FIG. 1 is a schematic diagram of a main plant air separation unit configured for operation with the liquefier device of the present invention.

[0015] FIG. 2 is a schematic diagram of the general operation of the argon liquefaction system in accordance with the present invention.

[0016] FIGS. 3a-3c are schematic diagrams of the oxygen and low and high pressure inlet piping for the liquefier device of the present invention.

[0017] FIG. 4 is a schematic diagram of the heat exchangers of the liquefier device of the present invention.

[0018] FIG. 5 is a schematic diagram of the turbine and booster system of the liquefier device of the present invention.

[0019] FIG. 6 is a schematic diagram of the liquid nitrogen pump system of the liquefier device of the present invention.

[0020] FIG. 7 is a schematic diagram of the backup gas nitrogen system of the liquefier device of the present invention.

[0044] FIG. 8 is a schematic diagram of the air separation plant liquid oxygen filter house.

DETAILED DESCRIPTION OF THE INVENTION.

[0021] The following detailed description is of the best mode or modes of the invention presently contemplated. Such description is not intended to be understood in a limiting sense, but to be a non-limiting example of the invention presented solely for illustration thereof, and by reference to which in connection with the following description and the accompanying drawings one skilled in the art may be advised of the advantages and construction of the invention.

[0022] The following detailed description will describe the liquefier device of the present invention with reference to an air separation plant site having an inlet gas air flow of 780,000 standard cubic foot per hour at the inlet meter box, and will make over 650 tons a day of saleable liquids, running with the liquefier device.

[0023] THE BASE LINE. The inventor will first explain one way an air separation plant making over 650 ton a day of liquid product could run. The following explanation is based on an oxygen content of 4 ppm and zero argon on all pure nitrogen streams, and on a standard cubic foot of gas at one atmosphere and at 70 degrees Fahrenheit. The plant site location is around sea level, with an 80 degree Fahrenheit dry bulb temperature and a 70 degree Fahrenheit wet bulb temperature. In addition, the Table included herein provides temperature, pressure, and flow readings for each reference numeral point or step within the air separation plant and liquefier device assembly as described herein with reference to the FIGS., as well as the Figure location, and other comments.

[0024] THE AIR SEPARATION PROCESS. Referring now in particular to FIG. 1, the air around us is the air 1 used by the air separation plant to make saleable liquids, and initially is to be filtered at filtering system 100. Normally there is a four-stage compressor 101 used to bring up the air to a runnable pressure, and three intercoolers that will remove condensed water at 102. After the fourth compression stage there is a possible vent valve 103 which is normally closed. The compressed air is now cooled with a fan cooled aftercooler 104, then cooled again with refrigeration unit 105. Water is condensed during compression and is sent to the water separation unit 106 where the water is removed at 107. The air is still holding a lot of moisture and must be dried down to -110 degrees Fahrenheit dew point, which is

achieved by a molecular sieve bed 108. The drying action will break up a small amount of the sieve material into a fine dust that is now removed by the dust filter 110. The air is now ready to use.

[0025] There is a line to the instrument air supply header controlled by an on/off valve 112 normally open to send a supply of filtered air to the backup gas nitrogen system (see FIG. 7) at point 2. All the rest of the air is metered at 111 and sent through line 3 to the main heat exchanger 113. The air exiting the main heat exchanger 113 in line 4 is sent to the third tray of the high pressure column 114. Condensed liquid will fall to the bottom of the high pressure column 114 and will be removed in line 5. This liquid at point 6 must be cooled by a subcooler 117 prior to being elevated in line 7 to point (8) and split into either line 9 to the top of crude argon condenser 120 or into line 10 to the 44th tray of the low pressure column 116. Referring again to the high pressure column 114, the rest of the gas that entered into the column 114 moves up the column thru 38 trays, and is removed at the top of the column 114 in line 200 as pure nitrogen gas. The nitrogen gas in line 200 splits off to line 201 which leads into the tube side of the reboiler 115 inside the low pressure column 116 bottom liquid. The reboiler 115 will condense the gas nitrogen to a liquid nitrogen. This liquid nitrogen flow exiting the reboiler in line 220 will also be split, with most of the liquid nitrogen to be returned to the high pressure column 221, and the rest will be directed in line 222 to the subcooler 117.

[0026] In addition to splitting off to line 201, there is a stream of pure nitrogen gas off the high pressure column 114 in line 200 that will be removed in line 202 to the main heat exchanger 113, where the gas nitrogen stream is warmed and exits the main heat exchanger 113 at point 203. The gas is then directed to the high pressure nitrogen inlet line to the liquefier, shown in FIG. 3c. Referring again to FIG. 1, most of the liquid nitrogen flow in line 220 exiting the reboiler 115 is directed in line 22 to the high pressure column 114, but the remainder is directed in line 222 to the subcooler 117. The subcooler 117 will remove more heat from the liquid flow so that upon exiting the subcooler 117 in line 223, the flow can be used in the low pressure column 116 without a major flash off. The liquid is elevated to the top of the low pressure column 116 to a control valve in line 224 that will meter, and depressurize the flow. The amount of liquid nitrogen needed to make up the heat loss of the main operation is added at point 549 from point 544 (FIG. 6), which is the flow from the new

liquefier. Prior to reaching point 549, the flow of liquid nitrogen from point 544 is split, such that one flow is directed to the pure argon system (FIG. 2 point 545) and another flow is directed to a control valve 548 that will meter and depressurize the flow at point 549, which as indicated above is joined by the flow in line 224 resulting in a joined flow in line 225.

[0027] The joined flow 225 will enter the low pressure column 116 at tray 65. The gas at the top of the low pressure column 116 exiting in line 210 is mostly nitrogen. The liquid nitrogen from the liquefier device in line 544 that is directed to the pure argon system (FIG. 2, point 545) will return as a low pressure nitrogen gas (FIG. 2 point 558) and is joined with the low pressure 210 nitrogen gas exiting the low pressure columns 116 in line 210, and the joined flow in line 214 is directed to the subcooler 117. The exit of the gas nitrogen from the subcooler 117 in line 215 will now enter the main heat exchanger 113, and the low pressure nitrogen gas then exits the main heat exchanger 113 to the low pressure nitrogen inlet line to the liquefier device of the present invention, shown at point 216 in FIG. 3b.

[0028] Referring again to the low pressure column 116 in FIG. 1, going down the column to tray 55, this is the point where waste nitrogen and a large amount of carbon monoxide will exit the process. The waste nitrogen stream 50 exits the low pressure column 116 to the subcooler 117. At the exit of the subcooler (117) in line 51 the waste nitrogen stream enters the main heat exchanger 113, and then exits the main heat exchanger 113 in line 52 a warmed stream to a control valve where the flow is metered. After the control valve the warmed waste nitrogen stream in line 53 is then used to reactivate the molecular sieve bed 109, which is off line. The waste nitrogen stream 53 is therefore sent to the tube side of a gas fired heater 122 and then will exit in line 54 to the top of the off line molecular sieve bed 109. The bed is first heated, then cooled by the waste nitrogen, and the gas will exit to atmosphere at line 55. Referring still again to the low pressure column 116, going down the column to tray 44, this is the location where the liquid in line 10 from the bottom of the high pressure column 114 will enter. The liquid in line 9 from the bottom of the high pressure column 114 enters the crude argon condenser 120, where it is used to condense the crude argon in the tube side of the reboiler 119. A small amount of the liquid from the bottom of the high pressure column feed in line 9 will be removed in line 11, where it is metered and then sent in line 12 to the low pressure column 116 tray 42. The rest of the liquid from line 9 exiting the bottom of the high pressure column 114 is vaporized during the condensing of the crude argon in the

reboiler 119. The gas formed from such vaporization exits the high pressure column 114 in line 13 and is metered by a control valve, and afterwards is brought line 14 to the 43rd tray of the low pressure column 116. Going down the low pressure column 116 to tray 24, this is the location where the amount of argon gas is the highest in the low pressure column. This gas is fed line 15 to the crude argon column 118. The liquid at the bottom of the crude argon column 118 exits in line 16 to a metered control valve. After the control valve the liquid in line 17 is sent back to the 24th tray of the low pressure column.

[0029] Staying with the crude argon column 118, the gas in line 15 from the low pressure column 116 which enters the crude argon column in line 16 rises to the reboiler 119 thru 38 trays. The gas will turn to liquid and gas in the reboiler 119 tube side. The liquid and gas will exit to the phase separator 121, and the gas off of the phase separator 121 is directed to the argon liquefaction system (FIG. 2, point 400). The liquid from the phase separator 121 is directed to the crude argon column 118, tray 38. Back to the low pressure column 116, going down the column to just below the tray number one, the gas found here is called “pure oxygen.” The gas oxygen will be removed from the low pressure column 116 in line 320 to the main heat exchanger 113 where the gas is warmed. After the heat exchanger, the warmed gas is directed to the oxygen inlet line to the liquefier device (see FIG. 3a, point 321). Back to the low pressure column 116, the bottom liquid is “pure liquid oxygen.” The reboiler 115 is changing the liquid oxygen into gaseous oxygen that drives the low pressure column 16. Most of the gas will go up the column, but the process of removing a large amount of gas oxygen will cause a lower pressure. The lower pressure will mean a lower temperature, which will lower all running pressures all the way back to the main air compressor 101. The small amount of liquid oxygen will need to be removed in line 300 to flush out the solid contamination. This liquid oxygen will be sent to the subcooler 117, and after the subcooler 117 the flow in line 301 will be metered but the level control of the reboiler height will be valves 336, or 343, or 357 in FIG. 8. The liquid oxygen flow is sent to FIG. 8 at point 302. Also referred at the bottom of FIG. 1 is point 40 from FIG. 7, which is a cold box nitrogen purge used to keep a positive pressure on the insulated cold box to keep out the wet air. Another set of points come around the low pressure column 166 feed 211 to the safety relief valve 213 and burst disk 212, which set up is cold and needs a warming nitrogen flow which it receives from FIG. 7 point 39 to insure it works when needed.

[0030] THE PURE ARGON SUBSYSTEM. Referring now primarily to FIG. 2, there are two major flows shown, one of which is the nitrogen for cooling, and the other is the argon to process. The nitrogen flow comes in from FIG. 1, point 545 as a cool liquid nitrogen that will branch off to two control valves, both of which control valves control the liquid nitrogen baths they are supplying. The flow out of one control valve 546 is to the pure argon recondenser holding tank 126 that will bottom fill the heat exchanger 125 shell side. The liquid nitrogen will be vaporized and exit in line 555 to a pressure control valve and then to line 557. The second flow from FIG. 1, point 545 goes to another control valve set to hold a liquid level in line 547 on the shell side of the pure argon column condenser 131. This liquid nitrogen will be vaporized and exit the condenser 131 in line 556 to a pressure control valve, after which it will join line 557 and head back to the main air separation unit at FIG. 1, point 558.

[0031] The argon to process comes in from FIG. 1, point 400. This crude argon flow will enter the cold side of argon heat exchanger 133 and exit warm in line 401 heading to a joined flow with line 403 of hydrogen. The joined flow 404 is directed to the argon compressor 134, which is a two stage compressor with one intercooler. The compressed argon hydrogen flow exiting the argon compressor 134 in line 405 is cooled by an after cooler 135 and exits the aftercooler 135 in line 406 to be joined by a make-up flow of hydrogen. The make-up flow of hydrogen comes from a tube trailer 136, exits to a small line 407 then is pressure regulated to supply 408 to the compressed argon hydrogen flow 406 to make the combined flow 409 to the argon flash arrester 137. Upon exiting the flash arrester 137 at line 410, the flow is directed to a deoxo-catalyst bed 138 where the hydrogen and oxygen in the argon will be combined to make water vapor. The name of the flow at this point changes to combusted argon. The exit of the deoxo-catalyst bed 138 in line 411 is very hot with a lot of humidity. The combusted argon flow is now cooled by an aftercooler 139, after which the high humidity will now be water in line 412. Next, the water is removed using a phase separator 140 with a bottom water drain control valve exiting to atmosphere at 432. The combusted argon is still at 100% relative humidity upon exiting the phase separator 140 in line 413. The combusted argon must be dried to -110 degrees Fahrenheit dew point, and so the flow is sent to a drier bed 141. At the exit of the drier bed 141 in line 414 there is some dust with the combusted argon, which is removed by a dust filter 143. Now the combusted argon in line 402 is dry, dust free and ready to be used, and is directed to an argon heat exchanger 133.

[0032] The combusted argon 402 is warm as it enters the argon heat exchanger 133. At the cold side of the argon heat exchanger 133 the flow 415 is directed to a hydrogen separator 127, and is almost forming a liquid as it enters the hydrogen separator 127. The gas in line 416 upon exiting the hydrogen separator 127 will rise to the tube side of the argon reboiler 128 due to the condensing action of the reboiler. The reboiler 128 is not cold enough to liquefy the left over hydrogen from the deoxo-catalyst bed 138, and therefore will collect at the top of the reboiler tube side and all the argon and nitrogen will liquefy and fall at 417 to the bottom of the hydrogen separator 127, as there are no trays here. The hydrogen at the top of the reboiler is removed at 419 to a flow control valve and is sent back in line 403 to joined suction flow 404 of the argon compressor.

[0033] The liquid at the bottom of the hydrogen separator 127 is removed at 418 to a level control valve that in line 420 feeds the pure argon column 130. This flow contains argon and nitrogen, with a trace of oxygen and hydrogen. This liquid was not subcooled and will flash after decompression. The liquid and gas mixture will separate, and the gas will rise thru distillation trays and the liquid will overflow the tray to the tray below until it collects at the bottom.

[0034] The liquid at the bottom of the pure argon column will first collect around the outer shell ring 129 of the reboiler shell side 128, and after that ring is full, the liquid will fill the bottom of the pure argon column 130. This liquid is then removed at 425 to a level control valve and is joined at 427 with the recondensed argon in line 431 heading to the pure argon tank 124. The gas that entered the pure argon column 130 will rise thru distillation trays until it is condensed in the tube side of the condenser 131. The condenser 131 shell side is full of liquid nitrogen and this makes it cold enough to liquefy in line 421 the nitrogen in the argon but will not liquefy the hydrogen. The liquid and gas bubbles will be removed in line 422 to the phase separator 132. A small amount of gas is removed to a flow control valve that exits at 423 to atmosphere. This valve is always very cold and needs a warming purge flow, which is received from the backup gas nitrogen system (FIG. 7, point 37). The liquid of the phase separator 132 exits in line 424 back to the pure argon column 130 top tray and acts as a cold cap stopping gas argon from passing.

[0035] The argon in the storage tank 124 has a vent line 428, and the argon transport trailer 123 has a similar vent line 429 both of which will vent excess pressure through a vent auto pressure control valve. The vented gas will share the same line at 430 to the tube side of the argon recondenser 125 where it will be liquefied, and in line 431 the liquid is returned to the joined line 427 to the argon storage tank 124.

[0036] There are two argon dryer beds used in this process, identified in FIG. 2 at 141 and 142. As illustrated in FIG. 2, dryer bed 141 is shown as the dryer being used, and dryer 142 is on reactivation. The reactivation is performed by the nitrogen off of the purge header from FIG. 7, point 36. The dryer vessels have their own heaters and only need a dry gas nitrogen to move the contamination out to vent at 433.

[0037] THE TAKE OR VENT INLET PIPING TO THE LIQUIFER. As illustrated in FIGS. 3a-3c, there are three inlet flows to the liquefier, all three of which come from the air separation plant main heat exchanger's warm side (FIG. 1). These are the gas oxygen inlet flow, the gas nitrogen inlet flow from the low pressure side of the air separation plant main heat exchanger's warm side, and the gas nitrogen inlet flow from the high pressure column.

[0038] Referring now to FIG. 3a, the gas oxygen inlet flow as shown comes from the warm side of the main heat exchanger, FIG 1, point 321. This gas oxygen flow is now controlled by a flow meter 325 in order to prevent or stop an over draw of production. The flow is set by the air separation plant, and if the reading of flow meter 331 is not equal to flow meter 325 then any excess flow will be vented. The venting of excess gas oxygen is seen by flow meter 327, which controls the vent valve 329. If the pressure is too high the relief valve 328 will open. If the flow meter 327 shows a flow, then there is a problem. Valve 326 is the main flow control. There is a check valve 330 feeding the flow meter 331. The exit of the inlet process is oxygen gas to the liquefier at FIG. 4, point 332.

[0039] In FIG. 3b, the low-pressure gas nitrogen flow is shown coming from the warm side of the main heat exchanger in FIG. 1, point 216. This low-pressure nitrogen flow is now controlled by flow meter 250 to stop an over draw of production. The flow is set by the air separation plant, and if flow meter 256 is not equal to flow meter 250 then any excess will be vented. The venting of excess is seen by flow meter 252 which controls the vent valve 254.

If the pressure is too high the relief valve 253 will open. If the flow meter 252 shows a flow then there is a problem. Valve 251 is the main flow control. There is a check valve 255 feeding the flow meter 256. The exit of the inlet process is to the liquefier at FIG. 4, point 257.

[0040] In FIG. 3c, the gas nitrogen flow from the high-pressure column comes from the warm side of the main heat exchanger in FIG. 1, point 203. This high pressure nitrogen flow is now controlled by flow meter 231 to stop an over draw of production. The flow is set by the air separation plant, and if flow meter 237 is not equal to flow meter 231 then any excess will be vented. The venting of excess is seen by flow meter 233 which controls the vent valve 235. If the pressure is too high, the relief valve 234 will open. If the flow meter 233 shows a flow, then there is a problem. Valve 232 is the main flow control. There is a check valve 236 feeding the flow meter 237. There is also a two-inch branch line feeding an on or off valve 238 that feeds a purge nitrogen gas supply to FIG.7, point 33. The main exit of the inlet process is to the liquefier in FIG. 4, point 239.

[0041] THE LIQUIFIER. Referring now to FIG. 4, the heat exchangers and flash pots for the liquefier device are illustrated diagrammatically. This is located in a well-insulated box with a nitrogen purge coming in from the backup gas nitrogen in FIG. 7, point 41. The three gas streams described with reference to FIGS. 3a-3c from the air separation unit will enter the liquefier cold box at different points. The oxygen gas stream comes in to the liquefier device from FIG. 3a, point 332. The oxygen gas stream flow is passed sequentially through three heat exchangers, namely, oxygen cooler 144, boiler 145, and condenser 146, and then enters the tube side of oxygen flash pot 147. The exit of the flash pot tube side will be a subcooled liquid oxygen, which is directed to the liquid oxygen filter house shown in FIG. 8, point 305. The draw of oxygen will be the change of state from gas to liquid. There is a change of pressure needed to make the pressure of the liquid oxygen here higher than the low-pressure column's feed. This change in pressure is accomplished by the height of the flash pot 147. The flash pot 147 should be about fifteen feet higher than the low pressure liquid oxygen line off of the low pressure column heading to the oxygen filter house. This means the gas oxygen stream to the flash pot should not be cold enough to condense prior to the entrance to the flash pot 147.

[0042] The low pressure nitrogen gas stream to the liquefier device comes in from FIG. 3b, point 257. This low pressure nitrogen stream joins the flow downstream from pressure exit control valve 264, and the combined flow in line 265 exits to the turbine boosters in FIG. 5, at point 265.

[0043] The high pressure column gas nitrogen stream to the liquefier device comes in from FIG. 3c, point 239. This stream joins the equal pressure flow downstream from the line exit of control valve 455, forming the combined flow 462. This combined nitrogen stream flow 462 will now branch off to two lines containing control valves 456 and 457. Control valve 456 will add heat to the heat exchanger 152 called the preheater. The exit of the preheater 152 and the exit of the auto control valve 457 will join and exit to turbine package in FIG. 5, at point 458.

[0044] In addition, there is a flow from the turbine package or assembly, FIG. 5, point 273, to an auto control valve 274 (FIG. 4) that will add heat to the preheater 152 and exit back to the turbine at FIG. 5, point 275. There is also a flow off of the boiler 145 going to the preheater 152 that needs to be warmed prior to being decompressed as shown FIG. 5, point 288.

[0045] The major flow of compressed nitrogen gas from the turbine assembly at FIG. 5, point 500 branches off to three auto control valves 501, 502, and 503. Auto control valve 501 will be set to warm the oxygen cooler 144. The exit of the flow 501 will join the exit flows of 502 and 503. The exit of auto control valve 503 will warm the preheater 152. The auto control valve 502 will bypass the heat exchangers and move a warm gas flow into the boiler 145. The boiler 145 has a liquid nitrogen bath that must be boiled away. The gas nitrogen from the three auto control valves (501, 502, and 503) will boil the liquid nitrogen in the boiler 145. The gas from line 500, FIG. 5 will be cooled off but will not condense, but the liquid nitrogen bath in the boiler 145 will turn to gas nitrogen. The cooled-off gas nitrogen from point 500 will go to the next heat exchanger 146 called the condenser, where the gas nitrogen is exchanging its heat with the exhaust of the four turbines, making the gas into a two-phase liquid gas nitrogen stream.

[0046] The two-phase stream is sent to the next heat exchanger 150 called the added cooling

heat exchanger. Here the two-phase nitrogen stream will be cooled a little more but will still be a two phase stream at the exit. The two-phase stream is then directed into the pump flash pot 149 tube side where the nitrogen stream will be all liquid. The exit temperature at the pump flash pot 149 will be set to hold a boiling point of the boiler 145 after the pump. The liquid nitrogen is cold enough to be used. The liquid nitrogen off of the pump flash pot 149 will branch off to five places, which are to the liquid nitrogen pump (FIG. 6 point 510), then to the air separation plant (FIG. 6 point 511), then to the auto control valve 512 back feeding the pump flash pot 149, then to the tube side of the nitrogen production flash pot 148, and lastly to the auto control valve 513 feeding the shell side of the oxygen production flash pot 147.

[0047] Transition from FIG. 4 to FIG. 6. Following the flow of liquid nitrogen off of the pump flash pot 149 to the liquid nitrogen pump (FIG. 6 point 510), this liquid nitrogen flow can bypass the pump during start up, through a branch line containing valve 522. After the pump is running, there is a check valve 523 which will stop a back flow until the valve 522 is closed. A flow from the auto control valve 522 thru check valve 523 can supply the boiler through line 528 (to FIG. 4) and the pump flash pot through line 529 to valve 530 in FIG. 4. [As an operation note, starting a pump sometimes needs priming, and the priming can be done to a low pressure point using the pump flash pot shell side thru FIG. 4, point 529 opening valve 530 as valve 522 (in FIG. 6) is closing.]

[0048] Two separate liquid nitrogen pumps 169 and 170 are shown in FIG. 6, which are used for the movement of the liquid nitrogen to the boiler. Two pumps 169 and 170 are provided because the carbon seal on the pumps will wear out, and providing two pumps will allow the operation to stay running as the pumps are switched to replace the carbon seal. Only one pump should be running at a time. In FIG. 6, the inlet valve to the pump 169 is auto valve 520, and the exit valve is auto valve 524, which will feed a check valve 526. The inlet valve to the pump 170 is auto valve 521, and the exit valve is auto valve 525, which will feed a check valve 527. Flow from the pump in use will branch off to the heat exchangers in FIG. 4, point 529 to check valve 530 feeding flash pot 149, and FIG. 4, point 528, where it will feed the boiler 145. The amount of liquid to the boiler 145 will be regulated by the bypass level control valve 523 if the pump is off, or a slowly changing pump speed. The flow from FIG. 6, line 529 to FIG. 4 goes to auto control valve 530. The flow thru level control valve 530 is

to the shell side liquid level of the pump flash pot 149 and this is normally closed.

[0049] The next branch off of the pump flash pot 149 in FIG. 4 is to FIG. 6, point 511. There is a dump to atmosphere branching from line 511 through auto control valve 542. Line 511 also leads to a normal running open valve 543 this will close check valve 541 and go to line 544 as the liquid back to the air separation plant (see FIG. 1). If the liquefier is not able to feed the air separation plant, then liquid from the nitrogen storage tank 171 is used. A liquid flow off the nitrogen storage tank 171 is provided by opening valves 539 and 540. After starting the liquid pump 172 the nitrogen flow will go to check valve 541, then to a closed auto valve 543, then to line 544 feeding the air separation plant. At all times, the flow to the air separation plant is controlled by the level controls of the pure argon condenser 131 flow through line 547, the level controller of pure argon recondenser 126 flow through line 546, and the metered flow at line 549 to the low pressure column.

[0050] The next branch off from the pump flash pot 149 is to the level controller valve 512 (FIG. 4) sending liquid back to the shell side of the pump flash pot. This is normally closed. The next branch off from the pump flash pot 149 is to the level controller valve 513 (FIG. 4) sending liquid to the shell side of the oxygen production flash pot (147). This is also normally closed.

[0051] The last branch off from the pump flash pot 149 is to the tube side of the nitrogen production flash pot 148 (FIG. 4). The liquid nitrogen exiting the flash pot 148 branches to valve 514 and to line 515 (see FIG. 6). The valve 514 is a liquid level control valve to control the liquid height of the shell side of the nitrogen production flash pot 148. This is normally closed. The branch off to line 515 is the production liquid nitrogen to the nitrogen storage system. If the production is not good it will be sent to dump thru valve 535. When the liquid nitrogen is found to be good there is a last purge valve 536 prior to the tank valve which is normally closed. The valve 537 is the production metering valve and is the entry to the nitrogen storage tank 171. The nitrogen storage tank 171 will be monitored to one psig. The tank venting will be thru valve 538 to atmosphere. The liquid temperature to control the venting will happen in the production flash pot 148 liquid level and the gas exit pressure 459 (see FIG. 4).

[0052] Referring now to the liquid nitrogen feed to the boiler 145 in FIG. 4 from line 528, FIG. 6, after the liquid nitrogen leaves the pump flash pot 149, the liquid must be cool enough to stay as single phase liquid thru the pumping stage then up to the boiler, but not be too cool to stop the boiling action when it enters.

[0053] Vaporized nitrogen coming out of the boiler 145 is routed to the preheater 152. The preheater 152 can be warmed by three flows, namely: the booster four aftercooler exit called the major flow controlled by valve 503, the booster one aftercooler exit controlled by valve 274, and the high pressure column and turbine exhaust flow controlled by valve 456. This can be monitored by the auto opening of valve 451. Valve 451 will drain excess liquid produced by the four turbines that is not used by the three flash pots.

[0054] The exit of the vaporized nitrogen flow from the preheater 152 goes to the turbine assembly illustrated in FIG. 5, at point 288. This nitrogen gas is sent to four flow meters 289, 290, 291, and 292. Each flow meter is connected to its own turbine expander and sets the variable guide vanes for each turbine expander. Flow meter 289 is the inlet to turbine expander 153. Flow meter 290 is the inlet to turbine expander 157. Flow meter 291 is the inlet to turbine expander 161. Flow meter 292 is the inlet to turbine expander 165. The guide vanes 154 of turbine expander 153 are set by flow meter 289, the guide vanes 158 of turbine expander 157 are set by flow meter 290, the guide vanes 162 of turbine expander 161 are set by flow meter 291, and the guide vanes 166 of turbine expander 165 are set by flow meter 292. All four turbine expanders exit to a common header with one exit (to FIG. 4, point 450).

[0055] Point 450 in FIG. 4 is where the exit from the four turbine expanders goes into a phase separator 151. The phase separator 151 will hold a liquid level controlled by the exit temperature of the turbines and the draining four auto control valves. The temperature of the turbine exit has to do with the pressure of the boiler 145 and the feed temperature from the preheater 152. The four auto control valves are the over flow valve 451, the filling of the shell side of the oxygen production flash pot 147, valve 452, the filling of the shell side of the nitrogen production flash pot 148, valve 453, and the filling of the pump flash pot 149, valve 454.

[0056] Filling of the oxygen production flash pot 147 shell side by a level control valve 452,

this should be the only filling valve needed for the flash pot 147. Another valve 513 is provided in case it is needed but is closed on normal operation. The liquid nitrogen being supplied to the flash pot 147 by level control valve 452 is not subcooled and will flash when decompressed. The rest of the liquid will boil away as the tube side liquid oxygen is cooled. The exit oxygen temperature control is from the liquid height of the nitrogen shell side bath, and the pressure held on the exit nitrogen gas in line 461. The vent valve 382 on the oxygen storage tank 177 (see FIG. 8) is the only a pressure control valve on the tank, but the valve should not be always open. The opening of the vent valve 382 should be monitored and the temperature of the oxygen production flash pot 147 should be controlled. The oxygen storage tank should never run below 0.5 psig or above 1.5 psig without an adjustment, and the vent valve 382 will open at one psig.

[0057] Looking at the nitrogen production flash pot 148 in FIG. 4, auto level control valve 453 is the only valve that should be used to fill the shell side of the nitrogen production flash pot 148. Valve 514 is also there if needed, but is closed during normal operation. This liquid nitrogen passing through control valve 453 will come in without subcooling and will flash when decompressed. The rest of the liquid to the shell side from valve 453 will be boiled off, as the liquid nitrogen on the tube side is cooled. There is a vent valve 538 on the nitrogen storage tank 171 (see FIG. 6). The exit production liquid nitrogen temperature control is from the liquid height of the nitrogen shell side bath, and the pressure held on the exit nitrogen gas in line 459. The vent valve 538 on the nitrogen storage tank 171 is the only pressure control valve, but the valve should not be always open. The opening of the vent valve 538 should be monitored and the temperature of the nitrogen production flash pot 148 should be controlled. The nitrogen storage tank 171 should never run below 0.5 psig or above 1.5 psig without an adjustment, and the vent valve 538 will open at one psig.

[0058] The pump flash pot 149 has a level control valve 454 which should be the only liquid nitrogen supply to the shell side. Other valves, including valves 530 and 512, should be closed and are there if needed. The pump flash pot 149 tube side liquid nitrogen must be monitored to control its flash off point. The liquid should be a single phase as it exits the nitrogen pump, but not so cold that it stops the boiler as it enters. The tube side liquid nitrogen therefore has to be monitored and the shell side liquid nitrogen height and pressure controlled.

[0059] After all three flash pots 147, 148, and 149 have taken what they need from the three percent of produced liquid off of the turbine exhaust phase separator 151, there should be a small amount left over. This is passed through a level control valve 451 and liquid that is not subcooled will flash when decompressed. The flashing liquid nitrogen is put into a low pressure line used by the nitrogen production flash pot exhaust gas. As this valve 451 opens and closes it will show how the exit temperature of the four turbines are doing. If the valve 451 closes a little, that shows more liquid is being used by the flash pots, or the preheater is running to warm, or the boiler pressure is changing to a lower pressure.

[0060] The three flash pots 147, 148, and 149 shell sides will exit gas nitrogen. The oxygen production flash pot 147 will exit the shell side nitrogen gas in line 461 to the condenser 146. At the exit of the condenser pass there is a branch off to a pressure control valve 260 or a check valve 261. Check valve 261 will take a small flow during startup to the turbine exhaust header but when the turbine exhaust pressure goes above the flash pot pressure auto pressure control valve 260 will move the gas to a low-pressure line. During normal operation, check valve 261 is closed and pressure control valve 260 is controlling. The nitrogen production flash pot 148 shell side will exit the shell side gas in line 459 to the added cooling heat exchanger 150, then join with the exhaust from valve 451, and the joined flow is to the condenser 146. The flow off of the condenser 146 will pick up the exit of the auto pressure control valves 260 and 262, and then enter the boiler 145. The gas off of the shell side of the pump flash pot 149 in line 460 will go to the added cooling heat exchanger 150. The exit off of this pass will go to the condenser 146, and exit to a branch off to a check valve 263 and to an auto pressure control valve 262. Check valve 263 will take a small flow during startup to the turbine exhaust header but when the turbine exhaust pressure goes above the flash pot pressure, an auto pressure control valve 262 will move the gas to a low pressure line. Normal operation is check valve 263 closed and pressure control valve 262 is controlling. Now the low pressure line off the three flash pots 147, 148, and 149 will go to the boiler 145, then to the oxygen cooler 144, and then to auto pressure control valve 264.

[0061] The four turbine exhaust flow at point 450 from FIG. 5, discussed in greater detail below, will go thru the turbine exhaust phase separator 151, and the gas off the top of the separator 151 will go into the condenser 146, while all of the liquid of the phase separator 151

will go to the three flash pots 147, 148, and 149 and the over flow valve 451. Upon the gas stream off of the turbine exhaust phase separator 151 exiting the condenser 146, during a startup mode of operation, this gas stream will pick up the exit of the two check valves 261 and 263, but during normal operation the pressure of the exhaust of the turbines will be much higher and close both check valves 261 and 263. The flow of gas from the condenser 146 will enter the boiler 145, and at the exit of the boiler 145 the gas will enter the oxygen cooler 144. The exit of the oxygen cooler 144 is to a pressure control valve 455.

[0062] The pressure control valve 264 should run wide open if all the flow from the low pressure nitrogen inlet line (FIG. 3b, line 257) can enter the liquefier. The flows from valve 264 and from FIG. 3b, line 257 will join, and go to the turbines (FIG. 5, point 265). This joined gas nitrogen flow will also join the flow from surge control check valve 272 (FIG. 5), then pass through the flow meter 270. The flow meter 270 is needed to predict a surge on the first booster 155. The booster 155 will draw in the nitrogen gas and compress the gas. The compressed gas will pick up the heat of compression and will exit to the aftercooler 156, which is a double air cooling fan system. Each fan in an embodiment is a 25-horse power belt driven fan, one is a fixed pitch fan, and the other is a variable pitch fan. The aftercooler 156 is set to hold a 90 degree temperature on the compressed nitrogen gas exit.

[0063] The nitrogen gas exit from the aftercooler 156 will branch off to three places, namely, a flow to the surge control return gas flow through control valve 271, a flow 273 to warm the preheater 152 (FIG. 4), and a flow to the next booster 159 through check valve 276. The flow through the auto surge control valve 271 will open if the math surge curve is approached. If the surge control system is called into action, then valve 271 will slowly open and the check valve 272 will open, and the flow to the booster 155 will increase. The surge control system is normally not active, but is used on startup. The next flow is to the preheater 152 at point 273 (FIG. 4). The pass through the preheater 152 is normally a small flow to keep the line active, but if the system is upset due to a failure of a nitrogen pump 169 or 170, the boiler 145 liquid will flash to gas, and the excess cold gas to the turbines will cause the turbines 153, 157, 161, and 165 to produce liquid across the blades, and the turbines will all fail. The control valve 274 (FIG. 4) is a temperature controller set to hold the flow in line 288 (FIG. 5) to about -155 degrees. The exit of flow from auto control valve 274 through the preheater 152 to line 275 (FIG. 4) is a very small flow now moved to line 275 in FIG. 5.

[0064] The last flow from the aftercooler 156 is to the check valve 276 heading to the next booster 159. The exit of the check valve 276 is joined with a small flow in from line 275 (from FIG. 4) that is a cold gas. The small flow of cold gas from line 275 will not move the inlet temperature to the booster 159 by even one degree during normal running. The gas of the check valve 276 will also be joined by the flow from surge control check valve 276 if the surge control system is active. All of the joined flows will enter the flow meter 277. The flow from flow meter 277 enters the booster 159. The exit of the booster will enter the aftercooler 160 (having the same design and operation as the aftercooler 156). Out of the aftercooler 160 the flow will branch to the auto surge control valve 278 and check valve 279 (having the same design and operation as the surge system 271), and the line to the flow meter 280.

[0065] The flow from the surge control system 282 check valve and the flow from the aftercooler 160 will enter the flow meter 280. The gas will be compressed by the next booster 163 and exit to the aftercooler 164. The exit of the aftercooler 164 will branch off to the surge control valve 281 and to the booster 167. The surge control system is normally closed, but for startup valve 281 slowly opens to a check valve 282 which will add flow to the booster 163 inlet.

[0066] The rest of the exit flow from aftercooler 164 will go to a joined flow of the surge control system exit check valve 285 and from line 458 from FIG. 4. All the flow is metered by flow sensor 283 used to predict the booster 167 surge. The flow is now called the major flow. In the booster 167 the gas will go up in pressure and temperature. The temperature will be controlled by an aftercooler 168 to hold the temperature at about 90 degrees. The exit of the aftercooler 168 flow will split to the surge control system 284. The surge control system 284 should be closed on normal operation, but on start up the valve 284 is slowly opened and that gas will move through check valve 285 to the booster 167 inlet. The flow that was not used by the surge controller system will exit to in line 500 to FIG. 4 as the major flow.

[0067] FIG. 7 THE BACKUP GAS NITROGEN SYSTEM. Referring now to FIG. 7, the backup gas nitrogen system is shown, which includes a liquid nitrogen storage tank 174 having its own venting system 46. The liquid nitrogen will move from storage tank 174 into

the tube side of evaporators 178 where the liquid nitrogen is changed into a gas nitrogen. At the exit of the evaporators 178 there is a pressure regulator 45. If the purge nitrogen header should fall below its normal running pressure, then the regulator 45 will open, but otherwise the regulator 45 is closed.

[0068] There is an air feed 2 coming from the air separation unit in FIG. 1 to the back up gas nitrogen system in FIG. 7, which is to the instrument air supply. In FIG. 1, valve 112 is an open and closed valve feeding air to the auto control valves to open and close the valves the computer is controlling. This flow has above 78 psig of air pressure. Check valve 19 (FIG. 7) is provided on air feed 2 to stop a back flow of air. The exit of the check valve 19 will enter the selector 20 which will allow the air to pass during normal operation to the instrument air system 21. If the instrument air supply falls to a lower pressure then the set point, pressure regulator 30 will take over. Back flow is stopped by check valve 31.

[0069] The gas nitrogen supply coming in to the back up gas nitrogen system from FIG. 3c, line 33 can supply all the purge and instrument nitrogen for the whole plant. After the gas nitrogen is supplied, there is a check valve 32 (FIG. 7) to protect the pure nitrogen. If instrument air supply point 2 is not up to set point pressure then the check valve 31 will open and the pressure regulator 30 will now supply the instruments nitrogen needed, this will open to point 21. The main purge header, shown by the line extending vertically in FIG. 7, will wrap around the whole plant site with a two inch line. The purge header has many branch offs which are also illustrated in FIG. 7. The main supply to the purge header is the feed off of line 33, FIG. 3c, and if this is not up to pressure then regulator 45 off of the backup tank 174 will supply the nitrogen gas to the purge header.

[0070] The purpose of each of the branches off of the main purge header will now be explained. As shown in FIG. 7, there is a branch to FIG. 8, point 44 off of the purge header which provides a nitrogen supply to the oxygen filter house. As shown in FIG. 8, the main flow is to the warming nitrogen flow through flow meter 60, to open or close auto valve 61, to check valve 62, to service the filters 175 and 176 as needed. There is also a branch flow from point 44 off to provide a nitrogen purge flow to the oxygen filter box at point 47.

[0071] There are four separate branches 34, 35, 42, and 43 off of the main purge header to the

turbine package shown in FIG. 5. The branch off at point 34 is providing a sealing gas supply in line 75 to turbine 153 and in line 76 to turbine 157. The branch off at point 35 is similarly supplying a sealing gas supply in line 77 to turbine 161, and in line 78 to turbine 165. The branch off at point 42 is supplying the turbine case purge, and the branch off at point 43 is supplying the oil accumulator.

[0072] Another flow off of the main purge header is to point 41 in FIG. 4, which is to the liquefier cold box purge. The flow off of point 40 to FIG. 1 is to the cold box purge. The flow off of point 39 to FIG. 1 is to a warming purge flow to the low pressure column relief valve 213 and burst disk 212. The flow off of point 38 is a purge flow of warm gas to defrost the backup storage tank vent valve (46). Finally, the flow off of points 36 and 37 goes to FIG. 2. The flow off of point 36 is to regenerate the argon drier beds, and as shown in FIG. 2 is working on argon drier bed 142, this flow will go to atmosphere 433. The flow off of point 37 will warm up the vent valve to atmosphere off of the separator 13 shown as flow 423 in FIG. 2.

[0073] THE OXYGEN FILTER HOUSE. Some air separation plant sites have built-in heat pumps and gel trap filters to remove solid concentrations in the liquid oxygen at the reboiler. Some plants have a filter to the transport trailers at the filling station. Some plants have a filter to the storage system. Those plant sites will not necessarily need the liquid oxygen filter house illustrated in FIG. 8, although the present oxygen filter house will reduce the losses and manpower needs of the existing system after the plant switches to the new liquefier of the present invention.

[0074] The inventor's new liquefier takes almost all the oxygen production out of the air separation plant as gas. This will leave behind a small amount of liquid oxygen that has some solid contamination which must be removed to hold down the concentration of the contamination. The oxygen filter house system has two gases and one liquid to move around without blending. The gasses here are pure nitrogen gas, and atmosphere air, and the liquid is pure liquid oxygen. To do this, each system must be protected. The best known way to protect a purity is to keep the pressure above atmosphere pressure, and then to use a blocking system, or a way to stop one flow from moving into the next one. Since the pressures here are above atmosphere pressure, a double block and bleed system is used. This will stop flow

by a valve whose exit is to atmosphere. If a valve that is used to block a flow were to leak, then that flow could leak but only to the atmosphere, and not to the next product. All the double block and bleed nest of valves must have a relief valve.

[0075] The liquid oxygen flow from the air separation plant comes in from FIG. 1 to the oxygen filter house in FIG. 8 as a subcooled liquid, at point 302. There is a check valve 335 on the entry to the filter house, which is provided to prevent a back flow of liquid oxygen. If the liquid oxygen in line 302 is not pure enough to put to storage, or if both filters have clogged, the liquid oxygen must go somewhere. One place the liquid oxygen with a bad purity should go is to the dump. But, if the filters are being worked on and are not able to be used, then there is a bypass to allow the solids to go to storage during a short time the filters are being worked on.

[0076] If the oxygen produced by the air separation plant is to be dumped, the whole system is assumed to be or going bad. Quick action must be taken, and all the valves to be closed at once are 313, 316, 381, 61, 63, 69, 64, 70, 343, 357, 346, 360, 377, 378, 339, 372, 351, 365, 352, 366, 342, 355, and 369. In addition, all the valves to open at the same time are 68, 338, 345, 376, 359, 315, 66, 72, 341, 350, 364, 354, 368, 371, and 380. The valves to control the flows are valve 312, 68, 336, 177. Valve 312 controls the height of the tube side of the oxygen production flash pot vessel 147 (FIG. 4). Valve 68 controls the warm nitrogen flow seen at flow meter 60 to a flow of 100 scfh but will see zero flow single making the valve 68 to auto flow control to a wide open. Valve 336 controls the liquid height of the reboiler bath vessel 116 (FIG. 1). Then the vent pressure control valve 382 on the storage tank, which will hold a one psig on the storage tank. This will vent all trapped gas and liquids to a total dump to protect the storage tank from contamination.

[0077] When the purity is established, the system of opening the different subsystems starts. The largest flow will be the liquefier oxygen (from FIG. 4, point 305) to storage. On production dump the flow from the liquefier past check valve 310 to dump is controlled by valve 312. When the purity is good from the liquefier, valve 312 continues to dump while auto level control valve 313 is opened in manual mode. The flow to valve 313 just opened will vent out of the bleed valve 315. Once the liquid oxygen is at a steady flow out of bleed valve 315, valve 316 is slowly opened, while valve 315 is closed. The flow will then go out

the bleed valve 380. Once the liquid flow is steady from bleed valve 380 and the purity is still good, then valve 381 to storage is opened. The amount of liquid now moving to storage and to dump will cause the auto level control valve 312 to see a lower level than the set point and begin to close. When valve 312 is about 5 percent auto open, valve 313 is put into auto level control auto mode. Auto level control valve 312 is to be set to a higher liquid level control point than valve 313, and is to be kept in auto control mode in case the flow out of the vessel 147 starts to back up so the liquid oxygen will have a place to go. The system as just described has now put liquid oxygen to storage from the liquefier.

[0078] When the purity of the air separation plant's liquid oxygen is good, then for a short time the oxygen with all the solids will go to storage during the time the filters are being worked on. The filters must be opened slowly, and dumping or bypass liquid to storage can continue. In the embodiment shown in FIG. 8, filter 175 will be set up to filter, and filter 176 will be put on reactivation. All of the valves in the filter system will be positioned as if you are going to dump with the air separation plant liquid oxygen, and going to storage with the liquefier liquid oxygen, to here. Liquid oxygen from the production plant comes in from FIG. 1, point 302 to a check valve 335 leading to a shell side reboiler level control valve 336 connected to a dump valve 338. Opening valve 342 will cause a backward flow of liquid oxygen out bleed valve 341. Once a steady flow of liquid oxygen is seen exiting bleed valve 341, then valve 339 is opened and valves 341 and 338 are closed. The system is now set up so that the production plant liquid oxygen is bypassing the filters and going to storage. Flow control is still provided from liquid level control valve 336.

[0079] Setting up filter 175 for service. The liquid oxygen is at a good purity and first open reboiler auto level controller valve 343 in manual mode is opened about 25%. This will vent liquid oxygen out bleed valve 345. When a steady stream of liquid oxygen is detected, then valve 346 is opened, and bleed valve 345 is closed. This will vent liquid oxygen out bleed valve 350. The line supplying bleed valve 350 is small and it should take a few minutes to cool down enough to allow a steady flow of liquid oxygen to exit. A close eye must be kept on the active liquid controller, as it is very possible to over draw the liquid from the reboiler, and if this is starting to happen the auto controller valve 336 will close. If the liquid from the reboiler is being overdrawn then for a short time valve 350 should be closed until the reboiler height is reestablished and the auto controller valve 336 reopens. Then, valve 350 is

reopened. By monitoring the temperature sensor 348, the cooling process can be tracked. After the liquid oxygen is flowing at a steady stream out valve 350 and the purity is still satisfactory, then valve 352 is opened to vent out bleed valve 354 and valve 350 is closed. After a steady stream of liquid oxygen is seen exiting valve 354 then open valve 355 and close valve 354. The reboiler auto controller valve 336 is also then set to a higher level and reboiler auto level controller 343 is set to auto mode with a set point at normal reboiler height. The bypass line is then closed by closing valves 342 and 339, and then opening valves 338 and 341. The system is now filtering the solids out of the liquid oxygen from the air separation plant, and the liquefier liquid oxygen is joined to storage.

[0080] Next, filter 176 is reactivated, going from the same sequence as above. Recap closed valves are 61, 63, 64, 69, 70, 345, 357, 360, 377, 378, 339, 350, 351, 372, 365, 354, 366, 342, 369, 380, and 315. The valves open at this time are 338, 341, 346, 352, 355, 376, 371, 359, 364, 368, 316 and 381. The valves in auto control are 68, 313, 312, 343, 336, and 382.

[0081] Bleed valve 364 is open so any liquid could vent, but to make sure valve 61 is opened so that a flow will be started and seen by flow monitor 60. Flow monitor 60 will be set to 100 scfh and for now valve 68 will control the flow. Then flow controller valve 69 is opened in manual mode to 25% open, and the gas nitrogen will vent out of valve 72. Auto flow controller valve 68 will then start to close, because valve 69 is taking some of the flow. Then, valve 70 is opened, and valve 72 is closed. Auto control valve 68 is set to 90 scfh and auto flow controller valve 69 is adjusted to a set point of 100. If the flow falls below 90 scfh then valve 68 will be called to open. If valve 68 is called to open, then the operator will be notified. The solid contamination the filter removes will turn to gas before the filter temperature 362 hits -90 degrees Fahrenheit. When the temperature hits -80 degrees Fahrenheit the reactivation is finished. Now, valves 69, 70, and 364 are closed, and valve 72 is opened. Valve 68 is in control and set to open if the flow goes below 90 scfh as seen by flow monitor 60. Closing valve 61 therefore will stop the entry of nitrogen gas and by default valve 68 will auto open.

[0082] Moving to the cool down of filter 176, the cleaned exit flow of filter 175 is used to cool down filter 176. Opening valve 351 will vent liquid oxygen out bleed valve 371. Once a steady stream of liquid oxygen is seen exiting valve 371, valve 371 is closed, and auto flow

control valve 372 is opened, and will be open 25% in manual mode. This will pass a liquid oxygen flow through a check valve (373), to a flow monitor (375), and exit valve 376. Once a steady flow of liquid oxygen is seen exiting valve 376, then valves 378 and 364 are opened. The cool down flow will be seen on flow meter 375.

[0083] Auto flow controller valve 372 will be put into auto control mode, and be set to 100 scfh controlling the flow seen at flow meter 375. The cooling process will be seen on temperature monitor 362. This process of cooling the filter will take hours due to the small flow. Once the temperature monitor 362 reaches a -250 then the cool down mode is complete, and the filter 176 will be put on standby mode.

[0084] To set up a standby mode for filter 176, the flowing valves must be closed; 351, 372, 378, 364, and the valves to be open are 371 and 376. The process of standby is to let a cooled filter 176 sit with valves closed. If there is any gas expansion, the vessel is protected by relief valve 363. In addition, there will be a cycling of opening and closing valve 364 once every ten minutes, since protecting a vessel with only a relief valve may be insufficient in reducing the expansion of gas trapped.

[0085] The next mode of operation of the liquid oxygen filters is dull filter running, which is how to move the filtration from one filter to the next. The standby mode is stopped. The only valve in operation on filter 176 is valve 364, which will open and close on a timer of once every 10 minutes for one tenth of a second. This will stop on an open sequence, and valve 357 will open in manual control to 25% open. A flow of oxygen liquid will be seen coming out of bleed valve 359. Then valve 360 is opened and valve 359 is closed. Liquid oxygen will go out through valve 364. During the startup of filter 176 the amount of liquid oxygen to be used will cause auto level control valve 343 to start closing. If valve 343 were to close, then the valve opening on auto level control valve 357 which is in manual mode is reduced to 10%. After liquid oxygen is exiting valve 364 then valve 366 is opened, and bleed valve 364 is closed. Liquid oxygen will flow out of bleed valve 368. After that valve 369 is opened. Now both filters 175 and 176 are filtering.

[0086] The next step is to stop filter 175. Level controller valve 343 in manual is set at 5% open, and level controller valve 357 is put into auto mode with a set point of the reboiler

height. This will take about 3 to 5 minutes to settle out, and then valves 343, 346, 351, 352, and 355 are closed, and valves 354, 350, and 354 are opened.

[0087] Filter 175 is drained, with any liquid oxygen in filter 175 will drain out of valve 350 as the liquid turns to gas. In addition, valve 61 is opened and auto control valve 63 is set to 100 scfh. This will vent nitrogen gas out of valve 66. Then valve 64 is opened and valve 66 is closed. Auto flow control valve 68 is set to open below 90 scfh, and auto control valve 63 is set to open below 100 scfh. This should cause valve 68 to close because the flow will be above the set point. The liquid in filter 175 will be draining out of valve 350.

[0088] Filter 175 is put in to heat up, after the liquid is drained out of valve 350. Then the flow will stay the same. The point to monitor is the filter temperature sensor 348. When the filter temperature hits -80 degrees Fahrenheit, the heat up is done.

[0089] To put filter 175 into cool down, the heat up is stopped by closing valves 61 and 63. This will cause auto flow control valve 68 to open due to a loss of flow. The set point for valve 68 is open below 90 scfh. Valve 64 is then closed, and bleed valve 66 is opened. Using the clean liquid oxygen out of filter 176, valve 365 is opened to bleed valve 371 is closed. After valve 371 has a steady flow of liquid oxygen exiting it, then valve 372 opened and valve 371 is closed. Valve 372 is put in manual mode and open 10%, and once liquid oxygen comes out of valve 376, open valve 377 and close valve 376. Flow meter 375 will show a flow and should be set to a flow rate of 100 scfh and auto flow control valve 372 will be used to control the flow. The flow will exit valve 350. Once the flow cools down the filter to -250 as seen on temperature sensor 348 then the cool down is done.

[0090] Put filter 175 to stand by mode. Stop cool down and close valves 365, 372, 377, and 350. Open bleed valves 371, and 376. Now cycle valve 350 open and closed once every ten minutes to stop an over pressure.

[0091] Put filter 175 into dull operation mode. When needed filter 175 will be put into dull operation with filter 176. First open auto level control valve 343 in manual mode at ten percent open. This will vent liquid oxygen out of bleed valve 345. When a steady flow of liquid oxygen exits bleed valve 345, then open valve 346, and close bleed valve 345. The

flow will exit valve open valve 350. The temperature monitor 348 will show the progression of cool down to operation. Once the flow out of valve 350 shows a steady stream of liquid oxygen then open valve 352 and close valve 350. The flow will now exit bleed valve 354. Once bleed valve 354 shows a steady flow of liquid oxygen then open valve 355, and close valve 354. Now put auto level controller valve 343 into auto mode and set auto level controller valve 357 into manual mode at five percent open. Once the system is working for a few minutes and is stable, then put the filter 176 into stop mode. Put valve 357 into auto level control.

[0092] Put filter 176 into a stop mode. The system just switched over from filter 176 on line to filter 175 on line. Now stop filter 176 and close all valves 357, 360, 366, and 369. Now open 368, 364, and 359. Any liquid in filter 176 will be able to drain out of valve 364. Then again go through the warm up steps above.

[0093] During the operation of the filters there is a differential pressure gauge to show filter clogging. This should be monitored and logged to find out how long the filter can be in operation. The differential pressure gauge for filter 175 is 347, and the filter 176 has differential pressure gauge 361. This is a list of relief valves found on FIG. 8. On the liquid oxygen from the liquefier to the filter house is relief valve 311 to protect the line if valves 312, 313, and check valve 310 closed with liquid oxygen trapped and changing state to a gas. Relief valve 314 is there to protect the line if valves 313, 315, and 316 closed with liquid oxygen trapped and changing state to a gas. Relief valve 340 is there to protect the line if valves 339, 342, and 341 closed with liquid oxygen trapped and changing state to a gas. Relief valve 349 is there to protect the line and filter 175 if valves 352, 351, 350, 64, 346, and 377 closed with liquid oxygen trapped and changing state to a gas. Relief valve 370 is there to protect the line if valves 371, 351, 365, and 372 closed with liquid oxygen trapped and changing state to a gas. Relief valve 374 is there to protect the line if valves 372, check valve 373, 378, 376, and 377 closed with liquid oxygen trapped and changing state to a gas. Relief valve 344 is there to protect the line if valves 343, 354, and 346 closed with liquid oxygen trapped and changing state to a gas. Relief valve 358 is there to protect the line if valves 360, 357 and 359 closed with liquid oxygen trapped and changing state to a gas. Relief valve 356 is there to protect the line if valves 357, 343, 336, and check valve 335 closed with liquid oxygen trapped and changing state to a gas. Relief valve 67 is there to protect the line if

valves 69, 68, check valve 62, and 63 closed with liquid oxygen trapped and changing state to a gas. Relief valve 71 is there to protect the line if valves 72, 70, and 69 closed with liquid oxygen trapped and changing state to a gas. Relief valve 363 is there to protect the filter 176 and the lines if valves 366, 365, 364, 70, 360, and 378 closed with liquid oxygen trapped and changing state to a gas. Relief valve 367 is there to protect the line if valves 366, 368, and 369 closed with liquid oxygen trapped and changing state to a gas. Relief valve 379 is there to protect the line if valves 381, 380, 342, 355, 369, and 316 closed with liquid oxygen trapped and changing state to a gas. Relief valve 353 is there to protect the line if valves 352, 354, and 355 closed with liquid oxygen trapped and changing state to a gas. Relief valve 65 is there to protect the line if valves 63, 64, and 66 closed with liquid oxygen trapped and changing state to a gas. Relief valve 337 is there to protect the line if valves 336, 338, and 339 closed with liquid oxygen trapped and changing state to a gas.

[0094] TABLE

Temperature (Fahrenheit)	Pressure (psig)	Flow (scfh)	Ref. No.	Location (Fig. No.)	Notes
ref	ref	ref	ref	ref	all of the nitrogen that enters the liquefier
45.10	78.44	15500.000000	2	FIG. 1&7	instrument air removal (psig). To FIG. 2
45.1	78.44	15500.000000	2	FIG. 7&1	Instrument air feed just after MS's filters FIG. 1
43.93	77.09	780000.000000	3	FIG. 1	warm side MHE (psig) point 113
-277.12	73.17	780000.000000	4	FIG. 1	exit MHE 113 enter HPC 114 (psig)
-275.94	73.44	437000.000000	5	FIG. 1	Liquid at the bottom of the HPC 114 (psig)
-280.00	51.50	437000.000000	6	FIG. 1	HPC 114 bottom liquid raised 55' now entering the SC 117 (psig)

-292.00	48.61	437000.000000	7	FIG. 1	HPC 114 bottom liquid exiting the SC 117 (psig)
-305.00	35.00	437000.000000	8	FIG. 1	Raised 45' split to control valves feeding POINTS 9 & 10. (psig)
-308.00	23.61	252000.000000	9	FIG. 1	Liquid into POINT 120, shell side (psia)
-309.28	18.83	185000.000000	10	FIG. 1	From POINT 114 bottom liquid after control valve into the POINT 116 tray 44, (psia)
-307.80	26.11	2000.000000	11	FIG. 1	liquid exiting the point 120 to its control valve (psia)
-308.51	18.97	2000.000000	12	FIG. 1	liquid from the POINT 120 after the control valve now entering the POINT 116 tray 42 (psia)
-307.00	20.50	250000.000000	13	FIG. 1	gas exit the POINT 120 to a control valve. (psia)
-308.90	18.90	250000.000000	14	FIG. 1	Gas from the POINT 120 control valve to POINT 116 to tray 43 (psia)
-301.55	20.27	206300.000000	15	FIG. 1	LPC 114 tray 24 gas to CRA 118 (psia)
-300.00	23.27	199013.839220	16	FIG. 1	liquid exit CRA 118 (psia)
-301.55	20.27	199013.839220	17	FIG. 1	liquid from CRA 118 after the control valve to LPC 116 tray 24 (psia)
80	78.42	15500.000000	19	FIG. 7	check valve to the instruments
80	78.4	15500.000000	20	FIG. 7	all the gas needed to run the instruments system. normally air.
80	78.38	15500.000000	21	FIG. 7	Feeds auto valves
80	66.93	0.000000	30	FIG. 7	instrument nitrogen to instrument air pressure regulator

80	65	0.000000	31	FIG. 7	backup nitrogen check valve
80	66.95	16810.000000	32	FIG. 7	check valve inlet gas nitrogen to purge system
37.00	66.97	16810.000000	33	FIG. 3&7	Nitrogen from valve 238 to FIG. 7 the nitrogen to purge system
37.00	66.97	16810.000000	33	FIG. 7&3	from FIG. 3
80.00	65.00	4000	34	FIG. 5&7	Seal gas from FIG. 7 to feed points 75 and 76
80	65	4000.000000	34	FIG. 7&5	Seal gas to turbines on FIG. 5
80.00	65.00	4000	35	FIG. 5&7	Seal gas from FIG. 7 to feed points 77 and 78
80	65	4000.000000	35	FIG. 7&5	Seal gas to turbines FIG. 5
80.00	65.00	6500.000000	36	FIG. 2	pure nitrogen gas from FIG. 7 to argon dryer bed on reactivation.
80	65	6500.000000	36	FIG. 7&2	Argon drier regeneration FIG. 2
80.00	15.00	200.000000	37	FIG. 2&7	nitrogen gas purge flow to warm up vent valve for 423 flow.
80	65	200.000000	37	FIG. 7&2	Warming purge to the refined argon separator nitrogen vent valve FIG. 2
80	65	200.000000	38	FIG. 7	Warming purge to the instrument nitrogen back up tank 174 vent valve
80.00	65.00	200.000000	39	FIG. 1	from FIG. 7 gas nitrogen to warm the burst disk and relief valve
80	65	200.000000	39	FIG. 7&1	Warming purge for low pressure column vent and relieve valve FIG. 1
80.00	65.00	800.000000	40	FIG. 1&7	this is a nitrogen gas to purge the cold box coming from FIG. 7

80	65	800.000000	40	FIG. 7&1	Cold box casing purge FIG. 1
80.00	65.00	200.000000	41	FIG. 4&7	nitrogen purge flow from FIG. 7 to liquefier box purge
80	65	200.000000	41	FIG. 7&4	Liquefier casing purge FIG. 4
80.00	65.00	400.000000	42	FIG. 5&7	FIG. 5 turbine duct cas- ing purge from FIG. 7
80	65	400.000000	42	FIG. 7&5	Turbine duct casing purge FIG. 5
80.00	65.00	10.000000	43	FIG. 5&7	FIG. 5 nitrogen pres- sure to the oil accumu- lator from FIG. 7
80	65	10.000000	43	FIG. 7&5	to FIG. 5 turbine oil ac- cumulator
80	65	300.000000	44	FIG. 7&8	To oxygen filters, warming nitrogen purge and case purge FIG. 8 point 44
80.00	65.00	300.000000	44	FIG. 8&7	from FIG. 7, warming nitrogen and purge inlet psig
80	60	0.000000	45	FIG. 7	purge backup pressure regulator
80	125	0.000000	46	FIG. 7	Back up nitrogen tank 174 vent
80.00	65.00	200.000000	47	FIG. 8	oxygen filter case purge FIG. 8 psig
-311.60	18.39	37900.000000	50	FIG. 1	waste nitrogen from tray 10 from point 116 LPC to SC 117
-282.00	17.64	37900.000000	51	FIG. 1	waste nitrogen from SC 117 to MHE 113 (psia)
37.00	16.50	37900.000000	52	FIG. 1	Waste nitrogen exit MHE 113 to a flow control valve then MS bed (psia)
37.00	15.90	37900.000000	53	FIG. 1	waste nitrogen flow, af- ter control valve to the MS reactivation heater 122 (psia)

37.00	15.90	37900.000000	54	FIG. 1	hot or cold waste nitrogen to mol sieve bed on reactivation
80.00	14.70	37900.000000	55	FIG. 1	waste nitrogen to vent after the mol sieve on reactivation
80.00	65.00	100.000000	60	FIG. 8	warming nitrogen inlet flow meter psig
80.00	65.00	100.000000	61	FIG. 8	auto valve for warming nitrogen inlet psig
80.00	64.99	100.000000	62	FIG. 8	warming nitrogen inlet flow check valve psig
80.00	64.98	0.000000	63	FIG. 8	warming nitrogen auto valve to filter number 175 psig
-298.00	23.92	0.000000	64	FIG. 8	shut off valve for warming nitrogen on filter number 175 psia
80.00	14.70	0.000000	65	FIG. 8	warming nitrogen relief valve psia
80.00	14.70	0.000000	66	FIG. 8	warming nitrogen auto double block and bleed vent psia
80.00	64.98	0.000000	67	FIG. 8	warming nitrogen header relief valve psig
80.00	64.98	0.000000	68	FIG. 8	warming nitrogen header vent psig
80.00	64.97	100.000000	69	FIG. 8	warming nitrogen auto valve to filter number 176, psig
80.00	64.96	100.000000	70	FIG. 8	shut off valve for warming nitrogen on filter number 176, psig
80.00	64.96	0.000000	71	FIG. 8	warming nitrogen relief valve psig
80.00	64.96	0.000000	72	FIG. 8	warming nitrogen auto double block and bleed vent psig
80.00	65.00	2,000.000000	75	FIG. 5	Nitrogen gas from point 34 for seal gas to turbine 153

blank	blank	2,000.000000	76	FIG. 5	Nitrogen gas from point 34 for seal gas to turbine 157
80.00	65.00	2,000.000000	77	FIG. 5	Nitrogen gas from point 35 for seal gas to turbine 161
blank	blank	2,000.000000	78	FIG. 5	Nitrogen gas from point 35 for seal gas to turbine 165
72.81	14.50	795754.864039	100	FIG. 1	Air separation filter house 795,754.8 scfh air flow (psia)
168.00	85.51	795754.738708	101	FIG. 1	exit the 4th stage (psig)
168.00	60.00	0.125331	102	FIG. 1	The three intercoolers condensation will strip away this. The solubility of this gas in the first waters. (psig)
168.00	85.51	0.000000	103	FIG. 1	MAC VENT (psig)
90.00	83.31	795754.738708	104	FIG. 1	exit aftercooler (psig)
38.00	82.81	795754.738708	105	FIG. 1	chiller unit exit
38.00	82.31	795746.763479	106	FIG. 1	chilled air out of the water separator (psig)
38.00	82.81	7.975229	107	FIG. 1	water separator water blow down (psig)
50.00	80.51	246.763478	108	FIG. 1	molecular sieve beds and dust filter removes this (psig)
vessel	vessel	vessel	109	FIG. 1	second mol sieve vessel
45.47	78.51	795500.000000	110	FIG. 1	the exit of the dust filter (psig)
44.74	77.24	780000.000000	111	FIG. 1	Main flow meter (psig)
45.10	78.44	15500.000000	112	FIG. 1	open or closed valve to instrument air system

vessel	vessel	0.000000	113	FIG. 1	the main heat exchanger five pass heat ex- changer
vessel	vessel	vessel	114	FIG. 1	vessel the high pressure column
vessel	vessel	vessel	115	FIG. 1	this is the high pressure reboiler in the low pres- sure column
vessel	vessel	0.000000	116	FIG. 1	vessel the low pressure column
vessel	vessel	0.000000	117	FIG. 1	the sub cooler, five pass heat exchanger
vessel	vessel	vessel	118	FIG. 1	vessel the crude argon column
vessel	vessel	vessel	119	FIG. 1	this is the crude argon column reboiler in the argon condenser
vessel	vessel	0.000000	120	FIG. 1	Vessel the crude argon condenser, two pass heat exchanger, phase exchanger
vessel	vessel	0.000000	121	FIG. 1	Vessel the crude argon phase separator
heater	heater	heater	122	FIG. 1	heater for mol sieve
-295.00	20.00	38670.824876	123	FIG. 2	REF ARGON TRANSPORT TRAILER
-295.00	20.00	1299339.715842	124	FIG. 2	REF ARGON STOR- AGE TANK
heat ex- changer	heat ex- changer	heat exchanger	125	FIG. 2	argon recondenser ex- changer side
liquid holder	liquid holder	0.000000	126	FIG. 2	argon recondenser liq- uid nitrogen side
hydro- gen separa- tor	hydro- gen separa- tor	hydrogen separa- tor	127	FIG. 2	ARGON HYGROGEN SEPERATOR
-297.00	26.00	14191.128395	128	FIG. 2	argon reboiler tube side

-297.00	26.00	7095.564197	129	FIG. 2	outer shell holding liquid argon
vessel	vessel	0.000000	130	FIG. 2	ARGON PURE COLUMN
heat exchanger	heat exchanger	0.000000	131	FIG. 2	pure argon condenser heat exchanger
-307.00	24.70	7587.889152	132	FIG. 2	pure argon phase separator
heat exchanger	heat exchanger	heat exchanger	133	FIG. 2	crude and combusted argon heat exchanger
98.00	15.00	7491.413203	134	FIG. 2	argon compressor
98.00	56.90	7491.413203	135	FIG. 2	argon compressor after-cooler
80.00	3500.00	240000.000000	136	FIG. 2	hydrogen tube trailer
88.00	56.00	7844.826016	137	FIG. 2	argon flame arrester
87.00	56.00	7844.826016	138	FIG. 2	oxygen and hydrogen catalyst bed
heat exchanger	heat exchanger	0.000000	139	FIG. 2	deoxo water cooled aftercooler
heat exchanger	heat exchanger	0.000000	140	FIG. 2	combusted argon water phase separator
95.00	55.00	7368.313118	141	FIG. 2	one of two dryer vessels this one is on line
80.00	65.00	6500.000000	142	FIG. 2	one of two dryer vessels this one is on reactivation
vessel	vessel	vessel	143	FIG. 2	argon dust filter
heat exchanger	heat exchanger	heat exchanger	144	FIG. 4	Four pass heat exchanger called the oxygen cooler

heat exchanger	heat exchanger	heat exchanger	145	FIG. 4	Five pass heat exchanger called the boiler
heat exchanger	heat exchanger	heat exchanger	146	FIG. 4	Six pass heat exchanger called the condenser
flash pot	flash pot	flash pot	147	FIG. 4	Shell and tube heat exchanger called the oxygen production flash pot
flash pot	flash pot	flash pot	148	FIG. 4	Shell and tube heat exchanger called the nitrogen production flash pot
flash pot	flash pot	flash pot	149	FIG. 4	Shell and tube heat exchanger called the nitrogen pump flash pot
heat exchanger	heat exchanger	heat exchanger	150	FIG. 4	Three pass heat exchanger called the added cooling heat exchanger
phase separator	phase separator	phase separator	151	FIG. 4	Exhaust of the turbines phase separator
heat exchanger	heat exchanger	heat exchanger	152	FIG. 4	Four pass heat exchanger called the pre heater
-155.00	420.00	180,000.000000	153	FIG. 5	turbine expander inlet
-287.00	84.00	180,000.000000	153	FIG. 5	turbine expander outlet
guide vanes	guide vanes	guide vanes	154	FIG. 5	inlet guide vanes
55.00	14.90	398,184.701923	155	FIG. 5	155 turbine booster inlet
245.00	26.74	398,184.701923	155	FIG. 5	155 turbine booster outlet
245.00	26.74	398,184.701923	156	FIG. 5	156 turbine after cooler inlet
90.00	25.74	398,184.701923	156	FIG. 5	156 turbine after cooler outlet
-155.00	420.00	180,000.000000	157	FIG. 5	turbine expander inlet

-287.00	84.00	180,000.000000	157	FIG. 5	turbine expander outlet
guide vanes	guide vanes	guide vanes	158	FIG. 5	inlet guide vanes
87.00	25.74	398,184.701923	159	FIG. 5	inlet to turbine 159
255.00	42.32	398,184.701923	159	FIG. 5	outlet of turbine 159 to aftercooler
255.00	42.32	398,184.701923	160	FIG. 5	into aftercooler 160
90.00	41.32	398,184.701923	160	FIG. 5	exit of 160 aftercooler
-155.00	420.00	180,000.000000	161	FIG. 5	turbine expander inlet
-287.00	84.00	180,000.000000	161	FIG. 5	turbine expander outlet
guide vanes	guide vanes	guide vanes	162	FIG. 5	inlet guide vanes
90.00	41.32	398,184.701923	163	FIG. 5	flow into turbine booster 163
265.00	66.52	398,184.701923	163	FIG. 5	flow out of 163
265.00	66.52	398,184.701923	164	FIG. 5	turbine booster after cooler 164 inlet
90.00	65.52	398,184.701923	164	FIG. 5	turbine booster after cooler 164 outlet
-155.00	420.00	360,000.000000	165	FIG. 5	turbine expander inlet
-287.00	84.00	360,000.000000	165	FIG. 5	turbine expander outlet
guide vanes	guide vanes	guide vanes	166	FIG. 5	inlet guide vanes

50.00	65.00	1,465,374.701923	167	FIG. 5	flow into turbine booster 167
250.00	112.82	1,465,374.701923	167	FIG. 5	flow out of turbine booster 167
250.00	112.82	1,465,374.701923	168	FIG. 5	flow into turbine booster after cooler 168
90.00	111.82	1,465,374.701923	168	FIG. 5	flow out of turbine booster after cooler 168
pump	pump	pump	169	FIG. 6	liquid nitrogen pump
pump	pump	pump	170	FIG. 6	liquid nitrogen pump
-320.00	1.00	0.000000	171	FIG. 6	LIQUID NITROGEN STORAGE TANK
80.00	14.70	0.000000	172	FIG. 6	NITROGEN TANK PUMP BACK PUMP
-280	120	1163160.000000	174	FIG. 7	NBT Backup liquid nitrogen storage tank HOLD 36 HOURS
filter	filter	filter	175	FIG. 8	oxygen filter number 1
filter	filter	filter	176	FIG. 8	oxygen filter number 2
tank	tank	tank	177	FIG. 8	oxygen storage tank
80	80	0.000000	178	FIG. 7	tube side nitrogen evaporators
-290.89	70.00	841180.060000	200	FIG. 1	total gas exiting the top of the HPC 114 (psig)
-290.89	70.00	630180.060000	201	FIG. 1	nitrogen gas split off of 200 going to the re-boiler 115. (psig)
-290.89	70.00	211000.000000	202	FIG. 1	this is the gas at the top of the HPC 114 that is removed to the entry MHE 113 cold side (psig)

37.00	67.00	211000.000000	203	FIG. 1&3	high pressure nitrogen off of MHE 113 warm side. (psig) to FIG. 3
37.00	67.00	211000.000000	203	FIG. 3&1	From 113 MHE high pressure column gas nitrogen from FIG. 1 controlled by the ASU
-317.40	17.31	362637.548954	210	FIG. 1	top of the LPC 116 pure nitrogen gas exit (psia)
80.00	17.30	0.000000	211	FIG. 1	Low pressure column common line to a burst disk and a relief valve
80.00	14.70	0.000000	212	FIG. 1	burst disk to protect the low pressure column
80.00	14.70	0.000000	213	FIG. 1	relief valve to protect the low pressure column
-317.40	17.31	371184.701923	214	FIG. 1	Low pressure nitrogen blended flow to the SC 117 (psia).
-282.00	17.10	371184.701923	215	FIG. 1	combined pure nitrogen low pressures exit the SC 117 to MHE 113 cold side (psia)
37.29	14.94	371184.701923	216	FIG. 1&3	exit of MHE 113 low pressure pure nitrogen gas to FIG. 3 (psia)
37.29	14.94	371184.701923	216	FIG. 3&1	Low pressure nitrogen flow from 113 MHE FIG. 1
-292.59	75.97	630180.060000	220	FIG. 1	liquid nitrogen removed from the POINT 115 re-boiler. (psig)
-292.59	75.97	498180.060000	221	FIG. 1	liquid to the top tray #38 of the POINT 114, cold cap. (psig)
-292.59	75.97	132000.000000	222	FIG. 1	Pure liquid nitrogen from POINT 115 to the POINT 117 subcooler. (psig)
-303.00	54.10	132000.000000	223	FIG. 1	The POINT 115 pure liquid nitrogen exit SC 117 raise 45' to auto control valve. (psig)
-317.40	17.31	132000.000000	224	FIG. 1	liquid nitrogen out control valve (psia)

-317.40	17.31	134345.000000	225	FIG. 1	combined liquid nitrogen to LPC 116 (psia)
37.00	66.99	211000.000000	231	FIG. 3	High pressure column gas nitrogen flow meter flow set by ASU
37.00	66.99	211000.000000	232	FIG. 3	inlet to liquefier auto valve
37.00	66.98	0.000000	233	FIG. 3	High pressure column gas nitrogen over load flow meter
37.00	14.70	0.000000	234	FIG. 3	relief valve EXIT
37.00	14.70	0.000000	235	FIG. 3	over load auto vent valve EXIT
37.00	66.98	211000.000000	236	FIG. 3	inlet to liquefier check valve
37.00	66.97	211000.000000	237	FIG. 3	inlet flow meter to liquefier high pressure column gas nitrogen and purge system
37.00	66.97	16810.000000	238	FIG. 3	Open or closed valve, for the nitrogen purge system
37.00	66.96	194190.000000	239	FIG. 3&4	High pressure column gas nitrogen to FIG. 4 the liquefier
37.00	66.96	194190.000000	239	FIG. 4&3	higher pressure from FIG. 3 point 239
37.29	14.93	371184.701923	250	FIG. 3	low pressure nitrogen flow meter set by ASU
37.29	14.93	371184.701923	251	FIG. 3	inlet to liquefier auto flow control valve
37.29	14.93	0.000000	252	FIG. 3	Low pressure nitrogen over load flow meter
37.29	14.93	0.000000	253	FIG. 3	relief valve EXIT
37.29	14.93	0.000000	254	FIG. 3	over load auto vent valve EXIT

37.29	14.93	371184.701923	255	FIG. 3	inlet to liquefier check valve
37.29	14.93	371184.701923	256	FIG. 3	Into liquefier low pressure gas nitrogen flow meter
37.29	14.93	371184.701923	257	FIG. 3&4	low pressure gas nitrogen inlet to liquefier to FIG. 4
37.29	14.93	371184.701923	257	FIG. 4&3	low pressure nitrogen gas from inlet or vent FIG. 3 point 257
-255.00	17.00	5000.000000	260	FIG. 4	low pressure nitrogen gas through 260 from 147 shell side
-255.00	17.00	0.000000	261	FIG. 4	low pressure nitrogen gas through 261 = zero due to low pressure
-255.00	17.00	15000.000000	262	FIG. 4	low pressure nitrogen gas through 262 from 149 shell side
-255.00	17.00	0.000000	263	FIG. 4	low pressure nitrogen gas through 263 = zero due to low pressure
50.00	15.00	27000.000000	264	FIG. 4	lower pressure gas nitrogen through 145 boiler then to 144 oxygen cooler then through valve 264
45.00	14.90	398184.701923	265	FIG. 4&5	all low pressure gas nitrogen to FIG. 5 point 265
55.00	14.90	398,184.701923	265	FIG. 5&4	From FIG. 4 low pressure nitrogen feed to 270
55.00	14.90	398,184.701923	270	FIG. 5	155 booster inlet flow controller
80.00	25.74	0.000000	271	FIG. 5	155 turbine surge controller inlet
80.00	14.90	0.000000	271	FIG. 5	155 turbine surge controller outlet
80.00	14.90	0.000000	272	FIG. 5	155 turbine surge check valve outlet
80.00	14.90	0.000000	272	FIG. 5	155 turbine surge check valve inlet

90.00	25.74	1000.000000	273	FIG. 4&5	hot gas from 156 FIG. 5 to here
90.00	25.74	1,000.000000	273	FIG. 5&4	hot gas from 156 outlet to FIG. 4, 274 control valve
90.00	25.74	1000.000000	274	FIG. 4	Control valve hot gas into 152
-260.00	25.74	1000.000000	275	FIG. 4&5	cooler gas exit 152 to FIG. 5
-240.00	25.74	1,000.000000	275	FIG. 5&4	from FIG. 4 exit of 152, to here after check valve 276.
88.00	25.74	397,184.701923	276	FIG. 5	flow into 276 check valve.
88.00	25.74	397,184.701923	276	FIG. 5	Flow from 276, to turbine flow controller 277
87.00	25.74	398,184.701923	277	FIG. 5	flow controller 277, booster inlet 159
80.00	41.32	0.000000	278	FIG. 5	inlet to 159 surge controller
80.00	25.74	0.000000	278	FIG. 5	outlet of 159 surge controller
80.00	25.74	0.000000	279	FIG. 5	flow exit check valve 279 surge control inlet to 159
90.00	41.32	398,184.701923	280	FIG. 5	flow through flow controller 280
90.00	65.52	0.000000	281	FIG. 5	turbine booster surge controller inlet 281
80.00	41.32	0.000000	281	FIG. 5	turbine booster surge controller 281 exit.
80.00	41.32	0.000000	282	FIG. 5	exit of the surge check valve 282
80.00	41.32	0.000000	282	FIG. 5	turbine booster surge check valve 282 inlet

50.00	65.00	1,465,374.701923	283	FIG. 5	flow through flow controller 283 START MAJOR FLOW
90.00	111.82	0.000000	284	FIG. 5	turbine booster surge controller 284 inlet.
80.00	65.00	0.000000	284	FIG. 5	turbine booster surge controller 284 exit.
80.00	65.00	0.000000	285	FIG. 5	turbine booster surge controller check valve outlet
80.00	65.00	0.000000	285	FIG. 5	turbine booster surge check valve 285 inlet
-155.00	420.00	900000.000000	288	FIG. 4	temp out of 152 pre heater on gas nitrogen to turbine expanders FIG. 5, (510 FLOW = 528 FLOW)
-155.00	420.00	900,000.000000	288	FIG. 5&4	from FIG. 4 point 288, to here
-155.00	420.00	180,000.000000	289	FIG. 5	inlet flow controller, sets the guide veins
-155.00	420.00	180,000.000000	290	FIG. 5	inlet flow controller, sets the guide veins
-155.00	420.00	180,000.000000	291	FIG. 5	inlet flow controller, sets the guide veins
-155.00	420.00	360,000.000000	292	FIG. 5	inlet flow controller, sets the guide vanes
-292.66	37.93	2000.000000	300	FIG. 1	liquid oxygen removed from LPC 116 to SC 117 (psia)
-298.00	34.93	2000.000000	301	FIG. 1	liquid oxygen from SC 117 to auto control valve (open or closed) (psia)
-298.00	23.93	2000.000000	302	FIG. 1&8	liquid oxygen to oxygen filter system. FIG. 8 (psia)
-298.00	23.93	2,000.000000	302	FIG. 8&1	ASU liquid oxygen to filter box, from FIG. 1 psia

-298.00	24.00	161521.037842	305	FIG. 4&8	Liquid oxygen to FIG. 8
-298.00	24.00	161,521.037842	305	FIG. 8&4	inlet liquid oxygen from liquefier from FIG. 4 psia
-298.00	23.89	161521.037842	310	FIG. 8	inlet check valve liquid oxygen to filter box FIG. 8, psia
-298.00	23.89	0.000000	311	FIG. 8	relief valve on the liquid oxygen header psia
-298.00	23.89	0.000000	312	FIG. 8	auto control valve liquid oxygen to dump system psia
-298.00	23.89	161521.037842	313	FIG. 8	auto control valve liquid oxygen to storage system psia
-298.00	23.88	0.000000	314	FIG. 8	relief valve on the double block and bleed psia
-298.00	23.88	0.000000	315	FIG. 8	auto control valve double block and bleed vent psia
-298.00	23.88	161521.037842	316	FIG. 8	auto control valve liquid oxygen to storage system psia
-292.66	21.93	161521.037842	320	FIG. 1	gas oxygen removed from LPC 116. To cold side of MHE 113.(psia)
37.00	19.93	161521.037842	321	FIG. 1&3	gas oxygen removed from MHE 113 warm side to FIG. 3 point 321. (psia)
37.00	19.93	161521.037842	321	FIG. 3&1	Low pressure oxygen gas flow from 113 FIG. 1
37.00	19.92	161521.037842	325	FIG. 3	Inlet flow meter, control feed flow set by ASU
37.00	19.90	161521.037842	326	FIG. 3	Oxygen inlet to liquefier auto flow control valve
37.00	19.89	0.000000	327	FIG. 3	over load flow meter
37.00	14.70	0.000000	328	FIG. 3	relief valve EXIT

37.00	14.70	0.000000	329	FIG. 3	over load auto vent valve EXIT
37.00	19.89	161521.037842	330	FIG. 3	inlet to liquefier check valve
37.00	19.87	161521.037842	331	FIG. 3	Gas oxygen to liquefier flow meter.
37.00	19.86	161521.037842	332	FIG. 3&4	Oxygen inlet to liquefier FIG. 4
37.00	19.86	161521.037842	332	FIG. 4&3	Oxygen gas from FIG. 3 to here
-298.00	23.93	2000.000000	335	FIG. 8	liquid oxygen from asu to oxygen filter check valve psia
-298.00	23.93	0.000000	336	FIG. 8	entry to oxygen dump or bypass filters psia
80.00	14.70	0.000000	337	FIG. 8	relief valve on the double block and bleed psia
80.00	14.70	0.000000	338	FIG. 8	asu liquid oxygen to dump system psia
80.00	14.70	0.000000	339	FIG. 8	liquid oxygen to bypass the filters psia
80.00	14.70	0.000000	340	FIG. 8	bypass double block and bleed relief valve psia
80.00	14.70	0.000000	341	FIG. 8	bypass double block and bleed vent valve psia
80.00	14.70	0.000000	342	FIG. 8	bypass liquid oxygen exit to storage psia
-298.00	23.93	2000.000000	343	FIG. 8	asu liquid oxygen entry valve to filter 175, psia
-298.00	23.92	0.000000	344	FIG. 8	relief valve on the double block and bleed psia
-298.00	23.92	0.000000	345	FIG. 8	double block and bleed vent valve psia

-298.00	23.92	2000.000000	346	FIG. 8	inlet valve to filter 175, psia
-298.00	0.00	0.000000	347	FIG. 8	delta pressure controller for 175
-298.00	0.00	0.000000	348	FIG. 8	temperature indicator and controller for 175
-298.00	22.92	0.000000	349	FIG. 8	relief valve on the dou- ble block and bleed psia
-298.00	22.92	0.000000	350	FIG. 8	double block and bleed vent valve psia
-298.00	22.92	0.000000	351	FIG. 8	inlet to cool down sys- tem to 176 psia
-298.00	22.92	1999.101368	352	FIG. 8	inlet to double block and bleed exit psia
-298.00	22.91	0.000000	353	FIG. 8	relief valve on the dou- ble block and bleed psia
-298.00	22.91	0.000000	354	FIG. 8	double block and bleed vent valve psia
-298.00	22.91	1999.101368	355	FIG. 8	filter 175 to storage header psia
-298.00	23.93	0.000000	356	FIG. 8	inlet asu liquid oxygen header relief valve psia
-298.00	23.93	0.000000	357	FIG. 8	asu liquid oxygen entry valve to filter 176 psia
80.00	14.70	0.000000	358	FIG. 8	relief valve on the dou- ble block and bleed psia
80.00	14.70	0.000000	359	FIG. 8	double block and bleed vent valve psia
80.00	14.70	0.000000	360	FIG. 8	inlet valve to filter 176, psia
80.00	0.00	0.000000	361	FIG. 8	delta pressure controller for 176

-155.00	0.00	0.000000	362	FIG. 8	temperature indicator and controller for 175
-155.00	63.00	0.000000	363	FIG. 8	relief valve on the double block and bleed psig
-155.00	63.00	121.567188	364	FIG. 8	double block and bleed vent valve psig
-155.00	63.00	0.000000	365	FIG. 8	inlet to cool down system to 175, psig
-155.00	63.00	0.000000	366	FIG. 8	inlet to double block and bleed exit psig
80.00	14.70	0.000000	367	FIG. 8	relief valve on the double block and bleed psia
80.00	14.70	0.000000	368	FIG. 8	double block and bleed vent valve psia
80.00	14.70	0.000000	369	FIG. 8	filter 176 to storage psia
80.00	14.70	0.000000	370	FIG. 8	cool down double block and bleed relief valve psia
80.00	14.70	0.000000	371	FIG. 8	cool down double block and bleed vent valve psia
80.00	14.70	0.000000	372	FIG. 8	cool down auto flow control valve psia
80.00	14.70	0.000000	373	FIG. 8	cool down check valve psia
80.00	14.70	0.000000	374	FIG. 8	cool down system relief valve psia
80.00	14.70	0.000000	375	FIG. 8	flow indicator and controller of the cool down system psia
80.00	14.70	0.000000	376	FIG. 8	double block and bleed vent valve psia
80.00	14.70	0.000000	377	FIG. 8	cool down auto valve inlet to 175, psia

80.00	14.70	0.000000	378	FIG. 8	cool down auto valve inlet to 176, psia
-298.00	20.00	0.000000	379	FIG. 8	storage header relief valve psia
-298.00	20.00	0.000000	380	FIG. 8	double block and bleed vent and purge valve,psia
-298.00	19.99	163520.139210	381	FIG. 8	liquid oxygen to storage tank psia
-298.00	15.70	100.000000	382	FIG. 8	oxygen storage tank vent psia
-304.00	18.11	7286.413203	400	FIG. 1&2	Gas out Crude argon phase separator 112 (psia) to FIG. 2
-304.00	18.11	7286.413203	400	FIG. 2&1	crude argon to AHE 133 cold side.
98.00	15.00	7286.413203	401	FIG. 2	Crude argon out of the AHE 133 warm side
102.00	50.50	7368.313118	402	FIG. 2	into the warm side of the combusted argon heat exchanger
80.00	16.34	205.000000	403	FIG. 2	Out of the 128 to control valve hydrogen excess return
98.00	15.00	7491.413203	404	FIG. 2	inlet to AP 134. crude Argon hydrogen
240.00	60.00	7491.413203	405	FIG. 2	exit of AP 134 to after-cooler 135
88.00	58.00	7491.413203	406	FIG. 2	exit after cooler 135
80.00	3500.00	240000.000000	407	FIG. 2	From Hydrogen tube trailer 136 to control valve
80.00	60.00	353.412813	408	FIG. 2	After control valve extra hydrogen feed
88.00	56.00	7844.826016	409	FIG. 2	Blended crude argon and hydrogen into argon flash arrester 137

87.00	56.00	7844.826016	410	FIG. 2	into argon deoxo 138
900.00	55.00	7368.313118	411	FIG. 2	into combusted argon after cooler 139
88.00	54.50	7368.313118	412	FIG. 2	into combusted argon water separator 140
88.00	54.00	7368.313118	413	FIG. 2	into combusted argon dryer bed on line 141
104.00	52.00	7368.313118	414	FIG. 2	into combusted argon dust filter 143
-282.00	42.15	7368.313118	415	FIG. 2	Out of the cold side of the combusted argon heat exchanger 113 to hydrogen separator 127
-297.00	40.11	7163.313118	416	FIG. 2	Gas from 127 to hydrogen separator condenser tube side 128
-297.00	40.11	7163.313118	417	FIG. 2	Liquid from 128 tube side hydrogen separator condenser return to 127
-297.00	40.11	7163.313118	418	FIG. 2	Argon and nitrogen liquid from hydrogen separator 127
-298.00	40.00	205.000000	419	FIG. 2	hydrogen gas from tube side of the 128 to a control valve
-297.00	25.11	7163.313118	420	FIG. 2	418 liquid argon and nitrogen to tray 30 after control valve
-307.00	24.90	7587.889152	421	FIG. 2	Mostly gas nitrogen and hydrogen gas off the top of the pure argon column
-307.00	24.70	7587.889152	422	FIG. 2	All of the hydrogen gas, and nitrogen gas from the tube side of the 131 the condenser to the 132 separator
-307.00	14.70	67.748921	423	FIG. 2	All of the hydrogen gas and a little nitrogen gas from the 132 separator, vent to atm.
-307.00	24.70	7520.140231	424	FIG. 2	Liquid nitrogen from 132 phase separator back to the 38 tray of the 130 column

-297.00	26.00	7095.564197	425	FIG. 2	129 overflow of pure liquid argon, now bottom liquid of the 130 column, Pure liquid argon to auto control valve to storage
-297.00	20.00	7734.164975	427	FIG. 2	total liquid argon after auto control valves to storage
-250.00	20.00	425.733852	428	FIG. 2	124 Storage tank, gas off to auto control valve
-250.00	20.00	212.866926	429	FIG. 2	123 Transport trailer, gas off to auto control valve
-250.00	19.50	638.600778	430	FIG. 2	123 gas off, and 124 gas off, after the auto control valves to the tube side of the 125 argon recondenser
-297.00	27.60	638.600778	431	FIG. 2	125 tube side recondensed liquid argon to auto control valve to storage
87.00	55.05	0.000000	432	FIG. 2	combusted argon water out of phase separator
80.00	65.00	6500.000000	433	FIG. 2	argon dryer bed reactivation vent
-287.00	84.00	900000.000000	450	FIG. 4&5	From FIG. 5 point 450 turbines exhaust to the 151 with 3% liquid droplets
-287.00	84.00	900,000.000000	450	FIG. 5	turbine discharge header
-286.00	80.00	2000.000000	451	FIG. 4	over produced liquid nitrogen in the 151, major flash off.
-286.00	80.00	5000.000000	452	FIG. 4	liquid nitrogen from 151 to oxygen flash pot 147=high flash
-286.00	80.00	5000.000000	453	FIG. 4	liquid nitrogen from 151 to nitrogen production flash pot 148
-286.00	80.00	15000.000000	454	FIG. 4	liquid nitrogen from 151 to pump flash pot 149

50.00	67.00	873000.000000	455	FIG. 4	higher pressure nitrogen gas out of 145 boiler to 144 oxygen cooler then through valve 455
45.00	66.50	1000.000000	456	FIG. 4	branch off to pre heater 152
45.00	66.50	1066190.000000	457	FIG. 4	controlling valve to add back pressure for 456 to cross the pre heater 152
43.00	65.00	1067190.000000	458	FIG. 4&5	TEMP CHANGE, point 458 to FIG. 5
43.00	65.00	1,067,190.000000	458	FIG. 5	from point 458 FIG. 4 to here
-316.30	18.00	5000.000000	459	FIG. 4	gas nitrogen out of the 148 nitrogen production flash pot to 150 ADDED COOLING HEAT EXCHANGER
-300.00	18.00	15000.000000	460	FIG. 4	gas nitrogen out of shell side of 149 pump flash pot
-300.00	18.00	15000.000000	460	FIG. 4	low pressure cool nitrogen to 146 condenser from 149 shell side
-316.00	18.00	5000.000000	461	FIG. 4	gas nitrogen out of the shell side of the 147 oxygen production flash pot
-316.00	18.00	5000.000000	461	FIG. 4	low pressure cool nitrogen to condenser from 461
45.00	66.50	1067190.000000	462	FIG. 4	ref point 462
90.00	111.82	1465374.701923	500	FIG. 4&5	from FIG. 5, major flow into the liquefier from the 168 after cooler
90.00	111.82	1,465,374.701923	500	FIG. 5&4	flow not taken by surge controller 284, now to 500. FIG. 4
90.00	111.82	1465374.701923	501	FIG. 4	one of three branch off of point 500, to the 144 oxygen cooler
90.00	111.82	426895.739765	502	FIG. 4	one of three branch off of point 500, bypass

90.00	111.82	300000.000000	503	FIG. 4	one of three branch off of point 500, to the 152 per heater
-299.00	100.00	900000.000000	510	FIG. 4&6	liquid nitrogen to the recirculation pump FIG. 6, PUMP HOUSE
-299.00	100.00	900000.000000	510	FIG. 6&4	from FIG. 4, this is the pump inlet flow or by-pass
-299.00	100.00	10892.152969	511	FIG. 4&6	liquid nitrogen to FIG. 6 feed to ASU
-299.00	100.00	10892.152969	511	FIG. 6&4	Liquid nitrogen from FIG. 4 to dump or return to asu
0.00	0.00	0.000000	512	FIG. 4	liquid nitrogen to shell side of the 149 pump flash pot off of production = low flash
0.00	0.00	0.000000	513	FIG. 4	liquid nitrogen to the shell side of the 147 oxygen production flash pot from production = low flash
0.00	0.00	0.000000	514	FIG. 4	liquid nitrogen to the shell side of the 148 nitrogen production flash pot off of production= low flash
-310.00	90.00	554482.548954	515	FIG. 4&6	production liquid nitrogen to storage FIG. 6
-310.00	90.00	554482.548954	515	FIG. 6&4	from FIG. 4, liquid nitrogen to storage or dump
-299.00	100.00	900000.000000	520	FIG. 6	valve inlet to pump 169
-299.00	100.00	0.000000	521	FIG. 6	valve inlet to pump 170
-299.00	100.00	0.000000	522	FIG. 6	pump bypass to 145 boiler FIG. 4
-299.00	100.00	0.000000	523	FIG. 6	pump bypass to boiler check valve
-260.00	420.00	900000.000000	524	FIG. 6	outlet valve from pump 169

80.00	14.70	0.000000	525	FIG. 6	outlet valve from pump 170
-260.00	420.00	900000.000000	526	FIG. 6	Pump 169 exit check valve
80.00	14.70	0.000000	527	FIG. 6	Pump 170 exit check valve
-286.00	100.00	900000.000000	528	FIG. 4&6	pumped liquid nitrogen from FIG. 6 to the 145 boiler
-260.00	420.00	900000.000000	528	FIG. 6&4	liquid nitrogen to FIG. 4, for the 145 boiler
0.00	0.00	0.000000	529	FIG. 4&6	pumped liquid nitrogen from FIG. 6 to the shell side of the 149 pump flash pot
-260.00	420.00	0.000000	529	FIG. 6&4	liquid nitrogen to pump flash pot 149 FIG. 4
-286.00	90.00	0.000000	530	FIG. 4	Pumped liquid nitrogen inlet of the shell side of the 149 pump flash pot = high flash off.
80.00	14.70	0.000000	535	FIG. 6	last purge point before inlet to nitrogen storage
80.00	14.70	0.000000	536	FIG. 6	last purge valve
-310.00	90.00	554482.548954	537	FIG. 6	storage entry valve
-310.00	15.70	500.000000	538	FIG. 6	storage tank vent valve
80.00	14.70	0.000000	539	FIG. 6	NITROGEN TANK PUMP BACK
80.00	14.70	0.000000	540	FIG. 6	PUMP BACK VALVE
80.00	14.70	0.000000	541	FIG. 6	PUMP BACK CHECK VALVE
-299.00	14.70	0.000000	542	FIG. 6	LIQUIFER NITROGEN TO DUMP

-299.00	100.00	10892.152969	543	FIG. 6	LIQUIFER NITROGEN TO ASU
-299.00	100.00	10892.152969	544	FIG. 1&6	from FIG. 6, liquid nitrogen from liquifier return flow to asu
-299.00	100.00	10892.152969	544	FIG. 6&1	to FIG. 1 liquid nitrogen return to ASU
-314.00	59.00	8547.152969	545	FIG. 1&2	CROSS OVER POINT 545 TO FIG. 4 (psia)
-314.00	59.00	8547.152969	545	FIG. 2&1	Liquid nitrogen from FIG. 1 to 126 and 131.
-314.00	35.00	747.152969	546	FIG. 2	liquid nitrogen after level control valve to 126
-310.00	22.00	7800.000000	547	FIG. 2	Liquid nitrogen after level control valve to 131
-314.00	59.00	2345.000000	548	FIG. 1	FIG. #1 part of the liquifier feed back to the plant before the control valve (psia)
-317.40	17.31	2345.000000	549	FIG. 1	liquid nitrogen from liquifier after control valve (psia)
-308.00	35.00	747.152969	555	FIG. 2	gas nitrogen off of the 126 to a pressure control valve
-310.00	22.00	7800.000000	556	FIG. 2	gas nitrogen off of the 131 to a pressure control valve
-315.00	17.80	8547.152969	557	FIG. 2	gas from 126 and 131 after the pressure control valves
-315.00	17.80	8547.152969	558	FIG. 1	gas nitrogen from the pure argon system, cross over from FIG. 4 (psia)
-315.00	17.80	8547.152969	558	FIG. 2&1	gas nitrogen to FIG. 1
-280.00	80.00	873000.000000	450 - (452 + 453 + 454 + 451)	ref	turbine exhaust gas from 450 after 151 to 146 condenser

-316.00	18.00	7000.000000	459+4 51	ref	low pressure cool nitrogen to condenser from 459 +451
ref	ref	20000.000000	460+4 59	ref	460+459 cold gas nitrogen to added cooling heat exchanger
90.00	65.52	398,184.701923	ref	ref	flow not taken by surge controller 281, now to 283
-255.00	17.00	27000.000000	ref	ref	combined low pressure nitrogen gas to boiler
90.00	41.32	398,184.701923	REF	REF	flow not taken by surge controller 278, now to 280
-245.00	80.00	873000.000000	ref	ref	combined high pressure nitrogen gas to boiler
ref	ref	900000.000000	ref	ref	cold nitrogen gas to the condenser 146

[0095] The liquefier presented herein will boil liquid nitrogen to generate running gas pressures for the turbines. The liquefier is designed to work with an air separation plant, running at a stable state. The air separation plant will supply a steady stream of gaseous nitrogen and oxygen from the main heat exchanger warm end. Then, from the new liquefier, a stream of sub cooled liquid nitrogen and liquid oxygen will be sent to storage, along with a small amount of liquid nitrogen that will be returned to the air separation plant to make liquid oxygen in the low pressure column, and liquid argon both to storage. The air separation plant will be running at a reduced pressure due to the low pressure column's lower pressure. The air separation plant will be running on a maximum oxygen gas removal mode. The air separation plant, with a MAC flow like shown above, and this presented liquefier will produce liquid argon, and 2,000 scfh oxygen liquid needed to keep the hydrocarbons under 5% and remove all the krypton and xenon solids that would normally build up in the low pressure column's reboiler and be cleaned up in the oxygen filters. The plant can run a lower pressure by having almost all the oxygen removed as a gas, then oxygen gas will be liquefied in this invention, then put to storage as sell able product. The liquefaction of the oxygen gas from the low pressure column, that is not needed for a pipe line gas customer can then take place in the present liquefier. All the gas nitrogen that is not needed for a pipe line customer can be liquefied in the presented liquefier.

[0096] The presented liquefier will produce sell able liquid for less cost than what is being used today. The compressing of gas to a pressure needed to make liquid costs a lot of money. The temperature of the liquids to storage can be adjusted to meet the storage tank positive pressure requirements. The sub cooler in the distillation cold box has no control passed original design for reducing the liquid oxygen to storage temperature. This invention gives the control. The oxygen filter system can be used on any plant making liquid oxygen. This will produce liquid oxygen with less contamination. This liquefier can be placed at the end of a long pipe line to liquid at remote location. This will reduce shipping cost, and reduce truck traffic around the main plant. This liquefier can also be placed on-board a ship moving liquefied natural gas. This will keep the liquid cold to stop the venting.

[0097] While the present invention has been described at some length and with considerable particularity with respect to the several described embodiments and particularly with respect to the particular and principal intended embodiment, it is not intended that it should be limited to any such particulars or embodiments or any particular preferred embodiment but is to be construed with reference to the particular appended claims so as to provide the broadest possible interpretation of such claims in view of the prior art and, therefore, to effectively encompass the effective and intended scope of the invention with respect both to apparatus for practicing the invention and to methods of performing and practicing the invention. As used throughout, ranges are used as shorthand for describing each and every value that is within the range. Any value within the range can be selected as the terminus of the range.

CLAIMS

WHAT IS CLAIMED IS:

1. A liquefier device configured for use with an air separation plant comprising:
 - a heat exchanger system provided in an insulated housing containing an oxygen cooler, a preheater, a boiler, a condenser, an added cooler heat exchanger, a turbine exhaust phase separator, an oxygen production flash pot, a nitrogen production flash pot, a nitrogen pump flash pot, a plurality of level control valves for controlling the liquid height of a nitrogen bath in the flash pots, and a system of inlet and outlet lines connecting therebetween,
 - an oxygen gas stream, a low pressure nitrogen gas stream, and a high pressure gas nitrogen stream from the air separation plant to the heat exchanger system,
 - a turbine assembly operably connected to the heat exchanger system including a plurality of turbine expanders connected in parallel, and a plurality of turbine boosters connected in series, each turbine expander and turbine booster having an associated inlet flow meter, each turbine expander having variable guide vanes, and each turbine booster having an associated aftercooler and surge control valve, and
 - a nitrogen pump system operably connected to the heat exchanger system for increasing the pressure of a liquid nitrogen stream to the boiler,
 - the oxygen gas stream being connected to pass sequentially through the oxygen cooler, boiler, and condenser, entering the tube side of the oxygen production flash pot, and exiting as a subcooled liquid oxygen output to storage,
 - the low pressure nitrogen gas stream from the air separation plant joining a nitrogen flow from the oxygen production flash pot and the combined flow connecting to the turbine boosters of the turbine assembly,
 - an exit flow of compressed nitrogen gas from the turbine boosters providing a major nitrogen gas flow to the heat exchanger system, which flow branches into a first branch having a control valve set to warm the oxygen cooler, a second bypass branch, and a third branch having a control valve set to warm the preheater, the branches then rejoining and providing a warm flow to the boiler in order to boil away a nitrogen bath, cooling the flow which then enters the condenser and undergoes a heat exchange with the exhaust flow from the turbines and forming a two-phase liquid gas nitrogen stream which enters the added cooling heat exchanger to further cool the two-phase nitrogen stream, which is then directed to the pump flash pot to produce a single phase liquid nitrogen stream,
 - a branch connecting the liquid nitrogen stream exiting the pump flash pot to the

nitrogen pump system, where the flow pressure is increased, and a first flow from the pump system feeding the boiler, and a second flow from the pump system connecting back to the shell side of the pump flash pot,

the first flow from the boiler feeding the preheater where the nitrogen flow is vaporized, and then connecting to an inlet to the turbine expanders, and the exit exhaust flow from the turbine expanders connecting to the turbine exhaust phase separator,

a controlled liquid nitrogen flow from the phase separator to flash pots, and a gas stream off of the phase separator leading to the condenser, boiler, and oxygen cooler, to a pressure control valve and joining the high pressure nitrogen inlet line, and

another branch connecting the liquid nitrogen stream exiting the pump flash pot to the tube side of the nitrogen production flash pot, the output of which is a subcooled saleable nitrogen product.

2. The liquefier device of claim 1 in which the aftercoolers are set to hold a ninety-degree temperature on the compressed nitrogen gas exit from the turbine package.
3. The liquefier device of claim 2 in which the aftercoolers additionally comprise a double air cooling fan system, in which each fan is a 25-horsepower power belt driven fan, one fan is a fixed pitch fan, and the other fan is a variable pitch fan.
4. The liquefier device of claim 3 in which the nitrogen pump system includes two separate nitrogen pumps each having its own inlet valve, exit valve, and check valve, and only one of which pumps is in operation at one time.
5. The liquefier device of claim 4 in which the nitrogen pump system additionally includes a pump bypass line having a pump level control valve to regulate the amount of liquid to the boiler when the pumps are off or there is a slowly changing pump speed.
6. The liquefier device of claim 5 additionally comprising a flow line to an auto control valve leading to the shell side of the pump flash pot, which control valve is normally closed.
7. The liquefier device of claim 1 additionally comprising a backup gas nitrogen system.

8. The liquefier device of claim 1 additionally comprising a liquid oxygen filter system comprising an inlet from the outlet of the oxygen production flash pot including a check valve and auto control valve for either directing the liquid oxygen to dump or storage depending upon the determined purity of the liquid oxygen.
9. The liquefier device of claim 1 in which the vaporized nitrogen exit flow from the preheater turbine expanders must not be cold enough to cause more than a three percent liquid exhaust from the turbines.
10. A process for the production of liquid nitrogen and oxygen from an air separation unit comprising:
- feeding separate oxygen and high and low pressure nitrogen gas streams to a liquifier device as a pure gas;
 - passing the oxygen gas sequentially through an oxygen cooler, boiler, condenser, and an oxygen flash pot to provide a liquid oxygen stream,
 - feeding the liquid oxygen stream to an oxygen filter house, measuring the liquid oxygen purity, and then moving purified the liquid oxygen to storage, whereby the oxygen is drawn to the oxygen filter house by a change of state from liquid to gas,
 - feeding a low pressure nitrogen gas stream from the flash pots sequentially through the condenser, boiler and oxygen cooler, and joining the low pressure stream from the flash pots with the low pressure nitrogen stream from the air separation plant,
 - feeding the joined low pressure nitrogen stream to a plurality of turbine boosters and aftercoolers arranged in series to increase the pressure and cool the nitrogen stream, and providing a major nitrogen flow,
 - feeding the major flow in branch lines to the oxygen cooler, preheater, and a bypass, and then rejoining the major flow,
 - feeding the rejoined major flow to the boiler to give pressure to the turbines, then from the boiler to the condenser as a gas, then from the condenser to an added cooler as a two-phase liquid to lower the temperature, and then to a pump flash pot cooled by a nitrogen bath at low pressure, and exiting the pump flash pot as a single phase usable liquid nitrogen,
 - feeding a portion of usable liquid nitrogen off of the pump flash pot to a liquid nitrogen pump system,
 - upon exit from the pump system, feeding a first regulated flow of usable liquid

nitrogen to the boiler and boiling to a vapor point, whereby the pressure vapor point of the vapor is held back by guide vanes in a plurality of turbine expanders, then upon exit from the boiler feeding the vaporized nitrogen flow to a second preheater, and then to run the plurality of turbine expanders arranged in parallel to yield a lower pressure nitrogen gas flow, which exiting gas is a close to liquid temperature low pressure gas and almost at its boiling point, and will remove the latent heat of vaporization from the higher pressure nitrogen stream and lower pressure nitrogen stream,

feeding the lower pressure nitrogen gas flow from the turbine expanders into a turbine exhaust phase separator regulated to produce no more than three percent liquid off of the phase separator, to hold a liquid level controlled by the exit temperature of the turbines and draining auto control valves, which temperature depends on boiler pressure and preheater feed temperature, and then to the condenser to add refrigeration to the condenser,

feeding the gas stream off of the phase separator to the condenser, then to the boiler, then to the oxygen cooler, making more liquid, and upon exiting the oxygen cooler to a line containing a pressure control valve joining the higher pressure nitrogen stream inlet, which is used to heat the preheater and bypass the preheater and connects to the last turbine booster, joining to make the major flow,

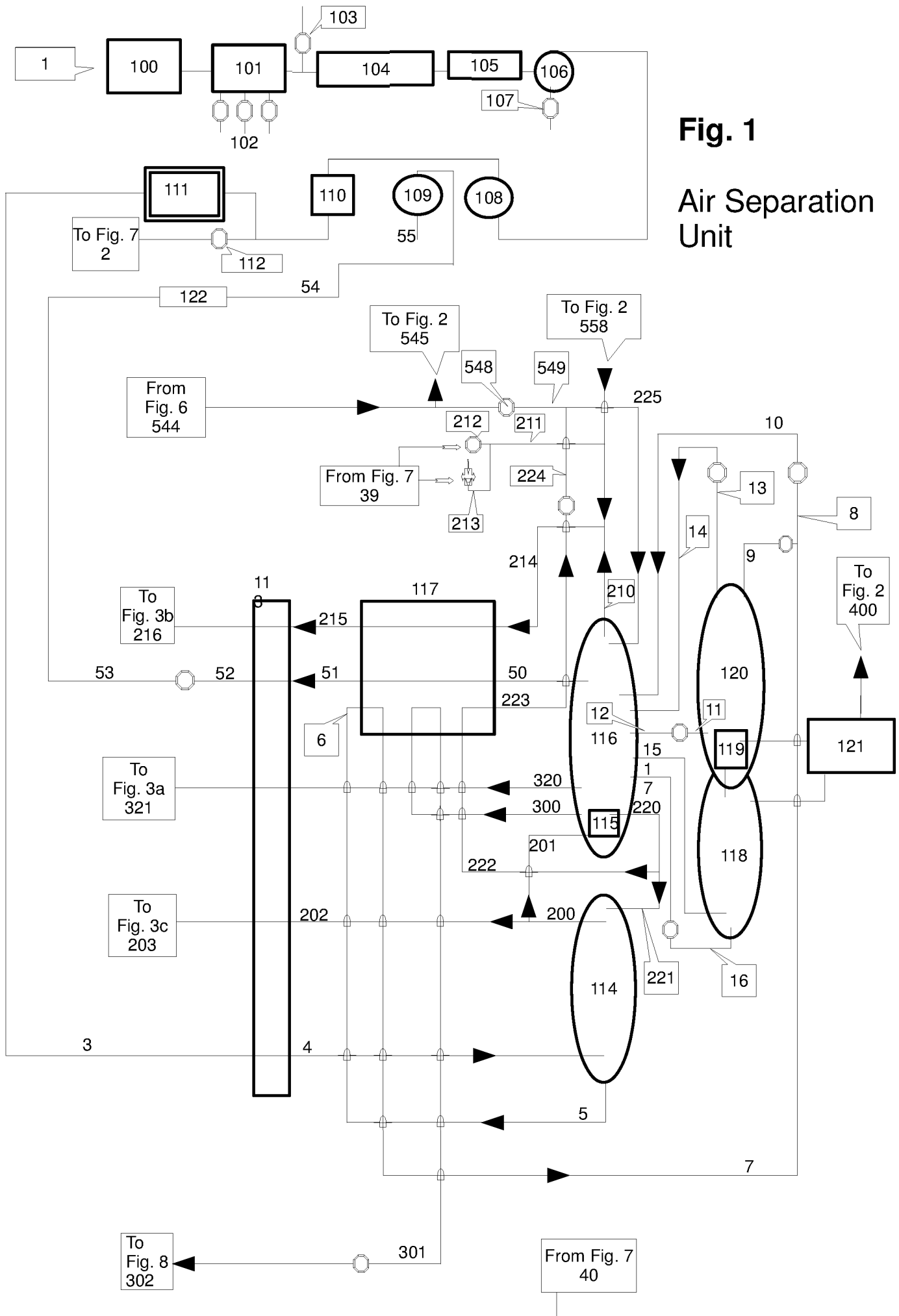
feeding the liquid off of the phase separator to the oxygen flash pot, the nitrogen production flash pot, and pump flash pot as regulated by separate auto level control valves, and any remaining liquid off of the phase separator to a control valve to flash the liquid and then is fed to a low pressure line to the nitrogen production flash pot exhaust gas,

feeding a low pressure flow to the air separation plant to add refrigeration to the low pressure column and argon system, and

feeding a nitrogen flow from the pump flash pot, to the production flash pot, and then to storage.

11. A liquefier device comprising:

an open loop refrigeration system using one or more counter flow heat exchangers and flash pots in order to achieve its liquids, turbine boosters to provide heat of compression to a boiler, turbo expanders to provide refrigeration to a condenser, and a pump to build the pressures to the turbo expanders.



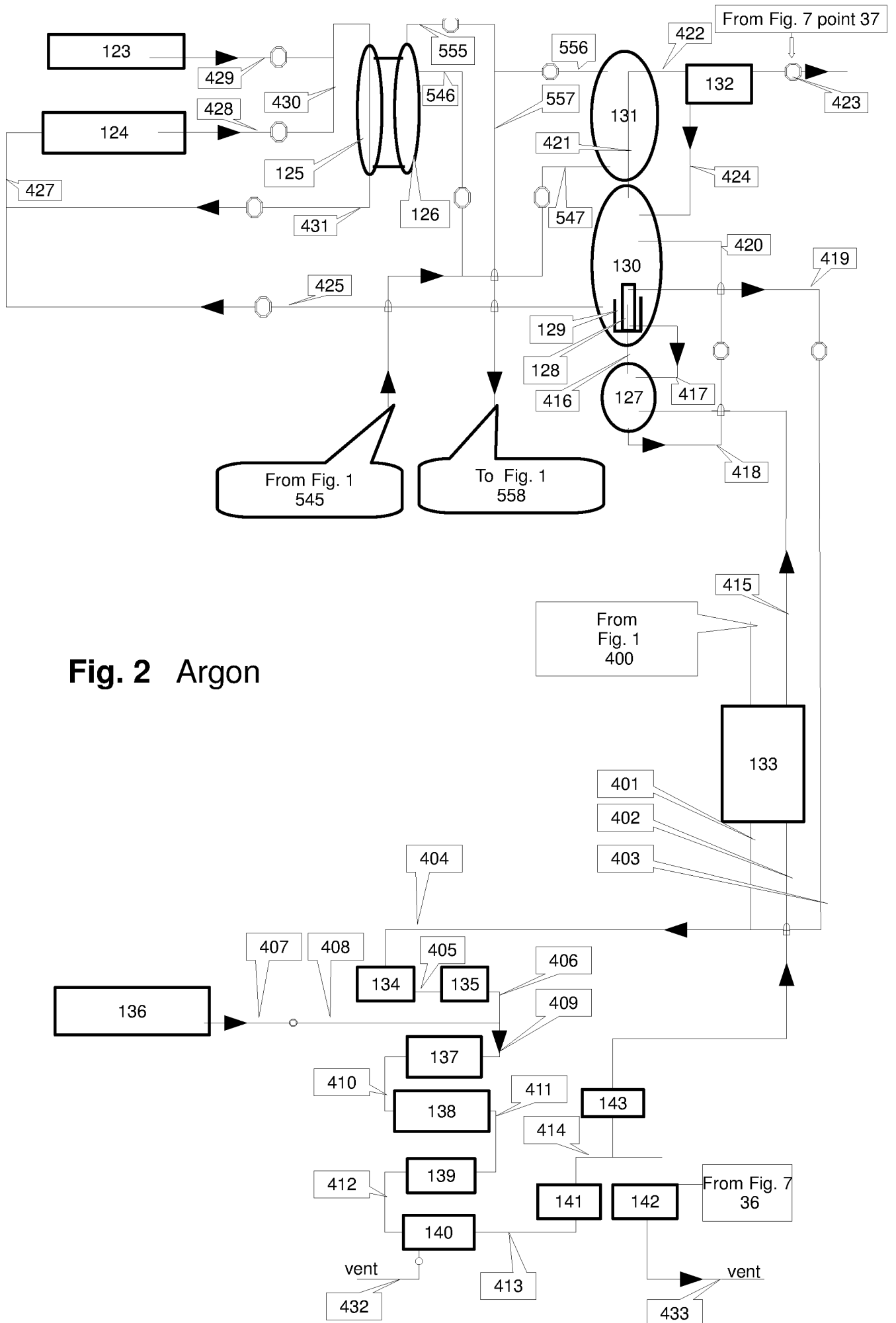
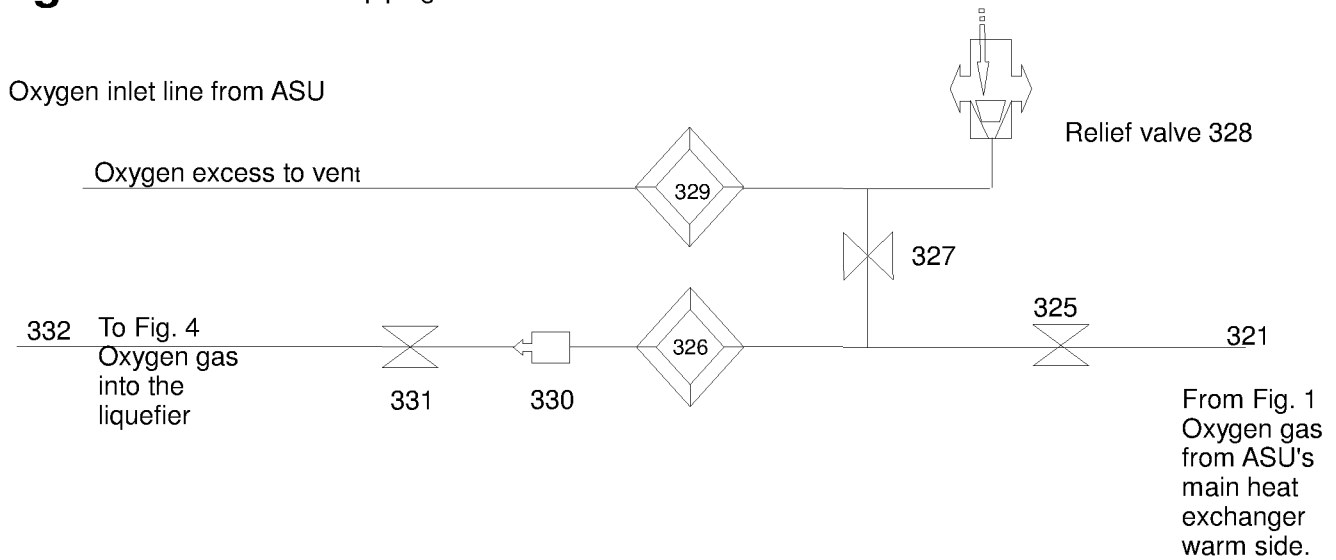
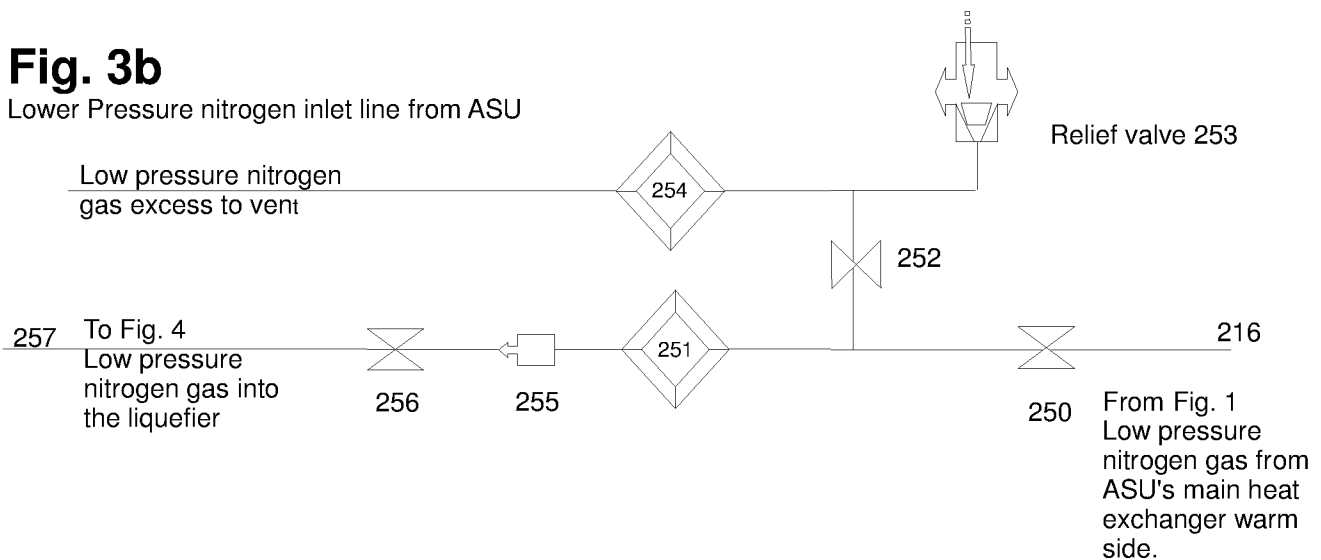


Fig. 3a Take or vent inlet piping**Fig. 3b**

Lower Pressure nitrogen inlet line from ASU

**Fig. 3c**

Higher pressure nitrogen inlet line from ASU

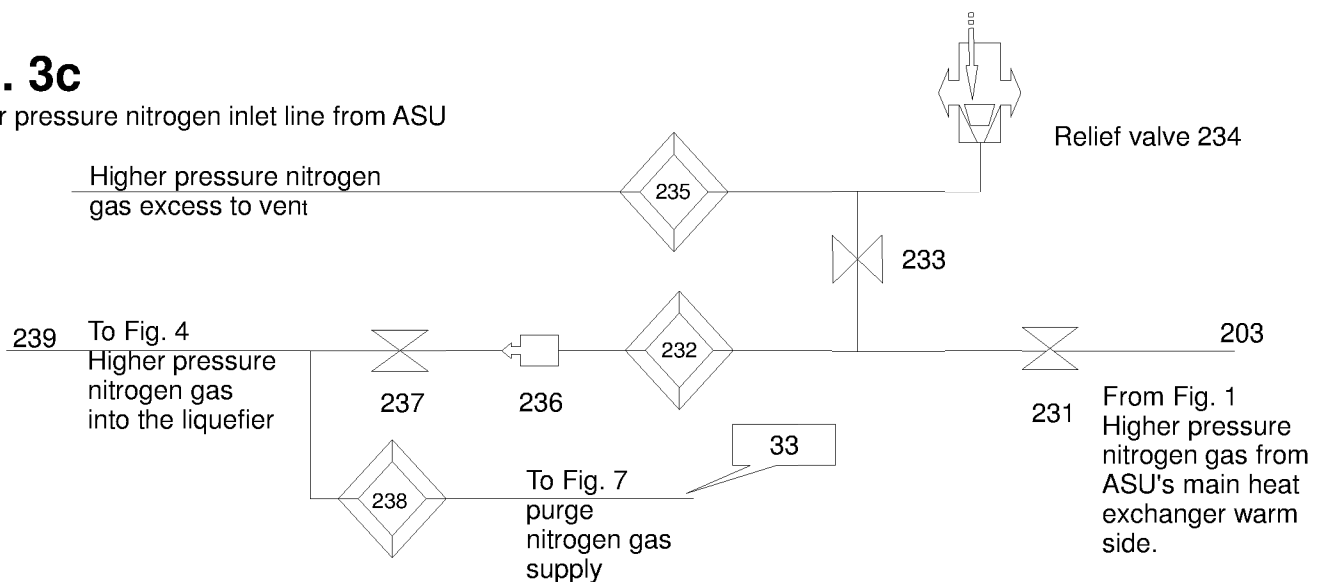


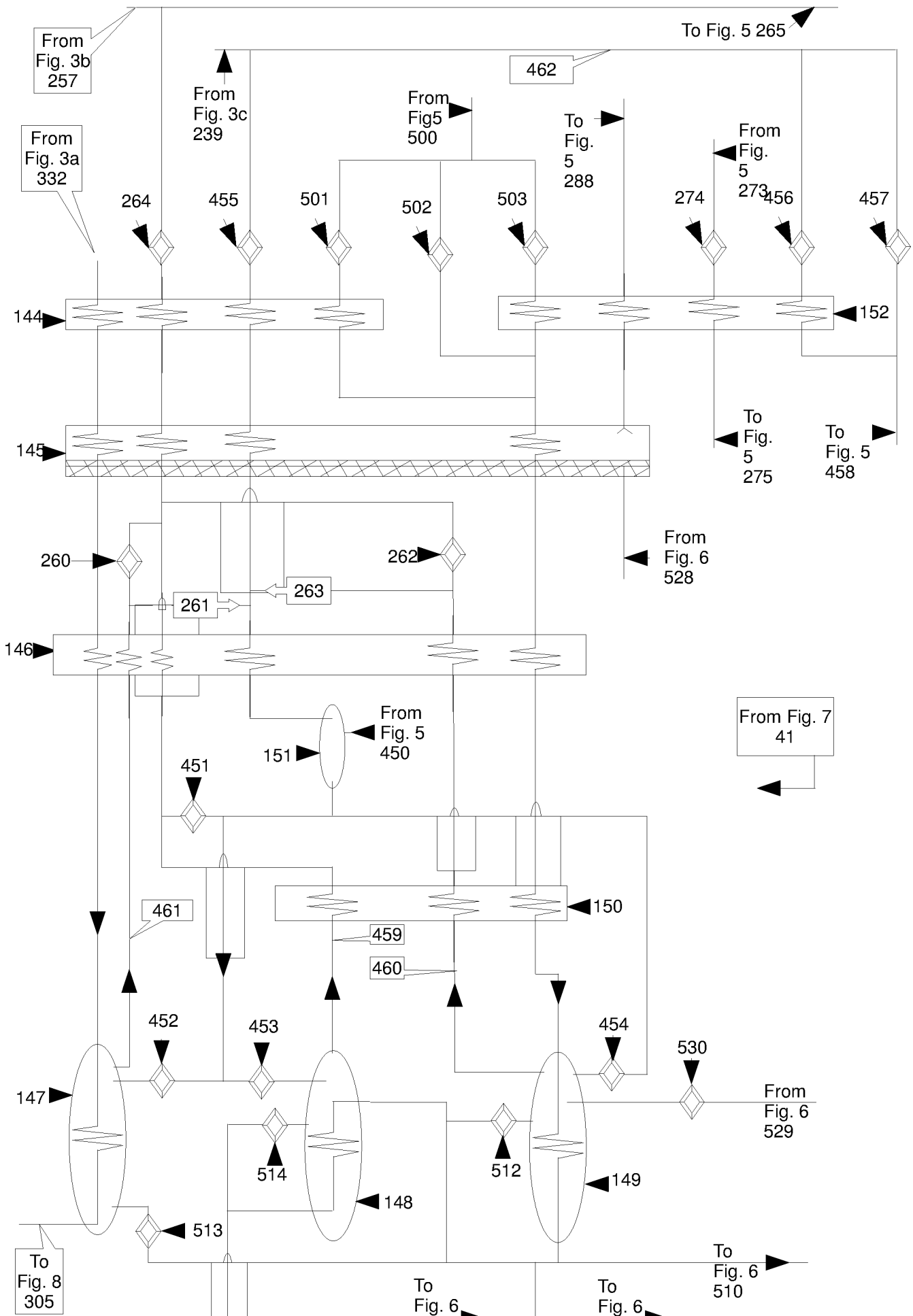
Fig. 4 THE LIQUEFIER HEAT EXCHANGERS.

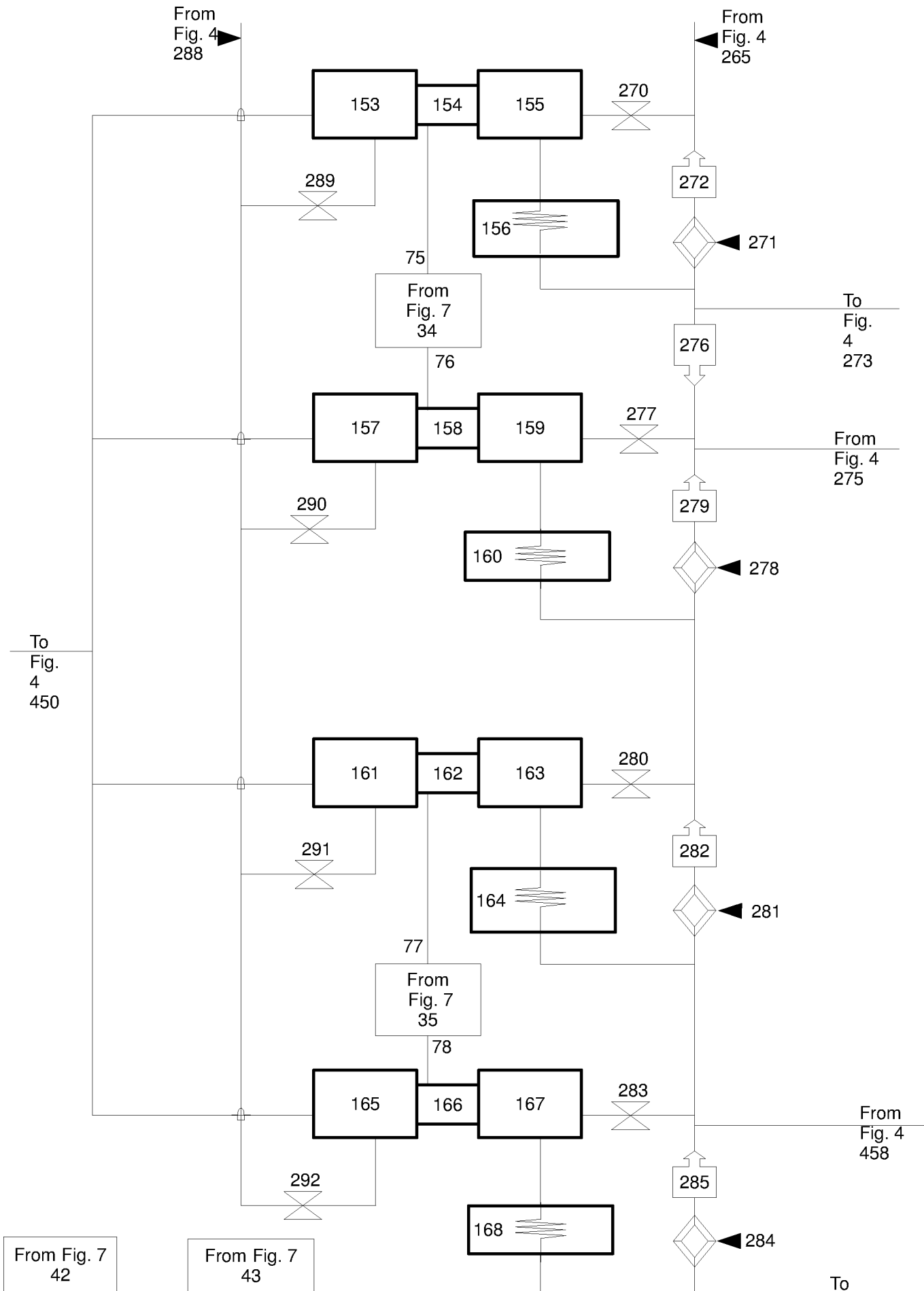
Fig. 5 Turbine Package

Fig. 6 Nitrogen pump systems

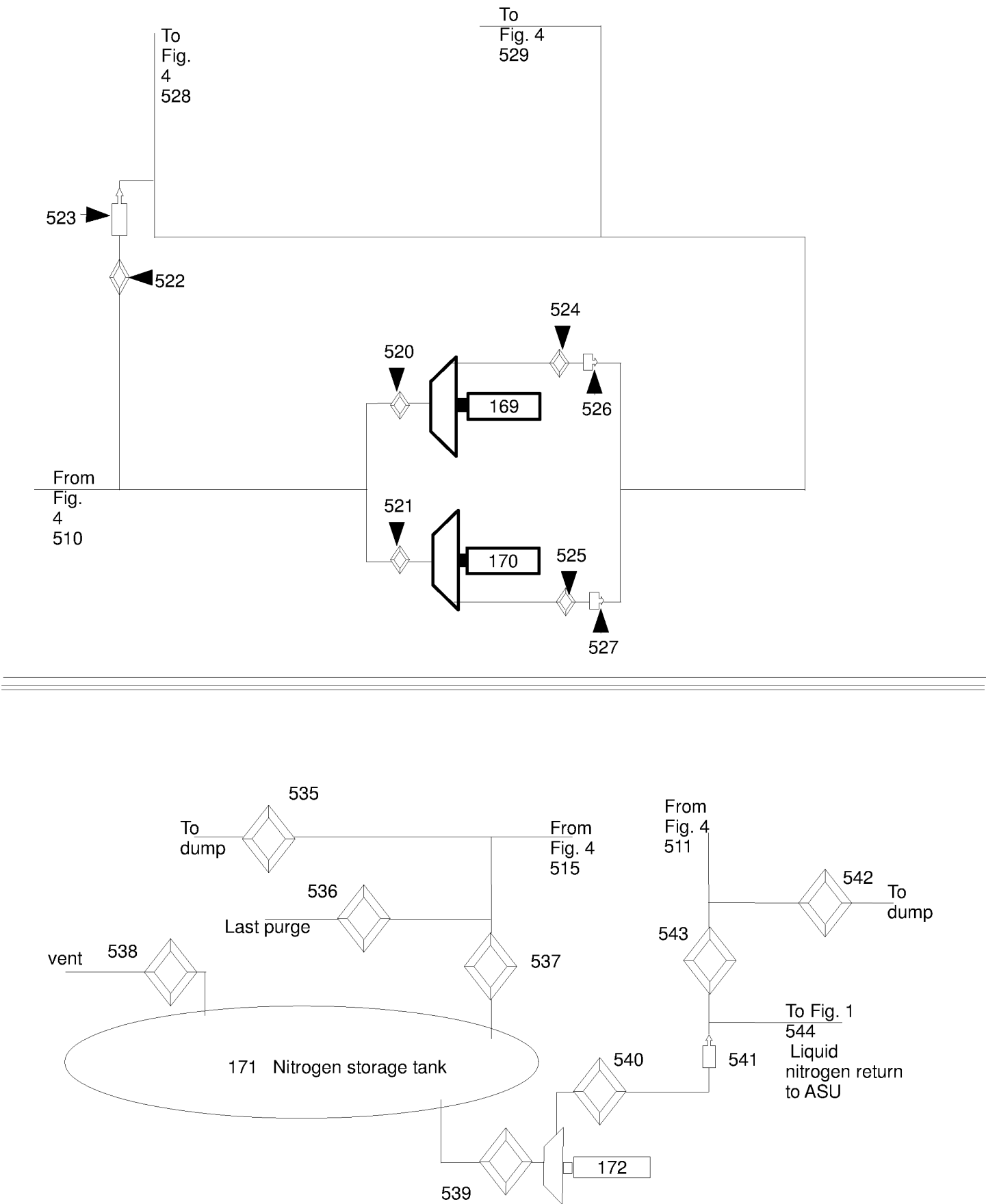


Fig. 7

BACK UP GAS
NITROGEN SYSTEM

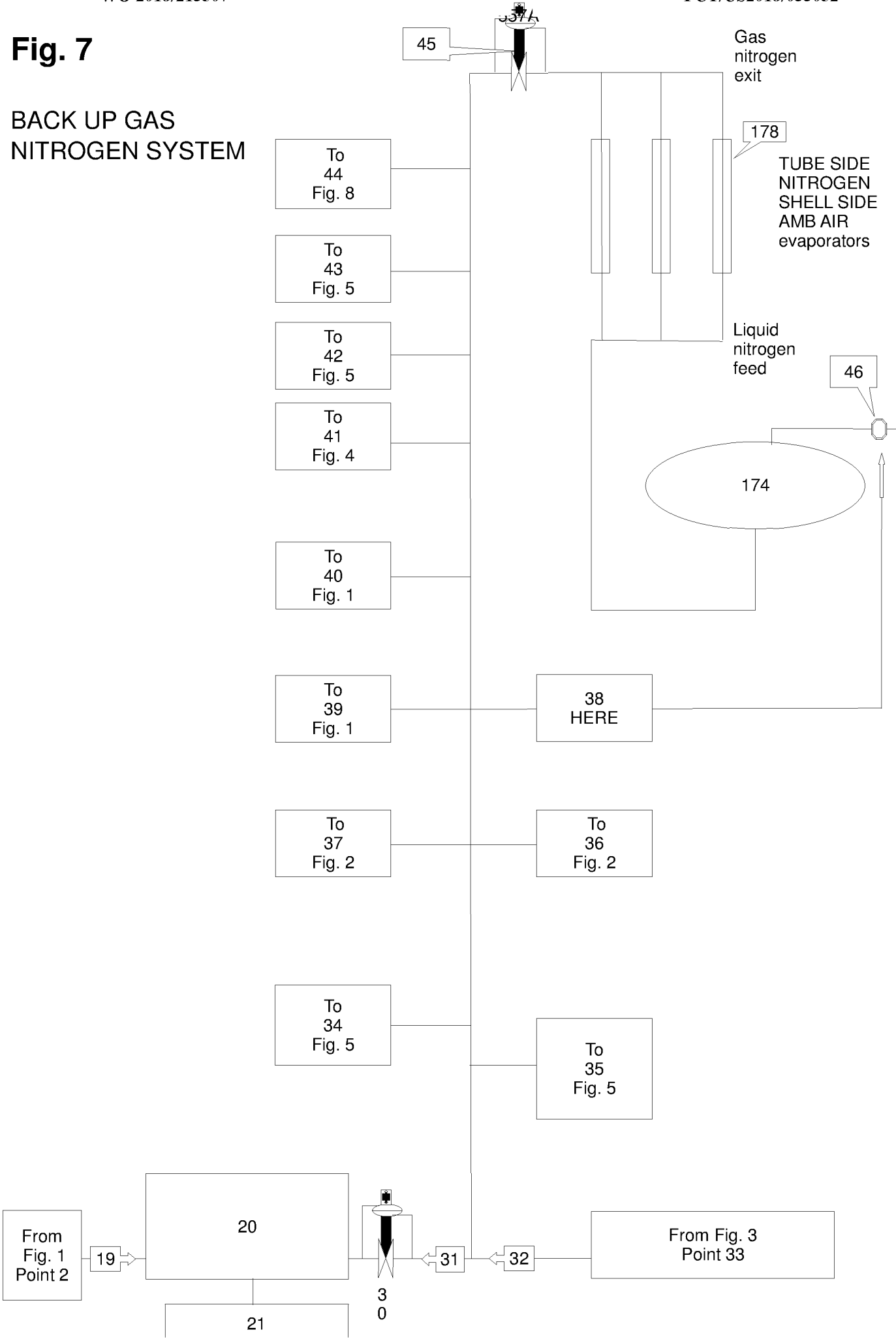


Fig. 8**Liquid Oxygen Filters**